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VOLUME II, NUMBER 1.

REVIEW OF TWO SERIES OF AMPHIBIANS

By

RICHARD DECKERT

PUBLISHED BY THE SOCIETY
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OCTOBER, 1915

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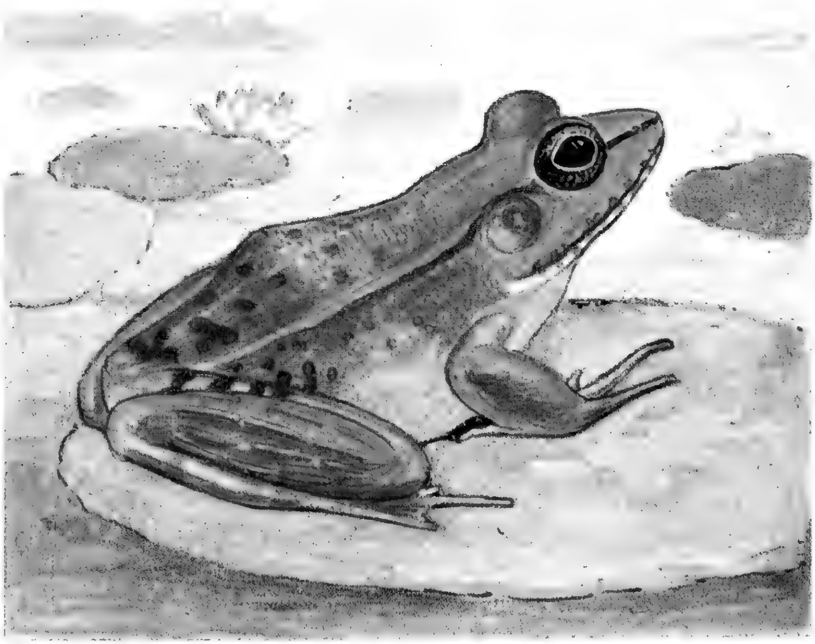
FIG. 1. HARLEQUIN FROGS, *DENDROBATES*

Blue-legged Frog, *Dendrobates typographus*, Keferst.

Ornate Frog, *D. tinctorius*, Schneid.

Scarlet Frog, *D. t. ignitus*, Cope



Richard Deckert, pinx

FIG. 2. LARGE-EYED FROG, *RANA CHRYSOPRASINA*, COPE

REVIEW

OF

TWO SERIES OF AMPHIBIANS*

By Richard Deckert.

(Color plates from drawings by the author.)

Introduction.

The species described in these articles belong to the Class Amphibia and the living members can be roughly defined as Vertebrates which undergo an external metamorphosis, hatching from eggs (spawn) as tadpoles or larvae, and gradually assuming the adult form. These larvae have gills at some stage of their development and several species complete the metamorphosis inside the egg and emerge as gillless and tailless frogs.

Most amphibians lose these larval gills, except some of the salamanders, like *Necturus* and *Proteus,* after attaining the adult form. Several of the American land salamanders of the genus *Amblystoma* retain the gills throughout life, if the conditions for developing into the land form are unfavorable, and have been known to breed in this semi-larval state.

The members of the *Amphibia* are divided into three Orders, as follows:

The *Apoda* or limbless amphibians, have a vertebral column with rudimentary ribs and amphicoelous vertebrae sometimes to the number of 300. Each vertebra is cupped before and behind and articulated with the adjoining member by means of a cartilaginous plate. Only one lung is present. The shape of these animals is cylindrical, the head is not distinct from the body, there is no tail and the anus is placed at the posterior end of the body. The body shows no internal rudiments of limbs, is naked and ringed by furrows running around it similar to the segments of an earthworm. A few species have calcareous de-

*The specimens described in these reviews have been preserved and donated to the American Museum of Natural History. Marked with all possible data, they are now available for study.

posits in the form of bony scales under the skin. The eye is small, the mouth usually wide, and the teeth large. These animals lead a subterranean life, burrowing in the soil of tropical and subtropical countries. The larvae live in the water until the absorption of the gills. The eggs are round or oval, and are joined together by a gelatinous string. This Order embraces fifty species.

The next order is the *Caudata* or tailed amphibians. These creatures have a spinal column formed of from thirty-seven to ninety-eight vertebrae, which are amphicoelous or opisthocoelous, that is cupped in front and behind or only behind. The skin is naked, the head broad, flat and distinct from the body. All *Caudata* have limbs, although some species only rudimentary ones (*Amphiuma*). Sternal apparatus as well as pelvis always present, although the latter is sometimes rudimentary (*Siren*). All members of this order have a tail throughout life. Lungs are usually present, although the *Plethodontinae* have no lungs; breathing solely through their slimy skin. All salamanders or tailed amphibians hatch from eggs and undergo a metamorphosis from larval to adult form. All of the known species, which number about one hundred and fifty, breathe through gills at some period of their existence.

The last order, *Salientia,* or tailless amphibians, is the one to which all species treated in these articles belong. They are characterized by their form and the presence of four well developed limbs. With all the tail is absent in the adult form.

The skeleton is simple, with comparatively a large and broad skull and a short spinal column, consisting of from five to nine vertebrae and which terminates posteriorly in an elongate pelvis. This peculiar pelvic arrangement is necessary for the attachment of certain muscles that are used in leaping or acting as springs in giving impetus to the enormous leaps, which are possible by most members of this order. Short ribs are present only in one family, (*Discoglossidae*). The limbs are always four in number with four digits on the hand and five on the foot, but in a few species some of the digits are rudimentary or absent (*Stumpffia*). Some tree-toads have a rudiment of a fifth finger on the hand. The skin is either smooth or dry, and more or less granular or warty, but always naked. In a few species (*Mantophryne, Ceratophrys*) there are calcareous deposits in the skin in the shape of bony plates or granules. The eye is usually large, bright and so very mobile that it can be lowered into the skull until even with the top of the head.

The life habits of frogs and toads present considerable variation. Some species are terrestrial, some arboreal, some aquatic and others subterranean. The food consists of living insects chiefly, but some of the larger species are cannibalistic, and a few of the largest will eat small mammals, birds and snakes.

The order consists of nine families, divided into eleven subfamilies numbering about 1,200 species.

In the descriptions to follow it should be particularly noted that the color patterns are described from *living* subjects throughout. The greater number of the past descriptions of the rarer amphibians are from preserved specimens, and some confusion has resulted owing to the rapid fading of these animals, with a consequent marked change, not only in hue but in *pattern*. The greater number of the colored figures are for the first time sketched from life.

FROGS AND TOADS FROM COSTA RICA.

On May 20, 1914, Mr. Lee S. Crandall, Assistant Curator of Birds at the Zoological Park, and Donald Carter, a student at the Park, returned from a six weeks' collecting trip in Costa Rica. The trip resulted in the capture of many interesting birds and other animals, among the latter being ten species of frogs, toads and tree toads; most of them never before exhibited in this country. Following is a list of the species:

Family BUFONIDAE—Toads.
    Marine Toad, *Bufo marinus,* Seba.

Family HYLIDAE—Tree Toads.
    Baudin's Tree Toad, *Smilisca baudini,* Dum. & Bibr.

Family CYSTIGNATHIDAE—Arch-Jawed Toads.

Underwood's Toad, *Hylodes underwoodi,* Blgr.
Barred Piping Toad, *Hylodes polyptychus,* Cope.
Brown Piping Toad, *Hylodes rhodopis,* Cope.

Family RANIDAE—Frogs.

Subfamily RANINAE—True Frogs.

Large-eyed Frog, *Rana chrysoprasina,* Cope.
Godman's Frog, *Rana godmani,* Gthr.

Subfamily DENDROBATINAE—Harlequin Frogs.

Blue-legged Frog, *Dendrobates typographus,* Keferst.
Scarlet Frog, *Dendrobates typographus ignitus,* Cope.
Ornate Frog, *Dendrobates tinctorius,* Schneider.

Family BUFONIDAE—Toads.

The toads of this family have no teeth in either jaw, the shoulder girdle is arciferous or dilatable, and the vertebrae are procoelous, or cupped in front and without ribs. The tips of the fingers and toes are either obtuse, (genera *Notaden, Pseudophryne, Nectes, Bufo*), pointed, (*Myobatrachus, Rhinophrynus, Cophophryne*) or triangular, and carrying medium-sized or large adhesive disks or pads, (*Engystomops* and *Nectophryne*). The *Bufonidae* are distributed over all parts of the globe except, of course, the Arctic and Antarctic regions, which have no amphibians. Central America and northern South America have the most genera, as well as the greatest number of species. The species number about one hundred and fifty, grouped in nine genera. Of these genera, *Notaden* (one species) and *Myobatrachus* (one species) are Australian, *Pseudophryne* (four species) is Australian and African, *Nectophryne* (seven species) is African and Indian, *Nectes* (four species) Javan and Sumatran, *Cophophryne* (one species) Indian, *Engystomops* (three species) Central—and South American, *Rhinophrynus* (one species) is Mexican and *Bufo* (about one hundred and thirty species), cosmopolitan with the exception of Madagascar, New Guinea and the Australian region.

The habits of this family are terrestrial except the genus *Nectes,* which is aquatic and has enormous webs on the hind feet. *Nectophryne* is more or less arboreal as indicated by the enormously dilated and padded fingers and toes.

Most of the *Bufonidae* are excellent burrowers, hiding by day and coming forth at dusk to hunt insect prey. Few species, however, are strictly nocturnal, some of the genus Bufo (*Bufo fowleri B. calamita B. quercicus*) having been observed hunting in the brightest sunshine. The genera *Rhinophrynus* of Mexico and *Notaden* and *Myobatrachus* of Australia, are almost exclusively termite and ant-eaters, herein approaching most of the species of the family *Engystomatidae* (the narrow-mouth frogs) whom they also resemble in external appearance, small head, enormously fat body, short arms and legs and comparatively smooth skin.

In their movements the *Bufonidae* are not as agile as the true frogs (*Ranidae*), usually proceeding by short hops, walking, crawling or in rare cases running. They are excellent climbers, taking advantage of every unevenness to obtain a hold, and maintaining their balance in most trying situations. With this they combine great persistence, especially when trying to escape from some pit, well or terrarium. They are but indifferent swimmers and divers with the exception of the genus *Nectes,* and will only enter the water to soak their skin, and during the breeding season for the purpose of depositing their spawn.

All species that have come under observation are great feeders, eating untold numbers of insects, most of which are injurious to plant life. In this they take the place of the insectivorous birds on the ground at night and therefore merit our protection, which unfortunately has been withheld to a great extent until lately. This was probably due to ignorance of their habits, and also to the often unprepossessing appearance of these harmless creatures. The flesh of the larger species is said to be quite as edible as that of some of the true frogs, but is eaten only by a few aboriginal tribes of tropical countries.

In appearance most of the *Bufonidae* are squat, fat and warty. There are, however, some smooth skinned, long legged tropical species that remind one of a true frog.

Marine Toad, *Bufo marinus, Seba.* (*Bufo agua,* Latr., *Bufo ictericus,* Spix., *Bufo horridus,* Daud.) (Boulenger, Cat. Batr. Sal. P. 315).

Color: Brownish or greenish-olive, yellowish or reddish-brown or plain dark brown above with or without large, black, insuliform spots, these usually edged with pale yellow. Sometimes a light median line from behind the head to above the vent. There may be a few scattered whitish spots on the back and sides. Arms and legs sometimes distinctly banded with dark brown. The cranial crests, parotoids and larger warts are usually light, reddish brown. Below this toad is dirty white or yellow with or without brown spots.

Structure: The head is broad and crowned with very prominent bony crests diverging from above the nostrils, edging the canthus rostralis, curving around the orbit above, and sending out and down a branch before and behind the eye, several more or less distinct branches towards the median line above, and one connecting with the enormous parotoid glands. These glands curve down over the arms, and in a toad six and a half inches from snout to vent, attain a length of one and three-quarter inches and a width of one and three-eighth inches. They are studded with large pores. There is a distinct bony ridge along the upper jaw on the edge of the mouth. The tympanum is about one-half the diameter of the eye, and very distinct. The body is covered with large round warts. The skin is loose and much wrinkled and creased. Arms and legs are long and powerful, hands and feet large. The ends of fingers and toes are tipped with dark brown. The toes are moderately webbed. Metatarsal tubercle moderately developed.

Size: Adults range from five inches to eight and one-half inches in length from snout to vent.

Range: Southern Mexico through Central and South America to Southern Argentina. Many of the West Indian Islands.

Thirty-one specimens of the giant marine toad, of all sizes from two to seven inches in length were collected. These large toads are very common throughout their range and no doubt are beneficial in helping to keep the insect life of those regions

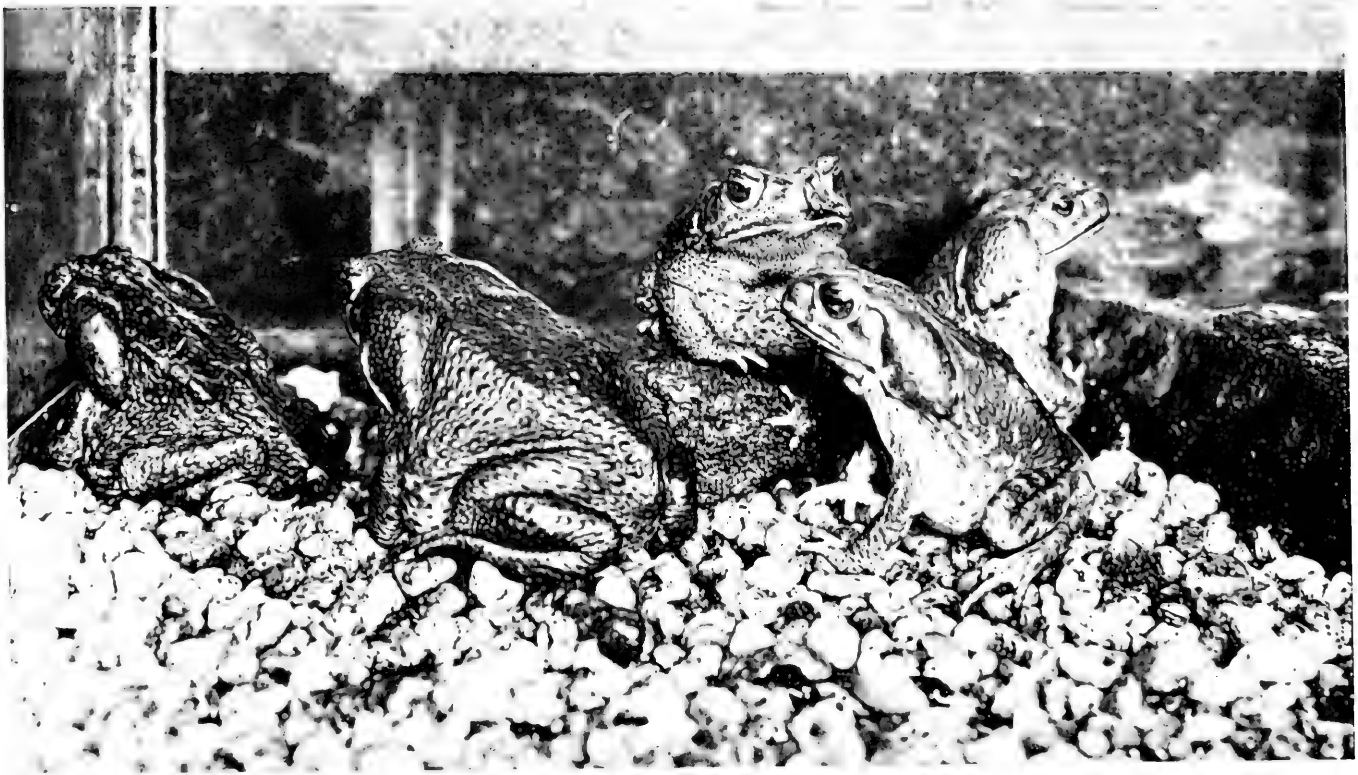


FIG. 3. MARINE TOAD, *BUFO MARINUS*, SEBA

within reasonable bounds. This is the largest species of the true toads, only exceeded in size by *Rana goliath* and *Rana adspersa,* both African frogs, and possibly *Ceratophrys dorsata* of Brazil. The male can be distinguished from the female by the horny pads on the inner fingers, and by a blackish area on the throat indicating the presence of a large gular pouch. This dark area may be sprinkled with lemon-yellow, especially in young males. The writer has often observed the males sitting with this pouch partly distended in the pan of water provided for their soaking bath in the spacious cage in the lobby of the Reptile House, especially after they had fed well, but so far has not heard their call. The warts on the upper surface of the males are covered with small horny spines, making these toads exceedingly rough to the touch, in contrast to the females, whose warts are round and smooth. When picked up, the male of this species gives voice to a series of harsh squawks similar to those produced by some toy animals. The female is silent, and when handled will shake the whole body as if in a rage, then puff it up enormously but deflating it after a little while with a loud hiss. From the enormous parotoid glands, Dr. J. J. Abel, of Johns-Hopkins University in Baltimore, has recently extracted two distinct and powerful poisons, called respectively *Epinephryn* and *Bufagin.* The latter poison, Dr. Abel has found by experimenting, has many times the strength of *Digitalin,* the "fox-glove" poison, and like this, it affects the heart action. This species has proven one of the hardiest in captivity, seemingly being immune to the festering and bleeding ulcers with which captive toads so often are infested, and to which the majority of them succumb. In the Reptile House these toads are fed on all kinds of insects, and also large earth worms and cockroaches. A few of the largest toads sometimes get an extra tid-bit, such as very young mice or rats.

Although the giant among toads and able to swallow the largest of insects and worms as well as small mammals, this species is not cannibalistic. The writer had repeatedly tried to induce them to eat very young common toads and frogs, which they will snap up but reject immediately. In spite of their enormous size and bulky appearance, the "marine toads" are remarkably agile and quick on their feet. When insects are thrown into their cage they instantly become alert and with a series of rapid hops, almost cat-like in their stealth, come forth from the darkest corner of their cage where they usually spend the day piled on top of one another and sleeping. Some specimens eventually become so tame that they will take insects and worms from one's hand. The tongue of this toad is very flexible, seemingly more so than in other species. The writer has seen some of the larger specimens snap up a grasshopper or mealworm fully four inches from the toad's head. The species breeds during the rainy season, the eggs being quite small and laid in two strings very similar to those of our own common toads, in puddles, ditches, ponds and canals. The matamorphosis is comparatively rapid, and the baby toads are tiny, measuring scarcely three-eighths of an inch from snout to vent. The call of the male is said to resemble the barking of a dog.

Family Hylidae—Tree Toads.

This family is divided into two subfamilies, the *Amphignathodontinae* and the *Hylinae*. It is the latter subfamily only, that we have to deal with in this article. The *Hylinae* or Tree Toads are characterized by the dilatable shoulder girdle, the presence of teeth in the upper jaw, vertebrae cupped in front, absence of ribs, and dilated transverse processes of the sacral vertebra. The end-phalanges of the fingers and toes are claw-shaped and support more or less prominent, adhesive disks. These disks secrete a sticky fluid which, aided by the moist and granular surface of the belly, enable the tree-toads to climb trees, vines and even the glass sides of a terrarium with perfect ease. The skin of the *Hylinae* is always moist and slimy, thus enabling them by means of increased evaporation to withstand greater heat than other amphibians. Tree-toads often can be seen sitting for hours in the most glaring sunlight.

Their skin may be quite smooth or covered with warts of various sizes. In some species of the genera *Hyla, Nototrema, Nictymantis* and all those of *Pternohyla, Corythomantis, Triprion* and *Tetraprion,* the skin of the head adheres to the skull. The *Hylinae* includes some of the brightest colored and most attractive of all the frogs and toads. All of the species have great powers of color-change. Some of them are really marvellous in this respect. This applies especially to the genus *Hyla*. Most of the *Hylinae* live on the trees, vines, shrubs and other plants, but a few, however, have such tiny adhesive disks that they are of little use, compelling the creatures to live on the ground. All species are insectivorous, although many of the larger ones incline to cannibalism. The family *Hylidae* contains sixteen genera; one of these, *Amphignathodon,* belongs to a separate subfamily. With the latter there are teeth in both jaws. It includes but one species, *A. guentheri,* of Ecuador, and is exceedingly rare.

The other fifteen genera are included in the subfamily *Hylinae.* There are about two hundred and forty known species of which the genus *Hyla* alone has about one hundred and eighty. The pupil of the eye of the toads of this genus is horizontal elliptic. The toes are webbed. Adhesive disks distinct, sometimes very large. The distribution of the *Hylidae* is as follows: The genus *Hyla* is almost cosmopolitan with over thirty species in Australia and Australasia, about one hundred and thirty-five species in Mexico, Central and South America, seven species in the West Indies, ten species in North America, and one species in Europe and Asia. This latter, *Hyla arborea,* has two subspecies in China and Japan. Of the other genera, *Acris,* (one species, two subspecies) and *Chorophilus* (five species) are North American, *Smilisca* (one species) ranges from Texas through Mexico into Northern South America, and the genera *Nototrema* (eight species), *Hylella* (seven species), *Thoropa* (one species), *Phyllomedusa* (fourteen species), *Agalychnis* (four species), *Nictymantis* (two species), *Triprion* (two species), *Tetraprion* (one species), *Diaglena* (one species), *Corythomantis* (one species), and *Pternohyla* (one species) are Central and South American.

This distribution seems to show that the original home of the *Hylidae* was South America. One species of the otherwise North American genus *Chorophilus* occurs in the mountains of Peru (*Ch. cuzcanus*). Quite a number of species of this interesting family are remarkable in their breeding habits. They do not lay their eggs in ponds, ditches, lakes or swamps as is the habit of most frogs and toads, but use the axillae of large broad-leaved parasitic or other plants for this purpose. One species, *Hyla resinifictrix,* of Brazil, uses knot holes which it lines with the resinous sap of an aromatic tree (*Protium heptaphyllum*) and which soon become filled with rain water. The gigantic *Hyla faber,* also of Brazil, constructs nests or nurseries of mud, forming circular inclosures about twelve inches in diameter in shallow parts of ponds. The eggs are deposited and the tadpoles reared in these nurseries. Other species, (*Hyla goeldi*) and species of the genus *Nototrema* carry the spawn in a pouch on the back until the tadpoles hatch. This pouch is formed by the introverted skin of the back and is possessed by the female only. Species of the genus *Hyla* have the strongest voices of any of the *Salientia.* The call may be a shrill pipe, whistle, a very loud rattle, croak or bark, or a bell-like note (*Hyla gratiosa,* of Florida, *H. faber,* of Brazil) that can be heard in some cases for more than a mile. Each species has its distinctive call and the din produced by these and other toads and frogs in tropical forests during the breeding seasons is said to be ear-splitting.

Baudin's Tree Toad, *Smilisca baudini, Hyla baudini* Dum. & Bibr. (Boulenger Cat. Batr. Sal. P. 371).

Color: The body color is green of varying shades from dark olive through bright pea-green to pale, golden green. A dark band from the eye to the shoulder, covering the tympanum and sometimes extending to the groin, a light spot beneath the eye, and a dark band curving over the upper arm at its insertion. The groin of both sexes is bright yellow, also the throat of the male. Undersides white. These marks are always present. Markings which sometimes disappear with the assumption of pale shades are, a broad band on the middle of the back with two branches extending on the eyelids, two or three cross bars on arms and legs and a few smaller dark spots on the back.

Structure: The head is broad and flat, canthus rostralis acute, eyes large, reddish golden in color and very far apart. The skin is smooth or very finely granular. The legs long, toes two-thirds webbed, fingers slightly webbed, with adhesive disks smaller than the tympanum. The latter two-thirds the diameter of the eye. The vomerine teeth are situated slightly behind the internal nares, and arranged in a straight series which is interrupted in the middle, thus separating the genus *Smilisca* from *Hyla*. The male has two large gular pouches, one on each side of the throat.

Size: This species is large for a tree toad, reaching a length of three and a half inches from snout to vent. The male is smaller than the female; two and a half inches being the average size.

Range: From southwestern Texas through Mexico to Panama. Four specimens of this fine tree toad were captured near Guapiles, Costa Rica, by Mr. Crandall and his assistant. They were heard calling at night from a piece of waste ground, and their cry was traced to several old tin cans partially filled with water in which the tree toads were sitting. In their cage in the Reptile House they seem to prefer dark corners, where they sleep during the day, coming forth at night and climbing all over the glass sides of their vivarium. They have not been seen feeding since their arrival, although tempted with all kinds of small live insects.

Family Cystignathidae—Arch-Jawed Toads.

This is a most difficult family to define as it approaches the *Bufonidae, Hylidae, Pelobatidae,* and *Ranidae* in internal as well as in external identification characteristics. Its distribution is South American and Australian almost exclusively. One species (*Liopelma hochstetteri,* the only amphibian there), being found in New Zealand, where it is rare, and four species entering North America.

The family has the following internal structural characteristics: A dilatable shoulder girdle, teeth in the upper jaw only, (subfamily *Cystignathinae*), in both jaws (*Hemiphractinae*), or no teeth at all (*Dendrophryniscinae*). The terminal phalanges or finger and toe ends are never claw-shaped, although sometimes carrying adhesive disks as in the *Hylidae*. The family is composed of three subfamilies, the *Hemiphractinae,* helmet-heads, so called from the shape of their enormous heads which carry large bony protuberances reminding one of the casques or helmets of ancient knights, the *Cystignathinae,* arch-jawed toads, including the greatest number of species, and so called from the enlargement of the lower jaw of some species, and finally the *Dendrophryniscinae,* toads without teeth.

The genera are so numerous and so poorly defined that almost every author gives a different number of the same (Cope, thirty-seven genera, Gadow thirty-two genera, Werner thirty genera, etc.). There are about two hundred and fifty species, of which Australia has about thirty and the remainder are from South America.

Their habits are very diversified, some being burrowers, some strictly aquatic and a great number of species are arboreal, living like tree toads (*Hylidae*) and resembling them in appearance.

Most of the Australian species have a vertical pupil, indicating nocturnal habits.

In size the *Cystignathidae* range from the enormous *Ceratophrys dorsata,* measuring nine inches from snout to vent, and *Leptodactylus pentadactyles,* six to eight inches from snout to vent, to the small *Pseudis minuta,* which measures only three-quarters of an inch from snout to vent. Both extremes in size are found in tropical America. In South America, Central America, Mexico and the West Indies the tree-living species predominate, whereas in Australia the members of this family without exception are burrowers. The largest genus is *Hylodes,* having more than eighty species, *Leptodactylus* has about thirty-five, *Paludicola* has thirty-two and *Ceratophrys* has seventeen species. The other genera have from one to twelve species each.

The breeding habits of this family vary considerably. Some species like *Hylodes martinicensis* carry the tadpoles on their backs while others like some of the *Hylidae* lay the eggs in foamy masses in the axillae of large-leaved plants; but the breeding operations of the majority of the species are unknown The tadpoles of two species grow to an enormous size; that of *Calyptocephalus gayi,* a giant water frog of Chile, reaches six inches, the adult frog is six to seven inches from snout to vent, while the tadpole of *Pseudis paradoxa,* also a water frog of the Guyanas, is larger still, one specimen being ten and one-third inches long, three and one-third inches of this total is taken up by the body and head, and the tail, which is thick and muscular, measures almost four inches in width by six and two-third inches in length. The size of the larva is all the more remarkable since the adult frog measures only two to two and a half inches from snout to vent.

Underwood's Toad, *Hylodes underwoodi,* Boulenger (Guenther, Biologica Centr. Am.).

Color: The general color is sepia-brown with a W-shaped mark on the shoulders. This mark may be much darker than the ground color or very pale, yellowish brown. The rest of the back is marbled with dark brown, and the arms and legs of some specimens are banded with dark brown. Undersides bluish white, specked with brown.

Structure: The head is long and the snout pointed. The eyes are large with the interorbital space smaller than the eyelid and the skin is rough with large elongated warts, giving this frog some resemblance to our cricket frog. The fingers and toes are free, subarticular tubercles prominent, and the adhesive disks minute, scarcely produced.

Size: From snout to vent the length is one to one and one-quarter inches. The specimens collected were immature and from one-quarter inch to three-quarter inches in length from snout to vent.

Range: Known only from Costa Rica.

Barred Piping Toad, *Hylodes polyptychus,* Cope (Guenther, Biolog. Centr. Am.).

Color: The general color is a dark, brownish olive with a white band between the eyes. The arms and legs are indistinctly barred, with a rich pink spot on the groin which is hidden when the frog is at rest.

Structure: The skin is finely granulated. The head is broad with the interorbital space equal to or larger than the diameter of the eye. Tympanum small and distinct. Subarticular tubercles distinct. Disks on fingers and toes small, but distinct. Toes not webbed.

Size: The single specimen examined was one and a quarter inches from snout to vent.

Range: Costa Rica.

Brown Piping Toad, *Hylodes rhodopis,* Cope, (Cope Proc. Acad. Phil. 1866).

Color: Brown prevails above, while below it is bluish white with a few scattered brown dots. There is a pale area in front of the eyes on top of the head and the canthus rostralis is margined with dark brown.

Structure: The head is long and pointed and the canthus rostralis acute. The nostrils are close to the top of the snout, the interorbital space is wider than the eye and the tympanum distinct and smaller than the eye. The fingers and toes are equipped with small disks. Subarticular tubercles distinct. The back has several longitudinal rows of warts arranged in the shape of a lyre.

Size: One specimen one and a quarter inches from snout to vent was examined.

Range: Mexico to Costa Rica.

All these small frogs were shy and delicate and did not live long.

Family RANIDAE—Frogs.

The *Ranidae* belong to the second group of tailless amphibians, the *Firmisternia,* so-called because the halves of the shoulder girdle are united below, forming a firm median bar or *metasternum,* instead of overlapping as in the *Arcifera,* to which all previously described frogs and toads belong. The vertebrae are cupped in front.

The *Ranidae* are divided into the following subfamilies according to the arrangements or absence of teeth:

Subfamily *Ceratobatrachinae,* having teeth in both jaws and consisting of only one genus and species, *Ceratobatrachus guentheri,* of the Solomon Islands. This is a large, huge-headed land frog with horn-like appendages on the eyelids, snout, sides of body and limbs.

Subfamily *Raninae* or true frogs with teeth in the upper jaw only. This is the most numerous branch of the family, comprising about forty genera with some three hundred and seventy species. These are so diverse in identification characteristics and habits that it would be impossible to describe all the genera in this paper, and but a few examples will be mentioned here.

Genus *Polypedatus* (*Rhacophorus*), frogs resembling tree toads in having the tips of the fingers and toes with adhesive disks, but the end phalanges not claw-shaped as in the *Hylidae.* Some species of this large genus have enormous webs between the fingers as well as the toes. They have been called flying frogs but do not actually fly, only jumping from great heights occasionally and using the large expanse of web as a parachute. Fifty-four species are known from southern and eastern Asia, and sixteen from Madagascar. Many species of this genus lay their eggs between leaves glued together by the female to form a sort of funnel which they suspend over a ditch, pond or brook, so that when the tadpoles have hatched they will drop into the water below their nest. This queer mode of depositing eggs is also practiced by the African genus *Chiromantis,* which resembles *Polypedates,* except that it has no web between the fingers and that the two inner fingers are opposed to the outer ones, enabling these frogs to grasp twigs and stems in climbing. Their movements are slow and mechanical, like those of the African and Madagascan cameleons. "Cameleon frogs" would therefore be an appropriate popular name for these queer creatures.

Hylambates with about twenty species, all African, is also a tree frog in the true sense. Our own so-called tree frogs are really tree toads, being grouped with the toads in the super-family *Arcifera.*

The genus *Hylambates* has some highly colored frogs with odd and picturesque color patterns. The female of one species (*H. brevirostris*) has been found by Boulenger to have a singular habit of nursing, carrying the eggs about in her mouth. The African and Madagascan genus *Rappia* is also very numerous, having about thirty known species. They are mostly small tree-living frogs with rather short, stout limbs, all beautifully colored and have great powers of color-change.

The female of one species from Madagascar has the singular habit of winding the eggs, which resemble a string of beads, around her forelegs.

Trichobatrachus, only one species of which is known so far, is peculiar in the possession of hair-like papillae forming a thick fringe on each side of the flank, also on the upper side of the thighs. This frog inhabits Central Africa.

Phyllobates, having five species, all small frogs, is a South American genus. The tadpoles of *Ph. trinitatis* of Trinidad, British West Indies, adhere to the back of the male by means of their suckers, and are thus carried from evaporating pools to more permanent ones. *Arthroleptis* comprises twenty species, mostly African. One species, *A. seychellensis,* of the Seychelle Islands, was found on some tree ferns carrying its tadpoles in the same manner as the genus described before, with the exception that the larvae adhered to the back of the adult by means of a sticky secretion.

Rana, the type genus of the whole family, is also the largest, having about one hundred and fifty species, of which fifteen inhabit the United States.

The Indian region including most of the islands of the Indian and Pacific Oceans, has the greater number of species, Africa has but a slightly smaller number.

The structural description of the genus is as follows: The pupil of the eye is horizontal and the tongue deeply notched and free behind. Teeth on the upper jaw and on the vomers, (small protuberances in the upper jaw), between or slightly behind the internal nares or nostrils. The fingers are free and the toes are more or less webbed. The fourth and fifth metatarsal bones of the central part of the foot diverge, but are united by the web. The terminal phalanges may be simple and pointed or T-shaped, sometimes carrying disks. The external ear plate (tympanum) is usually distinct. The males of most species have vocal sacs, which may be internal (*Rana catesbiana, R. sylvatica, R. temporaria*), or external, protruding through slits under the angle of the lower jaw or over the arm insertion when they are distended in calling (*R. esculenta, R. aesopus, R. tigerina*).

Nuptial excrescences in the shape of horny or spiny pads, spikes or granules may be found on the forelimbs and hands of the males of many species, reaching their greatest development in *Rana liebigii* of the Himalayan region, India.

The males of this genus are further distinguished by their heavy forelimbs or arms which in the aforementioned species are enormously developed. Gadow says in his "Amphibia and Reptiles" (Cambr. Nat. Hist.): "All species of *Rana* spawn in the water, except those of the Solomon Islands, where the only permanent bodies of water are roaring mountain torrents unsuitable for the metamorphosis of amphibian larvae."

One species from this group of Islands, *Rana opisthodon,* lays its eggs in moist crevices in rocks near the water. The larvae undergo the whole metamorphosis from tadpole to frog inside the eggs and emerge as perfect frogs, absolutely tailless. The tip of the snout of the young frog is armed with a short, horny protuberance which is used to perforate the egg and is absorbed soon after the animal has emerged. The largest species of all frog-like amphibians is *Rana goliath* of the Cameroons, attaining a length of twelve inches from snout to vent. Next in size are *Rana adspersa* (nine and one-quarter inches), of South and Central Africa, *Rana macrodon* (nine inches) of India and Malaysia, *Rana catesbiana* (six to eight inches) of North America, *Rana tigerina* (six to seven inches) of India and Malaysia, and *Rana guppyi* (six to seven inches) of the Solomon Islands. All these large species are cannibalistic and large examples of our own bull frog have been known to swallow half-grown rats, small chicks, ducklings, sparrows, toads and young snakes.

Insects, of course, make up the greater percentage of the food.

Some species of this genus are quite terrestrial, only entering the water during the breeding season, while others are typical water frogs never wandering far from their native stream, pool or swamp.

The genus *Gampsosteonyx* resembles an ordinary frog, but has vertical pupils. The terminal points of the fingers end in sharp, bony claws which perforate the skin of the finger tips. One species is known: *G. batesi* from the French Congo.

Subfamily DENDROBATINAE—Harlequin Frogs.

These small frogs are separated from the others of the family by the absence of teeth from both jaws and comprise three genera: *Dendrobates,* of Tropical America, *Mantella,* of Madagascar and *Cardioglossa* with one species *C. gracilis* of the French Congo. The frogs of the genera *Mantella* and *Dendrobates* are very much alike in shape, size and in possession of a striking color pattern. Deep black, bright blues, brilliant reds, greens and yellows in many contrasting combinations are the colors which often form fantastic patterns.

The tiniest insects are the food of these little harlequins of the frogs' world and they are usually found near fallen decaying tree trunks, where they feed on small termites, or in banana plantations, where they can be seen in numbers about the fallen and decaying fruit which attracts myriads of small fruit flies.

Dendrobates has seventeen species, *Mantella* nine species and *Cardioglossa* has one.

Subfamily RANINAE—True Frogs.

Large Eyed Frog, *Rana chrysoprasina,* Cope (Boulenger, Cat. Batr. Sal. P. 49).

Color: The head is green and the back, sides and limbs a yellowish olive with a few brown specks. A dark line extends from the tip of the snout through the nostril and eye over the tympanum and below the lateral glandular fold to the groin. The edge of the upper jaw has a few small brown spots, the eye is brassy yellow and the sides and belly an immaculate golden yellow.

Structure: The head is broad, flat, snout acuminate, projecting beyond the mouth and the tympanum two-thirds the diameter of the eye, which is very large. The tips of the fingers and toes are slightly dilated, fingers very long and slender, and the toes webbed four-fifths of their length. The skin is very finely pustulated above and smooth underneath. There is a lateral fold on each side of the body and narrow longitudinal glandular ridges on the calf of the leg.

Size: The specimen examined was three and one-quarter inches from snout to vent.

Range: Costa Rica.

One adult, one young frog and several tadpoles of this beautiful species were collected near Guapiles. This frog is very shy, as most large-eyed frogs usually are, and seeks cover with great rapidity when disturbed. Like most water frogs it is a good feeder, and so far has proven a very satisfactory captive. When taken up it will sit quietly in the open hand and will not jump unless frightened by a quick movement. Several of the tadpoles have metamorphosed and are living now as young frogs in a vivarium with small tree toads on the main floor of the Reptile House. In the daytime they usually sit concealed under some moss, but come forth with the darkness and occupy the pan of water provided for them.

Godman's Frog, *Rana godmani,* Guenther (Biologia Centr. Am.).

Color: The color is greenish olive above with indistinct darker spots and whitish below.

Structure: The structure is like that of *Rana clamitans,* but with much shorter legs.

Size: One young specimen metamorphosed from a tadpole is in the Reptile House. This frog is just as shy as the preceding species, constantly hiding under a large, flat stone in its terrarium. The size of the adult is from two and one-half to three and one-half inches.

Range: Costa Rica.

Subfamily DENDROBATINAE—Harlequin Frogs.

Blue Legged Frog, *Dendrobates typographus,* Keferstein (Boulenger, Cat. Batr. Sal. P. 143).

Color: This frog is a brilliant red above and below with or without tiny black dots. The legs and forearms are brilliant dark blue or blue-black, and on the upper side of the thighs there is a row of small red dots. The blue of the inner arm extends across the breast.

Structure: The snout is obtuse and the canthus rostralis rounded. The tympanum is distinct but small, measuring about one-half of the diameter of the eye, and the interorbital space twice the width of the eye. The arms and legs are slender and moderately long with disks on the fingers and toes equal to or exceeding the tympanum in size. The skin is smooth and shiny.

Size: Adult frogs are one inch or less from snout to vent.

Range: Costa Rica. Eight of these queer little frogs were collected by Mr. Crandall. They were found prowling along the decaying timbers of a fallen fence, probably hunting for the small white termites that usually infest such places.

Scarlet Frog, *Dendrobates typographus,* subspecies *ignitus,* Cope (Proc. Acad. Phil. 1874).

Color: As the name implies, it is brilliant red all over except for a small star-shaped area on the breast and a larger one at the junction of the hind legs and the belly, beneath which is dark blue.

Structure: Exactly like *D. typographus* var. typica.

Range: Costa Rica. Rarer than the typical form. One specimen from Limon.

Ornate Frog, *Dendrobates tinctorius,* Schneider, (Boulenger Cat. Batr. Sal. P. 142).

Color: The color is very variable, the single specimen collected by Mr. Crandall was bright emerald green and black; the green predominating above and the black below.

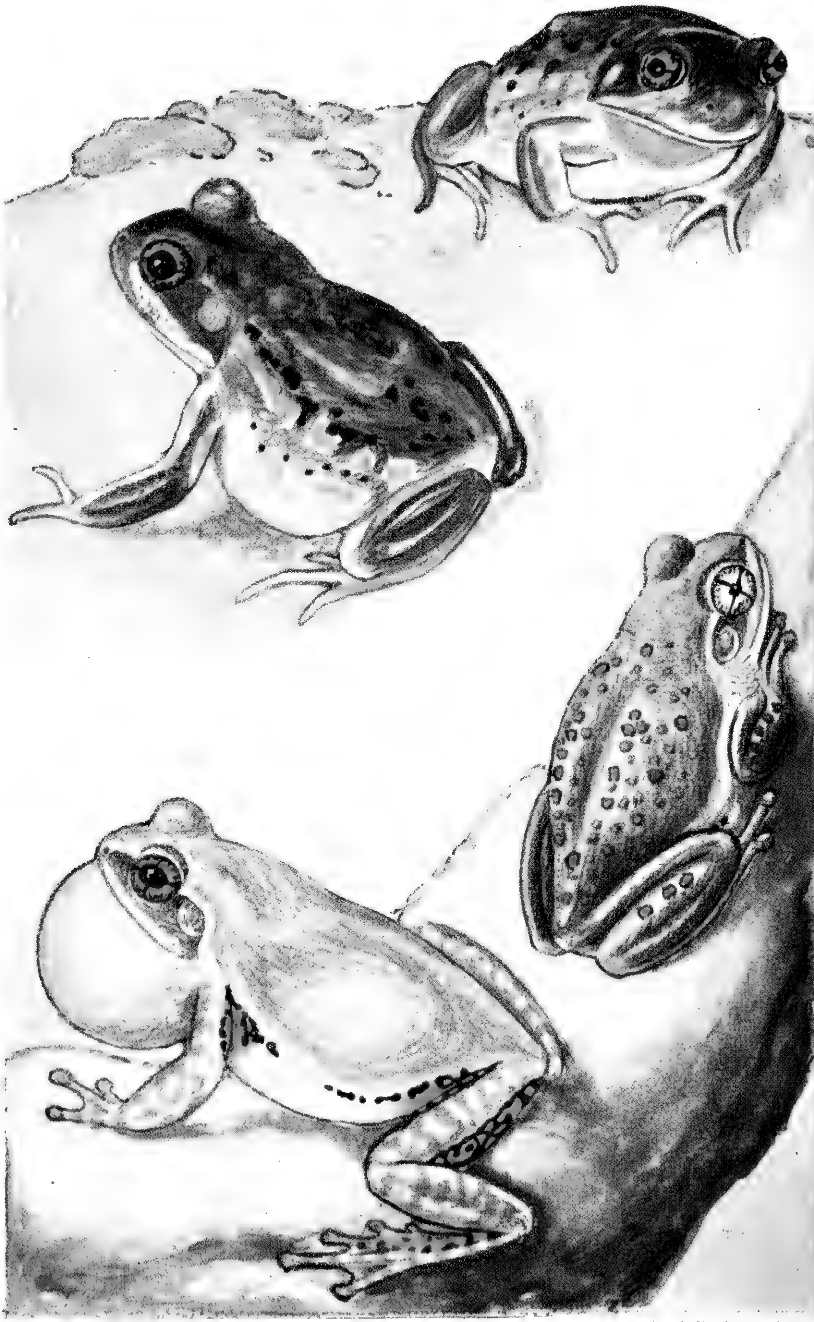
Structure: The snout is truncate and the canthus rostralis rounded. The interorbital space is wider than the diameter of the eye and the tympanum one-half the diameter of the eye. The arms and legs are slender, with the disks of the fingers and toes distinct. The skin is smooth and shiny. The male has a subgular vocal sac.

Size: From snout to vent it is one to one and one-half inches in length.

Range: Tropical America. This specimen has proven the hardiest of the smaller frogs brought from Costa Rica and lives on tiny fruit flies that are enticed into its terrarium with slices of banana, apple or pieces of wet bread. It can see a fly at quite some distance, and with short hops follows every turn of its flight until it alights within reach, when it is greedily snapped up. The tongue, which is not notched behind like that of the frogs of the genus *Rana,* can be thrust out for quite some distance. This curious little creature does not always hop, but will often elevate its body on its long slender legs and stalk around as though walking on stilts. The adhesive disks, although tiny, are large enough to enable this little frog to climb up the glass sides of its terrarium. Owing to their intensely bright coloration, Mr. Ditmars has suggested the very appropriate name of Harlequin Frogs for these odd creatures.

The frogs of the genus *Dendrobates* are known for the intensely virile poison contained in their skin secretion. This poison, especially that of *D. tinctorius,* has been put to several uses by the aborigines, one being that of an arrow poison, and another a bleaching agent, which turns the green of parrots' feathers to yellow. The poison, like that of the toads, has no power to injure by touch, acting only when injected into the circulation or rubbed into a deep wound. The life habits of these queer little creatures are also worthy of note, especially the nursing or carrying about of the tadpoles. These habits are shared by the frogs of the *Ranoid* genus *Prostherapis* and *Arthroleptis,* and by species of *Hylodes* of the *Cystignathidae.* As has been observed by the naturalists J. Natterer, H. S. Smith and A. Kappler, frogs of this genus will take their tadpoles upon their backs and carry them to another pool in times of drought. A. Kappler saw *D. tinctorius* and *D. trivittatus* in Surinam go into evaporating pools, sit still awhile and then emerge with tadpoles, some frogs carrying from twelve to eighteen, which adhered to their backs by means of a sticky secretion. Whether this secretion is exuded by the frog or the tadpole is not known as yet, nor has the sex of the nurse been determined up to the present writing.

Since the arrival of this collection additional material has been promised us by several gentlemen who have been to the canal zone and who, upon being shown the specimens, said that they were fairly abundant in those regions. Other interesting frogs, toads and tree toads have also been promised us from that region, and it is hoped that the writer will be enabled to make further observations on these interesting and little-known creatures. Much work is yet to be done in this line of investigation, and a large field is open for the student having the opportunity to observe these creatures in their natural environments.



Richard Deckert, pinx

FIG. 4. AUSTRALIAN "FROGS"

Sand "Frog", *Limnodynastes dorsalis*, Gray

Perron's Tree Toad, *Hyla perronii*, Bibron

(Two color phases)

FROGS AND TOADS FROM NEW SOUTH WALES.*

The Australian frogs and toads that are described in this paper will be of especial interest, since it is the first time that these important species have been exhibited in the Reptile House (alive) or the United States. Among them are included the following species:

Family BUFONIDAE—Toads.
Australian Toad, *Pseudophryne australis,* Gray.

Family HYLIDAE—Tree Toads.
Perron's Tree Toad, *Hyla perronii,* Bibron.
Golden Tree Toad, *Hyla aurea,* Lesson.
White's Tree Toad, *Hyla coerulea,* White.

Family CYSTIGNATHIDAE—Arch-Jawed Toads.
Sand "Frog," *Limnodynastes dorsalis,* Gray.
Silver "Frog," *Heleioporus pictus,* Peters.

Family BUFONIDAE—Toads.
Australian Toad, *Pseudophryne australis,* Gray. (Boulenger Cat. Batr. Sal. P. 277).

Color: Above, the body is blackish brown with a yellow or reddish narrow streak on the posterior back. The posterior sides of the arms are bright orange-yellow and the rear sides of the thighs usually have a few yellow spots. The throat, abdomen and under surface of the arms and legs are marbled black and white.

Structure: The head is rounded; canthus rostralis not produced. The interorbital space is as wide as the eyelid. The fingers and toes are short without web or dilatations. The skin is smooth or with a few indistinct flat warts. With the male there is an internal gular vocal sac, and an oval flat gland on the hinder side of each thigh. The pupil of the eye is horizontal.

*A resumé of the Families embraced in this article will be found in the preceding pages.

Size: One and one-quarter inches, snout to vent.

Range: Australia. The two specimens examined were from near Sydney, N. S. W. This little toad is said to be quite common all over Australia in localities favorable for amphibian life, and is interesting on account of its breeding habits. The large eggs are laid in damp places in numbers up to ninety under stones, stumps and other hiding places, and have been found in November, January and May near Sydney. Oviposition takes place after heavy rains and the next rain is depended upon to set the larvae free.

This may occur within two or three weeks, or three or four months. The embryo is very tenacious of life and, as noted above, will accommodate itself to remaining in the jelly-like mass of the egg for a long time. The actual limit for this has not yet been determined; four months being the longest time recorded. The two specimens now in our collection seem to be hardy, and live in company with *Hyla pickeringii* and *Dendrobates tinctorius* in a small terrarium, the bottom of which is covered with very damp wood-pulp.

They feed greedily on all kinds of small insects; the method of hunting differing from that of any frog or toad observed by the writer. Instead of hopping they slowly and deliberately creep up to their intended prey, moving each arm and leg separately, first an arm, then the leg of the opposite side, then the other arm and lastly the other leg, giving the whole movement a singular mechanical appearance. When about a half-inch from the insect, the tongue shoots forth with lightning-like speed and the insect vanishes. The toad retains its seemingly strained position until another victim is sighted, when the whole manœuvre is repeated. When disturbed, however, these toads hop in ordinary fashion.

Family HYLIDAE—Tree Toads.

Perron's Tree Toad, *Hyla perronii*, Bibron (Boulenger Cat. Batr. Sal. P. 390).

Color: Brown above, but subject to great variation and color-change. There may be a distinct pattern of dark marblings or dots, but when the animal is at rest, it is usually dark brown, without dark spots, though with bright yellow dots, which are lined with black and intermingled with emerald green spots slightly larger than the head of a pin. The abdomen is white, throat (male) marbled with brown, and the arm-insertion (behind), the groin and the concealed surface of thigh, calf and foot are bright orange, marbled with black. These colors are not seen when the frog is at rest. The eye is silver with the pupil contracted to a tiny square with four black lines radiating from it and dividing the eye into quarters. When active the color fades until the whole frog is pale reddish or yellowish brown and the arms and legs barred with darker brown. The color of the eye also changes, becoming bright yellow as the pupil expands into a regular, horizontal oval.

Structure: The head is broader than long, snout rounded and canthus rostralis rounded. Loreal region slightly concave. Interorbital space equal in width of the diameter of the eye. Tympanum distinct and two-thirds the diameter of the eye. The fingers are half webbed and the toes about three-fourths webbed, with large adhesive disks about half the diameter of the eye. The upper surface is sometimes smooth and occasionally covered with small roundish warts. A fold of skin extends from the eye over the tympanum to the shoulder, and another fold across the breast. The male has a large subgular vocal sac. The entire lower surfaces are granulated.

Size: It attains a length of two and a half inches from snout to vent.

Range: Northern and Eastern Australia and Tasmania.

One specimen from near Sydney, New South Wales, is in the collection of the Reptile House. It usually sits in a corner and near the top of its vivarium, with the pupils contracted, apparently sound asleep. At dusk it becomes active, climbing slowly over the glass sides of the case until it spies an insect, when it is capable of making enormous leaps. It does not seem particularly shy, and will allow itself to be handled, clinging to one's fingers with its sticky toes. When the plants in the Reptile House are being syringed in the morning and evening, the sound of the splashing water stimulates this tree-toad to giving voice to its loud call. This call resembles the noise of the pneumatic drill used by structural iron workers, and might be described as a loud, metallic rattling. The throat pouch is expanded into a large globe, larger than the tree-toad's head, while the entire body vibrates with the force of the exertion used in producing the call.

Golden Toad, Golden "Frog," *Hyla aurea,* Lesson (Boulenger Cat. Batr. Sal. P. 410).

Color: The general body color is a bright metallic green, sometimes bluish, sometimes yellow in tone. From the tip of the snout through the nostrils, over the eyes and tympanum to the groin, extends a wide brown band, and on the back there are usually a series of spots of varying size and shape, but of the same color, which sometimes fuse into longitudinal bands. A brown band, which becomes yellow or silver, passes from the tip of the snout along the upper margin of the mouth and ends at the shoulder. From the nostril through the eye, interrupted by the tympanum, is a black streak which ends behind the shoulder. The arms and legs are brown, the former spotted, and the latter longitudinally banded with green. All of the brown spots and bars may become beautifully golden or coppery bronze, and the glandular, lateral fold a pale, golden color. The color at the groin is deep blue-black. The sides are green, sometimes with a bronze shading, the tympanum bronze and the under sides pure, silvery white. The entire toad is subject to strong color changes, sometimes becoming plain blue-black with metallic reflections. The eye is large, brilliant and of a beautiful, reddish-gold color.

Structure: In general form it is like a *Rana.* The head is a little longer than broad, the interorbital space narrower than the eyelid, tympanum about half the diameter of the eye, canthus rostralis distinct and the loreal region concave. The fingers are free and the toes almost entirely webbed. The disks of the fingers and toes are small. The skin may be entirely smooth or warty above. A longitudinal fold extends from the eye to the groin. The male has two internal vocal sacs.

Size: It attains a size of two and a half to three and a half inches from snout to vent.

FIG. 5. GOLDEN TREE TOAD, *HYLA AUREA*, LESS.

FIG. 6. WHITE'S TREE TOAD, *HYLA COERULEA*, WHITE

Range: The Golden Tree Toad is found throughout Australia and some of the Australian Islands.

This is one of the commonest of Australian toads and is called "bell frog" in its native country. In shape, habits and actions it is absolutely different from any other species of the genus *Hyla,* so much so that other naturalists have made it the type of a distinct genus, *Ranoidea,* Tschudi. But the internal structure is that of a typical *Hyla* and Boulenger in his admirable "Catalogue of Batrachia Salientia," has included it among the *Hyla,* where it rightly belongs. It is a large, gorgeously colored species and reminds one of a water frog in appearance as well as in habits. In its terrarium in the Reptile House it will sit for hours on the ground or in the pan of water provided, never attempting to climb up the sides of its cage like its cagemates. It is also like the water frogs, distinctly cannibalistic, seemingly preferring small frogs to any other food. It is a greedy feeder and will eat all kinds of insects. After sundown its call can be heard in the Reptile House. This call is a long, drawn-out and loud croak, very coarse but sometimes ending in a bell-like note, "bong"; also very loud. The species is quite hardy and can endure considerable cold. At a low temperature it loses its beautiful tints and assumes a plain blackish-olive or blue-black color. It is most beautiful and active at a temperature of about 70 degrees F. When taken up it will struggle violently, and upon being released, hop away in a series of rapidly executed, enormously long leaps, reminding one of a water frog. Its eggs are laid in a white, frothy mass in pools, canals, wells or other permanent bodies of water, differing herein from most Australian frogs. Oviposition takes place during August and September. If these months should be dry, however, the species waits until the following spring. In its native country this species frequents permanent bodies of quiet water, never climbing on the bushes and trees surrounding such places, but always remaining at the water's margin, plunging into the protecting element at the slightest alarm, like a true water frog. The "golden frog" is hunted at night by the Australian natives (Bushmen), with the aid of lanterns and torches. Numbers of them are spitted upon a sharp stick as they are caught, roasted over an open fire, and eaten with great relish by the natives, without taking the trouble to remove the viscera.

White's Tree Toad, *Hyla coerulea,* White (Boulenger Cat. Sal. P. 383).

Color: The general color of the body is a bright, leaf-green to dark olive above; undersides pinkish-white, and the concealed surfaces of the thighs and arms, fleshy-pink. A few round or elongate white spots are sometimes present on the sides, limbs and back.

Structure: The head is large, broad and flat, with rounded and truncate snout, canthus rostralis distinct, loreal region concave and the interorbital space much wider than the diameter of the eyelid. A strong fold extends over the tympanum, which is from two-thirds to four-fifths the diameter of the eye, to above the arm insertion. The hands are large, fingers are webbed one-third and the toes almost entirely webbed. The adhesive disks are very large, those of the hands equal in diameter to the tympanum, those of the feet smaller. There is a tarsal fold, and the subarticular tubercle is prominent. The skin is smooth and shiny, much thickened on the head and scapular region, studded with large pores, and the under surfaces are granulate. The male has a large gular vocal sac.

Size: This species is one of the largest of the *Hylidae*, attaining a length of five inches; our largest specimen measuring four inches from snout to vent.

Range: Australia, Tasmania, Australasia, Malaysia. The nine specimens exhibited in the Reptile House are from New South Wales. This large and fine species is a typical *Hyla* in appearance as well as in habits. In its coloration, it is one of the most constant of all *Hylas,* resembling in this respect our own *Hyla cinerea, s. carolinensis.* The upper sides are always some shade of green. The iris is a beautiful, golden bronze when the frog is awake, and when asleep may be pale, silvery-blue. In the Reptile House it shares its terrarium with *Hyla aurea.* Unlike the latter, it is tame and confiding, and when picked up will cling to the hand, climb around it looking for a comfortable spot to sit, and upon finding one will settle down, tucking its hands and feet well under. A German naturalist named Riedel relates the following amusing incident, illustrating well the phlegmatic disposition of this tree-toad: He had taken a specimen to show a friend, placing it on the cover of a large beer-stein, such as are in general use in Germany. Whenever the owner lifted the stein and tipped the cover back to take a drink, he turned the tree-toad upside down in doing so. The latter did not jump, but clung to the cover with its enormous hands, and when the cover was placed in its natural position it immediately settled down in its former position, tucking its hands and feet under its body, always a sign of contentment. It remained thus on the cover of the stein for over half an hour, being frequently disturbed by the drinking operations of the owner.

This toad has the sense of locality very much developed, returning again and again to the same spot for basking or sleeping. In this it resembles our *Hyla versicolor*. On cold nights when all the other tree-toads in the collections creep under cover, these big fellows will be seen sitting motionless in their accustomed places. It will also sit for hours in the brightest sunlight, apparently as indifferent to the burning heat as it is to the cold. The voracity of this species is in keeping with its size. Anything is welcome from mice and small frogs to all kinds of insects, worms and small crustaceans. It will eat until abnormally gorged. In cleaning the vivarium, I had occasion to put these large tree-toads temporarily in another vivarium containing *Hyla arborea*, *Bufo calamita* and *Rana temporaria*. The big fellows were hardly placed in this cage when they attempted to capture and eat the smaller amphibians, and if they had been left to their own devices, would soon have swallowed all the rightful inhabitants. The call of the male can be heard in the Reptile House usually late in the afternoon, and consists of the syllables "*kra-kra-kra-kra*," repeated about twenty times. At first it is not loud, but gains in volume as the cry proceeds, until near the end it resembles the barking of a large dog. The enormous finger disks give this frog unusual clinging powers, and when one is lifted from its place, it will usually grasp any object near and hold on with such strength and tenacity that great care must be exercised not to injure the animal in trying to loosen its hold. *Hyla coerulea* breeds in permanent bodies of water such as cisterns, wells, reservoirs and canals. The spawn, like that of *H. aurea,* is laid in the water in large clumps and enveloped in a foamy mass that floats on the surface. In its native land, this species is found in numbers under the roofs of outhouses, verandas, and other places of concealment; sometimes coming into the dwelling houses at night, attracted by the light of lamps and by the presence of insects. When there is rain, the frogs around a house will set up a deafening din, almost driving the occupants to distraction. The species should be useful as an insect-destroyer on account of its size and proportionate voracity. The geographical distribution of this tree-toad is very extensive, ranging throughout most of the islands of the Pacific and even some of the Indian Ocean, this being probably due to the ease with which the frog can be carried from place to place in cargoes of lumber or fruit. The phlegmatic habits of this species, no doubt, also favor such distribution.

Family CYSTIGNATHIDAE—Arch-Jawed Toads.

Sand "Frog," *Limnodynastes dorsalis,* Gray (Boulenger Cat. Batr. Sal. P. 261).

Color: The color is variable, usually an olive brown, with or without spots. Our specimen is blue-black above with a few inky black spots on the sides and posterior back. A broad, yellow streak extends from in front of the eye to the commissure of the mouth, and a series of broad yellow spots, which in some specimens is blended into a band, from behind the tympanum to the groin. A second series of yellow blotches occurs below this, and a number of greenish-yellow spots on the upper eyelids and back and a narrow yellow streak on the coccygeal region. The outer edge of the tarsus and outer toe are yellow, and the rest of the foot bluish white. There are some yellow spots on the arms, belly white, and the throat yellow. The eye of both sexes is bright, golden-yellow.

Structure: The head is large and the snout rounded. The mouth is very wide, eyes large, very prominent and brilliant in coloring, pupil vertical and the interorbital space equal to the width of the upper eyelid. The tympanum is distinct and two-thirds of the size of the diameter of the eye; skin smooth above and below; arms and legs short, and the fingers and toes slender. Subarticular tubercles prominent. A cuneiform shovel on the tarsus. A parotid-like swelling on the calf (male only). The male has a subgular vocal sac. There is an elongate, yellow gland extending from beneath the eye to above the arm-insertion (see color description).

Size: Our specimen measures two inches from snout to vent.

Range: Australia.

This odd creature has a startling resemblance to our spade-foot toads, *Scaphiopus,* of the family *Pelobatidae,* in habits, coloring and structure. In Australia it occurs in sandy regions which are dry the greater part of the year—in fact, without permanent bodies of water, and is therefore compelled to await the occasional heavy rains for the consummation of its breeding operations. This is likely to happen almost any time of the year. The spawn is laid in frothy clumps in the temporary pools formed by these rains, and the metamorphosis is correspondingly rapid, exactly as in our *Scaphiopus.* In *Scaphiopus,* however, the eggs are laid in strings. The species is fairly common on the south coast and is called "sand frog" by the farmers. It is sometimes dug up in the gardens. Its habits are nocturnal as indicated by the vertical pupil, and it feeds chiefly on the large spiders that abound on the ground at night. In the Reptile House this frog is kept in a small terrarium in company with the Silver Frog and seems fairly hardy. It is a good feeder with cannibalistic tendencies. By day it lies buried in the fine gravel, but at night comes forth, sitting partly buried, alert for any insect that may come its way. It progresses by short hops of startling rapidity.

Silver "Frog," *Heleioporus pictus,* Peters (Boulenger Cat. Batr. Sal. P. 272).

Color: The body is yellowish or grayish olive with large black, brown or green spots. There is sometimes a pale yellowish vertebral line. A long, white gland extends from beneath the eye to the shoulder, and a black streak from the nostril through the eye to above the shoulder. The belly is white, and the throat (male) yellow. The arms and legs barred with the same color as the large spots on the back, and the eye is a pale, brassy yellow.

Structure: The head is moderately large and the snout rounded. Eyes close together; fingers and toes short; subarticular tubercles well developed and metatarsal tubercle large. Arms and legs short; tympanum indistinct; skin smooth and the toes very slightly webbed.

Size: Adult males one and a half to one and three-quarter inches from snout to vent.

Range: Australia (Victoria and New South Wales).

This species is not nearly so nocturnal as the preceding, and is always ready to feed on insects placed in its terrarium. In New South Wales it is called "silver frog" and seems fairly common around Sydney. Its eggs are laid in pools formed by the heavy rains and the metamorphosis is rapid, keeping pace with the evaporation of the water in the temporary pools. This species does not seem to be possessed of great powers of color-change, the specimens living in the Reptile House keeping the same dress under various conditions, which would induce other frogs, at least, to change from light to dark or vice versa. The call is a rattling croak which is not very loud, the throat pouch being inflated to the size of a small marble during the call. The "silver frog" is rather shy, squatting low in its vivarium upon being approached, and when further disturbed will dart about in great haste, seeking concealment. It is a ready feeder, however, and we hope to be able to keep it alive for some time to come.

ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

VOLUME II, NUMBER 2.

A TETRAPTERYX STAGE IN THE ANCESTRY OF BIRDS

By

C. William Beebe,
CURATOR OF BIRDS

PUBLISHED BY THE SOCIETY
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FIG. 7. TETRAPTERYX STAGE IN THE ANCESTRY OF BIRDS
The drawing is based on characters present in Archaeopteryx, and in the young of living birds

A TETRAPTERYX STAGE IN THE ANCESTRY OF BIRDS

BY C. WILLIAM BEEBE,
Curator of Birds.

I. Introduction.

II. Pelvic Wing:
- White-winged Dove.
- Domestic Pigeons.
- Jacana.
- Great Horned Owl.
- Archaeopteryx.

III. Argument.

PART I.—INTRODUCTION.

Our knowledge of the genealogy of birds is in inverse ratio to the abundance of these organisms on the earth today. We know of quite primitive forms of fish—both fossil and living—of reptiles and of mammals. But of living birds, those which show encouragingly primitive characters exhibit also an equal number of extremely specialized ones.

Some six or seven million years ago in the Cretaceous Period we know that there lived creatures which undeniably deserve the name of birds. Ichthyornis was a strong-flying, tern-like type with numerous, recurved teeth, and Hesperornis was also toothed, but practically wingless, essentially a diving bird, and on shore probably more helpless than a seal.

In the Jurassic, let us say four million years earlier, two more or less complete fossil skeletons have been discovered, and an odd feather or two of the famous Archaeopteryx, the *sine qua non* of avian genealogy. Teeth again we find in a very lizard-like head; delicate, weak, wing bones supporting a good-sized but rounded wing, and the fore limb terminating in three well developed, clawed fingers; a long, vertebrated tail, with a pair of excellent feathers sprouting at each joint and a pair of feet admirably adapted for perching. The unmistakably reptilian traces give weight to Huxley's superclass Sauropsida.

Slight though this evidence is compared to the imposing array of fossil reptiles and mammals, it nevertheless provides an unmistakable lead in the direction of small, arboreal, lizard-like creatures along a still earlier line of ancestry.

I do not wish in this paper to discuss, except in one respect, the various characters of Archaeopteryx. I am working out a life-sized restoration of a flock of seven of these winged creatures of ancient times and not until this is completed shall I feel confident of expressing any new views on the general character of this much discussed creature.

My present thesis, while in a way independent of Archaeopteryx, yet is given force in dynamic presentation by consideration of this strange creature.

Perhaps the most astounding thing about this being is the perfection of its wing and tail feathers. Without going into reasons, I am convinced that Archaeopteryx was a bird of very limited powers of flight. I am not certain that it could flap at all and if it could, its aerial feats hardly equalled those of a modern tinamou or domestic fowl. It certainly had very excellent powers of scaling, and in this direction probably exceeded any modern flying squirrel or lemur.

Whether this be conceded or not is aside from my point, which is concerning the origin of this wing. Our knowledge of the workings of evolution often enable us to visualize the growth and later development of an organ, its subsequent specialization and perhaps ultimate degeneration, while we utterly fail to explain its origin or early development. It is well within the limits of gradual cumulative variation to admit the change from an Archaeopteryx to a modern wing. The wing bones increase in size and those of the hand coalesce, the fingers become mittened in flesh and tendon; the primaries increase in number creeping out upon the phalanges, and the muscles wax stronger, become larger and find adequate place for attachment upon a greatly enlarged sternum. But how could the wing have reached its Archaeopteryx stage of development?

In Mexican or Neotropical jungles bordering rivers and streams it is a common sight to see great iguanas resting high among the upper branches and foliage. When suddenly alarmed or toward sunset, these great reptiles do not bother to climb slowly down along their back trails which they so laboriously mounted earlier in the day. They recklessly launch out into mid-air and with legs widely extended, body flattened, toes clutching at the empty air, they hurtle downward, landing with a crash into the underbrush or with a splash in the water. Perhaps their flattening may help somewhat to break their fall, but I doubt if this would save their life were they to land upon hard ground. Twice, in fact, I have seen iguanas after a bad take off, half turn in the air, so that they landed in the water on their side or in one case actually upside down, when the reptile seemed stunned for a minute before it turned over and swam from sight. Here, it seems to me, we have a very probable *anlage* of scaling flight, as ultimately perfected in Archaeopteryx.

But if we arm our imaginations with a prejurassic, parachuting lizard on the one hand, and Archaeopteryx on the other, we still have a hiatus which no logical combining of proportional characters will bridge. Suppose if you will that the scales along the posterior edge of the fore leg and those along the tail begin to lengthen. Carry these along to a fair development and then start the hopeful organism out into mid-air and it will prove an utter failure. The scaly primaries may be sufficient to support the front part of the body, but the tail scales would certainly not suffice both to balance and to bear up the remainder of the lizard. The result would be a woeful sagging which must bring instant disaster,—a herpetological Darius Green which could not hope to leave offspring to work out their fossil destiny. The development of scaling flight with nothing to correspond to the great lateral and caudal membranes of flying mammals is inconceivable. Something is needed to bridge over the very beginnings of the parachuting wing function. Even a flying fish has two nodes of aerial support during its brief essay into a thinner medium. It spreads capable little planes aft as well as forward. Cut off the pelvic fins and I imagine it would plop hindmost into the water almost as soon as it emerged. Some such accessory has always seemed to me necessary if we are to complete our lizard-to-Archaeopteryx line of ascent.

Recently, while examining the fresh body of a four-days'-old White-winged Dove in the New York Zoological Park, I observed on its almost naked body a remarkable development of sprouting quills across the upper part of the hind-leg, and extending toward the tail across the patagium just behind the femur. A second glance showed that this was no irregular or abnormally precocious development of part of the femoral pterylum, but a line of primary-like sheaths, many of which had a very definitely placed *covert*. The iguana-Archaeopteryx puzzle flashed through my mind and I at once followed up the clue thus given. For the two sketches illustrating my idea of the Tetrapteryx Stage of alar evolution I am indebted to Mr. Dwight Franklin.

Part II.—Pelvic Wing.

The detection of this interesting character occurred in August, too late for observations on many forms of nestling birds. I embody in the following notes all that I have been able to gather together on the existence of this curious *pelvic* or *femoral wing*.

White-Winged Dove.

Melopelia asiatica (Linn.)

Several of these birds had been reared during the present season in the special breeding cages of the New York Zoological Park. On August 19 a four-days'-old squab, the only nestling of a second brood, was found dead in its nest and brought to me.

Its leaden grey body appeared almost bare, being covered sparsely with the characteristic short, greyish white, filamentous down. Three areas showed precocious development of contour feathers, the wing proper, the pelvic wing and the tail. In the former, twenty-two flight feathers were developed, of which ten were primaries averaging 10 mm. in length, nine were secondar-

FIG. 8. DOMESTIC PIGEON SQUAB

Showing great development of the pelvic wing. The leg is flexed, hence this atavistic wing is folded

FIG. 9. SQUAB OF WHITE-WINGED DOVE

Four days old, with wing and leg extended, showing the wide spread pelvic wing

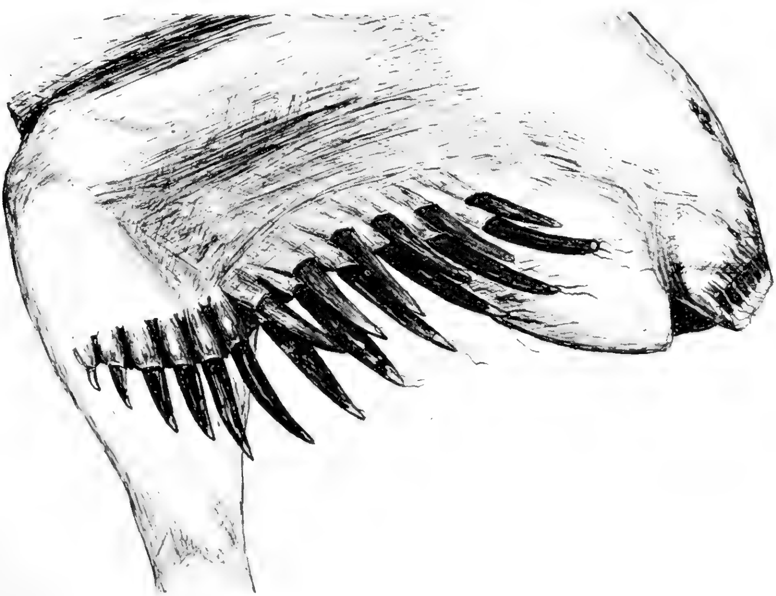

FIG. 10. DETAIL OF PELVIC WING OF WHITE-WINGED DOVE, SHOWN IN FIG. 9

The wing consists of twelve flights and six coverts

ies, grading inward from 8 to 5 mm., and three were tiny tertiaries. The primaries had only a single row of strongly developed, greater coverts. Four rows of secondary coverts were sprouting, the central ones pure white, indicating the future color pattern of the wing.

Next in development to the wing proper, were the feathers of what, for lack of a better name, I call the pelvic wing. This seems inexplicable on any other hypothesis than the vestigial secondary plane, which must have been of the utmost importance in the ancestral scaling flight.

This area begins on the anterior outer edge of the crus or leg proper, about one-third of the distance down from the knee. From this place it extends backward across the tibia almost at right angles to the backbone of the body, and, posterior to the femur, following the patagium, which lies between the leg and the body. It ends on the side of the body at an equal distance from the outer tail feather and from the pelvis between the acetabula. The areas are similar on both sides. There are twelve main or flight feathers. Feathers 1 to 6, extending from the body outward along the femoral patagium, all have a well-developed covert. The next six flights, numbers 7 to 12, lie close together on the flesh of the leg itself and show no signs of coverts. Counting from within outward these feathers measure as follows:

Flights	4.5	5.5	5.5	6	6	6	6	5.5	5	4	3	1 mm.
Coverts	3.5	4	4	5	5.5	5.5						mm.

The tail is much less advanced than the pectoral and pelvic wings, the rectrices and a single row of upper and another of under coverts being all equally advanced, measuring uniformly 3 mm. in length.

The pelvic wing tract is not apparent in the adult pterylosis of *Columba livia* as given by Nitzsch.[1] Its course is approximately along the upper margin of the crural tract, and continuing toward the tail well into the posterior part of the femoral or lumbar pterylum. In fact, the remaining pterylae of the body are very indistinctly demarcated in the down of this young squab.

[1]Pterylography, Nitzsch, Ed. by Sclater, 1867, plate VII, fig. 2.

Domestic Pigeons.

Columba livia Bonn. (var.)

The pelvic alar tract is less regular in domestic pigeons than in wild birds, but is remarkably well developed. I give the results of my examination of four squabs taken at random from a large number.

A. The first was about a week old and the pelvic alar tract shows seven flights and four coverts. Always counting postero-anteriorly, the measurements in millimetres are as follows:

Number of feather	1	2	3	4	5	6	7
Length of flights	6	7	8	6.5	5.5	3	2
Length of coverts	4	6	5	3			

B. A squab two weeks old shows ten flights. The posterior four are uniform; they have well developed upper coverts, which are small and lie close above the main feather. From the 5th onward the coverts give place to a row of under coverts. As we go forward, the flights and their coverts become less closely associated, until only the slight difference in elevation of the two most anterior pairs reveals their true relationship. The most anterior flight is isolated and covertless.

Number of feather	1	2	3	4	5	6	7	8	9	10
Length of upper coverts	5	5	5	3.5						
Length of flights	6	7	8.5	9	7	6.5	6.5	5.5	4	3
Length of under coverts					4	3.5	4.5	4.5	4	

The precocious development of the feathers of this tract may be realized when compared with those of the true wing and tail in this same bird. The primaries and secondaries are all under five millimetres and the rectrices not more than two in length, while, as we have seen, seven out of ten of the pelvic flights are six millimetres or more, the general average over seven, and the maximum length nine millimetres.

C. A squab about three weeks old shows twelve pelvic flights. The arrangement of coverts is as follows:

Flight No. 1—small upper covert.
2—small upper covert.
3—down covert.
4—down covert.

5—small under covert.
6—down under covert.
7—large under covert.
8—large under covert.
9—large under covert.
10—large under covert.
11—no covert.
12—no covert.

D. A squab of five weeks shows that no additions occur at the posterior end of the pelvic alar tract. The next contour feathers to appear at this point form an ascending series of three, parallel to the backbone and at right angles to the pelvic alar tract. The first four flights with their upper coverts are well grown, far ahead of the rest of the body plumage. The coverts indeed are quite full grown, downy and white-shafted. As in squab C the flights from the 5th onward have under coverts. Altogether there are nine flights with coverts, and three anterior covertless ones.

While considering this newly observed character of pigeons, I thought of the feather-footed breeds and sent for a pair which I carefully dissected. I found no connection between these feather-footed and feather-legged domestic breeds and any unusual development of the pelvic alar tract. The feathers, which have been bred to great length, sprout from the scaly covering of the tarsus and phalanges and not from the leg proper or the femoral patagium, which is the seat of the character under consideration.

Jacana.

Jacana jacana (Linn.)

In a half developed embryo the rectrices and pelvic alar feather papillae are well ahead of all others, even of the wing proper, and are the only ones which show any trace of pigment. In the pelvic alar tract there are four flights and three upper coverts, the anterior flight lacking a covert. In a second embryo, a day or two older, five flights and four coverts are visible in this tract.

Great Horned Owl.

Bubo virginianus (Gmelin)

A brief examination of a living bird showed that the great development of soft plumage on the leg of this species arises from the pelvic alar tract. I was led to expect this from the pterylosis of *Strix bubo,* as given by Nitzsch.[1]

In his figure of *Columba livia*[2] there is, as I have said, no hint of the great development of the pelvic alar tract in the young bird, nor its remarkable disagreement with the lines of demarcation of the pterylae of the adult.

Judging merely from the pterylosis of the adult, many species of *Coraciiformes, Scansores* and *Piciformes* should show most interesting developments of this tract in the young birds.

Archaeopteryx.

The foregoing observations on various species of living birds were inaugurated and completed before I took up the question in regard to Archaeopteryx. I realized that any trace of this pelvic alar tract which might be present in this ancient bird would be of superlative interest and significance, but until I carefully examined a full-sized photograph of the Berlin specimen I was not aware of the existence of feathers other than those on the wing and tail. I succeeded in finding distinct traces of strongly marked feathers on both sides of the tibia and of still larger feathers, lying between the pelvis and the bent back head. It seemed to me that such very evident traces could not have escaped the observation of other students of this wonderful fossil and I began a search of the literature. I was delighted to find that the tibial feathers had already aroused considerable discussion and I present this in abstract to show how variously the scientific mind has reacted to evidence of this character, unsupported by any other more modern proof. The London Archaeopteryx shows no trace of these feathers, so the whole evidence lies with the single fossil in the Berlin Museum.

[1]Pterylography, 1867, plate II, fig. 9.
[2]Id, plate VII, fig. 2.

The bibliography of this discussion is a short one:

VOGT:
"L'Archaeopteryx macrura.—Un intermédiaire entre les oiseaux et les reptiles." *Revue Scientifique,* 1879, (2) IX, p. 245.
EVANS:
"On portions of a Cranium and a Jaw of the Archaeopteryx," Preface to reprint, 1881, pp. 4-6.
DAMES:
"Ueber Archaeopteryx," *Paleontologischer Abhandlungen,* 1884, II. pp. 39-41.
ABEL:
Grundzüge der Palaeobiologie der Wirbeltiere, 1912, p. 343.
HEILMANN:
"*Vor Nuvaerende Viden om Fuglenes Afstamning,*" p. 14. Saertryk of Dansk Ornithologisk Forenings Tidsskrift.

Vogt is the first to mention the feathers whose impressions are visible on the leg of Archaeopteryx. "Le tibia était couvert de plumes dans toute sa longueur. L'Archaeopteryx portait donc des culottes, comme nos faucons, avec les jambes desquels sa jambe a le plus de resemblance, suivant M. Owen." [1]

J. Evans devotes several pages to these feathers and their significance, and a few years later Dames takes issue with him. The following sentences present Evans' view: " . . . . along the outer margin of the right tibia, there is a series of eight or possibly nine feathers of much the same character as those along the tail, and nearly, though not quite, of the same length . . . . Prof. Marsh has, indeed, already suggested that the power of flight probably originated among the small arboreal forms of reptilian birds, and has instanced the flight of *Galeopithecus,* the flying squirrels (*Pteromys*), the flying lizard (*Draco*) and the flying tree-frog (*Rhacophorus*) as indicative of how this may have commenced. Should it eventually prove to be the case that there were what may be termed supplementary wing-feathers on the hinder extremities of such early forms of birds as the Archaeopteryx, his views as to the origin of the powers of flight will be satisfactorily confirmed."

Under the heading "Das Federkleid," Dames devotes considerable space to these tibial feathers. He admits them as

[1]Quite unconnected with the present thesis, but interesting as a sentiment expressed thirty-six years ago, the following paragraph by Vogt is worthy of note: "M. Volger se berçait dans l'espérance que S. M. l'empereur Guillaume achèterait la piecè (Archaeopteryx) pour la conserver à l'Allemagne. Sa Majesté n'entra pas dans ces vues. Ah! si au lieu d'un oiseau, il s'etait agi d'un canon ou d'un fusil pétrifié!"

culottes or what we would call a booted feathering, but denies their function as assisting in flight. Without following his involved arguments, he says in part:

"Zunächst ist es nicht richtig, dass diese Federn dieselbe Consistenz gehabt haben, wie die des Flügels und des Schwanzes, denn sie sind weit undeutlicher erhalten, auch beträchtlich kürzer (Länge durchschnittlich 32 mm. lang) als die Schwanzfedern, welche im mittleren Theil des Schwanzes ungefähr 65 mm. lang sind; . . . . sondern halb so lang . . . . Wenn man aber trotz alle dem doch noch an der Möglich keit, dass Archaeopteryx auch mit den Hinterbeinen geflogen sei, festhalten wollte, so wäre dem noch entgegenzuhalten, dass diese Eigenschaft nothwendig auch irgend welchen Ausdruck im Bau der Knochen der Hinterextremitäten erlangt haben müsste."

The two most recent commenters on this subject differ as completely as do Evans and Dames. Abel in his interesting subheading of "Die mangelhafte Ausbildung des Flugvermögens von Archaeopteryx," writes: "Die zweizeilige Befiederung der Unterschenkel spricht dafür, dass diese Federn den Flug der Archaeopteryx als Fallschirmapparate unterstützt haben."

Heilmann, writing in Danish, gives his opinion in an equally pithy phrase; "it is improbable that the feather coating on the tibia (as assumed by some authors) was of any importance in flight, as it appears too weak.[1] "

Part III.—Argument.

The pelvic alar tract as I have found it in modern birds is remarkably uniform in position, originating on the anterior outer side of the tibia below the knee, and extending back, along the femoral patagium, to the body and toward the tail. The feathered patagium between the extended leg and the body must have been of the greatest importance, for the feathers sprouting in this area in the young bird are of very large size and invari-

[1]Altsaa rimeligvis paa Overgangen mellem Faldskaermssvaeven (som vi f. Eks. traeffer den hos Flyveegern) og ubehjaelpsom Flagreflugt.

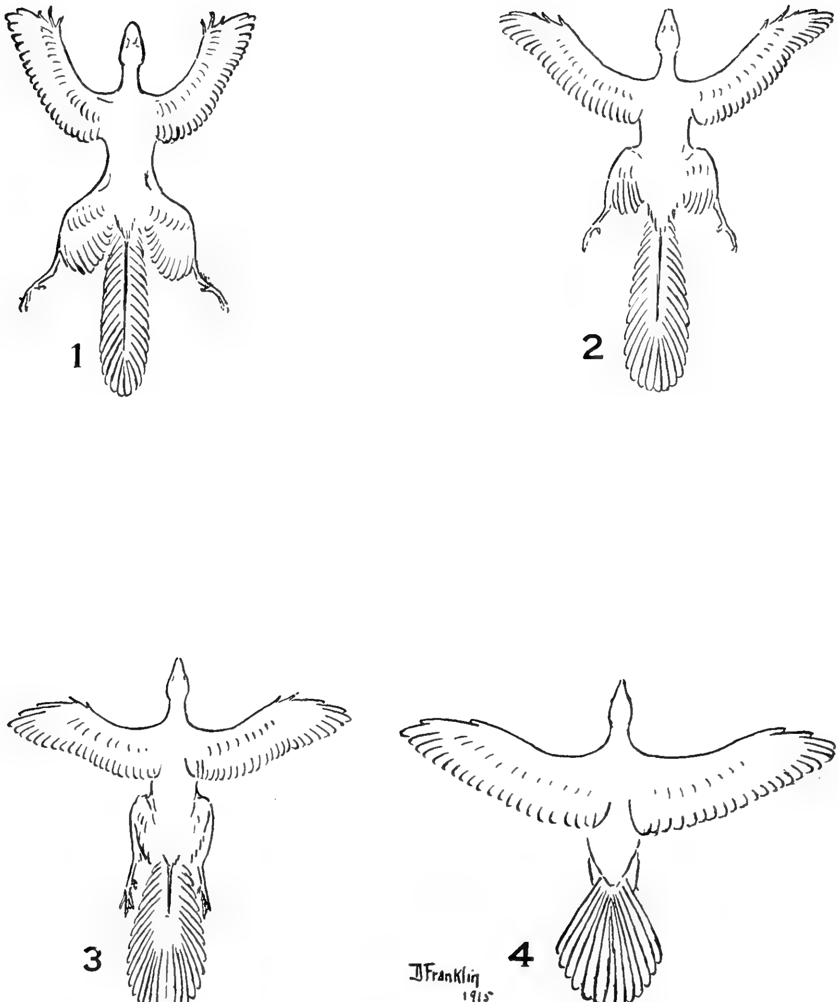

FIG 11. THE EVOLUTION OF BIRDS FROM THE TETRAPTERYX STAGE (No. 1), THROUGH ARCHAEOPTERYX-LIKE STAGE (No. 2), TO THE MODERN BIRD (No. 4).

The principal changes were the feathering and mittening of the fingers; the great strengthening and centralizing of the pectoral wing; the correlated reduction of the femoral or pelvic wing; the shortening of the tail and the concentration of the tail-feathers

ably provided with coverts. This is the pterylum which we hope to find paralleled or directly represented in Archaeopteryx.

The most cursory examination of the fossil reveals the beautifully preserved wing and tail-feathers. Very faint and not at all certain traces have been thought by several observers to represent a ruff of soft feathers at the base of the neck. We have already seen the diverse opinions which the two rows of tibial feathers have aroused. Besides these feathers there have been noted traces of small, soft, covert-like feathers covering the bases of the wing and tail feathers. The remainder of the body has, wholly without reason, been adjudged as scaly. On circumstantial evidence, but equally improbably, others have considered it as quite naked. The most reasonable hypothesis is that the body was fully clothed in soft, rather downy plumage. When the bird died, it fell upon the mud of some river or shore and there, like the remains of gulls which we may find today, it was slowly disintegrated by the elements to a point where all the soft, body plumage was detached and washed or blown away. At the time of being imbedded in the fine silt it retained only the strongly socketed wing and tail feathers and those clinging to the hinder extremities.

The most perfectly preserved part of the London specimen of Archaeopteryx is the tail. From base to tip it is almost without a flaw, and the relative length and position of the feathers are as distinctly seen as in the living bird. The outline of the tail as a whole is like that of a broad, truncated feather, tapering gradually to the base. I mention these details in order to compare them with those of the tail in the Berlin specimen of Archaeopteryx. Here the tip of the tail is lost, but the base is quite distinct. We can observe the same gradual narrowing, due to the increasing shortness of the feathers toward the pelvis. Between the bent-back head and the pelvis, however, we see impressions of feathers which are longer than any at the base of the tail. Their origin is indefinite, somewhere near the pelvis or femur, and they arch up and backward as distinctly as many of the tail-feathers themselves. It seems reasonable to me that this group of feathers, which somewhat resembles a diminutive wing, may represent the pelvic alar tract which is so remarkably developed in modern squabs.

This character is plainly visible in any good photograph of the Berlin Archaeopteryx. Lankester[1] shows it very distinctly in his reproduction of the fossil. As to the much-discussed tibial feathers, I agree with Evans and Abel that they seem too pronounced in outline to be classed with the downy feathers such as we see on our booted falcons. I think they are the distal elements of the pelvic wing, of far less importance as a *fallschirmapparate* than the larger feathers near the pelvis, which probably arose from the femoral patagium. Most students of this bird have ignored these tibial feathers and in restorations they are usually omitted. Miss Woodward in her artistic plate[2] shows them as soft and fluffy.

Heilmann has approached the general subject of the origin of birds in a most delightful manner. His illustrations show real imagination, using that much abused word in its most admirable sense. Unfortunately his Danish text limits the possibility of wide appreciation. While, as I have shown, he does not believe that the tibial feathers were of volant function, yet, curiously enough, in his very original and dramatic restoration of Archaeopteryx,[3] he has indicated a line of large feathers near the pelvis, which in position correspond to the inner feathers of my pelvic wing.

The argument of Dames against the possibility of the hind leg functioning in aerial activity is at fault. It is naturally impossible to conceive of a skilful flier, flapping with both arms and legs, and with ability for sustained and directive flight, to have evolved such a complicated dermal apparatus without corresponding changes in muscles and bones. But in Archaeopteryx or in our prejurassic Tetrapteryx, the function of the pelvic wings would have been merely passive parachutes. In this early stage, as probably also in Archaeopteryx, flight was merely gliding or scaling. The fingers were too free, the arm bones too delicate, the sternum small or absent, and these facts considered in

[1]Extinct Animals, 1905, p. 238.

[2]Evolution in the Past, Knipe, 1912, p. 96. (II).

[3]Vor Nuvaerende Viden om Fuglenes Abstamning, fig. 11.

connection with the small, weak pelvis, makes it impossible to picture the bird as flying skilfully about.

In earlier, lizard-like, aboreal forms, the scale-anlagen of the wing feathers were correlated with corresponding developments along the hind leg, the two increasing equally in size and evolving feather lightness with change in structure.

Even in Archaeopteryx, with its broad, excellent wing, the hand shows little or no correlated adaptation. The absence of two digits has probably no avian, or certainly no volant significance, for we find identical conditions in the manus of carnivorous, bipedal but terrestrial dinosaurs, such as Ceratosaurus, Ornithormimus and Ornitholestes.

If we admit Archaeopteryx to the direct line of lizard—Tetrapteryx—bird geneology, we must conceive of it as having reached a stage where the pectoral wing was becoming dominant, and beginning to afford support to the creature in general. The elongated flight feathers were now extending backward and superceding the passive function of the pelvic wing. With this concentration of motive and supporting power was soon to be correlated a shortening and reduction of the long unwieldy tail.

In succeeding generations the pelvic wings would become more and more reduced. Having arisen from among the surrounding scales, they had, for a time, volplaned through the air of early ages, a character passive and, as future centuries would show, of merely transitory function. Yet they were of tremendous importance in allowing the pectoral scales to develop, to become feathers, and then to assume an importance which was to make the class of birds supreme in the air. Yet the function of the pelvic wings had been so passive and negative that no special muscling had been necessary, no increase nor coalescence of bony tissue. Little by little the line of feathers and their coverts sank again into insignificance and became lost among the body plumage. It affords an excellent example of what Professor Henry F. Osborn would call the phylogenetic accelleration of a character, followed by its gradual reduction.

Millions of years after they were of use, the feathers of the pelvic wing are still reproduced in embryo and nestling. And for some unknown reason, Nature makes each squab pass through this Tetrapteryx stage. The line of feathers along the leg of the young bird reproduces on this diminutive, useless scale the glory that once was theirs. No fossil bird of the ages prior to Archaeopteryx may come to light, but the memory of Tetrapteryx lingers in every dove-cote.

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By

C. William Beebe,

CURATOR OF BIRDS

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FIG. 12. THE CINNAMON TREE OF THE BIRDS
The Utinga Jungle

Volume 2. Number 3.

NOTES ON THE BIRDS OF PARÁ, BRAZIL

BY C. WILLIAM BEEBE,
Curator of Birds.

PART I.—INTRODUCTION.

Belem or Pará is a city of about two hundred thousand inhabitants. It is a hundred miles from the sea, on the south bank of the Amazon delta, and only one hundred and sixty kilometres south of the equator, built on low swampy land. The birds in the vicinity have been collected assiduously and offer little chance of novelty to the transient ornithologist.

During the first part of May of the present year I had the opportunity of spending a little time in the jungle in the immediate suburbs of Pará. Through the courtesy of the Governor and of Dr. Snethlage I was given the use of a house at the water-works, in a large restricted area of jungle known as Utinga, and here every facility was afforded for collecting and study. Unexpectedly meeting Mr. George K. Cherrie, who had just come down the Amazon, I prevailed upon him to share our opportunities and with my companion Mr. G. Inness Hartley, spent a few days together. I found the region to be of much greater interest than I had expected and by resorting to a rather novel method of observation I obtained a new angle upon life in these tropical lowlands, and one which profoundly impressed me as to future possibilities in this direction.

PART II.—GENERAL ECOLOGY.

The Utinga water-works consisted of a pumping station from which radiated long open cement water-ways and closed pipes leading straight through the jungle. The light jungle began at the very edge of the small clearing which was within a few minutes' walk of the tram line leading directly back to the heart of the city.

It was without question quite the hottest, most humid tropical place I have ever encountered. I qualify with humid as I have known the dry heat of India to be much greater, as 110° F. at eleven P. M. at Agra. But this moist heat was in excess of any corresponding temperature I have known in Malaysia, Borneo, Mexico or elsewhere. It was the rainy season and the first day of our stay bore out the reputation of Pará for precipitation, the rain pouring down much of the day. During all of the remainder of our stay, the weather was ideal, clear until about 2:30 P. M., when dark clouds and wind came up, the rain continuing until 4 P. M. On only one day it rained for twenty minutes in the morning, with the afternoon shower as usual. The nights were, of course, cool.

Birds were most abundant from 8 to 10 A. M. and 2 to 5 P. M. while at mid-day, all songs and chirps ceased and only the occasional note of an insect broke the stillness.

Most of the birds had just passed the breeding season, and a goodly proportion of those secured were full-grown young. Both young and adults were molting or just completing the molt. In general they corresponded to our northern birds in August and September. A few, however, were preparing to nest and several were building. Blue tanagers had a nest a few yards from our house with two young which flew on May 8th. Yellow-backed caciques had several small colonies in isolated trees near native houses and were breeding.

Much of the land between the small streams or igarapés was marshy and covered with an almost impenetrable cover of undergrowth. Occasionally a slight rise resulted in dry ground and here the growth became higher, more open and assumed the general character of almost primitive tropical jungle. A narrow trail opened into jungle of this character only a few yards from our house in the pumping-station clearing. It led straight northwards for about two hundred yards when it ended in open, overgrown fields. Along this trail the undergrowth was fairly dense, with here and there a giant buttressed tree, surrounded by lesser trees of many species.

On the first tramp I took in the jungle I noticed a number of small birds in the upper branches of a tree which grew alongside of this trail. Not until I had passed that way several times did I come to realize that this particular tree had some powerful attraction for birds of many species. Knowing the shortness of time at my disposal I determined to concentrate my efforts on this tree which was a species of wild cinnamon. The present paper has to do chiefly with the facts thus obtained.

Once having our attention called to this bird tree, Mr. Hartley and I kept on the watch for others. Several hundred yards away along a pipe line we discovered another. It was a real giant, towering high above all the surrounding growth and we named it the toucan tree as it appeared to be especially attractive to these birds. It was covered with an abundance of good-sized scarlet fruit, the size of which accounted for the presence of medium and large birds such as toucans, caciques, trogons and kiskadees, instead of smaller callistes and flycatchers. A third berry-laden tree half a mile to the eastward straight through the jungle, bore oblong, yellow-skinned fruit appealing especially to woodpeckers and flycatchers, and from the brief glimpses we had as we passed, the constant abundance of birds would have furnished as interesting a list here as at the tree near our house.

I began my study of bird-life in the wild cinnamon tree by stealthy approaches, working my way through the jungle until I was close underneath. I soon found that this was quite unnecessary, as the birds among the upper branches paid no attention either to me or the sound of my gun. Three hours of constant observation beneath the tree resulted in many hours of pain from strained neck muscles. On the third day I brought out a canvas steamer chair and placing it in the trail at a convenient spot, found it to be ideal for observation. I could recline so that looking straight upward was no effort. With gun on my knees, glasses around my neck, note-book and dead birds on a stump within reach, I had discovered a truly *de luxe* method of tropical bird study. The biting flies, gnats and mosquitos made it impossible to sit absolutely quiet for more than a minute, and the ants soon found the legs of the chair gave easy access to one's person. On the whole, however, I was too much absorbed in the novelty of the method of work and its unexpected results to give any thought to these annoyances.

The principal jungle bloom was the heliconias, whose scarlet, jagged spikes glowed brightly against the dark foliage. Variegated leaves were abundant and when the slanting sun struck through the jungle, it often appeared vivid with color. The jungle about my seat was, of course, more or less impoverished by the nearness of the city and the presence of the waterworks. Black capuchin monkeys of more than one species were hereabouts and I saw as many as nine in a band. Three-toed sloths were common as were agoutis and small squirrels. But during my periods of watching no mammal came near the tree.

The more frequent sounds were the common ones of light jungle, Tinamou called and answered one another, gold-birds lifted their wonderful voices far away in the forest, toucans yelped, caciques squeaked and gurgled overhead, cicadas shrilled and buzzed and great bees and hummingbirds whirred past. The commonest cicada had a note like a person calling a cat *puss-puss-puss* kept up interminably in a high soprano. Another had a shrill, strident note which, when it gained full strength, quavered and broke into two alternating tones, which finally ran together into a true trill. After the daily rain, the tiniest of frogs would each strike up a single, shrill note, unceasingly reiterated. The most memorable sounds were the deep, gutteral voices of great frogs hidden in the igarapés, who reiterated the never answered syllable, wh——y? wh——y?

My business was chiefly with the birds which I could observe from my canvas seat. I spent from two to six hours each day for a period of one week in the immediate vicinity of the tree and during that time identified ninety-seven species of birds, none of which were more than a few yards from the trail. A further division of these is as follows:

Aerial species flying overhead	7
Birds of the surrounding jungle	14
Birds observed in the tree	76

FIG. 13. UTINGA JUNGLE FOREGROUND

FIG. 14. PARASOL ANTS ON THE MARCH

I shall reserve the details of the various species until later pages, and here give only a résumé of the more general points of interest.

Of the seven aerial species, one was a vulture, one a nighthawk, one a swift and four were swallows. These all came into view at one time or another across the patch of sky visible beyond the upper branches of the tree. Now and then birds of prey appeared, but at such great elevations that I was unable to identify them.

The fourteen birds of the surrounding jungle may be divided thus: one tinamou, dove, woodpecker, kingfisher, trogon, ani and woodhewer, two antbirds, two flycatchers and three finches. In one or two instances these were birds of adjoining fields which had strayed a little way into the undergrowth. The majority, however, were typical of the lower jungle strata, either terrestrial or living in the low undergrowth.

This series of strata of bird life visible to me as I sat quietly hour after hour was very striking, a phenomenon which would never come to one while moving about through the jungle. Bound to the ground were the tinamou, and almost as terrestrial were the rustling ground doves. In the lower underbrush finches, *Synallaxis* and antbirds moved restlessly; a little higher manakins whirred about and woodhewers hitched up the trunks. Then came the birds of the upper branches, callistes, tanagers, flycatchers, toucans and parrakeets. Then the low flyers—the swallows, martins, swifts and nighthawks, and finally the vultures, hanging like the faintest of motes in the sunlight high above the earth.

Part III.—Canella Do Matto and Its Bird Life.

The tree which I have already mentioned grew only about one hundred yards from our house at the pumping station and within five minutes' walk of the Pará tram line. It was at the side of a jungle trail, which, while seldom traversed by natives, was kept clear of vegetation by the workmen at the pumping station. It was smooth-barked, richly decorated with lichens and while only about fifteen inches in diameter at a man's height above the ground, it was very tall in proportion. The first branches were small, mostly dead and about fifty or sixty feet up. From this point the trunk split into lesser divisions and lifted its topmost foliage into the full tropical light and heat a hundred and ten feet above the ground. The berries were small, round and three-parted and, like the leaves, slightly acrid, with a spicy, aromatic flavor.

A few minutes after dawn I have counted eight birds in the tree and a half dozen would sometimes linger until dusk. As a rule, however, there were few in sight until 7:30 or 8:00 A. M., after which there would be a continual coming and going until the heat of mid-day drove all to shelter. The larger number of afternoon visitors came after the rain was over. Sunshine had much to do with the presence of the birds, and a cloudy half-hour meant but scanty notes as I sat beneath. With the reappearing of the sun, the birds would again begin to flock from the surrounding jungle.

Abundance of species and relative fewness of individuals is a pronounced characteristic of any tropical fauna. This was beautifully shown by my first two days' collection from the tree, collecting too, which was quite indiscriminate in character, very different from the more careful picking and choosing with which I shot on succeeding days. The first day I secured sixteen birds, all of different species. The second morning I got fourteen, all different, and only one of which was represented in the lot of the previous day. Thus in five hours' time I secured thirty specimens of twenty-nine species. From the entire district of Pará, three hundred and seventy-nine birds have been recorded. In this single tree within a week's time and during a period of intermittent observation I found seventy-six species.

The bird visitors to the tree arrived in one of two characteristic ways. Many came direct and swiftly, singly or in pairs, flying straight and with decision as if from a distance. A hundred yards away in any direction this convergence could frequently be observed, small birds flying over the summit of the jungle revealing a general flight direction treeward. Another method of arrival was wholly casual, loose flocks drifting slowly from the neighboring jungle, sifting into the tree and feeding

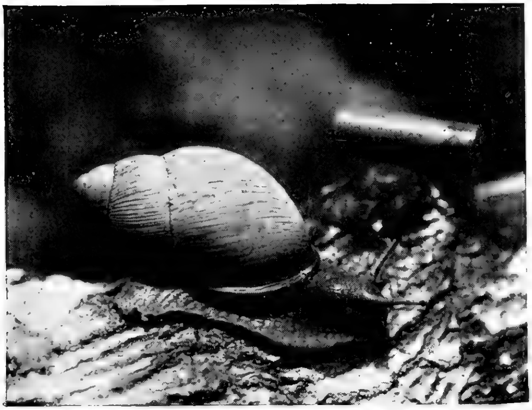

FIG. 15. GIANT LAND SNAIL

FIG. 16. NEST OF SAÜBA ANTS

for a time before passing on. When these left it was rather hastily and in answer to the chirps and calls of the members of their flock who had not been beguiled by the berries of this tree and hence had forged steadily ahead.

These more or less well-defined flocks are very typical of all tropical jungles. Little assemblages of flycatchers, callistes, tanagers, antbirds, manakins, woodhewers and woodpeckers are drawn together by some intangible but very social instinct, and unite day after day in these fragile fraternities which drift along, gleaning from leaves, flowers, branches, trunks or ground, each bird according to its structure and way of life. They are so held together by an invisible gregarious instinct that day after day the same heterogeneous flock may be observed, identifiable by peculiarities of one or several of its members. The only recognizable bond is vocal—a constant low calling; half unconscious, absent-minded little signals which keep the members in touch with one another, spurring on the laggards, retarding the over-swift.

At first I found it almost impossible to identify birds unless they were on the lower branches or silhouetted against patches of foliage. When in the upper branches and seen against the sky, birds with under-parts of black, blue or green all looked black. White under plumage appeared grey and buff seemed orange. Even when the tree was filled with the most brilliant callistes, not a bird was visible as long as they were motionless, but when the smallest, most drab of flycatchers moved head or tail I could at once detect it, and distinguish it from the moving leaves about it. Gradually I came to know all the more common species, beginning with the tail-flirting silver-beak tanagers, and before the end of my week's vigil, I seldom made the mistake of shooting a species with which I was already familiar.

While I watched, there came to my tree one species of pigeon, two hawks and two parrots, four hummingbirds and an equal number of toucans and woodpeckers. Fifty-nine were passerine birds of which there were eight each of the families of flycatchers, manakins and cotingas, and eleven tanagers.

Besides the seventy-six species which I positively identified by shooting or observation, I saw at least thirty-three more which eluded me, and of which a hasty glance told no more than that they were of new, and to me, unknown species.

The following is a list of the birds observed actually in the Canella do Matto tree.

COLUMBIFORMES 1

Splendid Pigeon, *Columba speciosa* Gmel.

ACCIPITRIFORMES 2

Brazilian Black Eagle, *Urubitinga urubitinga* (Gmel.).
Plumbeous Kite, *Ictinia plumbea* (Gmel).

PSITTACIFORMES 2

Tuipara Parrakeet, *Brotogeris tuipara* (Gmel.).
Dusky Parrot, *Pionus fuscus* (Müll.).

CORACIIFORMES

TROCHILIDAE 4

Red-vented Hermit, *Phaethornis ruber ruber* (Linn.).

Great Jacobin Hummingbird, *Florisuga mellivora mellivora* (Linn.).

Amazonian Wood-Nymph, *Thalurania furcata furcatoides* Gould.

Green-breasted Fairy, *Heliothrix auriculata phainolaema* Gould.

SCANSORES

RAMPHASTIDAE 4

Red-billed Toucan, *Ramphastos monilis* Müll.

Double-collared Aracari, *Pteroglossus bitorquatus bitorquatus* Vig.

Lettered Aracari, *Pteroglossus inscriptus inscriptus* Swains.

Gould's Toucanet, *Selenidera maculirostris gouldii* (Natt.).

PICIFORMES

PICIDAE 4

Spix's Amazonian Woodpecker, *Celeus jumana jumana* (Spix).

Waved Woodpecker, *Celeus undatus multifasciatus* (Mahl.).

Malherbe's Black Woodpecker, *Campephilus trachelopyrus* (Malh.).

Amazonian Gold-fronted Piculet, *Picumnus aurifrons* Belz.

PASSERIFORMES 59

FORMICARIIDAE 1

Sclater's Amazonian Bush-Shrike, *Thamnophilus amazonicus* Scl.

DENDROCOLAPTIDAE 7

Whiskered Recurved-Bill, *Xenops genibarbis genibarbis* Ill.

Wedge-billed Woodhewer, *Glyphorhynchus cuneatus cuneatus* (Licht.).

Eyton's Fulvous-throated Woodhewer, *Xiphorhynchus guttatus eytoni* (Scl.).

Chestnut-rumped Woodhewer, *Xiphorhynchus pardalotus* (Vieill.).

Picine Woodhewer, *Dendroplex picus picus* (Gmel.).

Layard's Woodhewer, *Picolaptes layardi* Scl.

Buffon's Barred Woodhewer, *Dendrocolaptes certhia certhia* (Bodd.).

TYRANNIDAE 8

Sulphury Flatbill, *Rhynchocyclus sulphurescens* (Spix).

Sclater's Flatbill, *Rhynchocyclus poliocephalus sclateri* Hellm.

Oily Flycatcher, *Mionectes oleagineus oleagineus* (Licht.).

Sharp-billed Flycatcher, *Tyranniscus acer* (Scl. and God.).

Yellow-vented Crested Flycatcher, *Elaenia flavogaster flavogaster* (Thunb.).

Gaimard's Crested Flycatcher, *Elaenia gaimardii guianensis* Berl.

D'Orbigny's Black-headed Flycatcher, *Myiarchus tuberculifer* (Lafr. and D'Orb.).

Azara's Flycatcher, *Empidonomus varius* (Vieill.).

PIPRIDAE 8

Banded-tailed Manakin, *Pipra fasciicauda* Hellm.

Red-headed Manakin, *Pipra erythrocephala rubrocapilla* Temm.

Slate-breasted Black Manakin, *Pipra leucocilla bahiae* Ridgw.

Orange-bellied Manakin, *Pipra suavissima* Sol. and God.

Pará Opal-crowned Manakin, *Pipra opalizans* Pelz.

Schomburgk's Manakin, *Piprites chlorion* (Cab.).

Blue-backed Manakin, *Chiroxiphia pareola pareola* (Linn.).

Eastern White-breasted Manakin, *Chiromachaeris manacus purus* Bangs.

COTINGIDAE 8

Cayenne Tityra, *Tityra cayana* (Linn.).

Red-cheeked Tityra, *Tityra inquisitor erythrogenys* (Selby).

Little Psaris, *Platypsaris minor* (Less.).

Cinereous Thickbill, *Pachyrhamphus rufus* (Bodd.).

Lichtenstein's Thickbill, *Pachyrhamphus marginatus* (Licht.).

Gold Bird, *Lathria cinerea* (Vieill.).

Schomburgk's Attila, *Attila brasiliensis* (Less.).

Cayenne Chatterer, *Cotinga cayana* (Linn.).

TROGLODYTIDAE 2

Swainson's Moustached Wren, *Thryothorus genibarbis genibarbis* Swains.

Venezuelan House Wren, *Troglodytes musculus clarus* Berl. and Hart.

TURDIDAE 1

Cabanis's White-throated Thrush, *Planesticus phaeopygus phaeopygus* (Cab.).

VIREONIDAE 3

Chivi Vireo, *Vireo chivi* (Vieill.).

Grey-naped Wood Vireo, *Pachysylvia thoracica semicinerea* (Scl. and Sal.).

Guiana Vireo-Shrike, *Cyclarhis gujanensis gujanensis* (Gmel.).

FRINGILLIDAE 2

Rothschild's Blue Grosbeak, *Cyanocompsa rothschildii* (Bartl.).

Great Saltator, *Saltator maximus* (Müll.).

COEREBIDAE 5

Brazilian Flowerpecker, *Coereba chloropyga chloropyga* (Cab.).

Turquoise Honey-Creeper, *Dacnis cayana cayana* (Linn.).

Black-backed Honey-Creeper, *Dacnis angelica angelica* Bonap.

Blue Honey-Creeper, *Cyanerpes cyaneus cyaneus* (Linn.).

Green Honey-Creeper, *Chlorophanes spiza spiza* (Linn.).

TANAGRIDAE 11

Blue-backed Green Tanager, *Chlorophonia chlorocapilla* (Shaw).

Northern Violet Euphonia, *Tanagra violacea lichtensteinii* (Cab.).

Cayenne Euphonia, *Tanagra cayennensis* (Gmel.).

Pará Blue-bellied Tanager, *Tanagrella velia signata* Hellm.

Spotted Tanager, *Tangara punctata punctata* (Linn.).

White-shouldered Blue Tanager, *Thraupis episcopus episcopus* (Linn.).

Palm Tanager, *Thraupis palmarum palmarum* (Wied.).

Silver-beaked Tanager, *Ramphocelus carbo carbo* (Pall.).

Scarlet-crested Tanager, *Tachyphonus cristatus brunneus* (Spix).

Pará Crested Tanager, *Tachyphonus surinamus insignis* Hellm.

Guira Tanager, *Hemithraupis guira guira* (Linn.).

ICTERIDAE 3

Great Green Cacipue, *Ostinops viridis* (Müll.).

Yellow-backed Cacique, *Cacicus cela* (Linn.).

Brazilian Red-rumped Cacique, *Cacicus haemorrhous haemorrhous* (Linn.).

The great abundance of birds in this particular tree was due, of course, to the multitude of ripe berries among its foliage. These were the primary cause of attraction. Lacking these, the birds would have had no special reason for visiting it more than the surrounding jungle. And it was surprising to discover how many of the birds which would usually be considered as fly-catching or insect eaters, had in this case turned frugivorous. It seems worth while to reclassify this arboreal avifauna by the *raison d'être* of their presence.

Feeding on tree berries

Pigeon, 1
Parrakeet, 1
Toucanets, 3
Woodpecker, 1
Flycatchers, 8
Manakins, 6
Cotingas, 7
Thrush, 1
Vireos, 3
Finch, 1
Honey-Creepers, 5
Tanagers, 11
Caciques, 3

Snail-eater

Hawk, 1

Insect-eaters of the trunk

Woodpeckers, 2
Woodhewers, 7

Insect-eater of the branches

Wren, 1

Casual Visitors

Hawk, 1
Parrot, 1
Hummingbirds, 4
Toucan, 1
Woodpecker, 1
Bush-Shrike, 1
Manakins, 2
Cotinga, 1
Wren, 1
Finch, 1

The greedy, noisy parrakeets were restless jungle birds, shifting from one feeding place to another, always gorging themselves, tearing off bunches of berries and wasting much more than they ate. Of the members of the Ramphastidae, the visitors to this tree were almost wholly toucanets, the smaller, more agile species which found less trouble perching on the rather slender branches. The toucan tree a few hundred yards away, hung its larger fruit on stouter branches and attracted the toucans of larger size.

Without exception all the flycatchers which I observed in the tree—eight species—were feeding on the berries, in spite of their wide gapes and insect-guiding bristles. This was not so surprising in the case of the six manakins and seven cotingas, but the three vireos and five honey-creepers must have been birds of originality to turn thus wholly frugivorous. The tanagers led all in numbers, eleven of them, and were feeding exclusively on the berries, and the same was true of the three caciques.

On the casual visitors it is unnecessary to remark. A wren hunted insects among the upper branches one day, and on another a hawk found a giant snail crawling up the trunk and proceeded to devour it.

The insect-eaters of the trunk were nine in number and showed no interest in the berry harvest. Two were woodpeckers and there were seven species of that interesting tropical family of woodhewers. These birds were abundant at Utinga. Their labor was confined to a careful search for insects on the trunk and larger branches. The smaller woodhewers such as *Xenops* and *Glyphorhynchus* usually drifted to the tree as members of the loose jungle flocks. The larger woodhewers were more independent, and usually seen singly or in pairs. The low, plaintive notes of the little wedge-billed woodhewer were typically like those of the loose flocks, keeping the members in touch with one another.

Woodhewers are the very essence of protective coloring, and their habits of life make of them wandering bits of loose bark, yet because of their constant motion, they are very easy to see even in the dim light of the under jungle. The moment they are quiet they vanish, and the keenest eye in the world could not recognize them. This similarity of dress is a remarkable feature of this whole family; big and little, short and long-tailed, with beaks blunt, sharp, straight, curved, thick or needle-thin. In these characters they differ, by these points they must know one another. But their pattern shows little variation. Their olives or browns almost invariably warm into rich foxy rufous on wings and tail, while over head and shoulders a shower of light streaks has fallen, bits of sunlight fixed in down.

And so came to a close my rambling observations on the bird life of this single Canella do Matto. Within the space of a week I had spent not more than twenty hours of neck-racked, vertical observation, shooting whenever necessary, holding up my glasses until my arms collapsed with fatigue. In return I had been able definitely to identify seventy-six species and to record the presence actually in the tree of at least one hundred.

In point of actual numbers I kept no sustained record, but during one vigil of two hours' length I counted four hundred and sixteen birds in the tree.

When I began I had no conception of such success and as I look back and realize the necessary desultory character of my observations, the list seems even more remarkable. Relay observation on the part of two or three watchers for a correspondingly greater length of time, or closer observation from a blind fixed in a nearby tree, would yield notes of incomparably greater thoroughness and value.

Part IV.—Notes on Some Invertebrates Near the Canella Do Matto.

I made no effort, during the short time at my disposal, to carry on any lines of observation, other than upon the avifauna of the one tree. Yet as I walked back and forth along the trail, or sat quietly during the rather rare periods when no birds were in sight, or rambled about in the surrounding jungle and along the overgrown igarapés, I made a few desultory notes on certain invertebrates of especial interest to me as forming the food of jungle birds.

The great land snail, *Strophocheilus oblongus* Müller, we saw now and then, partly hidden in crevices of bark, and early one morning I saw a plumbeous kite in the canella tree, holding the shell of one of these mollusks in his talons and devouring the inmate. The shells were strongly grained, and of a rich brown with salmon-colored mouth. An ordinary sized shell was about four or five inches in length, and when the mollusk was fully extended the whole organism reached seven and a half inches. On a tree-trunk leaning over an igarapé I counted fourteen of these mollusks crowded into one very shallow cavity.

I observed that spiders entered largely into the diet of the birds I examined and I was interested in watching the method of escape of several common species, whose webs were hung along the trail.

Acrosoma spinosa Linn., an exceedingly spiny, gaudy spider hung in the center of its web. Its scarlet, yellow and black coloring seemed to indicate an unsavory mouthful, and it was correspondingly slow to take alarm. Its large, round web was swung obliquely within a foot or two of the ground. At the center was a heart-shaped open space in which the spider hung by six legs, the other two being drawn back ready for action. The web slanted backward and the spider hung upside down, the brilliant colors of the upper side of the body being thus completely hidden. When the creature was alarmed, it dropped to the ground along a cable which it attached to the point of the heart-shaped space and paid out as it fell. The moment it touched land, it slipped under a leaf. If no further disturbance ensued it regained its courage in about three minutes, and climbed swiftly, winding in its cable and apparently swallowing it, as it went. When caught in the hand, it turned at once upon its back and feigned death.

A mottled, rectangular, rather flattened and much more toothsome appearing spider was *Epeira audax* Blk. Its lure was usually hung under a stump or a fallen sapling. When disturbed it invariably ran upward from the center of the web to the trunk, where it drew in its legs and squatted. In four instances its resting place was a bit of mossy or lichened bark, and although in full view, it merged perfectly with its surroundings. So perfectly, indeed, that the eye had to search carefully to rediscover it each time it sprinted to safety.

Epieira truncata Keys, was a smallish black spider, with yellowish-white markings on its back. It had still a third place of concealment. Wherever its web was hung, there was always some convenient leaf which the spider had half rolled up, tied fast with web and lined with silk. At the first sign of danger or when heavy rain fell, the architect rushed from the center of the web to the prepared sanctuary.

The commonest spider at Utinga, fat, round, black and beloved by birds was *Eriophora purpurascens.* Unlike all the others its point of vantage was not at the center of its web but in a specially prepared den. The web was invariably hung between the leaves of some shrub. At one side, usually above the web and in full view, three leaves were drawn loosely together and fastened. Between these the spider waited for tell-tale web vibrations, and in such places inquisitive antbirds and jungle wrens found and devoured it.

One day a short distance from the tree I watched an indecisive bout between one of these spiders and a small but courageous wasp. The contest must have been going on for some time as about half the web was already destroyed. The spider had left its den and was clinging to the center of the slack structure. The wasp was exerting every effort to destroy the remaining two or three chief supporting cables. She would alight and chew them with all her might. After a few futile attempts, buzzing with rage, she would fly at the strand, seize it in her mandibles, and darting backward in midair, endeavor to snap it. Then she alighted on a nearby leaf and carefully cleaned feet, wings and head.

After such a rest she would turn her attention to the spider itself, buzzing around as closely as she dared, and making sudden rear attacks.

Eriophora was never off guard for a moment and raising his grasping feet he offered an invincible front. As the wasp was only a fourth of the size of the spider she dared do nothing more in the line of direct attack. It appeared that all her efforts were directed to cutting the spider down to the ground when she could probably have mastered him. He evidently did not dare to attempt to reach his leaf shelter, and remained quiet, guarding against attacks, swaying in his half demolished web. Before any dramatic crisis could develop, a heavy downpour of rain came on and drove both creatures to shelter.

Caterpillars were abundant at this season and remains of them were found in the stomachs of about one bird in every three. The most noticeable, however, were too well-armed to fear sudden death at the beaks of birds. One appeared on the smooth bark of *Miconia*, like a great felted mass of long reddish hairs, each of which was a veritable barbed and stinging nettle. This larva has never been reared to maturity, but it is supposed to belong to the Limacodidae. These caterpillars climbed slowly up the trunks, making about ten feet an hour.

Another bizarre larva spent the day hidden on the under side of a banana frond, close to the midrib. It looked like a short, thick, arrow, notched posteriorly, with a rounded, blunt head fringed behind with a row of great spikes. The imago is the moth *Opsiphanes invires*.

A sphingine snake-head caterpillar of the genus *Macloryx* was seen once. It is unquestionably one of the most startling dénouements in nature to see this large, smooth, innocuous looking larva suddenly bend its head forward and down, and transform into a vivid representation of a serpent's head, even to the rapidly playing forked tongue.

The omnipresent saüba ants (*Atta* sp.) forced themselves on the attention of the most casual observer. All day long their interminable lines flowed back and forth from tree-tops to nest, conveying myriads of green leaf burdens. The single point which impressed itself upon me was the large number of ants getting free transportation. Every other leaf had from one to six ants of small size clinging to the swaying frond. Where the leaf was pliable and of large size they had all they could do to maintain their position as it was jerked along. These were doubtless some small form of the saüba citizenry but why the free transportation and what their function was I could not determine.

One of the most remarkable invertebrates which I observed was an aquatic hairy caterpillar. This was found in abundance in shallow pools and creeks. The first one which I saw seemed to be wriggling about in the throes of drowning, having, as I supposed, fallen from the overhanging foliage. I charitably scooped it out and set it to dry on a bit of palm leaf. It attempted to walk away, but in spite of the fact that much of its hairy coat dried at once, it staggered about, toppling over at each step and appearing more at ease squirming about on its side. Some distance further on I saw a dozen more in an open pool and then, realizing my mistaken kindness, went back and restored the caterpillar to its strange element. It seems that this is the larva of a small moth appropriately named *Palustra*, which has assumed an aquatic life. It swims by vigorous wriggles and uncoilings, and occasionally, like a mosquito larva, comes to the surface. It is not known, however, whether it breathes directly from the surface, or from the air entangled in its hairy coat.

Part V.—Notes on the Molt of Some Pará Birds.

My recent study of the molt, and especially of the tail molt, of pheasants has seemed to yield something of value in dividing these birds into subfamilies.[1] While disclaiming any preconceived belief in the use of this character in other groups, I have nevertheless lost no opportunity to record whatever data I could find in regard to this phenomenon. I intend as rapidly as possible to examine molting birds of all orders and to place the results on record. With this in view I present the facts derived from sixteen species which I examined at Utinga, near Pará, in Brazil in the early part of May. Fragmentary as they are, they show nevertheless that differences exist. Whether these, in some cases, are of only specific distinction, or whether of generic or family value, only future, more extensive investigations can prove.

As regards wing molt, I found only two exceptions to the regular formula of the primaries molting regularly and successively from within out, and the secondaries molting from the outermost inward. In the cotinga, *Platypsaris minor*, the primary molt appeared to be 1-2-3-4-10-5-6-7-8-9. The secondaries had two modes of molt. From the outer to the 4th pair; then from the 5th pair inward and the 12th pair outward, meeting about the 8th pair.

A specimen of *Dacnis cayana cayana* showed a similar break in the secondary molt, molting in both wings inward from the outer pair, and outward from the 9th pair, meeting at the 5th or 6th pairs.

[1]Zoologica. Vol. I, No. 15, p. 265.

In attempting to work out tail molt from dried skins in the Museu Goeldi I was impressed with the difficulty of accurate observation. It is almost impossible to examine thoroughly the entire individual rectrices without damaging the appearance of the skin, and the dried sheaths which are so often the sole clue to recent growth, crumble at the first touch of the pliers.

To summarize at once my data taken from fresh, unskinned birds, I record the following types of tail molt:

Centripetal, from the outside in,

Ramphastidae (3)
Picidae (1)

Centrifugal, from the center out,

Dendrocolaptidae (2)
Vireonidae (1)
Tanagridae (3)

Other types of tail molt,

$\left.\begin{matrix}2\\3\end{matrix}\right\rangle$ 1-4-5-6 Pipridae (2)

3 — 1-2-4-5-6 Cotingidae (1)

1 $\left\langle\begin{matrix}2\text{-}4\\3\text{-}5\end{matrix}\right.$ Coerebidae (2)

Ramphastos osculans *Ramphastidae.*

Two individuals collected from the same flock, May 9, were in almost the same stage of tail molt.

Ten rectrices. Molt from outside in.
Specimen A. Central, 2nd and 3rd pairs, old, unshed.
4th pair, blood sheath of 28 mm.
5th pair, growing 98 mm.

Specimen B. Central, 2nd and 3rd pairs, old, unshed.
4th pair, growing 59 mm.
5th pair, growing 106 mm.

In both birds the mode of molt of the primaries traveling outward had reached the 5th pair. That of the secondaries moving inward, had caused the renewal of eight feathers.

Pteroglossus inscriptus *Ramphastidae.*

Bird collected May 6th.
Ten rectrices. Molt from the outside in.
Central pair, just shed.
2nd pair, one-half grown, 44 mm.
3rd pair, growing, 84 mm.
4th and 5th pairs, new, full-grown.

Selenidera gouldii *Ramphastidae.*

Birds shot May 1st.
Ten rectrices. Molt from the outside in.
Central and 2nd pairs, old, unshed.
3rd rectrice (left), just shed.
3rd rectrice (right), blood sheath, 4 mm.
4th and 5th pairs, new, full-grown.

Celeus undatus *Picidae.*

Bird shot May 6th.
Twelve rectrices, ten functional, and an outer vestigial pair 20 mm. in length. Molt from the outside in.
Central and 2nd pairs, old, unshed.
3rd pair, blood sheath just appearing.
4th pair, growing, 36 mm.
5th pair, almost full-grown.
6th pair, full-grown.

Dendrocolaptes certhia *Dendrocolaptidae.*

Bird collected May 8th.
Twelve rectrices. Molt from the center out.
Central pair, new, full-grown.
2nd pair, nearly grown 96 mm.
3rd pair, blood sheath, 16 mm.
4th, 5th and 6th pairs, old, unshed.

Picolaptes layardi *Dendrocolaptidae.*

Bird collected May 6th.

Twelve rectrices. Molt from the center out.

Central, 2nd and 3rd pairs, new, full-grown.
4th pair, one-half grown.
5th pair, blood sheath, 19 mm.
6th pair, old, unsheath.

Pipra leucocilla *Pipridae.*

Bird collected May 3rd.

Twelve rectrices. Molt nearly complete; probably like that of the following species.

Central, 2nd and 3rd pairs, new, full-grown
4th pair, nearly full-grown.
5th pair, one-half grown, 18 mm.
6th pair, one-third grown, 8 mm.

Pipra opalizans *Pipridae.*

Two individuals collected on May 8th and 9th.

Twelve rectrices. Molt about the same stage in both. The second and third pairs are shed first and simultaneously; next the central, and then in succession the 4th, 5th and 6th pairs. This unexpected type of molt received confirmation from the fact of its occurrence in two individuals shot on successive days, in different parts of the Utinga jungle.

Specimen A. Juvenile male (Fig. 17).

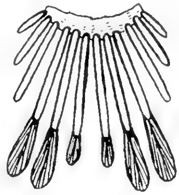

FIG. 17. TAIL OF MANAKIN

All twelve rectrices were blood sheaths, only the central, 2nd and 3rd pairs having broken through.

Central pair, 9 mm.
2nd pair, 11 mm.
3rd pair, 11 mm.
4th pair, 6 mm.
5th pair, 4 mm.
6th pair, 2 mm.

Both wings were exactly alike.

Primaries molting outward; 1st to 5th pairs new.
6th pair nearly grown.
7th pair three-quarters grown.
8th pair blood sheath, 7 mm.
9th and 10th pairs, old, unshed.

Secondaries molting inward; outer pair nearly grown.
2nd pair, blood sheath, 11 mm.
3rd pair, etc., old, unshed.

Specimen B. Adult male.

All twelve rectrices were blood sheaths, just breaking through. The sheaths all averaged 6 mm. in length.

Total Length

Right		Left
11 mm.	1st	11 mm.
14 mm.	2nd	15 mm.
13 mm.	3rd	14 mm.
11 mm.	4th	12 mm.
7 mm.	5th	8.5 mm.
7 mm.	6th	8 mm.

In these specimens the very specialized, opalescent crest feathers were in full molt, almost all of them ensheathed. These sheaths were slender, conical, pointed and lightly fluted. The general appearance of the ensheathed crown feathers was of a mass of obliquely lying, parasitic cocoons on a caterpillar.

Platypsaris minor *Cotingidae.*

Bird collected May 8th.
Twelve rectrices, all old, unshed.

Wings in full molt, both wings the same. Old feathers rufous buff; new ones black, with white basal spots.

Primary molt 1-2-3-4-10-5-6-7-8-9.

Secondary molt, outer to 4th pair.
5th pair inward and 12th pair outward, meeting about the 8th.

Primaries, Inner, 2nd, 3rd and 4th pairs, new, full-grown.
5th pair, nearly full-grown 54 mm.
6th pair, just breaking sheath, 20 mm.
7th, 8th and 9th pairs, old rufous feathers.
10th pair, new, full-grown.

Secondaries, outer pair, nearly grown, 52 mm.
2nd pair, short sheath, 4 mm.
3rd and 4th pairs, old, rufous feathers.
5th, 6th and 7th pairs, new, full-grown.
8th pairs, short sheath, 8 mm.
9th pair, etc., new, full-grown.

Attila brasiliensis *Cotingidae.*

Bird collected May 1st, juvenile.

Twelve rectrices, molt apparently 3-1-2-4-5-6. Old feathers, worn, brown almost rufescent; new ones brownish black.

3rd pair, growing, 40 mm.
1st pair, growing, 21 mm.
2nd pair, blood sheath, 8 mm.
4th, 5th and 6th pairs, old, unshed.

Primaries molting outward, six pairs renewed.
Secondaries show no molt.

Cyclarhis gujaranensis *Vireonidae.*

Specimen A. Bird collected May 1st, female.

Twelve rectrices. Molt from the center out.

Outer four pairs, old, unshed.

Central pair, new full-grown.
2nd pair, growing.

No wing molt.

Specimen B. Bird collected May 1st, juvenile, female.

Twelve rectrices. All old except central pair which are nearly grown.

Dacnis cayana cayana *Coerebidae.*

Specimen A. Bird collected May 3rd, juvenile, female.

Ten rectrices. Molt 1 < 2-4, 3-5

Central pair, new, full-grown, 36 mm.
2nd pair, 3rd pair } growing, 27 mm.
4th pair, 5th pair } blood sheath, 11 mm.

Specimen B. Bird collected May 5th, adult, male.

Tail has almost completed molt, outer pairs being nearly full-grown.

Wing molt three-quarters complete, showing an interesting and unusual type of secondary molt. Old feathers edged with green; new ones with blue.

Left Wing			Right Wing
987654321	1234 5 6789, etc.	987 6 54321	123456789
←	→ ←	→ ←	→
primaries	secondaries	secondaries	primaries

Secondaries, right wing, outer, 2d, 3d and 4th, new, full-grown.
5th, blood sheath.
6th, old, unshed.
7th, still growing.
8th and 9th, new, full-grown.

left wing, outer, 2nd, 3rd and 4th, new, full-grown.
5th, old, unshed.
6th, blood sheath, 7 mm.
7th, blood sheath, 17 mm.
8th and 9th, new, full-grown.

Chlorophanes spiza *Coerebidae.*

Bird collected May 5th.

Ten rectrices. Molt $1 < \begin{matrix} 2\text{-}4 \\ 3\text{-}5 \end{matrix}$

Central pair new, full-grown.

$\left.\begin{matrix}\text{2nd pair} \\ \text{3rd pair}\end{matrix}\right\}$ full grown
$\left.\begin{matrix}\text{4th pair} \\ \text{5th pair}\end{matrix}\right\}$ old, unshed.

Thraupis episcopus episcopus *Tanagridae.*

Specimen A. Bird collected May 9th. Fledgling, male, first day after leaving nest.

Twelve rectrices well grown, and apparently of equal length.

Measurements

Fledgling		*Adult*
19 mm.—	Central	—64 mm.
23 mm.—	2nd	—65 mm.
23 mm.—	3rd	—65 mm.
25 mm.—	4th	—66 mm.
23 mm.—	5th	—66 mm.
21 mm.—	6th	—65 mm.

Specimen B. Bird collected May 1st, male.

Twelve rectrices. Molt from the center out. The whole web of the new feather is blue, stronger on the outer web. Old feathers are black on the inner web, greenish on the outer.

Central pair, new, full-grown.

2nd pair, still growing, 6 mm. shorter than 1st.
3rd pair, unbroken blood sheaths.
4th (right), sheath just appearing.
4th (left), not yet shed.
5th and 6th pairs, old, unshed.

Ramphocelus carbo carbo *Tanagridae.*

Specimen A. Bird collected May 1st, male.

Twelve rectrices. Molt from the center out.

Central and 2nd pairs, full-grown.
3rd and 4th pairs, just drying up.
5th and 6th pairs, not quite full-grown.

Specimen B. Bird collected May 5th, adult male.

Tail in full molt, from the center out.

Central and 2nd pairs, new, full-grown.
3rd, 4th, 5th and 6th pairs, all with 13 mm. sheaths, but total length steeply graduated.

Primaries molting outward, two outer pairs still growing.

Secondaries molting inward, three outer pairs full-grown, next three in active growth.

Tachyphonus surinamus insignis *Tanagridae.*

Specimen A. Bird collected May 2nd.

Twelve rectrices in full molt from the center out, with unusually long time hiatus between the central and 2nd pairs.

Central pair, new, full-grown, 72 mm.

Outer five pairs all with 11 mm. sheaths.

Total lengths 2nd pair, 69 mm.
3rd pair, 54 mm.
4th pair, 40 mm.
5th pair, 31 mm.
6th pair, 25 mm.

Wing molt nearly complete; primaries outward, secondaries inward.

Specimen B. Bird collected May 5th.
Tail completing molt from center out.

Part VI.—Annotated List of Birds Observed.

A. Birds of the Wild Cinnamon Tree.

Columba speciosa (Gmel.) Splendid Pigeon.

Three were observed on May 2nd, one in the tree feeding on the berries, the others on adjoining branches. They flew at once when I walked past beneath.

Urubitinga urubitinga (Gmel.). Brazilian Black Eagle.

Twice in the same day this bird visited the trail near the tree, once perching rather low in the jungle and remaining motionless. An hour later it returned and alighted on one of the lower branches of the tree itself, preening its feathers and paying no attention to the small birds scolding from the shelter of the thick foliage to which they had fled. A specimen secured had a large green, blue, red and yellow mantis with a hundred or more of its eggs in his crop.

Ictinia plumbea (Gmel.). Plumbeous Kite.

Early on May 11th at a time when there were only three or four small tanagers in the tree, this bird suddenly appeared. I had stopped watching for a few minutes to rest my fatigued muscles, and on looking up I saw this hawk perched in the tree on a branch, so slender that it was still swaying from the impact of his alighting. He seemed to be picking at something on the branch beside him, but flew at once when I fired, apparently quite uninjured by the small shot which I had to use. I then found that he had been devouring a snail of large size in its shell (*Strophocheilus oblongus*).

Brotogeris tuipara (Gmel.). TUIPARA PARRAKEET.

Quite common in families or small flocks. Twice observed in the tree feeding on the berries, and one which I secured had twenty-three in its crop. The noisiest birds hereabouts. While sitting at the foot of the tree, half an hour would seldom pass without a pair or more of these parrakeets dashing past high overhead, screeching loudly. Other trees seemed to offer more permanent attraction than this one. They showed little fear and members of their flocks could be shot one after the other without frightening the remainder. In the evening they collected in flocks of thirty or forty and circled about high in the air before setting off steadily south-westward toward some distant roost.

Pionus fuscus (Müll.). DUSKY PARROT.

A pair alighted in the tree on May 4th and remained for five minutes before flying off in the direction of the toucan tree. I heard them now and then in other parts of the jungle but did not again catch sight of one.

Phaethornis ruber ruber (Linn.). RED-VENTED HERMIT.

The most abundant hummingbird. Two females spent much of their time searching surrounding heliconia blossoms for tiny insects and resting from time to time on a lower branch of the tree.

Florisuga mellivora mellivora (Linn.). GREAT JACOBIN HUMMINGBIRD.

Thalurania furcata furcatoides Gould. AMAZONIAN WOOD-NYMPH.

Heliothrix auriculata phainolaema Gould. GREEN BREASTED FAIRY.

These three species of hummingbirds were observed perching in the tree on several occasions. Two others were not secured and could not be identified by the glass.

Ramphastos monilis Müll. RED-BILLED TOUCAN.

In the cinnamon tree the visit of this large red-billed toucan was very evidently accidental as the berry-bearing branches were too slight to support his weight. I saw one on May 3rd, resting only for a moment before he flew on in the direction of the toucan tree. When the afternoon's rain was over, the yelping cries of these birds were the most conspicuous sound of the jungle.

Pteroglossus bitorquatus bitorquatus Vig. DOUBLE-COLLARED ARACARI.

Twice observed in the cinnamon tree, and still oftener in the toucan tree. From a flock of eight secured two. Brilliant as these birds are, it is remarkable how easily they escape observation when in the tree-tops. Even when one of a flock is discovered, the closest scrutiny with powerful glasses fails to reveal the remainder, until one by one they move and betray their whereabouts. When motionless they resemble an irregular knot or bunch of leaves. When the broken stub of a branch contains water, they all visit it in turn, drinking after eating a half dozen or more berries.

Colors: iris pale yellow, with a antero-posterior extention of dark brown pigment, giving the pupil an elongated appearance. Bare skin around eye blue, lower lid orange yellow; facial skin same red color as feathers of nape; upper mandible lemon yellow, whitish near base and at tip, black along cutting edge; lower mandible black on terminal two-thirds, greenish-white near base and along ventral line; legs and feet yellow green like the flank feathers.

Pteroglossus inscriptus inscriptus Swains. LETTERED ARACARI.

An occasional visitor to the tree, and when a flock of them came, they made such a commotion that callistes and other small birds could hardly get a foothold. Four out of a flock of five were shot about fifty yards from the tree and the following day the survivor remained near, through most of the hours of day-light, calling, and now and then feeding on the berries. The first bird shot was a young one and the rest actually followed it to within ten feet of where four of us were standing. Even after the third shot, the fourth bird came as boldly as ever in answer to the yells of the youngster. Bates and other writers speak of being mobbed by toucans in much the same manner.

Of the four birds, two were males, two females. The young molting male had the iris scarlet; crown above eye pale caerulean blue; eyelid, lores, beneath eye and around ear dark livid blue; broad line between eye and ear vermillion; skin back of nostrils bright blue; bill bright orange yellow and black; legs and feet sage green similar to the under tail web. The crop was filled with round, black seeds, which stained everything an indelible dark blue.

Selenidera maculirostris gouldii (Natt.). GOULD'S TOUCANET.

The commonest toucan in the tree, observed on four separate occasions in pairs or trios, but remaining only for a short time and very wary. The iris is lemon yellow above and below, shading off in front and behind into green, which changes to black next the pupil, giving it an extremely flattened, elongate appearance; bill black and white, with the terminal parts of both mandibles pale green; facial skin yellowish and bluish green; legs and feet bluish-green.

Celeus jumana jumana (Spix). SPIX'S AMAZONIAN WOODPECKER.

On May 3rd a single bird hammered at a soft place in the bark of the tree for five minutes, then caught sight of me beneath and fled silently.

Celeus undatus multifasciatus (Malh.). WAVED WOODPECKER.

Observed by Cherrie in the tree on May 5th. Had been eating berries.

Campephilus trachelopyrus (Malh.). Malherbe's Black Woodpecker.

Late in the morning of May 6th a pair alighted on the trunk ten feet from the ground and worked their way upward to the small branches before flying off through the jungle. A female collected some distance away had the iris pale orange, bill greenish horn, darker along the culmen; legs and feet deep olive green. Crop filled with large yellow seeds.

Picumnus aurifrons Pelz. Amazonian Gold-Fronted Piculet.

While watching a flock of *Dacnis* in the tree early in May, I noticed three small birds which at first glance reminded me of nuthatches. I secured two and found they were curious soft-tailed woodpeckers or piculets. Whether they came for berries or in hope of insect food I cannot say and I did not again have opportunity to observe them. The third bird remained motionless in a neighboring tree for some time. Pará is a new locality for this group, but these individuals seem to be quite typical.

Thamnophilus amazonicus Scl. Sclater's Amazonian Bush-Shrike.

While having no real right in an arboreal fauna I must include this species, as a male bird flew up from the underbrush when I shot at it and missed, and alighted for a moment on one of the lower branches. With several other species it was not uncommon in the surrounding jungle.

A few yards from the tree a little earlier in the day, I had stalked the same individual in thick underbrush, where it seemed to be at odds with a white-breasted manakin. After the latter flew off, the Bush-Shrike kept constantly in one place, close to the ground, singing every thirty of forty seconds. It was a simple refrain *whut! whee-whee! whee-whee! whee-whee!* When startled it uttered the *whut!* alone. It was difficult stalking ground but only a loud crackle of leaves made the bush-shrike shift its perch. The female appeared for a moment and the male repeated his song twice very rapidly, and turning close to her ruffled all his feathers, making himself into a perfect ball, blatantly displaying the usually concealed white patch, and with the spotted shoulders protruding conspicuously from the round, slate-colored mass. Keeping thus inflated he hopped around and around on his perch, completing a half turn at each hop, stopping for a second or two between hops and twisting so as to face her. At this time his song came irregularly. Twice he began it while on the hop, but did not end it. The moment the female slipped away, all his excitement ceased and he went hard at work on his never ending ditty. Once the shadow of a passing vulture fell upon him and cut short the refrain, but only for a moment. Great metallic bees buzzed close about the singer but were not noticed. I later found his crop crammed with small black ants.

Xenops genibarbis genibarbis Ill. WHISKERED RECURVED-BILL.

One seen on the tree, and once shot in the depths of the Utinga jungle.

Glyphorhynchus cuneatus cuneatus (Licht.). WEDGE-BILLED WOODHEWER.

The commonest woodhewer hereabouts, and observed almost every day on the tree, moving creeper-like up and around the trunk. The slightly upward curve of the beak gives to the bird a decidedly nuthatch profile. This species seemed about to nest and two females would have deposited eggs within a very few days. Its low, plaintive note often revealed its presence before it was seen.

Xiphorhynchus guttatus eytoni (Scl.). EYTON'S FULVOUS-THROATED WOODHEWER.

A pair of these large woodhewers were courting, a process which seemed to consist in the constant pursuit of one by the other. This took place along the trail on which the tree grew, and the birds alighted again and again in the tree but not to feed. After resting a moment, panting, they continued their endless chase. They were silent and only when the pursuer almost caught up did the other utter a sharp, querulous note. So fast did they fly that the two brown bodies would appear like streaks shooting in and out of the tree-trunks. As they were seen in the trail every day their nesting site was doubtless not far off.

Xiphorhynchus pardalotus (Vieill.). CHESTNUT-RUMPED WOODHEWER.

Seen only once and secured from one of the higher branches of the tree.

Dendroplex picus picus (Gmel.). PICINE WOODHEWER.

Next to *Glyphorhynchus* the commonest woodhewer seen near the tree. Once only did one alight on it, but others were seen constantly on the adjoining trunks. Owing to the large amount of white it was the most conspicuous of these birds. Several times I saw one alight crossways on a branch, the first time I have ever seen a woodhewer assume this passerine position.

Picolaptes layardi Scl. LAYARD'S WOODHEWER.

Dendrocolaptes certhia certhia (Bodd.). BUFFON'S BARRED WOODHEWER.

I saw neither of these species but I examined specimens in the flesh shot from the tree by Mr. Cherrie in my absence.

Rhynchocyclus sulphurescens (Spix). SULPHURY FLATBILL.

Abundant in tree. A dozen could have been shot at each period of observation, had I wished them. An adult and a young male which were secured were both feeding on the tree berries. The latter was in very much worn juvenile plumage and about to moult.

Rhynchocyclus poliocephalus sclateri Hellm. SCLATER'S FLATBILL.

A male collected in the tree on May 10th had both tree berries and small Diptera in its crop.

Mionectes oleagineus oleagineus (Licht.). OILY FLYCATCHER.

This was the commonest flycatcher which frequented the tree. I secured six and could have shot twenty on any of the days when I was on watch. Its bright buff breast rendered it one of the easiest birds to recognize, and after a day's observation I shot none by accident. Their food consisted both of tree berries and small insects.

Tyranniscus acer (Scl. and God.). SHARP-BILLED FLYCATCHER.

These little flycatchers were rather rare and usually early comers. I secured none after seven-thirty in the morning, and even then they had been feeding for some time. Those collected in the tree had fed altogether on the tree berries. They were breeding at this season. Even with my powerful field glasses, and with knowledge of the points of difference it was absolutely impossible to distinguish this species from either of the preceding forms of *Rhynchocyclus*. When eighty feet or more up, I do not think identification with glasses of these lesser flycatchers can be accomplished.

Elaenia flavogaster flavogaster (Thunb.). YELLOW-VENTED CRESTED FLYCATCHER.

Observed several times in the tree feeding on the berries. It kept lower down than the other smaller species and was recognizable by its clean-cut, white markings.

Elaenia gaimardii guianensis Berl. GAIMARD'S CRESTED FLYCATCHER.

Only among the top-most branches with other small Flycatchers. On two occasions when seen against a mass of dense foliage I detected the half-concealed, white crown, but usually the species merged wholly with the *Rhynchocyclus* and *Tyranniscus* feeding with it. It was feeding wholly on the tree berries.

Myiarchus tuberculifer (Lafr. and D'Orb.). D'ORBIGNY'S BLACK-HEADED FLYCATCHER.

This was the only species of flycatcher which ever got in the least excited over my presence at the foot of the tree. As I was getting into position for a prolonged period of observation, one or a pair of these birds would occasionally drop down from the upper branches and with crest raised, excitedly flutter from one branch to another uttering a continual sharp *tsip! tsip!* While the berries were eaten by all I examined, yet insects were never wholly absent, and more than once I saw birds of this species launch out high above the tree after passing insects. When seen against green foliage, even at a great height, the distinct areas of grey and yellow on the lower plumage were quite distinct.

Empidonomus varius (Vieill.). AZARA'S FLYCATCHER.

A specimen in worn plumage shot from the tree and three others near by. All must have been in the tree during the morning as all had tree berries in their crops.

Pipra fasciicauda Hellm. BANDED-TAILED MANAKIN.

Several times I had watched orange and black manakins in the lower branches of the tree and supposed they were the common red-headed species (*Pipra rubricapilla*). It is very probable that most of them belonged to that species, as all which Cherrie and I secured in the neighborhood of Utinga were *rubricapilla.* The single bird which I secured from the tree was the banded-tailed manakin. In its crop were two small beetles and seven tree berries.

Pipra erythrocephala rubrocapilla Temm. RED-HEADED MANAKIN.

The commonest manakin at Utinga. Early every morning a male would be perched on the same branch of the tree and twice I saw him driven away by other manakins. He never fed while I watched him, but sat sometimes for fifteen minutes without moving, paying no attention even to the sound of the gun or of the shot as it returned and swished through the leaves after I had fired a shot straight upward.

Pipra leucocilla bahiae Ridgw. SLATE-BREASTED BLACK MANAKIN.

Next to the red-crowned this manakin was most frequently seen. It was a female of this species which, with a male opal-crowned manakin, I secured from the tree with one shot. They had united to chase away the red-crowned bird from his perch and at once had flown upward beyond the usual height at which these birds are found. In the upper branches they joined a small flock which had come out of the jungle, and which soon left the tree and went on toward the north.

Pipra suavissima Sol. and God. ORANGE-BELLIED MANAKIN.

After a flock of roving jungle birds had left the tree I secured this specimen from their number. It had two tree berries and a great mass of insect larvae in its crop. I did not observe it again during my stay.

Pipra opalizans Pelz. PARA OPAL-CROWNED MANAKIN.

The female which I secured was in an adjoining tree, but only about twenty feet from the cinnamon tree, and within half an hour the small flocks of manakins appeared from which I got the male bird. There were five berries in the crop, which otherwise was empty. A day or two before seven or eight of these beautiful birds had been secured for Mr. Cherrie two miles away, by a native collector. Aside from these examples we saw nothing of the species.

Piprites chlorion (Cab.). SCHOMBURGK'S MANAKIN.

Shooting at what I took to be a flycatcher of some new species I secured a female of this species from one of the lower branches. It had been hopping about for some time in the neighboring jungle and its crop contained only small insects. It was quite alone and I saw nothing, nothing of its mate or of other individuals.

Chiroxiphia pareola pareola (Linn.). BLUE-BACKED MANAKIN.

Twice seen and one male secured. On May 5th a male had been flying back and forth for some time before I gave it careful attention. Although well above the ground, it showed its crown and back so distinctly that I knew it at once, and watched it through the glasses snatching berries and chasing some species of *Dacnis* through the branches.

Chiromachaeris manacus purus Bangs. EASTERN WHITE-BREASTED MANAKIN.

Although a day seldom passed when I did not see this species near the tree, it was only on the last day of observation that I saw it actually in the tree itself. Two manakins of unknown species were having a most excited time in the lower branches and making all the noise of which they were capable. The uproar drew two male white-breasted manakins from the jungle undergrowth and they flew up without hesitation to see what the matter was. When they reached the branch the row soon ended and all concerned sought privacy again. A pair was always to be found about one hundred yards from the tree on the edge of the jungle where an old cultivated field had grown up to dense briery undergrowth. A second pair must have had a nest within ten or fifteen yards of the trail, although most careful search failed to locate it. While sitting quietly near the tree the female often came close and peered at me, hopping from twig to twig, and at each flight producing the characteristic deep, low *whirrrrrrrrr!* the wing song by which these little jungle people give vent to their emotions—courtship, suspicion, fear.

Tityra cayana (Linn.). CAYENNE TITYRA.

One of these birds perched for some time in a tree close to our house on the first day of our stay at Utinga. I saw no more of the species until I found that late in the afternoon just after the rain or even while it was still falling, three of these tityras came to the tree regularly in company with one or two Cotingas. I saw them under these conditions on three separate occasions and watched them feeding on the berries at leisure.

Tityra inquisitor erythrogenys (Selby). RED-CHEEKED TITYRA.

One early in the morning of May 6th. Not seen again.

Platypsaris minor (Less.). LITTLE PSARIS.

At seven A. M. on May 6th the cinnamon tree seemed almost deserted. I arranged my canvas chair and lying back, searched the upper branches carefully with my glasses for signs of life. Suddenly I saw motion in the tip of what I had thought was a broken branch stub. Several minutes passed and as I could make nothing of it, I secured it and found it to be a female psaris. It had evidently been feeding elsewhere as well, as the stomach contained a large yellow seed and a green grasshopper, while in the crop were three tree berries.

Pachyrhamphus rufus (Bodd.). CINEREOUS THICKBILL.

Twice I observed the unmistakable female of this species feeding in the tree, but was unable to secure it. On the following day we shot a specimen some distance away. Its only food was hairy caterpillars. It seems a silent, quiet bird, slow in movement and stupid in taking alarm at the warning cries or flight of other birds.

Pachyrhamphus marginatus (Licht). LICHTENSTEIN'S THICKBILL.

Quite ignorant of what I was shooting at, I secured a female of this thickbill from the very top of the tree where it was feeding in company with callistes and flycatchers. It had breakfasted on a spider and several tree berries.

Lathria cinerea (Vieill.). GOLD BIRD.

The gold or greenheart birds as they are known in Guiana, were found in the Utinga jungle, isolated as usual, vague calling Voices, penetrating and ventriloqual. A great fig ten yards from my cinnamon tree was a favorite perch of one of these birds and twice or more each morning it came to the berry tree to snatch a mouthful of the fruit and dash back again. It would utter its call the moment it alighted, but I never heard it given elsewhere than from this perch in the dense heart of the great fig tree.

Attila brasiliensis (Less.). SCHOMBURGK'S ATTILA.

While observing this species and after I had secured a specimen I supposed I was dealing with some unknown form of flycatcher, although I had never known any member of the Tyrannidae with such a marvellous vocabulary as had these birds. Two individuals, one adult and a young male, were in the tree early on the morning of May 1st and ultimately I secured the latter and identified the species. They were exceedingly active and playful. The full-grown young bird would aproach its parent, fluttering its wings and begging for food, then being chased swiftly through the jungle and back again, or swinging around, would pursue the other in turn. The song, which was uttered every ten or fifteen seconds was exactly alike in the two birds. It was a high, liquid four note phrase, *wheedle-wheedle-wheedle-wheedle!* Four rapid repetitions was the rule, more rarely increased to five or six. But this was constantly varid from the more usual timbre. When uttered while in pursuit of one another it became higher and shriller, or when given as the overgrown youngster was swallowing a berry it was fairly gargled. Again only a single *whee!* would be uttered, standing for some unknown emotion. At least a score of variations or shades of utterance were heard in fifteen minutes. The note of suspicion or alarm, given when I made too loud a noise or when another bird or a squirrel alarmed them, was very different, a loud, sharp, woodpecker-like cackle. After this was uttered once or twice, during which time the birds were motionless, the wheedle call or song commenced, the Attilas becoming at once active.

They kept to the tree-tops and only by a quick, long-distance shot was I able to secure the young bird. The iris was pale hazel-brown; upper mandible horny black; lower also, with a large, fleshy-white patch mid-way along the rim on each side. The inner gape showed the loose yellow skin so characteristic of young birds; legs and feet slaty-blue; soles yellowish-flesh; claws dark brown.

The most unexpected fact was in connection with its food. The crop was full of berries and there were two which had not yet been swallowed, but in the gizzard were the recognizable remains of a small fish. The only way I can account for this unusual item of diet is that the birds must have been drinking at a jungle pool near by in which were many small minnow-like *Tetragonopterus,* and the young bird in some way had managed to seize and swallow one.

Cotinga cayana (Linn.). Cayenne Chatterer.

Once or twice these brilliant birds were seen in the mango trees near our house, but like the tityras I did not see them elsewhere than in the cinnamon tree in late afternoons. There were usually two, one in full color and the other a female or young bird. Their brilliance absolutely disappeared when seen against the bright sky, but in contrast with the green leaves or a cloud, lighted by the slanting rays of the sun, they flashed like great gems.

Thryothorus genibarbis genibarbis Swains. Swainson's Moustached Wren.

For two days in succession a pair of these birds remained in the neighborhood of the tree, occasionally visiting the lower branches, but only momentarily and, as far as I could judge not touching the berries, but intent only on insect prey. One made occasional attempts at song, but the season was evidently past or had not yet arrived.

Troglodytes musculus clarus Berl. and Hart. VENEZUELAN HOUSE WREN.

This is, of course, not a bird of the jungle and its presence in the tree was accidental, and as far as my observation went occurred only once. The bird seen was doubtless one of a pair which lived in and about the clearing about our house, and made deeper foraging inroads now and then into the jungle. It was probably the number and commotion of the small callistes and other birds feeding in the tree which drew the inquisitive wren thither early in the morning on May 6th.

Planesticus phaeopygus phaeopygus (Cab.). CABANIS'S WHITE-THROATED THRUSH.

Not uncommon in isolated pairs through the jungle, and an occasional visitor to the tree especially in late afternoons. They went about feeding in a business-like manner, apparently filling their crops in a short time. The nesting season for them had just begun.

Vireo chivi (Vieill.). CHIVI VIREO.

At 8 A. M. on May 5th I secured this bird from the upper branches of the tree, not knowing at what I was shooting except that it had a different carriage from the flycatchers and dacnis which thronged the upper foliage. Four tree berries were in its crop and a fifth still unswallowed in the mouth.

Pachysylvia thoracica semicinerea (Scl. and Sal.). GREY-NAPED WOOD VIREO.

Cyclarhis gujanensis gujanensis (Gmel.). GUIANA VIREO-SHRIKE.

I secured these birds within ten minutes of one another on May 2nd. Both were feeding on the berries of the tree.

The previous day we had shot elsewhere an adult male vireo-shrike and a young male of the year in very worn plumage. Comparison of these two showed the following differences:

	Adult	*Juvenile*
Length	147	143
Culmen	16	15
Culmen from nostril	10	9
Wing	70	65
Tail	55	55
Tarsus	20	21
Middle toe and claw	16	17

Bill: adult reddish horn; juvenile slaty grey; tips in both whitish.
Legs and feet: adult brownish blue; juvenile clear slaty blue.
Iris: adult reddish orange; juvenile hazel, paling outwardly.
Bare facial area: adult warm flesh; juvenile olive green.
Forehead: adult rich chestnut; juvenile grey like head.
Superciliary: adult rich chestnut; juvenile warm buff.

Cyanocompsa rothschildii (Bartl.). ROTHSCHILD'S BLUE GROSBEAK.

I saw this bird on two occasions feeding on the berries of the tree, although it was probably the same individual. The second time it descended to one of the lower branches and remained motionless for many minutes.

Saltator maximus (Müll.). GREAT SALTATOR.

Saw but one of this species in the tree and that quite an accidental visitor as it perched only for a few seconds on a lower limb and then flew straight off through the jungle. Two days later we secured a specimen a mile away, but saw no others during our stay.

Coereba chloropyga chloropyga (Cab.). BRAZILIAN FLOWERPECKER.

A few of these little birds were seen almost every day in the tree usually well up near the top, but unlike most of their companions feeding apparently altogether on small insects. The first one which I saw in the tree was on a lower branch by itself, singing with all its might. Its song was sweet, rather short and of a wheezy character with a quaint little lilt. This in spite of the fact that it was in very worn, shabby breeding plumage.

Dacnis cayana cayana (Linn.). TURQUOISE HONEY-CREEPER.

These exquisite little birds were one of the most abundant species which frequented the tree. I saw at least fifty during each period of two or three hours of observation. All which I secured were feeding on the berries. They usually kept to the upper branches, flying swiftly from the surrounding jungle summits, and moving actively about, now and then catching an insect but preferring the tree berries. This was the only species of the Family which ever came down to lower branches. When well up it was impossible to differentiate between this and the next species. The color of the turquoise honey-creeper is remarkable. When the bird is held between the observer and the light, no matter how oriented, whether sideways, head or tail on, it is a deep cobalt blue; when looked at with the light behind the observer, it is as intense a clear, shining turquoise. There is no position of feather or bird which will alter these colors.

Dacnis angelica angelica Bonap. BLACK-BACKED HONEY-CREEPER.

Still more active than the turquoise, this bird equalled it in numbers, and sometimes twenty were in the top of the tree at one time.

Cyanerpes cyaneus cyaneus (Linn.). BLUE HONEY-CREEPER.

The blue honey-creeper, perhaps the most beautiful of all this group, was much more common at the tree in the afteroon than in the morning. I was able to identify the males of these birds at any height and found them in the proportion of two in the morning to seven in the afternoon. I have counted eighteen individuals at one time. They seldom descended to the lower branches. In every specimen I examined there were a few insects in the crop in addition to the tree berries.

Chlorophanes spiza spiza (Linn.). GREEN HONEY-CREEPER.

The fourth member of this group, glowing with its green iridescence in the sunlight. Instead of insects these birds were plucking tree berries with their long curved beaks. They seemed equally abundant, whether at daybreak or after the daily rains in late afternoon. Eight males and two females were grouped together on one of the central branches for fully five minutes one morning, excited about something which the most careful scrutiny with my glasses failed to reveal.

Chlorophonia chlorocapilla (Shaw). BLUE-BACKED GREEN TANAGER.

This bird which appears to be new to this part of Brazil was shot accidentally. I aimed at a blue-bellied tanager in the tree, missed it, and this small, wonderfully-colored species, which I had quite failed to observe, dropped from an upper branch. It had two tree berries in the crop.

Tanagra violacea lichtensteinii (Cab.). NORTHERN VIOLET EUPHONIA.

Never present in large numbers but several pairs were sure to turn up in the tree during the day. They did not remain long, perhaps, because a berry or two must have made a cropful for such diminutive chaps. No matter how busy hopping about, they always found time every few minutes to stop and burst into their jubilant little song.

Tanagra cayennensis (Gmel.). CAYENNE EUPHONIA.

Decidedly rare in the tree. Saw four and secured one. Easy to identify when not silhouetted against the sky, the two lateral patches of orange feathers standing out in strong contrast with the blue black of the remainder of the plumage. The specimen which I shot had small green seeds in its crop, not those of the tree.

Tanagrella velia signata Hellm. PARÁ BLUE-BELLIED TANAGER.

On May 5th Cherrie shot a female of this beautiful bird from the tree and within five minutes I secured its mate. On three later occasions I observed this tanager, always in pairs and in the early morning. It could not be recognized with certainity in the upper branches as the yellow of the black was usually concealed. They fed greedily on the tree berries.

Tangara punctata punctata (Linn.). SPOTTED TANAGER.

Early visitors to the tree, coming singly or in pairs straight across the top of the jungle as if from a distance. They knew the tree well and began to feed as soon as they arrived. After they had eaten several berries they would appear satiated and either sit in the sun and preen their feathers or chase one another about, always returning from the surrounding jungle for another period of feeding before they left.

Thraupis episcopus episcopus (Linn.). WHITE-SHOULDERED BLUE TANAGER.

Blue tanagers were rare at the tree although common elsewhere, and when they appeared came singly or in pairs. I saw them there only three times. This may have been because they were nesting at this season, a pair of birds having a nest in a mango tree a few yards from our house. There were two young birds and these flew on May 8th.

Thraupis palmarum palmarum (Wied.). PALM TANAGER.

One bird shot in the tree in company with a flock of silverbeaks on May 8th. Its mate fed for some time afterwards on the tree berries. Although fairly common elsewhere on the borders of the jungle no more were observed in the tree.

Ramphocelus carbo carbo (Pall.). SILVER-BEAKED TANAGER.

The commonest bird at Utinga and almost constantly present in the tree. When large numbers of callistes and flycatchers were gathered together there would sometimes be only one silver-beak. Then with a rustle of wings a whole flock would fly up from the surrounding jungle, twenty or thirty in all, and without actual aggression but by sheer numbers would disturb most of the smaller birds. They would chase other birds half playfully or in turn be pursued by some flycatcher, but on the whole the tree-top assemblage of birds was a peaceful one. The quickest glance served to identify these tanagers, for though their white beak might be invisible, and their plumage appear jet black viewed against the bright sky, the characteristic sideways flirting of the tail never failed. Their sharp metallic *chip!* was another positive factor of identification. They were restless, never remaining very long in the tree but flying off one after the other to work their way slowly through the jungle.

Tachyphonus cristatus brunneus (Spix). SCARLET-CRESTED TANAGER.

One specimen with a number of honey-creepers was secured in the tree early on May 2nd. Did not note another during my stay.

Tachyphonus surinamus insignis Hellm. PARÁ CRESTED TANAGER.

Three or four times I observed this bird at the tree feeding on the berries and secured two specimens. Its peculiar markings enabled me to identify it at almost any height. On May 5th a male suddenly swooped down from the upper branches and showed great agitation upon finding me in my observation chair. I soon discovered that the cause was a female and single young in the undergrowth near by, who were attracted rather than frightened by the emotion of the male. They soon took themselves off, and in a few minutes the male crested tanager was again back feeding in the tree.

Hemithraupis guira guira (Linn.). GUIRA TANAGER.

Early on May 5th a pair of these birds high up in the tree. One of these I secured. The other continued feeding and flying about the tree with honey-creepers and flower-peckers for some time afterwards.

Ostinops viridis (Müll.). GREAT GREEN CACIQUE.

A small colony of these splendid birds was established near the toucan tree, to which tree they paid frequent visits. Only once did I see one in the cinnamon tree and then only for a minute. He snatched two berries, looked carefully about him, down at me and flew off through the jungle in the direction of the colony, a few hundred yards away.

Cacicus cela (Linn.). YELLOW-BACKED CACIQUE.

Five times I saw these birds in the tree feeding greedily on the berries. The slenderness of the branches seemed to bother them, however, and they never remained long. They constantly haunted the toucan tree several hundred yards away, which had larger berries and stouter branches. There were three separate colonies within the radius of a half mile, the nearest only a hundred yards from the tree and from our house in the yard of a native. In certain zones of the jungle the squeaks and gurgles of these birds were the dominant sounds throughout the day.

In spite of this indescribable squeaking and yelping, the yellow-backed caciques appear to have a consistent call or song. It may be written, *yank! yank! yank-keou-ke-wonk!*

Cacicus haemorrhous haemorrhous (Linn.). BRAZILIAN RED-RUMPED CACIQUE.

One individual was in the tree on May 6 with four yellow-backed birds. I could not secure it but watched it for more than five minutes.

B.—AERIAL BIRDS.

Catharista atratus brasiliensis (Bonap.). BRAZILIAN BLACK VULTURE.

Five minutes seldom passed, hour after hour, when one or more of these birds did not soar across the bit of sky visible above the cinnamon tree. Usually they were very high up, soaring, but occasionally just sweeping the tree tops with their pelican-like habit of alternate flapping and gliding. At sunset scores flew past southward, just clearing the jungle, or else collected on some dead tree until twenty or thirty had assembled, when all flew off in the same direction to some distant roost.

Chordeiles acutipennis acutipennis (Bodd.). SOUTH AMERICAN NIGHTHAWK.

Chaetura spinicauda spinicauda (Temm.). SPINE-TAILED SWIFT.

Tachycineta albinenter (Bodd.). WHITE-VENTED TREE SWALLOW.

Progne chalybea chalybea (Gmel.). GREY-BREASTED MARTIN.

Atticora fasciata (Gmel.). WHITE-BANDED SWALLOW.

Stelgidopteryx ruficollis ruficollis (Vieill.). BRAZILIAN ROUGH-WINGED SWALLOW.

The above six species were observed, the first in late afternoon and the others throughout the day, hawking about in the sky over the tree. None were very rare, the last named, perhaps, the most abundant. In clear weather they flew high, but as the clouds gathered they settled lower, following the shifting strata of volant insect life.

C.—BIRDS OF THE SURROUNDING JUNGLE.

Crypturus variegatus (Gmel.). VARIEGATED TINAMOU.

These tinamou were twice seen and heard daily within a few yards of the cinnamon tree. Their plaintive, sustained note was one of the commonest sounds of the jungle. They would reply to an imitation of their notes and even approach, but never close enough for a shot, and no especial effort was made to stalk them. The only specimen examined was one in the last stages of decomposition which had met its death a few feet from the cinnamon tree trail. It was being skeletonized by ants and there was left barely sufficient plumage for identification.

Geotrygon montana (Linn.). RED GROUND DOVE.

Not uncommon on the jungle floor, flushing with a loud noise of wings, and at first being confused with small tinamou. One which I secured showed no evidence of recent breeding.

Ceophloeus lineatus (Linn.). GREAT LINEATED WOODPECKER.

In late morning on May 9th as I sat watching under the cinnamon tree I was bothered for ten or fifteen minutes by what I thought were two men building a house. The hammering was loud and incessant, and I could tell when first one then the other began work as their boards gave forth varying tones. Often they would go at it together. Finally I heard a resounding rattle, more rapid and staccato than any hammering carpenter could produce, and my suspicion aroused, I walked to the end of the trail at the edge of the jungle. Out in a cleared field stood a headless, weatherbeaten royal palm and to this were clinging a pair of great lineated woodpeckers hammering intermittently and audible half a mile away.

Ceryle torquata torquata (Linn.). GREAT GREY KINGFISHER.

On May 8th one of these splendid kingfishers passed over the tree on its way from one igarapé to another.

Trogon melanurus melanurus Swains. BLACK-TAILED TROGON.

The commonest Trogon hereabouts, more often heard than seen.

Crotophaga ani Linn. COMMON ANI.

Abundant in the surrounding brushy fields, but seldom venturing far into even the more open jungle.

Thamnophilus aethiopes incertus Pelz. PELZELN'S BUSH-SHRIKE.

Not uncommonly seen and heard, and easy to recognize at sight after a specimen has been examined.

Cercomacra tyrannina Scl. TYRANT ANT-WREN.

A common species in the undergrowth of the jungle, frequently seen close to the base of the tree, hopping about or scratching among the dead leaves.

Synallaxis rutilans omissa Hart. PARÁ SPINETAIL.

A pair of these birds were nesting very close to the tree, and were never quite reconciled to my continued presence. Strangely enough, the occasional sound of the gun did not seem to alarm them. They kept rather low down, but five minutes seldom passed without one or the other coming to have a look at me, and voicing its dissatisfaction in a low *chut*. Specimens secured elsewhere showed that this species was both preparing to lay and brooding in early May.

Pipra aureola (Linn.). ORANGE-HEADED MANAKIN.

Not uncommon in the surrounding jungle, and I am almost certain that some of those in the tree itself were of this species.

Pitangus sulphuratus sulphuratus (Linn.). KISKADEE FLYCATCHER.

Conspicuous in appearance and vocally. An inhabitant of the open places but occasionally flying over or alighting on jungle near the tree.

Muscivora tyrannus (Linn.). FORK-TAILED FLYCATCHER.

This unmistakable species was seen several times flying over the tree.

Volatinia jacarini splendens (Vieill.). GLOSSY GRASSQUIT.

Common in the overgrown fields fifty yards beyond the tree at the edge of the jungle. Once a pair flew past down the trail headed for the pumping station clearing.

Brachyspiza capensis capensis (Müll.). CHINGOLO SONG SPARROW.

Heard singing in the nearest open glade and twice seen at the base of the tree.

Arremon silens (Bodd.). PECTORAL SPARROW.

These beautiful sparrows were not rare in the undergrowth at the base of the tree and as I was seated on watch, one or two would now and then flit across the trail with sharp chirps, coming back as closely as they dared to stare at me, hopping about nervously.

FAUNA OF FOUR SQUARE FEET OF JUNGLE DEBRIS

I.

For a week I had been studying the bird-life of a single tree, a Canella do Matto, as I have described in detail in the preceding number of ZOOLOGICA. On the last day as I was about to go, I concentrated my attention on the tree and the surrounding jungle, endeavoring to fix it indelibly in my mind. I realized that in a few minutes I would leave this place with which I had become so intimate, and should very probably never return. I had demonstrated a remarkable concentration of bird-life when attracted by the ripened fruit of a single jungle tree. It was the unparalleled insurgence of such a variety of organisms as can occur only in the tropics.

Now that there remained only a brief space of time I tried to conceive of some last thing I could do to re-emphasize this important phase of tropical life.

As I walked slowly up the trail toward the tree I heard a rustling among the leaves at one side, and in deep shadow beyond a dense clump of scarlet heliconias, I made out a tyrant antwren (*Cercomacra tyrannina*) scratching with all its might. To the kicking power of its small legs it occasionally added sudden flicks with the bill, given with such nice judgment and power, that it flung leaves larger than itself into the air and backward quite over its body. I had often wondered of what the food of these birds really consisted. Anyone could glance at the contents of a crop and gizzard and label it "small insects." But the actual details of this varied bill of fare, except in the case of very recently swallowed objects, was usually merged and lost in the comminuted mass of legs, elytra and antennae.

Acting on this hint I brought from my camping stores an empty war bag, and carefully scraped together a few handfuls of leaves, sticks, moss, earth and mold of all sorts. From directly under the Canella do Matto, I gathered four square feet of jungle debris, filled my bag and shouldered it. Then I said adieu to my trail and my tree, a sorrowful leave taking as is always my misfortune. For the bonds which bind me to a place or a person are not easily broken.

In this case, however, the bond was not altogether severed, and a week later when the sky line was unbroken by land, when a long ground swell waved but did not break the deep blue of the open sea, I unlaced my bag of jungle mold. Armed with forceps, lens and vials, I began my search. For days I had gazed upward; now my scrutiny was directed downward. With binoculars I had scanned without ceasing the myriad leaves of a great tree. Now with lens or naked eye I sought for signs of life on an infinitely smaller scale; the metropolis of a fallen leaf, the inhabitants of a dead twig. When I studied the tree-top life in the lofty jungle I was in a land of Brobdingnag; now I was verily a Gulliver in Lilliput. The cosmos in my war bag teemed with mystery as deep and as inviting as any in the jungle itself.

When I began work I knew little of what I should find. My vague thoughts visualized ants and worms, and especially I anticipated unearthing myriads of the unpleasant macuins, or bête rouge, whose hosts had done all in their power to make life in the jungle unhappy.

For ten days or more on the steamer trip north Mr. Hartley and I labored over the jungle debris. After two hours steady concentration our eyes rebelled and we had to desist. It seemed at times as if the four square feet had increased to forty, but the last handful was finally sifted and teased to shreds. Our method of work was to place a small pile on a newspaper spread on a table under the skylights of the smoking room, and with forceps and dissecting needle to search carefully every surface of leaf and frond and to split every twig and stem.

It was found that the safest way to capture the minute creatures which crawled or hopped about was to wet a small brush in alcohol, touch them with the tip and float them off in the liquid in a very small vial. Thus they were uninjured and we could pick them from a mass of earth or fungus without including any of the debris itself. Usually we worked with our naked eyes, but occasionally hunted over a particularly rich field with low power dissecting lenses.

Day by day our vials increased. Scores of creatures evaded our search. Many others, of which I had captured a generous number, I allowed to escape. My lilliputian census was far from the mere aggregation of ants and worms which I had anticipated, and a review of the whole showed that hardly any great group of living creatures was unrepresented.

Two objects indicated the presence of wild mammals. First a bunch of rufous hairs which in size, color and minute structure were identical with those of the common agouti, which was very common at Utinga. I also found sign of this rodent. Man himself was represented by two wads which had dropped from my gun-shots sometime during the week. One had already begun to disintegrate, wet, half decayed and inhabited by half a dozen tiny organisms.

Five feathers were the marks of birds, also doubtless the result of my study during the week. A body feather, and two primaries from a sparrow-like bird were indeterminate, but two brilliant, green plumes came without question from the body of a calliste. Of reptiles there was a broken skull of some lizard, half disintegrated with a few of the teeth still left. There was besides the small egg-shell of a lizard which had hatched and gone forth to live its life elsewhere in the jungle. A third reptilian trace may have been his nemesis—a good-sized shred of snake-skin. The group of amphibians was present even in this small area of four square feet—a very tiny, dried, black and wholly unrecognizable little frog. Fishes were absent, although from my knees as I scraped up the debris, I could almost see a little igarapé in which dwelt scores of minnows.

As I delved deeper and examined the mold more carefully for the diminutive inhabitants, I found that this thin veneer from the floor of the jungle appeared to have several layers each with its particular fauna. The upper layer was composed of recently fallen leaves, nuts, seeds and twigs, dry and quite fresh. As yet these showed but little change, and only the damage wrought by insects and other agencies while they were still on the trees. In this layer were small colonies of ants in hollow twigs and occasional huge solitary ones. Here lived in hiding small moths, beetles and bugs awaiting dusk to fly forth through the jungle. The lowest layer was one chiefly of matted, thready roots holding together compact masses of earthy soil, mixed with a large proportion of tiny bits of quartz. The animal life of this stratum was very meagre, occasional mites—especially red ones—and a few earth and round worms, the latter in much fewer numbers than in the middle layers.

Between the upper and the middle layers were sprouting nuts and seeds, with their blanched roots threaded downward into the rich dark mold, and the greening cotyledons curling upward toward light and warmth. Thus had the great Canella do Matto itself begun life. In my war bag were a score of potential forest giants doomed to a death in the salt ocean.

The middle layer, finally, was the all-important stratum. In it lived four-fifths of the small folk. This was composed of debris in full course of disintegration; leaves, sometimes partly green, usually brown or black, nuts half decayed, twigs half rotten. All still preserved their form, although some were ready to fall apart at a touch. All were soaked through, or at least damp and soggy. Often four or five leaves would be stuck together, stitched with the threads of fungi. In such a haven was always a host of living organisms.

Some of the half decayed leaves were very beautiful. Vistas of pale, bleached fungus lace trailed over the rich mahogany colored tissues, studded here and there with bits of glistening, transparent quartz. Here I had many hints of a world of life beyond the power of the unaided eye. And here too the grosser fauna scrambled, hopped or wriggled. Everywhere were tiny chrysalids and cocoons, many empty. Now and then a plaque of eggs, almost microscopic, showed veriest pin-pricks where still more minute parasites had made their escape. Contracting the field of vision to this world where leaves were fields and fungi loomed as forests, competition, the tragedies, the mystery lessen not at all. Minute seeds mimicked small beetles in shape and in exquisite tracery of patterns; small beetles curled up and to the eye became minute seeds of beautiful design. Bits of bark simulated insects, a patch of fungus seemed a worm, and in their turn insects and worms became transmuted optically into immobile vegetation. Scores of little creatures were wholly invisible until they moved. Here and there I discovered a lifeless boulder of emerald or turquoise—the metallic cuirass of some long dead beetle.

Some of the scenes which appeared as I picked over the mold, unfolded suddenly after an upheaval of debris, were startling. When we had worked with the lens for many minutes, all relative comparisons with the surrounding world were lost. Instead of looking down from on high, a being apart, with titanic brush of bristles ready to capture the fiercest of these jungle creatures, I, like Alice in Wonderland, felt myself growing smaller, becoming an onlooker, perhaps hiding behind a tiny leaf or twig. This feeling became more and more real as we labored day after day, and it added greatly to the interest and excitement. Close by would appear, under the lens, piles of great logs and branches protruding from a heaped up bank of precious stones. Mauve, yellow, orange and cerulean hues played over the scene. Over a steep hill came a horned, ungainly creature with huge proboscis and eight legs, and shining, liver-colored body, all paunch, spotted with a sickly hue of yellow. It was studded with short, stiff bristles, and was apparently as large as a wart hog and much more ugly. It was a mite, one of the biting mites of the tropics, but under the lens a terrible monster. We put one of these on our arm to see if its bite corresponded to that of the legions of macuins which tortured us daily in the jungle. Under the lens I saw the hideous creature stop in its awkward progress and as it prepared to sink its proboscis we involuntarily flinched, so fearful a thing seemed about to happen.

In the middle layer, that of most active change, and surcharged with life, ants were abundant, together with small colonies of termites. These were the only social insects, the twigfuls consisting of from five to fifteen members. All the other organisms were isolated, scattered here and there. Life in these lowly places, so far beneath the sunlight, is an individual thing. Flocks and swarms are unknown, and the mob has no place here. Each organism must live its life and fulfil its destiny single-handed. Even when two individuals were found together it was apparently more through accident of environment than from any gregarious instinct. In fact the same tropical law which holds good in regard to plants and the larger creatures of the sunlighted world overhead applies here. I found numbers of different species, but very few collections of individuals of the same kind.

Flatworms were rather rare, but small, white ones were found now and then flowing slowly along in their characteristic manner over the surface of damp, half decayed leaves, as flatworms do the world over. Roundworms, small, white and threadlike were present in equally small numbers. Earthworms of small size, one or two inches in length, were common. They moved slowly along in orthodox angleworm fashion until something alarmed them when they instantly became a maze of twisting, snapping curves, dancing all about in a most unwormlike fashion. The head and especially the collar were brightly colored, from reddish to an intense scarlet.

Centipedes and millipedes were common, all small, in keeping with the diminutive size of the other inhabitants of this little world. The largest centipede was less than an inch in length and scurried along on eighty-four legs. Very few were dark colored. Almost all were dead white, with yellowish brown heads and jaws. The larger millipedes were slow moving in spite of their abundance of feet, but small ones of various species were very agile, and slipped in and out of fungi forests in a most disconcerting way. They were about evenly divided between the groups of Polydesmoidea, Julioidea and Gerphiloidea.

Scorpions were decidedly rare, and two small and one medium sized specimen were all we could discover. Pseudoscorpions, however, were abundant and conspicuous. I secured fifty, and could have taken three or four times as many. They would rush out excitedly when disturbed, and unlike all the other creatures of the underworld did not seek to hide. Instead,

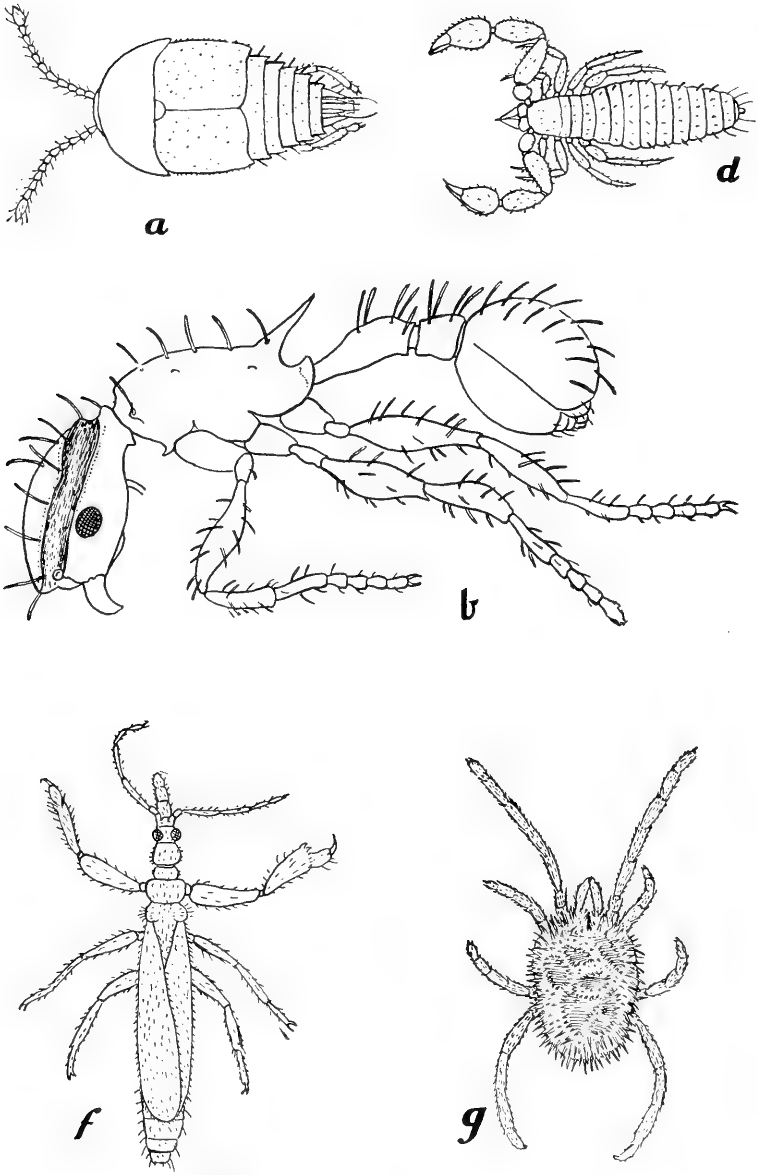

FIG. 18. REMARKABLE INSECT FORMS, CHIEFLY NEW
Found in the surface of a Tropical Yard of Jungle.

a, An unknown form, beetle, roach or cricket. *b*, The worker of a new genus and species of ant, *Blepharidatta brasiliensis* Wheeler, an extraordinary form, with small-eyed workers fitted for a subterranean life. The general structure is very simple and primitive. *d*. Pseudoscorpion, or false scorpion, a member of a compact, widely distributed family of Arachnida, with a pronounced superficial resemblance to true scorpions. *f*, Unknown, even as to order. *g*, A mite, one of the vast host of *bête rouge*, or maquins, the most troublesome pests of tropical jungles.

they bravely sought open spaces, walking slowly and feeling ahead with their great pincer-tipped arms, which they brandished with the greatest ease, although these weapons were as long as their entire bodies. When really alarmed, they scurried backward, holding up their chelae in readiness. Their bodies were whitish, but their arms and pincers deep reddish brown. While there were several species, these superficially fell into two distinct types. The most abundant kind was pot-bellied, with heavy chelae, and was slow in movement. The other had a narrow, lighter body and very delicate slender chelae, and ran with great speed when alarmed. These, however, always ran forward, not backward like the others.

Harvest men were represented by a single daddy-long-legs which looked decidedly out of place among this dense debris. I rather fancy he was strolling on the surface when my onslaught bagged him and his surroundings.

Very small and very pale colored spiders lived in the middle layer in fair numbers. We saw about two score altogether. They were usually slow or moderately gaited, like their more abundant relatives, the mites. Only twice did we see a spider dash off with any of the speed which characterized those which lived in the jungle above ground.

Next to the ants the mites and ticks were the most abundant organisms. Hardly a leaf or bit of mold was free from them. We could have gathered hundreds. They were of many species and all colors, red, brown, purple, black and flesh. Some were naked and shining, others clothed in bristly hairs to their very feet. All were repulsive, slow, and so awkward that it was inexplicable how creatures with such lack of correlation could ever manage to find food, much less a mate. They were always crawling slowly along, tumbling over every obstacle in their path. Ticks were much rarer than mites.

Numbers of very simple insects were common. Silverfish or Thysanura of several species ran like active little ghosts out of their hiding places and scurried swiftly to another which they fancied safer. Their nimble movements made them exceedingly difficult to capture. Collembolas, almost equally primitive, were usually white, but now and then a purple one appeared. Not only were they capable of active running, but when the brush wet with alcohol was about to touch them, they leaped to a distance of twenty to thirty times their own length. Again and again this enabled them to escape. When they landed they remained motionless for some time and were most difficult to discover. Among the specimens collected were Campoclea, and many individuals of Collembola, belonging at least to three different genera *Isotoma, Lepidocyrtus* and *Schöttella.*

Termites, or "white ants," lived in small colonies of six to thirteen individuals in small twigs, in the upper layer of debris. Sometimes they seemed to be living in close association with real ants with no signs of hostility on either side.

A very few immature wood roaches represented the order Orthoptera, while the Hemiptera or true bugs had only a slightly better showing. Earlier stages of these insects lived in the middle layer, while those in the upper were quite adult and were ready to fly.

Beetles of small size were abundant and of numerous species. Of about fifty which I gathered, about sixty per cent were rove beetles. All the others were slow travellers, or on discovery pretended to be dead, but the rove beetles were very agile, and never lost any opportunity of trying to escape capture. There were members of Rhynchophora of the Tribe Tylodini; of the Families Thorictidae, Phalacridae, Pselaphidae and Tenebrionidae. Also of Clivina, Scyclonaenus, Oxytelus, and Platystethus; Staphylinidae were, as I have indicated, by far the most numerous.

Some tiny flies had apparently just emerged from their pupae in the upper layer, these being the only representatives of their order, while of the Lepidoptera there were only two small moths among the dry leaves of the top stratum.

Ants were the most abundant form of life, both in numbers and species. They lived in the upper layers and with the exception of the great, black, solitary fellows who apparently had been walking about on the top of the leaf stratum, all were of small size. Their colonies were apparently complete but very small, a very small twig being packed full of individuals from six to fourteen in number with a half dozen pupae.

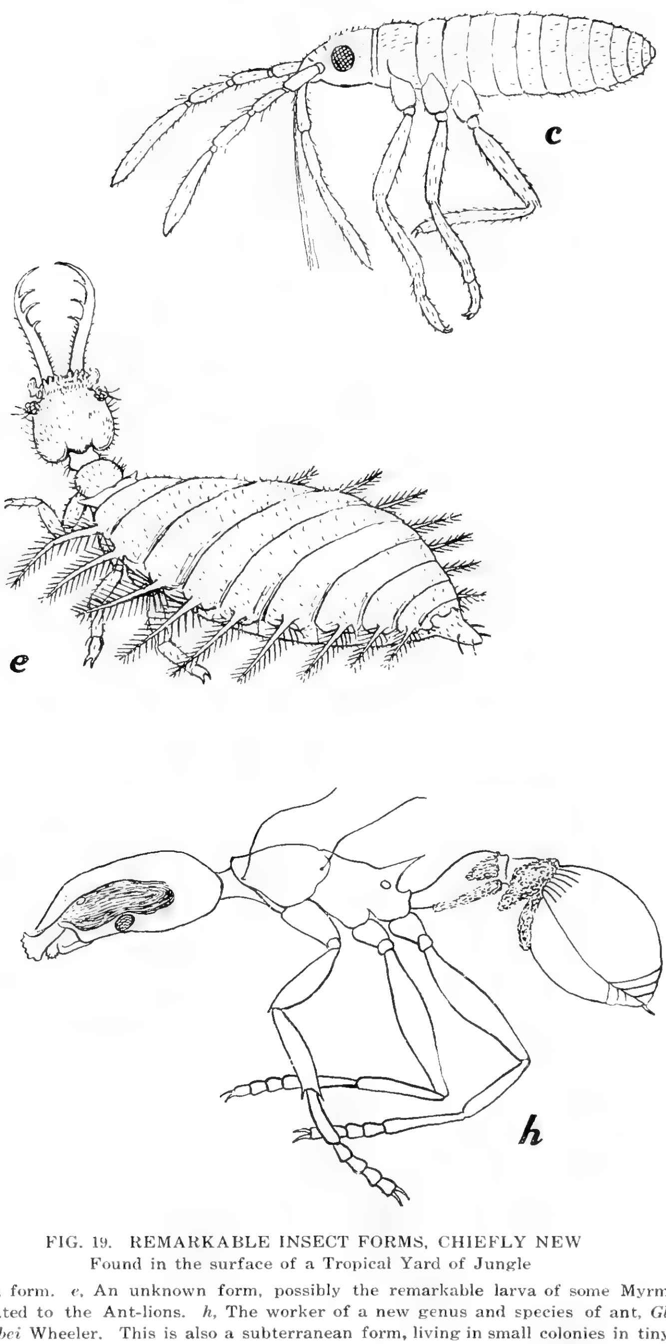

FIG. 19. REMARKABLE INSECT FORMS, CHIEFLY NEW
Found in the surface of a Tropical Yard of Jungle

c, Unknown form. e, An unknown form, possibly the remarkable larva of some Myrmeleonid species, related to the Ant-lions. h, The worker of a new genus and species of ant, *Glamyromyrmex beebei* Wheeler. This is also a subterranean form, living in small colonies in tiny twigs. In the colony from which the species was described, there were only three workers, three females, and two males.

Finally mollusks were found in small numbers, all very small, some with flat shells, others with steeply turreted ones. These were young specimens of two species of *Leptinaria* and several very young *Polita,* or *Vitrea* as it is more generally called.

In addition to all these was a host of unknown forms, immature or in some unrecognizable early stage of development. Some had huge jaws and the body encircled with a dense chevaux-de-frise of horny, frond-like spikes. Others were so simple that their relationships could only be guessed at.

One thing was evident early in my exploration. I was having to do with a world of small people. No insects of large size were in any layer of the debris. The largest would be very small in comparison with a May beetle. Another fact which impressed me was the durability of chitin. The remains of beetles, considering the rareness of living ones, was remarkable. The hard wing cases, the thorax armor, the segments of wasps, eyeless head masks, all these still remained perfect in shape and vivid in color. Even in the deepest layers where all else had disintegrated and returned to the elements these shards of death were as new.

Day after day as I worked with my face close to the mold, I was constantly aware of the keen, strong, pungent odor. It hinted of the age-old dissolution, century after century, which had been going on. Leaves had fallen, not in a sudden autumnal down-pour, but in a never ending drift, day after day, month after month. With a daily rain for moisture, with a temperature of three figures for the quicker increase of bacteria, and an excess of humidity to foster quick decay, the jungle floor was indeed a laboratory of vital work—where only analytic chemistry was allowed full sway, and the mystery of synthetic life was ever handicapped and ever a mystery.

Before the vessel docked we had completed our task and had secured over *five hundred* creatures from this lesser cosmos. At least twice as many remained, but in making calculations I estimated that the mold had sheltered a thousand organisms that were plainly visible to the eye.

When I had corked my last vial and the steward had removed the final pile of shredded debris, I leaned back and thought of the thousand little creatures in my scant four square feet of mold. Then there came to mind a square mile of jungle floor with its thin layer of fallen leaves sheltering many more than six billion of these creatures. Then I recalled the three thousand straight miles of continuous jungle which had lain westward up the course of the Amazon, and of the hundreds of miles of wonderful unbroken forest north and south. My mind faltered before the vision of the unnamable numerals of this uncharted census, of the insurgence of life which this thought embraced. It seemed quite clear that no Tyrant Antwren need ever go hungry, as long as he had strength to turn a leaf.

Leaving out the hints of vertebrates which in numbers were almost negligible, the lower types of creatures may roughly be grouped as follows:

Flatworms (Platyhelminthes)	2%
Roundworms (Nemathelminthes)	2%
True Worms (Vermes)	3%
Myriapods (Myriapoda)	6%
Scorpions (Scorpionida)	1%
Pseudoscorpions (Pseudoscorpionida)	8%
Harvest men (Phalangida)	1%
Spiders (Araneida)	3%
Mites and Ticks (Acarida)	14%
Silverfish (Thysanura)	2%
Collembola (Collembola)	3%
Termites (Isoptera)	10%
Roaches (Orthoptera)	1%
Bugs (Hemiptera)	2%
Beetles (Coleoptera)	10%
Flies (Diptera)	1%
Moths (Lepidoptera)	1%
Ants (Hymenoptera)	30%

As shown by this list, ants were the dominant form of life, so I have chosen to mention these in detail as representative of the interest of this method of investigation. They have been thoroughly worked out by Prof. Wheeler,* and the unexpected result of this mode of intensive study is well illustrated by a paragraph from one of Prof. Wheeler's letters. Referring to the nineteen vials of ants which I had sent him he says: "I have just found time to mount them up and to my surprise discover among them representatives of two new and remarkable genera! That you should have found these is indeed remarkable, because Professor Goeldi, formerly the director of the Pará Museum, collected ants very assiduously in that region and sent them to Forel for description. Moreover, one of my students, Mr. William M. Mann, who has been with me several years, collected very extensively in Brazil and recently enumerated all the known Brazilian forms with a description of the new species he had taken, and neither of these men came across the two very peculiar little ants which you found. I take it that they did not work in the leaf mould as you did and that probably when other collectors adopt your method an extensive ant fauna will be unearthed even in Brazil, which has been pretty well worked for ants within recent years. . . . I have named the two new genera and species *Blepharidatta brasiliensis* and *Glamyromyrmex beebei.*"

The seventeen species of ants which I discovered in this four square feet of jungle mould are as follows:

1. *Pachycondyla harpax* Fabr. (workers).
2. *Euponera* (*Trachymesopus*) *stigma* Fabr. (workers).
3. *Ponera opaciceps* Mayr. (workers).
4. *Anochetus mayri* Emery (deälated female).
5. *Solenopsis subtilis* Emery (workers, males, deälated female).
6. *Crematogaster victima* F. Smith. var. (deälated female).

*Two new Genera of Myrmicine Ants from Brazil, Bull. Mus. Comp. Zool. Harvard, LIX, No. 7.

7. *Pheidole flavens* Roger subsp. *exigua* Emery (soldiers, workers, males, deälated female).
8. *Pheidole subarmata* Mayr. (workers, deälated female).
9. *Trachymyrmex* sp. (deälated headless female).
10. *Cyphomyrmex rimosus* Spin. (deälated female).
11. *Rhopalothrix* (*Octostruma*) *balzani* Emery (workers, deälated female).
12. *Strumigenys subedentata* Mayr. (deälated female).
13. *Prenolepis steinheili* Forel (workers, males).
14. *Rhizomyrma goeldii* Forel (workers).
15. *Camponotus* (*Myrmothrix*) *abdominalis* Fabr. var. (deälated female).
16. *Blepharidatta brasiliensis* Wheeler.
17. *Glamyromyrmex beebei* Wheeler.

The solitary deälated females of the species of numbers 4, 6, 9, 10, and 15 were evidently establishing colonies. At least eight of the species, those of the genera 2, 3, 5, 11, 12, 14, and the two new genera 16 and 17 are hypogaeic or subterranean ants, with small-eyed workers. With the exception of numbers 1 and 15, all of the species are small or very small.

Taking ants alone, we thus find that in numbers they formed about thirty per cent of the visible fauna of the jungle mould. With the exception of the two species all were adapted by their small size to life in the leaf mould, and fifty per cent were structurally fitted for subterranean existence.

III.

I have made a single interesting comparison between this fauna of four square feet of tropical jungle debris and that of a corresponding area in a temperate and an Arctic latitude. In the tropical material, as I have stated, we found, at the very lowest estimate, one thousand visible organisms. In four square feet of leaves and moss from an uncleared area in the woods of the New York Zoological Park were two hundred and sixty creatures. From a slightly larger area, approximately a square yard, of tundra moss from Labrador, twenty-seven living organisms were unearthed. This last material consisted chiefly of white reindeer moss, near a grove of fir trees from the North West River on Lake Melville, ninety miles directly west of Rigolet up the Hamilton Inlet. For this I am indebted to A. Sheard, Esq., of the Grenfell Association, who was kind enough to gather it personally for me.

The value of this comparison is, of course, relatively superficial, but nevertheless it is not without interest and should stimulate effort in this comparatively unworked ecological field.*

Fauna of Four Square Feet	*(New York)* *Temperate*
True Worms (Vermes)	14%
Myriopods (Myriopoda)	10%
Pseudoscorpions (Pseudoscorpionida)	1%
Harvest Men (Phalangida)	4%
Spiders (Araneida)	8%
Mites and Ticks (Acarida)	1%
Silverfish (Thysanura)	3%
Bugs (Hemiptera)	8%
Beetles (Coleoptera)	8%
Moths (Lepidoptera)	1%
Ants (Hymenoptera)	40%

The lists speak for themselves, the interesting facts being the marked diminution in number of general groups, as well as species and individuals from the tropics northward. The dominance of ants in both temperate and tropical cases is worthy of notice, and the remarkable number of true worms in the north and of mites and ticks in the south. In none of the lists are eggs or cocoons included.

Attempts to identify the tropical organisms have shown how little knowledge we have of the life histories of these invertebrates. It was indeed fortunate when even a genus or subfamily could be told. The lack of a great central museum, library and collection of types in our country is keenly felt, as well as the handicap of the general habit of publishing new species in all sorts of magazines and periodicals, wholly unrelated except by the widest of zoological bonds.

*Consult W. L. McAtee, Science, N. S., Vol. XXVI, pp 447-449, and N Banks, id. p 637.

ZOOLOGICA
SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

VOLUME II, NUMBER 5.

THE GAFF-TOPSAIL
(*Felichthys felis*)

A SEA CATFISH THAT CARRIES ITS EGGS IN ITS MOUTH

BY

E. W. GUDGER

STATE NORMAL COLLEGE

GREENSBORO, N. C.

PUBLISHED BY THE SOCIETY
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AUGUST, 1916

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FIG. 20. GAFF-TOPSAIL CATFISH

Lateral view of a female, nineteen and one-quarter inches long.
From a drawing from life.

Zoologica Vol. II. No, 5. Frontispiece

THE GAFF-TOPSAIL

(*Felichthys felis*)

A SEA CATFISH THAT CARRIES ITS EGGS IN ITS MOUTH[1]

By E. W. Gudger,

STATE NORMAL COLLEGE, GREENSBORO, N. C.

Introduction.

At the 1908 meeting of the North Carolina Academy of Science, I gave a short paper on the oral gestation of this fish, but, not being ready to publish, the title only appeared in the proceedings published in *Science* (vol. XXVII, p. 991) and in the *Journal Elisha Mitchell Scientific Society* (vol. XXIV, p. 50).

For the Washington meeting of the American Association for the Advancement of Science in 1911, I prepared, but was unable to give in Section F., a paper bearing practically the same title. However, there was published in *Science* (1912, vol. XXXV, p. 192) an abstract, the data of which forms the closing paragraph of this paper.

Since the more technical data obtained in this research will be presented in a series of papers which will require several years for working up and for publication, it has seemed best to give without further delay an account of the search for incubating males of the Gaff-topsail and of the difficulties met with in obtaining and hatching the eggs, and to present the general data concerning this very interesting phenomenon together with the natural history of the fish.[2]

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[1]Contribution from United States Fisheries Biological Station, Beaufort, N. C. Published by permission of the Commissioner of Fisheries.

[2]I have pleasure in recording here the hearty thanks due my friends among the fishermen of Beaufort, N. C., for testimony as to the carrying of eggs by the fish, for advice as to where and how to take the fish, for specimens, and for a vast deal of arduous manual labor involved in the very extensive seinings carried on for six years. My especial thanks are due to Jack and Southey Mades and Henry Congleton; to W. E., C. F., and J. W. Wheatley; and to Wilbur Whitehurst, Arthur Newkirk, Pete and Billy Garner, Ed Simpson and Walter Longest.

THE SEARCH FOR THE GAFF-TOPSAIL.

Historical Account.

On July 26, 1906, while at Cape Hatteras, N. C., in company with Mr. N. F. Jennett, a pound-net fisherman of Pamlico Sound at that place, I was informed that, on the preceding day while looking over the fishes brought in from his nets, Mr. Jennett had found in his hands some catfish eggs having young on them. By their flat barbels, he had readily identified these little fish as Gaff-topsails in contradistinction to the other sea catfish. The eggs, he thought, were about the size of peas or slightly larger, but whether they came out of the mouth or the vent he could not say.

On returning to the laboratory of the Bureau of Fisheries at Beaufort, N. C. to which I was at that time temporarily attached as investigator engaged in research work in fish embryology, I began to look up the literature with a special reference to the egg-carrying habits of the catfishes and of other fishes.

This search has been kept up ever since, but the literature has been found to be so voluminous that only the data gathered in 1906 will at this time be reviewed. This is given in brief form that it may afford the reader something of an historical setting for the data to be presented herein. However, it is my purpose to publish at some future time a paper now in MS. reviewing the literature of the world on oral gestation in teleostean fishes.

Evermann and Bean, in 1898, in their "Report on the Indian River and its Fishes," say of *Galeichthys milberti,* a near relative of the Gaff-topsail, that "Mr. Stypman of Stuart, Florida, assures us that eggs are never found in this catfish, but that the young are brought forth alive. He says during March the adult females are found filled with well-developed young, each rolled up in a ball, and the various balls connected in a long string. He thinks they hatch out very much like the sawfish. Others give the same information and it sems certain that this species is ovoviviparous."

Evermann and Goldsborough in 1902 in their "Report on Fishes Collected in Mexico and Central America" describe another allied but heretofore unknown form, *Conorynchos nelsoni,* which carries its young in its mouth. This was a freshwater catfish taken in southeastern Mexico, from the Rio Usumacinto, 125 miles from its mouth. Two fish were collected, both males; of these one, 13.5 inches long, had one egg in its mouth, the other, 16 inches long, had thirty-nine eggs in the oral cavity at the time of its capture. Eight or ten other fish were captured at the same time but none carried eggs. All the eggs of the second fish save four were lost. These four after being in alcohol for two years averaged 10/16 of an inch in diameter.

Jeffries Wyman, while United States Consul at Paramaribo, Surinam, South America, had his attention called in 1857 to certain Siluroid fishes belonging either to the genus *Bagrus*, or one closely allied, which were said to carry their eggs in their mouths. These reports he verified by visits to the markets where these fish were offered for sale for food. He found either eggs or larvae in the mouths of various specimens of *jarra-bakka* and *njinge-njinge*, and was assured by the negro fisherman that *koepra* and *makrede* together with one or two forms had the same habit. The egg-carriers in all the fishes examined by him were males. The eggs of *jarra-bakka* ranged up to three-fourths of an inch in diameter. Of *njinge-njinge*, eight specimens nine inches long were examined. The eggs were in different stages of development, and the number contained in the mouth varied between twenty and thirty.

Günther in 1864 noted this curious habit in specimens of *Arius fissus* from Cayenne in the same region of South America. In fishes six to seven inches long, all males, he found some twenty eggs about the size of a pea, having on them advanced embryos. This habit, he observed, is not uncommon among American Siluroids.

In 1866, Boake described oral gestation in two species of Ceylon catfishes of the genus *Arius*. Their ova were "large" (he seems to have made no measurements of either ova or fish) and immediately after deposition are "taken up either by the fish that has laid them or by another of the same species, and, not swallowed but kept in the mouth until they are hatched and able to take care of themselves, a period of some weeks." Later he ascertained (presumably by dissection) that the egg-carrying fish was the male.

Boake sent to England some specimens of these fishes (two males and one female) which, coming into the hands of William Turner, were described by him in 1867. He confirmed Boake in all respects, and noted that one of his male specimens had ten eggs in its mouth, whereas one of Boake's specimens had thirteen. The other male, like the female, had the oral cavity empty. The "large" ova were about the size of grapes or small cherries and possessed embryos well along in development, measuring 1/2 to 7/10 of an inch in length. Some of Boake's specimens reached Günther also and he in 1866 described and named them. He commented on the habit of the male in carrying the large eggs in the spacious cavity of the mouth, and compared the fish with *Arius fissus* from South America, previously (1864) described by him.

In 1889, Day described the oral gestation of the males of two genera of Indian catfishes, *Arius* and *Osteogeniosus*. The former had eggs averaging .5 to .6 of an inch in diameter, and each carried as many as fifteen to twenty eggs in the mouth. The eggs were in stages of development varying from very early embryos to larvae nearly ready to take care of themselves.

Günther in his "The Study of Fishes" (1880), p. 160, has the following brief reference: "The Siluroid genus *Arius,* the males of which take care of their progeny, produces ova 5-10 mm. in diameter." On the same page, he gives a figure of the ovum of the *Arius boakei* marked "natural size" but measing 14 mm. in diameter. Finally Jordan in his "Guide to the Study of Fishes," (1905), vol. 1, p. 128, writes: "In certain sea catfishes (*Galeichthys, Conorynchos*) the male carries the eggs in his mouth, thus protecting them from attacks of other fishes." Again, in vol. II, p. 179, he says: "In most or all of the sea catfish, the eggs as large as small peas are taken in the mouth of the male and there cared for until hatched."

Having exhausted the literature in the library of the laboratory, I turned to the fishermen of Beaufort and began the taking of testimony, and was surprised to find how many of them had observed in a general way and now gave such unanimous testimony that the eggs are carried in the mouth. One man thought that the eggs came out in strings, another was not sure on this point, but his best recollection was that this was true, while another believed that they were hung in bunches in the roof of the mouth. All united in declaring that the eggs came out of the mouth and not out of the vent and that in size they were about equal to peas. One man phrased it that "The sea cat spits its young out of its mouth"; and all affirmed that when the fish are struck on the head or thrown into the boats, the eggs would fly out of their mouths. Boake credits the Ceylon fisherman with reporting a similar phenomenon when the egg-carrying *Arius* of that island is captured, the eggs being voided in such numbers that they are gathered from the bottoms of the boats and used for food.

Several other fishermen testified that the eggs are always carried in the mouth, sometimes as many as two handfuls, but not necessarily of the same age, and that they may be found in May and June. One man declared that the eggs were sometimes as large as the yolk of a small hen's egg and that they were "of a pinkish color between white and blood-red."

Data Obtained in 1906.

Structure of Spent Ovaries.

About this time, August 3-6, 1906, there were found in the laboratory pound net considerable numbers of Gaff-topsail catfish, all of which were brought in and examined. The ovaries presented some very interesting structures, but no extended description of them will be gone into here. They were of the ordinary teleostean type, bifurcated in front, but united behind to form the short oviduct which opens out in the urinogenital pore behind the anus. In the ovaries, only the anterior region bore eggs of any size, some of them being as large as small peas. Each of these eggs was enclosed in an investing follicle richly vascularized and was carried on a short pedicel. The middle section had only pedicels from which the eggs had broken away—the follicles having disappeared probably by resorption—together with small, almost microscopic ova in between. The posterior or oviducal part was very curiously plicated or folded longitudinally like the oesophagus of the frog and so abundantly vascularized that while alive it was of a rich beef-steak-red color.

Until August 13, our pound net daily gave us several of these catfish, the females predominating. These fish were all dissected and from the reduced condition of the reproductive organs—the ovaries running 2 to 2½ inches in length—it was clear that the breeding season was long over and that no further work could be done during this summer. Fig. 20, frontispiece, shows one of these spent females, but it might well represent a non-breeding male since there is nothing to distinguish the two sexes at any time other than the breeding season.

The structure of the ovary of *Felichthys,* in conjunction with the reported habits of *Galeichthys,* seemed to indicate that possibly the fish was viviparous, that the eggs might descend into the oviduct and there remain until hatched, nourished by transfusion of oxygen and food materials from the richly vascularized walls of the oviduct by which they might become partly enveloped. On the other hand there were the positive statements of a number of fishermen, men who presumably knew what they were talking about, that the fish incubated the eggs in its mouth. In this state of uncertainty, the question, owing to the lack of material, had to go over until the next summer.

The Search Continued—June-July, 1907.

Structure of Ripe Ovaries.

As soon as it became known that I had reached the Beaufort laboratory in June, 1907, the fishermen began to look out for catfish material for me. On June 4 they brought in a 21-inch female Gaff-topsail catfish which they had split open from snout to anus without finding any eggs. They had even cut into the ovary, following the idea, which had been advanced to them the previous summer that the eggs were possibly carried there, but had found in this only eggs still bound up in their stalked follicles. This ovary was about 4½ inches in length and was crowded with eggs in size from 10 mm. down. Having never before seen such enormous eggs in a teleost and finding ruptured follicles from which eggs had been evaginated not many days before, I came to the conclusion that these eggs must be ripe and that 10 mm. was the normal size for such.

Two days later the same men brought in two Gaff-topsails which had been caught but a few hours before and which were unmutilated. One fish, 16¾ inches long, proved on dissection to be a female with ovaries 3½ inches in length from tip to opening of oviduct. These organs were much distended with eggs 15 mm. in diameter, and occupied 50 to 60 per cent. of the body cavity. The second fish, also a female, was 21 inches long and had the most enormous and remarkable ovaries I had ever seen in any fish. They were 5½ inches long, tightly distended with eggs from 18 to 20 mm. in diameter and occupied from 75 to 85 per cent. of the body cavity. The other organs were very much reduced in size and crowded out of their normal position.

On June 13 there was brought in from our fyke net a 22-inch female with an ovary 5 inches in length, which by its flabby condition showed plainly that the season's eggs had been lately discharged. From all this mass of evidence it was clear that the breeding season of *Felichthys* was at hand, but, being intently occupied with the completion of another research in fish embryology, I was unable at the time to devote myself to this problem.

A week later, my other investigation having ended, I was ready to take up this research; but our fyke net having ceased to yield specimens and the much-expected new pound net having failed to arrive, the fishermen were called on to help.

The Finding of the Fish with Eggs in the Mouth.

On June 22, we went to the Narrows of Newport River some seven miles northwest from the laboratory. Here where the river proper enters the estuary of the same name, there are oyster reefs at the edges of extensive mud flats. As the tides swirl around these reefs, they dig out deep holes and in these holes the catfish congregate at low tide when their mud flat feeding grounds are nearly laid bare. At the uppermost of these reefs, after several unsuccessful hauls elsewhere, a big catch of Gaff-topsails was made. The number of these was unfortunately not noted, though the lengths of thirty-two egg-carriers were recorded. Probably there were from sixty to seventy-five of them in all.

From the mouths of these catfish there were obtained between 200 and 300 eggs. This is a minimum estimate, for, in the confusion and excitement due to such good fortune, no record was kept and afterward at the laboratory other eggs (to be described later), as they died, were put in the same bottles in which this day's catch was preserved. The fact that all these save thirteen were put into killing fluids was due to this same confusion and excitement which was enhanced by the threshing about of sharks and rays and the splashing of a large number of small fishes in the bottom of our boat, together with my being called on every minute to receive a new lot of eggs. Fortunately at the very last of the haul it occurred to me to try to carry in to the laboratory one of the ovigerous males, and to make sure that the thirteen eggs contained in the mouth were not lost, this was loosely sewed up with a bit of small cord. Although the fish was then put into a bucket of water which was renewed from time to time, it died, but the eggs reached the laboratory in good condition and when put into running salt water soon recovered and seemed perfectly normal.

In this connection Wyman may be quoted that in the bagre of Surinam "In many instances the foetuses were still alive through the parent had been dead for many hours." The context not indicating that the parent had been kept in water, it is probable that these larvae had lived because the moisture in the mouth of the parent had kept the egg-shells damp and hence permeable to oxygen.

Omitting small numbers, one catfish gave up eleven eggs, another thirteen, another fifteen, and others sixteen, twenty, twenty-one, twenty-six, the total amounting as stated above, to between 200 and 300 eggs. These eggs showed considerable variation in size, the extremes being from about 17 to 25 mm. in diameter, the average being from 18 to 20 mm. Their large size and great weight together with the extreme fluidity of their yolks, made them very difficult to handle for fear of hurting the embryos lying on the dorsal side. These embryos, as examination later showed, were in different stages, from that wherein the future fish was in the form of an axial rod with forming eye vesicles, to the young in the black-eyed free-tailed stage about 17 mm. long.

FIG. 21. HEAD OF AN EGG-CARRYING MALE GAFF-TOPSAIL CATFISH

The photograph shows the depressed floor of the mouth and the distended gill-covers

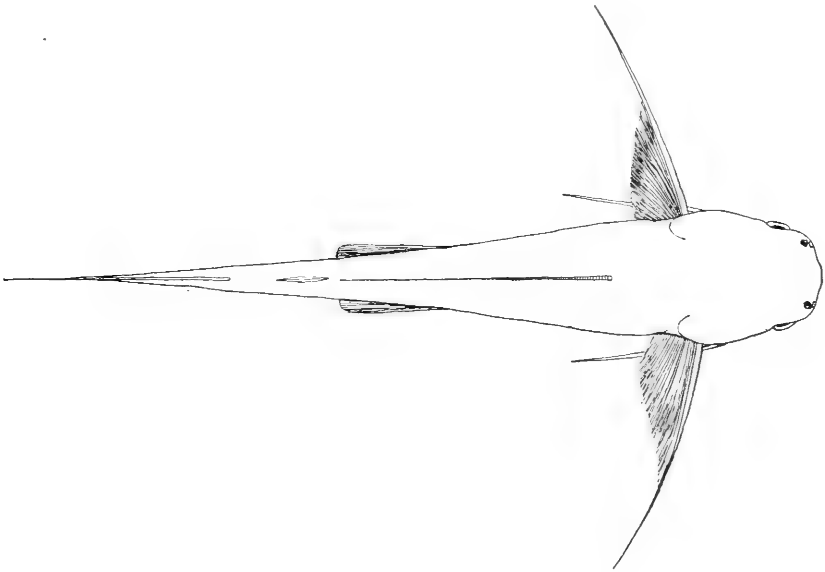


FIG. 22. GAFF-TOPSAIL CATFISH FROM ABOVE
The large head and prominent gill-covers give the fish a marked tadpole appearance. Pen sketch from a specimen 17½ inches long.

The method of procedure in obtaining the eggs was very simple. The fishermen, standing in water and mud up to their waists "fished" in the net, keeping the lead line on the bottom to prevent the escape of any fish. As the net came in the fishermen would grasp the fish just back of the head and in front of the dorsal spine, and keeping their mouths shut to prevent the escape of the eggs, would turn to the boat; then holding the fish with its tail upward, they would allow the eggs to fall or run out into a vessel of water. After being looked over for a minute, or counted in case there was a considerable number of them, they would be transferred to the killing fluid to make room for others.

On this trip only some half dozen egg-carriers were dissected, but in every case the fish was ascertained to be a male. In all the testis was small, stringy, often almost insignificant in size, indicating that the breeding season was past. With the proof by dissection that the male is the carrier of the eggs, the Gaff-topsail catfish falls in line with all other egg-carrying catfishes.

The eggs were loosely held in the mouth, some being pushed into the spaces between the branchial arches, but nowhere was there any evidence of arrangement. It was very noticeable that the mouth cavity, ordinarily so large as to be called enormous, was increased by a distension of the branchial region, but even more noticeably by a marked outpushing or rounding out of the whole hyoid and branchiostegal region. Instead of being flat or insunken as in most fishes and as in all the Gaff-topsails save ovigerous males, this region showed a rounded contour corresponding to the enlargement of the oral cavity, giving the fish a "double chin" appearance.

Figure 21 is a photograph of the head of a living male Gaff-topsail carrying eggs in his mouth. Note the depressed hyoid region and the out-spread gill covers. The mouth is held somewhat closed to prevent the escape of the eggs. Figure 22 is a pen drawing of a living Gaff-topsail, 17½ inches long seen from above. Attention is called to the great size of the head and especially to the width in the region of the gill covers.

Several other collecting trips were made during the summer of 1907 and considerable numbers of eggs were obtained. In one batch of eggs the embryos averaged 20 to 25 mm. in length and fully 3 mm. wide from inside of eyes, while their tails were about half as long as the bodies. Black pigment was noticeable along the dorsal region, the caudal fin rays were visible, and the yolk blood-vascular system was well developed, giving the eggs a beautiful pink or reddish color. (Here recall the fisherman's description.) The heads of the little fish were deeply sunken in the yolk and even the tails occupied little grooves. In this connection an interesting correlation was noted. The heads of the little fish were all twisted, right or left, only one eye being visible, and likewise the tails were twisted right and left. If the right eye was sunk, then the tail was twisted to the right, and vice-versa. This may be seen by careful inspection of figure 23 made from a photograph of the live eggs. However, it seemed to be a matter of indifference to which side the body was bent, for of the 114 eggs on hand, fifty-four had the embryos bent to the right and sixty to the left.

The last trip for 1907 was taken up Newport River on July 18. Again former experiences were repeated, for no catfish

FIG. 23. EGGS WITH LARVAE

Showing the insunken heads, curled tails and prominent yolk circulation.
From an instantaneous photograph.

were taken until the mud bottom of the upper oyster reef was hauled. Here was secured one male, 18 inches long and from his mouth were taken 21 actively wriggling larvae, one of which was lost. One of these, of average size, died on its way to the laboratory (probably having been injured in being taken from its father's mouth). After being hardened for 24 hours in 10 per cent. formalin, it measured as follows: Length all over from point of snout to tip of upper lobe of caudal 57 mm.; width, between eyes outside to outside, 11.25 mm.; length of dorsal spine, 14.65 mm. The yolk was 18 mm. in diameter measured in the long axis of the fish, and 16.5 mm. in diameter at right angles to the above—the vertical measurement or depth of the fish was unfortunately not noted. On these fish the black stippling was quite thick on the head and along the dorsal region of the body. It was thickest at the roots of the dorsals and on the body it was arranged in distinct lines following the myomeres. Although the eyes were well along in development, the faint choroid slit could still be seen on the ventral side. The anal papilla showed as a projection in the center of a triangle formed by the pelvic and anal fins. In the nasal region, between the two orifices, a flap-like papilla-shaped organ was noticeable.

Figure 31 shows these little fish in the stage of development referred to. It is from an instantaneous photograph made in direct sunlight. The larvae are as yet unable to lift their heavy yolks. Their mode of progression is by "skating" on their yolk sacs over the smooth bottom of the aquarium.

Further Search, 1908-12.

My summers during the years 1908-1912 were spent in the Fisheries Laboratory at Beaufort in strenuous endeavors to fill out my embryological series of the eggs of the Gaff-topsail and to find out if possible how the eggs are transferred. In this work the few successes were interspersed amid many failures. Had artificial fertilization been possible the first task would have been much lightened, and had the fish been small enough to keep in even large aquaria, the latter might have been possible. But as it was I was never able to get breeding males and females at the same time save once and then artificial fertilization failed; while for the second point there was no tank in the laboratory large enough to hold these considerable-sized fish. In addition there were other hindering causes which at times defeated all efforts to collect the ovigerous males. A brief recital of these will enable the reader to form an idea of the great difficulties under which research in the habits of fishes is pursued. Later the difficulties met with in the effort to hatch the eggs will be discussed.

Difficulties Due to Heavy Rains.

In 1908 I reached Beaufort on the afternoon of May 28. On the following day 4.02 inches of rain fell. On May 22 it had rained 3 inches, and the total rainfall from May 22 to 29 was 7.79 inches. The total rainfall for the month was 11.07 inches, being 8.05 inches above normal. Again, on July 9-10, 4.48 inches of rain fell in 24 hours, while in a similar period toward the close of the month the precipitation amounted to 5 inches.

The result of all this abnormal downpour was that the water at the head of the estuary of Newport River was so freshened that the catfish, especially males with eggs, were driven out of the deep holes along the mud flats at the Narrows and dispersed in the lower and broader reaches of the estuary where it was exceedingly difficult to find them. Thus it came about that the first lot of eggs was not obtained until June 11, the second lot on June 15, and the third and last on July 7. Consequently, the batch of eggs gotten on the first of these dates was far too old to furnish the early stages so earnestly desired, since, by reason of a grant[1] from the Carnegie Institution of Washington, an artist was at Beaufort to draw figures to illustrate the embryology of the fish.

Again in 1912, the search for the Gaff-topsail was greatly hampered by heavy downpours. On May 22 (the day of my arrival at the laboratory) the rainfall was 1.31 inches, and the precipitation from May 6-22, inclusive, was 7.51 inches. This so freshened the estuary of Newport River that the catfish were driven into the lower harbor, and possibly into the ocean. At least none were taken by any drag-net fishermen visited in Newport River, while the menhaden fishermen reported the taking "outside" of considerable numbers—more than usual.

[1]Figures 20, 22 and 28, reproduced in this paper, were drawn under this grant by Mr. E. A. Morrison. The photographs were all made by the author.

Effects of Cold Weather.

In 1911, more strenuous efforts than ever were made to obtain the early eggs. Having heretofore always reached Beaufort after the beginning of the breeding season, I made two trips this year. It should be noted, however, that the spring of 1911 was a late and cold one, extending well into May. There was a light frost in Beaufort on May 8, while toward the 20th it turned suddenly quite warm. The cold weather greatly delayed the breeding season, while it was greatly accelerated beyond the normal when the warm weather came.

On the first trip the laboratory was reached on May 13. On that day, and on the 15th, trips were made to our favorite fishing grounds. Here great numbers of catfish were taken, mainly large Gaff-topsails with enormous ovaries distended with many large eggs. While their bellies were tremendously swollen, their genital orifices were but little reddened, and no eggs could be obtained though vigorous efforts were made to spawn them.

The males, though smaller than the females, were adult, but from none could milt be obtained. None of the males of the first day's catch had "double chins" indicative of a readiness to receive eggs. However, those of the second day's collecting did have the depressed hyoid region, the throat enlargement, but none carried eggs nor could milt be obtained from any.

On the trip of May 18, not a single *Felichthys* was taken. Evidently it was too early, the ripening of eggs and sperms having been greatly retarded by the cold weather. It was necessary for me now to return to my college duties, but on May 20 Mr. Henry D. Aller, Director of the Laboratory, seined for me, but without getting a single cat.

On May 25, I returned to Beaufort and personally supervised another seining, from which were obtained the youngest lot of eggs but one ever gotten during the whole of this research. These eggs had on them blastoderms with forming embryos, but neither these nor any others ever taken showed the coveted segmentation stages. Further seinings brought in only older eggs, and failure and disappointment were the result of this expenditure of time and money.

Difficulties Due to Inexplicable Causes.

The most disheartening failures of all during this collecting work were those for which no cause could be assigned, for neither rain nor cold weather interfered. At various times during all these six years' work, but especially during the latter half of the season of 1910, trip after trip was made to all our hauling grounds, where in times past boatloads of catfish had been taken, but all were "water hauls," few fish and *no* eggs being taken. At one period some six or eight trips, covering two weeks, did not bring in a single egg. To make these trips, it was necessary to leave the laboratory from 3 a. m. to 7 a. m., in order to reach the seining ground at or before low water.

In the meantime many fishermen were visited. Some of these used seines 1,200 feet long and drifted over a mile of river. They caught few small catfish or none at all, and none carried eggs. A few undersized females had in their stomachs small gray holothurians, which are to be found "outside" only, and hence, it seems to be a possible conclusion that for some unknown reason the catfish had left the brackish river for the saltier ocean.

THE NATURAL HISTORY OF *FELICHTHYS FELIS.*

Description of the Gaff-topsail.

Felichthys felis, (*felis,* cat; *ichthys,* fish), whose portrait forms the frontispiece of this paper, is one of the two kinds of sea catfish found at Beaufort, the other being the much smaller *Galeichthys milberti* previously referred to. The body is elongated, but, as figure 22 shows, very large in the head region, the greatest depth being at the anterior edge of the first dorsal fin. The nostril is double. The eye, which has a vertical pupil, surrounded by a red iris, is placed low on the side of the head and just above the insertion of the maxillary barbel. This latter is flat and very long, reaching almost to the anterior base of the pelvic fin. The pectoral and dorsal spines are continued in long filaments, and these, together with the long, flat maxillary barbels, are such marked features as to make it impossible to confuse the Gaff-topsail with any other catfish found in the salt or

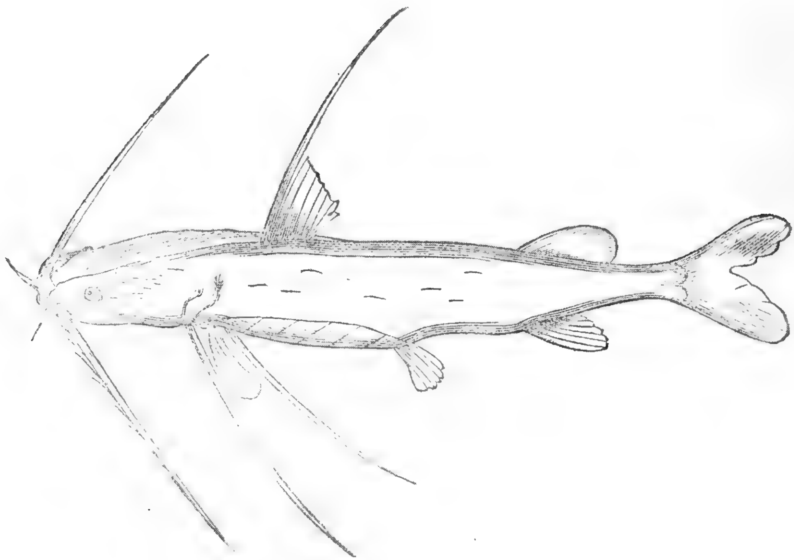


FIG. 24. MARCGRAVE'S GAFF-TOPSAIL
The earliest known figure of this fish (1648).

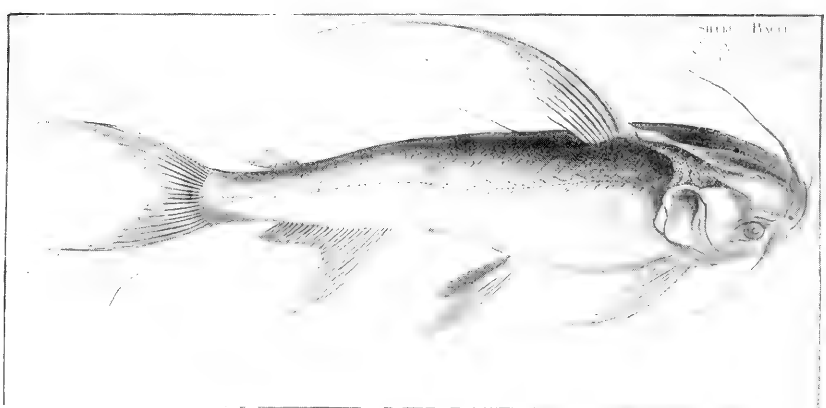


FIG. 25. BLOCH'S FIGURE OF THE GAFF-TOPSAIL (1794)

fresh waters of the United States. The caudal fin is large and deeply forked, the upper lobe being slightly the larger. The color of the fish is a beautiful silvery blue, darker above and lighter below, best seen in lateral view. The fins, especially those on the ventral part of the body, show a reddish tinge as first noted by Mitchill (1815).

History of the Fish.

The discoverer of our fish seems to have been George Marcgrave, in whose Natural History of Brazil (1648) there is figured and described a catfish with flat barbels and long filaments to dorsal and pectorals which is apparently the fish under consideration. Figure 24 is a photographic copy of Marcgrave's figure. This figure, as I have shown elsewhere (Gudger, 1912), was probably painted by Marcgrave himself while in Brazil sometime between 1638 and 1644. It has suffered many things at the hand of the engraver, who seems to have been one De Bray.

His description may be translated: "This Bagre, though of another kind, is in size and shape like the preceding; but it has a beard made of four ray-like barbels, two of which are eight digits long and wide like straps, and two are short ones. To the dorsal fin there is [attached] a similar strap nine digits long, and behind the gills barbels of the same kind. The other [fins] are similar to those of the preceding fish."

Attention is called to the four barbels, the two maxillary ones being long and flat or strap-shaped; and to the strap-shaped (*ligula*) dorsal and pectoral filaments. Another interesting point is to be found in the rays of the dorsal fin. While Marcgrave in 1644 knew nothing of the use of fin rays in distinguishing the genera and species of fishes, he has portrayed his fish with one spinous and seven soft rays in its dorsal fin, the correct number.

Marcgrave's figure and description have been copied by a large number of the old writers. Without going into details there may be named: Piso (1658), Willughby (1686), Ruysch (1718), Johnston (1758), and Bonnaterre (1788). However, that greatest ichthyologist of them all, Marcus Elieser Bloch, in 1794 figured and described a sea catfish from Surinam which he says is identical with Marcgrave's. Figure 25 here is a photograph of Bloch's fish. He notes that the nostrils are double, that the oblong eyes with black pupils and red irises are near the angle of the mouth. His figure shows four barbels, the two maxillaries being long and flat; and also the long filaments to dorsal and pectoral fins.

Doubt has been expressed as to the correctness of Bloch's identification, but the Eigenmanns in their great monograph on South American catfishes (1890) have identified Bloch's sea catfish with the Gaff-topsail.

Bloch's description gives the fin rays as follows: dorsal, I-8; pectoral, I-12; pelvic, 8; anal, 24. His figure has 26 rays in the anal, but he notes that Gronow counted 23 in the anal of another specimen; it also has I-7 in the dorsal which is correct, though his description says I-8; the figure likewise has 8 rays in the pelvic whereas the true number is 6. However, Bloch in 1794 may be forgiven for a miscount of the fin rays in his figure when Jordan and Evermann (1900) in their figure 52, plate XXIII, have the dorsal fin I-6, and anal 22.

The earliest American describer of the Gaff-topsail was Mitchill in 1815, who took it in the waters of New York. Indeed he definitely gave this fish a place in zoological literature by his splendid description which, however, need not be repeated here. The name *Felichthys felis,* by which the Gaff-topsail is known today, was assigned by Jordan and Evermann in 1900.

Habitat.

This fish is a sub-tropical form ranging as far north as Cape Cod, but is especially common along the South Atlantic and Gulf Coasts where it is abundant in brackish waters, for which it seems to have a predilection. Bloch as early as 1794 noted that, "This fish (the saltwater katfish) is found not only in Brasil but also in the great rivers of North America." By this he probably meant in the estuary mouths of these rivers which are brackish. The Eigenmanns note (1890) that it is found along the Atlantic coast of America from Cape Cod to Rio de Janeiro.

The earliest account given of the occurrence of catfish in North Carolina coastal waters is found in Thomas Ash's "Carolina," published at London in 1682. The reference to seamen indicates that the fish in question was a marine form, and, since (as will be shown later) the Gaff-topsail is the more abundant of the two marine Siluroids on our coast, we may conclude it to be Ash's fish. "—— Cat-fish, whose head and glaring eyes resemble a Cat; it's esteem'd a very good fish, it hath a sharp thorny Bone on its Back, which strikes at such as endeavor to take it; which by seamen is held venemous."

Again, John Lawson says (1714), "Catfish are round, blackish fish with a Great Flat Head, a wide mouth, and no scales. They sometimes resemble Eels in taste. Both this sort and another that frequents the salt water, are very plentiful." The "another sort that frequents salt water" was in all probability the Gaff-topsail. Brickell (1737), whose data seems largely to have been taken from Lawson, does little else than repeat the statements above given.

The first definite record of the occurrence of the Siluroid fish known as the Gaff-topsail in North Carolina waters was made by Yarrow in 1877. Since his day the fish has been well known and often recorded.

At Beaufort *Felichthys* is taken everywhere in the "rivers," which are really brackish estuaries. My best catches have been made at the very head of Newport estuary, within one mile of the limit of tide water, where at dead low water the density was 1.007.

It is very abundant on both coasts of Florida; in the Indian River so much so as to be a great nuisance to the fishermen. It is also abundant in all the sound-like lagoons and the estuarine river mouths opening into the Gulf of Mexico.

H. M. Smith (1907) says that the smaller relative of the Gaff-topsail, *Galeichthys* (weasel-fish) *milberti*, is the most abundant of the sea catfish at Beaufort, but I have not found it so in my many years of seining there. The Gaff-topsail is found in large schools, and I have often taken 100 or more at a haul, while my fishermen on one occasion caught a wagon-load, estimated at over 500, ranging from 20 to 25 inches in length. On the other hand I have never taken more than a half dozen at a time of the small-mouthed catfish. It seems to be a shy and possibly a rather solitary fish.

Swimming Habits.

The Gaff-topsail is a bottom liver, and generally not a very rapid swimmer. The strong tail and deeply forked caudal fin might lead one to think to the contrary, but, if the fish is viewed from above (Fig. 22), it is readily seen that the enormous head parts would render it impracticable if not impossible for the fish to get up much speed.

Although a bottom swimmer, nevertheless as the net comes in, the Gaff-topsail has the interesting habit of swimming near the surface of the water with the dorsal fin, or at any rate the filament, projecting above the water. This habit of carrying the dorsal fin and filament in an elevated position gives it its name, Gaff-topsail. DeKay as early as 1842 made note of this peculiar swimming habit. In Newport River at dead low water, when the fish, driven off the mud flats as the water lowers, collect in deep holes, this same habit may be noticed.

Furthermore, for two weeks in the summer of 1910 I kept a 12-inch *Felichthys* in a 4 by 6 foot wooden tank in the laboratory at Beaufort, and during this time it persisted in swimming at the surface of the water with its dorsal filament carried high out of water. At the same time two *Galeichthys* in the same tank as persistently swam at the bottom 6-8 inches below. Gaff-topsail larvae also show a marked tendency to swim at or near the surface of the water of their aquaria. Even more marked is their habit of "hanging" motionless at the surface, much as a frog does.

Behavior when Caught in a Net.

When caught in a seine, the Gaff-topsail has the very annoying habit of rolling itself up and very effectively entangling its dorsal and pectoral spines in the meshes. So firmly imbedded does it sometimes become that it is necessary to break its spines or to cut the net to get rid of it.

It is also a great annoyance to the fishermen in another way. All fish give off a slimy mucus which is very destructive to nets, causing them to rot rapidly, but of all fish known to me the Gaff-topsail, when caught, gives off not only the most slime, but the most tenacious. Only repeated washings and rubbings will take it off the hands, and it is almost impossible to get it off the nets. Fishing for and handling this catfish is a very nasty matter.

Defensive Habits.

So far as I have been able to ascertain the Gaff-topsail has no offensive habits. Twelve and fifteen-inch specimens kept in tanks with various other and smaller fishes showed no tendency to molest these latter. It is true that *Felichthys* is sometimes found with fish in its stomach, but it is not impossible that these were dead or at any rate disabled ones which were not able to escape the relatively slow moving catfish. Certain it is, as will be shown in the next section, that the food of this species is mainly crustacean.

However, weapons of defense are present in the shape of dorsal and pectoral spines and are capably used. If the fish is caught and held by the tail it will swing violently and convulsively to the right and left almost through an arc of 180°, endeavoring to strike with its pectoral spines. If picked up incautiously it will almost surely wound one. The only safe way to grasp it is across the back of the head in front of the dorsal spine, the thumb on one side and the fingers on the other behind the pectoral fins. Held firmly thus (see Fig. 21), it is almost incapable of inflicting a wound. Such wounds, while quite painful, are not especially dangerous, though bacteria carried in with the slime may set up an inflammation and the slime itself may possibly be toxic.

These points were covered by Thomas Ash, two and one-third centuries ago. Writing in 1682, he says of a marine catfish on the coast of North Carolina (for reasons given before, presumably the Gaff-topsail): ". . . . it hath a sharp thorny Bone on its Back, which strikes at such as endeavor to take it; which by Seamen is held venemous; yet, I saw one of our Seamen, the back of whose Hand was pierced with it, yet no poysonous Symptoms of Inflammation or Rancor appeared on the Wound, which quickly healed, that I concluded it was either false, or that of this Fish there were more kinds than one."

Food and Feeding.

The Gaff-topsail is an omnivorous feeder, almost anything being meat that comes to its mouth, whether fish or crab or worm. It seems to affect mud flats and after them submerged sand flats as feeding grounds. The water in the Beaufort region, where the sea cat-fish is found, is too muddy for any observations to be made on the feeding habits, but if one may judge of these by analogy after observing the habits of the young (4 to 6 inches long) in a large aquarium, it probably feeds by swimming a few inches above the bottom with its long barbels, tactile organs, just touching the surface of the mud. Whenever these touch anything edible, there is a quick turn, a sudden opening of the cavernous mouth and it is gone. I have often experimented with the young, and have found their barbels exceedingly sensitive to bits of oyster dropped into the aquarium. I have seen the little fish thus arrested, stop in full flight and even turn a somersault in its eagerness to get at the oyster. The fish, of course, would readily perceive moving objects and if these were edible, would snap them up. The feeding described above is more that of a scavenger.

The food of the adult is—anything edible. I have on dissection found the stomach filled with fish, worms, crabs. The latter, however, is its staple food, and I have taken from the stomach blue crabs so large that it was difficult to see how they could have been taken into the mouth and down the oesophagus. Autopsy has revealed the presence of ascidians, and, during one summer, certain small gray holothurians as noted above (page 138). H. M. Smith, (1907), notes similar feeding habits and food for the smaller ocean catfish, *Galeichthys milberti,* at Beaufort.

Before leaving this subject it may be noticed that in Florida this and the other marine catfish are accused of feeding on human feces. I have had a very detailed account of this from a man who is absolutely reliable, and his account has been corroborated by a scientific friend who has personally seen the fish thus engaged.

Parasites.

As might be expected from its omnivorous feeding habits, the Gaff-topsail harbors a considerable number of worm parasites. However, as the greater number of my autopsies have been performed at the fishing ground with other points in view and while greatly pressed for time, my notes merely record the finding of worms in the stomach. Further, however, it is interesting to note that another investigator, working at Beaufort on internal protozoan parasites, has found in the intestine of our fish considerable numbers of a large potato-shaped ameba having remarkably clear protoplasm and a rapid rolling motion. This and other results have not yet been published.

Use as Food.

The value of the Gaff-topsail as a food fish is, irrespective of other points, considerably diminished by the large size of its head and by the bony cuirass extending back to the origin of the first dorsal. Nevertheless, it has been, and is used as food. Bloch, (1794), says that it is eaten, but that its flesh is not especially palatable. Ash, (1682), remarks of the marine catfish that: ". . . . it's estem'd a very good Fish." The older American ichthyologists thought highly of it as a food fish. Thus Mitchill, (1815), says, "It is an exquisite fish for eating." While De Kay, (1842), writes: "Its flesh has been represented to me by those who have eaten it as having an exquisite flavor." But Jordan, (1884), while remarking that its flesh is palatable, says that it rarely is saved for food, for the most part being thrown away.

Various authors, Jordan and Gilbert (1883), Henshall (1891, 1895), Evermann (1899), Gregg (1902), and others, writing of this fish in our southern waters, say that by reason of the abundance of other and far better fish it is rarely eaten, save by negroes. I never knew the fish to be eaten at Beaufort, nor was there any demand for it for export save in one season. There was a considerable shortage of fish in 1908 and a New Bern fish dealer, who had a "buy boat" anchored in Newport River, bought Gaff-topsails along with other common (non-choice) fish to sell to the negroes of that town. I have eaten its flesh, in order to be able to report on it, and have found it not unpalatable, but not particularly appetizing. Perhaps, however, it was not well prepared.

Sounds Made by the Fish.

Felichthys felis makes two distinct sounds, one a croaking and the other a rasping sound. The first is the more common and is produced by the swim bladder. If the fish be grasped back of the pectorals, distinct pulsations may be felt with every croak. These are very apparent in a fresh and vigorous fish, especially if it shows signs of anger. Larvae also croak and by holding them in the fingers it will be noted that, as in the adults, pulsations may be felt in the body wall.

The rasping sound made by the Gaff-topsail was first thought to be due to the fish rubbing its superior and inferior pharyngeals together. However, it was soon noticed that the grating or rasping sound was accompanied by a spamodic jerk of the pectoral spines, and that if these were held immovable no rasping sound could be perceived although the croaking continued, the gritting noise beginning again when the spines were released. So it seems that these sounds are made by the spines as they rotate in their sockets.

On one occasion, after some resistance on her part, I took a large active female cat from the water and laid her down in the dip net on a small pile of oyster shells, whereupon she made a spitting noise for all the world like an angry tabby cat. I am not sure how it was done, but it was possibly a combination of the two sounds previously described, and the pile of oyster shells may have acted as a resonator aiding in combining the two sounds. This was the only occasion on which this peculiar sound was noticed.

Size of Breeding Females.

It will be of interest briefly to consider the size of breeding fish, and first of the females. In fish generally these run larger than the males, and in our catfish this is especially true, due largely to the enormous ovaries filled with huge eggs ranging up to 25 mm. in diameter.

FIG. 26. CEMENT CAST OF THE MOUTH OF THE MALE FISH CARRYING 55 EGGS
Dorsal view.

FIG. 27. CEMENT CAST OF MOUTH
Lateral view of Fig. 25.

The fish taken on May 13 and 15, 1911, are quite typical of breeding females. These had not spawned their eggs and hence had enormous bellies. The largest, taken May 15, measured: 19½ inches, 1; 20 inches, 2; 22½ inches (15 inches in girth), 2; 23 inches, 1; 23½ inches (14 inches in girth), 1; 24½ inches, 1; 25 inches, 1. This last was the most enormous catfish I ever have seen. She measured 19 inches in circumference just back of the dorsal fin, the filament only of which (whence the name Gaff-topsail as noted above) was 3¾ inches long. She had, however, not reached her maximum size for her eggs were not ripe—they could not be spawned.

Size of the Incubating Males.

This can best be set forth by giving the sizes of 32 egg-carriers measured on the initial trip taken in this research, June 22, 1907. It will be noted that their sizes run very uniform, but that they are markedly smaller than the females. On this day there were measured: 1, 15¾ inches over all; 4, 17½ inches; 9, 18 inches; 3, 18¼; 7, 18½; 2, 18¾; 1, 19; 1, 19¾; 1, 20; 1, 20½; 2, 21: 32 in all. Of these 32, 23 range from 17½ to 18½ inches; and generally speaking later observations confirm these figures as being the average.

How the Eggs Are Carried.

These breeding males, as previously noted, carry the eggs loosely in the mouth, the gill-covers being widened outwardly and the hyoid distended downward to make the "double chin" previously referred to. In this way the cavity of the mouth is enlarged and its capacity increased. As may be seen from figure 22, which is a pen and ink sketch of a 17½ inch breeding male, the Gaff-topsail, like most siluroid fishes, is largely head, and the head is mainly mouth. Figure 21 shows the mouth distended in the hyoid region to accommodate the eggs.

Size of Mouth Cavity.

A number of casts were made of the mouths of fish carrying large numbers of eggs, but of them only the largest will be considered here. This was of a 22-inch male burdened with fifty-five eggs, the largest number ever obtained from any Gaff-topsail in the course of this work. This fish was carried to the laboratory, seven miles away, that the capacity of its enormous "Keim-höhle" might be made. However, there was but a small quantity of plaster of Paris in the laboratory and *none* in Beaufort. In this predicament, Director Aller came to the rescue with the suggestion that cement be used, there being a barrel at hand. So a tolerably thick grout was made and the mouth filled with it, a towel being wrapped around the gills to prevent the escape of the cement before it had hardened. The head was then cut off, put out in a cedar thicket, where covered with a box it was left until the ants had eaten off the flesh. Later it was cleaned, shellacked, and photographed. Figures 26 and 27 are dorsal and lateral, views of this huge cast. The volume of this cast, up to the insinking in the oesophageal region, is 580 cc.

Size and Structure of the Skull.

In intimate connection with the size of the mouth is the matter of the magnitude of the skull. Reference to figures 20 and 22 shows that the head makes up a large part of the body, about one-quarter of the length and possibly an equal part of the bulk. The buccal cavity, as has been shown in the preceding section, is enormous. In order that the reader may get a clearer idea of what gives it this great size, two views of the skull are given. Figure 28 is Mr. Morrison's drawing of the dorsal surface, while figure 29 is a photograph of the ventral surface of the same skull. The buccal cavity extends the whole length of the under surface of the skull, the hinder part, the beginning of the oesophagus, being formed under the coalesced vertebrae.

Since such would be apart from the purpose of this paper, no attempt will here be made to work out the osteology of this very interesting skull. However, attention may be called to its armor-clad dorsal surface. This will explain why so much

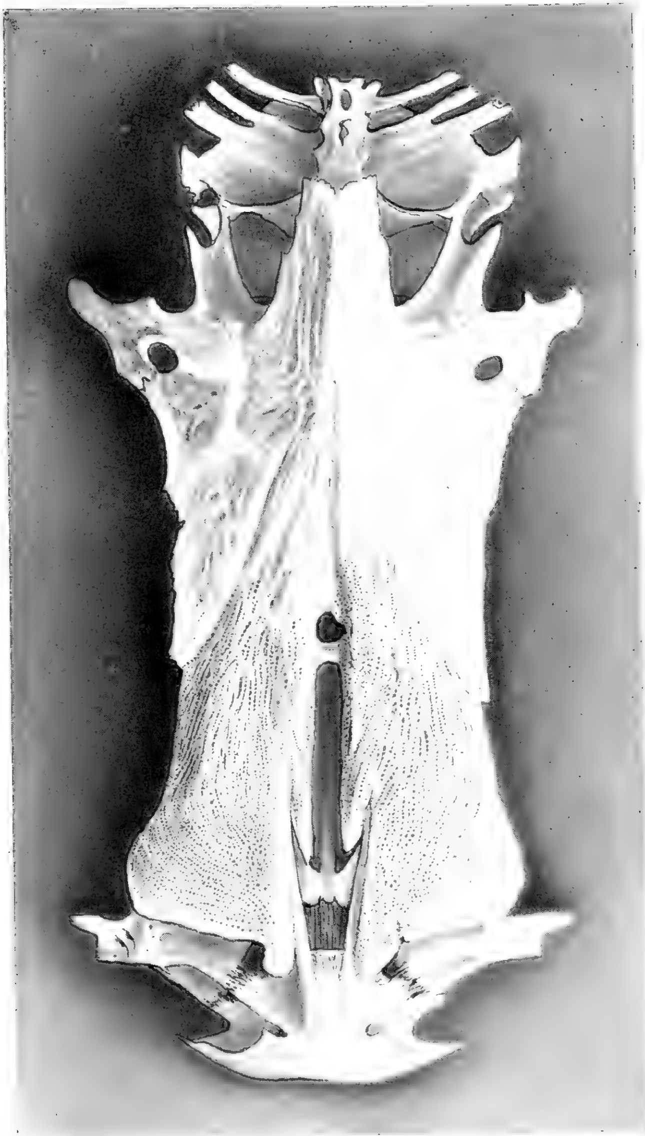


FIG. 28. SKULL OF THE GAFF-TOPSAIL
Dorsal view showing the fontanelle.

clubbing on the head is required to subdue an active catfish. There is, however, one easy method of quickly and comparatively easily killing a catfish. This is by inserting a knife blade through the slit in the anterior median line in the bony armor. Through this the brain is easily reached. This open space in the roof of the brain is called a fontanelle. In the higher bony fishes it is closed, and its presence here is an evidence of the lowly position of the catfish in the class Pisces. It is an inheritance from its shark ancestor, which had a very marked fontanelle in the corresponding region of its skull.

The only person, who, so far as has been found, seems ever to have noticed this structure in the skull of the catfish and consequently this method of killing it, was John Luccock. Luccock made a journey in 1808 to Rio de Janeiro and the River Plate, and twelve years later published a very interesting account of his travels which contains many valuable natural history notes. In speaking of the Bagre caught in the La Plata off Buenos Aires, he says: "It lives long out of water and is with difficulty killed by blows. I observed in the plate of the skull, between the eyes, a small aperture, covered with a thin whitish membrane, and imagined that through this, it might be killed by touching the brain. We accordingly introduced a filament taken from one of the bass cables, which produced an immediate paralysis and the fish died without further suffering."

Turning to the ventral surface of the skull of *Felichthys* we find some equally interesting structures. In the posterior region are the large round paired bullae containing the ear stones. Ventral and posterior to these we have a curious bony formation very like a crucifix, the two little semi-circular bones behind (above) it looking somewhat like a halo. I have the indefinite recollection of having somewhere read of the feeling of semi-veneration paid to the catfish skull showing these structures by the superstitious inhabitants of the Guianas and the neighboring islands but I have been able to lay hands on but one reference.

The Beebes in their charming book, "Our Search for a Wilderness", (1910) say that, while their vessel was anchored in one of the mouths of the Orinoco: "At the bottom, our hooks would be taken by great fierce-whiskered cats, bedecked with long streamers, which gave no end of trouble before they were quieted. They were pale yellow, and the head and back were encased in bone; Maestro the cook called them the Crucifix fish, and later showed us why. On the under surface of the bony armor is a large cross with a halo about it just above the arms. The crew never caught one of these fish without making the sign of the cross in their right palm".

The Beebes give a photographic reproduction of "the crucifix in the catfish", but their figure seems to have been made from a skull that had suffered considerable erosion. It does not have the sharpness and clearness of detail found in figure 29.

Size of Eggs and Number Carried.

The ripe eggs vary in size as is to be expected, running from 15-25 mm., but the average diameter is 19-20 mm.. The smallest number of eggs found in the mouth of any gestating male was two. Two fish were found, 13 and 15½ inches long over all, each with two eggs. Once, it is true, a large male was found carrying only one egg, but from the great size of his buccal cavity there is good reason to believe that other eggs had been thrown out in the process of capture. This I have known the Gaff-topsail to do. Large numbers of eggs are by no means unusual; a dozen fish have been taken with eggs in the thirty's; forty-five eggs have been taken twice; fifty were obtained from a 22-inch male; and greatest of all fifty-five from another fish of the same size.

Attempts to Hatch the Eggs Artificially and the Difficulties Met With.

Early in the course of this investigation it was seen that it would be necessary to carry these eggs by artificial means to the point of hatching and beyond, if an embryological series was to be obtained. However, it seemed doubtful if eggs accustomed to such a highly specialized brooding chamber could possibly be carried on to hatching in open jars of running sea-water.

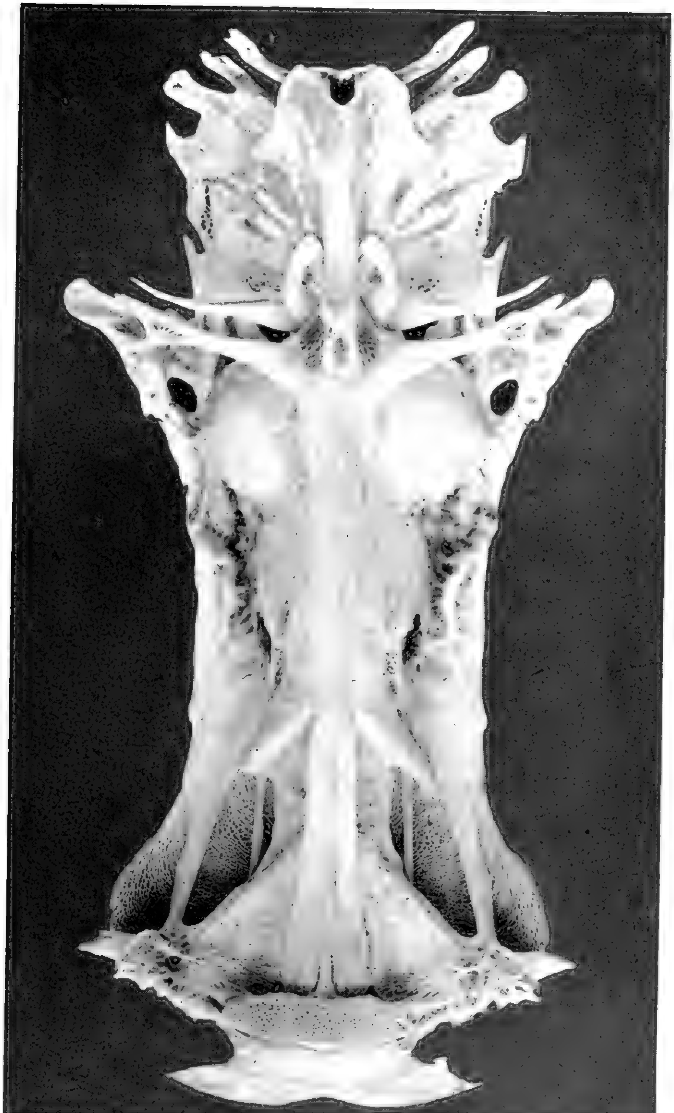


FIG. 29. VENTRAL SURFACE OF SKULL

Showing the "Crucifix in the Catfish."
Photograph of same skull as Fig. 28

Unfortunately it was never found possible to bring incubating males to the laboratory, for the fish either died or at best became sick and spat out their eggs. The eggs however could readily be brought in in pails of water renewed at intervals.

But for all this great difficulty was experienced in keeping these eggs alive. At first they were kept in shallow glass aquaria under running salt water, but the fine sediment from the water so thickly covered their shells that the supply of oxygen was to no inconsiderable degree cut off. That this was not the only cause of their "going bad" was, however, afterwards ascertained.

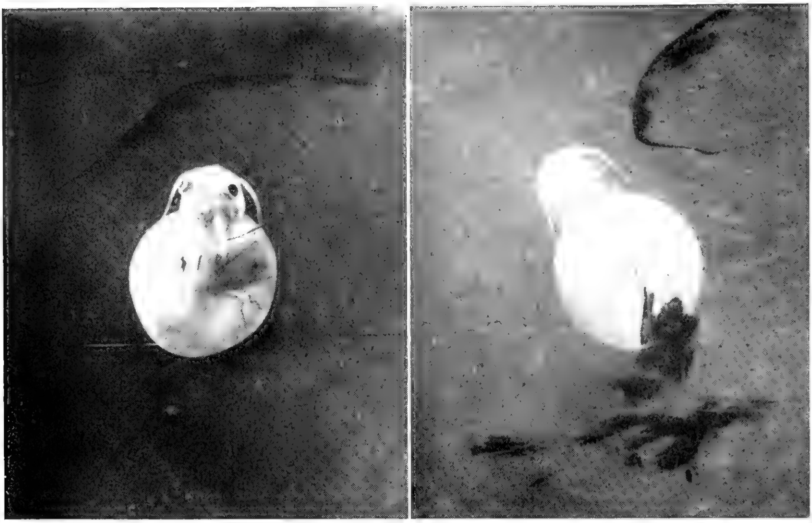
To remedy this, some of the eggs were put in filtered sea-water with *Ulva* and placed near a window but not in direct sunlight. Though some died, others did fairly well for a while. The greater number, however, were put in baskets of a coarse-meshed galvanized wire netting and hung in aquaria 9 inches deep under running salt-water—the idea of course being that the greater part of the sediment would fall through to the bottom. These baskets were hung with copper wire covered with thread and erroneously supposed to be paraffined. Possibly this combination made a weak electrolytic apparatus. At any rate, on the day following their suspension thirty-nine dead eggs were taken from the baskets. The baskets were then suspended by zinc-coated wires, but the mesh being rather large, the heavy eggs settled down in it in such a way as to cause congestion in the yolk circulation and finally death.

After the death of all the eggs, as noted in the preceding paragraph, another trip was made and another lot of eggs in fine condition was brought in. Each had an embryo on the top nearly ready to burst the shell. Each little fish rested in a groove in the yolk, the head lying flat with both eyes above the groove. The tail of each was bent, the caudal fin covering one eye and reaching to the edge of the other. Here again see figure 23.

The eggs continuing to die daily, in seeking to remove all possible causes, it was thought that the density or saltness of the water might be too great. This at the laboratory averaged 1.021, while at the Narrows of Newport River, where the fish were caught, it was at the surface 1.007. To obviate this possible cause a number of eggs were put into filtered sea-water diluted with filtered rain-water to a density of 1.016 and were placed under running water of the same kind carried over by a siphon. These eggs all died, possibly because the flow of the siphon was insufficient to aerate the water in which they were placed. Presently but one egg remained. The larva on this had burst its tough shell on the dorsal side, and through the slit had thrust its head and the anterior part of the body. With its projecting eyes, black with a golden ring, and its head parts faintly stippled in black, it presented a striking and beautiful appearance. Fig. 30, A and B, from photographs made on this day, give some idea of the dorsal and ventral surfaces of this egg; only colored drawings could do it justice. Probably as a result of the handling incidental to the photographing of this egg, is was found dead the next morning.

All other methods having failed to bring about the hatching of these eggs, it was determined to try the hatching jar devised by former Commissioner of Fisheries MacDonald and named after him. In this apparatus water is admitted to the bowl-shaped bottom of a tall glass jar, whence it rises up through the eggs and escapes by means of a pipe at the top. The purpose is to keep the eggs continually in motion and to carry off all sediment, bacteria, and mold spores by the escape pipe at the top. With the catfish eggs it was hoped that the current of water would be sufficiently strong to keep the eggs agitated, to lift them up enough to prevent the congestion of the ventral yolk-sac circulation consequent upon the considerable weight of yolk plus embryo. However, the outcome was only partially successful, for even in the hatching jars the mortality was very great.

On July 7, 1908, a trip to the Narrows was made in the hope that hatching eggs might be gotten. In this we were successful for two cats were taken. One, 17¼ inches long, carried thirty-six eggs. The little cat on one of these eggs had burst its prison and had thrust its head out of the rent in its shell as shown in figure 30 and the others were about ready to do so. The other male carried in his mouth six larvae 53-55 mm. long over all, sitting on yolk sacks so heavy that they could not yet lift them. Here again see figure 31. This would seem to fix the first week in July as the approximate hatching time.



A B

FIG. 30—A & B. A LITTLE GAFF-TOPSAIL THAT HAS JUST BURST THE SHELL

A—Dorsal view. B—Ventral view.

From an instantaneous photograph.

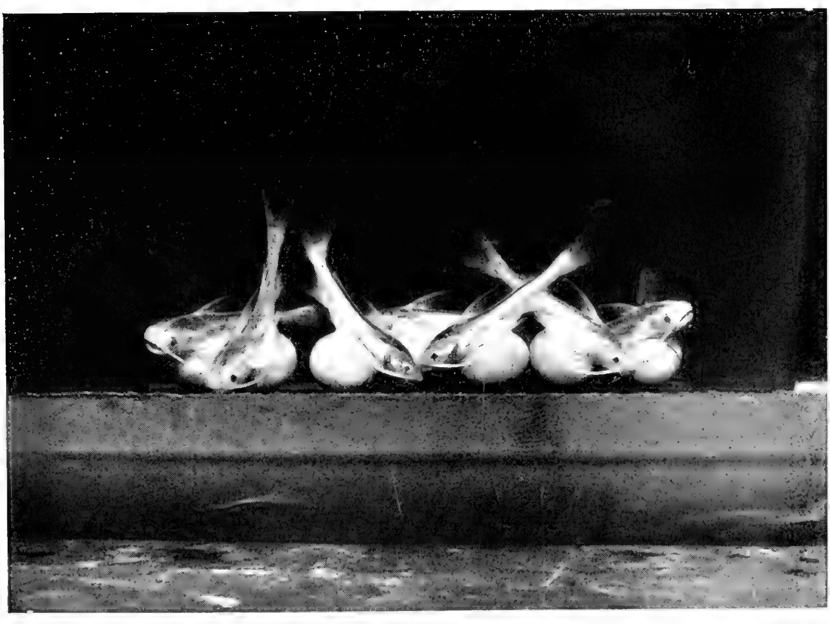


FIG. 31. LARVAE OF THE GAFF-TOPSAIL CATFISH

From an instantaneous photograph of the little catfish skating on their yolk-sacks at the bottom of an aquarium.

Great difficulty was experienced in hatching these eggs. Some died with congested yolk circulations as described above for the previous year, others gradually grew pale and finally died without any definite cause being found. And now there was developed a new trouble which threatened to carry off all the remainder at hatching time. Their shells seemed to grow rotten so that the fishlets by vigorous twistings could burst them at one place or another. When this took place in what may be called the anterior region, so that the head could be thrust forth, all was well. For this see figure 30. But when as more commonly happened, the shell burst elsewhere and the compressed yolk pushed out the investing wall with its plexus of blood vessels forming a hernia, death shortly ensued from strangulation of the circulation unless the trouble was relieved at once. At this stage in the history of the little cats, life was conserved only by constant vigilance. I kept watch by day and until 11 o'clock at night and the night fireman thereafter; and, whenever a "herniated" egg was discovered, the shell was torn partly or completely off the egg and the hernia pressed back into place with the smooth handle of a scalpel. This was a rather rest-disturbing matter since I was frequently awakened three or four times in one night. But the operation was for the most part successful since some 75 per cent. of the young so treated recovered. The majority of deaths in these "hulled" eggs resulted from the congestion of the ventral yolk circulation brought about by the weight of the fish and yolk or by the continued wriggling of the fishlets. Those from which the shells had been removed suffered especially, since their yolks flattened down greatly, while those whose shells were merely torn open, but not removed, suffered far less since their yolks were partially supported. All were put on beds of cotton wool at the bottoms of aquaria under jets of sea-water.

During the season of 1909 in endeavoring to hatch the eggs, the experience of the past seasons was repeated. The eggs went forward very well till they neared the time when they might be expected to hatch, then they died by fives and tens and twenties. An interesting phenomenon may here be noted which may offer a possible explanation for some of these deaths. On July 1 there was noticed inside the shell of an egg a small mass of greenish-yellow matter looking much like the fecal matter given off by a young baby and noted as such at the time. Further an embryo at the time of hatching or a few minutes thereafter had hanging from its vent a string of fecal matter. A third egg on the same day exhibited a similar state of affairs. All this leads one to question whether it may not be that some of these eggs which die just at the time of hatching are poisoned by fecal stuff given off by the embryos and confined within the egg shell.

The embryos from the paternal mouth, which were just ready to hatch, had far less difficulty in ridding themselves of their shells than the ones brought up in MacDonald hatching jars. And while it is probable that there is some mortality among the eggs incubated in the mouth of the father, there is no doubt that it is nothing like so great as that among eggs hatched artificially.

Just as the percentage of fish hatched in the paternal mouth is greater than that of those brought up in a hatching jar, so is it probable that the young incubated therein mature earlier than in the jars. This seems to be confirmed by this fact. On July 20, my fishermen, men whom I know well and in whom I have great confidence, brought in a little cat about four inches long taken from the mouth of a 20-inch male. This little fish was grown in the sense that its body walls had completely coalesced over the yolk. The men reported that they saw several little ones in their net. These they tried to catch, but they escaped through the meshes of the seine, the large fish, however, retained one in his mouth. This young one gave much trouble by jumping out of the bucket of water into the bottom of the boat, and finally escaped by jumping overboard as it was being handed to me at the wharf.

In contradistinction to the early hatching noted above in the mouth of the father, of the larvae in captivity, taken on July 7, 1908, the older ones did not close over their yolk sacs until August 5-8, while the corresponding dates for the younger captives was August 15-17. Making all allowance for difference in time of beginning incubation, the two or three weeks' interval separating the periods of yolk disappearance in the two sets of larvae is too long to be accounted for satisfactorily save on the ground that the young in the mouth of the paterfamilias develop more rapidly. This must be due to the fact that they feed while therein.

How the Embryological Series Was Obtained.

For six years (1907-1912) the search for the fish and its eggs went on, and with few successes and many defeats the series of eggs was pushed both backwards and forwards. By fitting in one egg here and another there and a third elsewhere, the series is now complete from invagination to the free swimming young in which the walls of the belly have closed over the diminished yolk sac and have coalesced into a raphe on the median line. The inability to obtain the segmentation stages is a great disappointment, for they only are lacking for the complete embryology, but, since the most strenuous efforts continued for six years have failed to obtain them, I have come to the reluctant conclusion that chance in the case of this fish will play more part in the collecting of eggs and embryos than any amount of hard and long continued effort.

Conclusion.

How the eggs are extruded, fertilized, and transferred is not known, but when these processes are effected the male incubates the eggs in his mouth not only until they are hatched by the bursting of the shell, but until the yolk has been absorbed and the young are able to take care of themselves. The largest number taken from the mouth of one male was fifty-five. A cement cast of his mouth had a volume of 580 cc. The volume of an average sized egg is 3.75 cc., of the fifty-five eggs 206.3, add 25 per cent for interstices; total space occupied by the fifty-five eggs equals 258 cc. This fish was 22 inches long and of average size. The eggs average 19-20 mm. in diameter, and the young fish at the end of the period of incubation are 85-100 mm. long. The length of this period can not be stated definitely, since it has been found to be impossible artificially to carry the eggs and embryos to the stage of the free-swimming young. However, it is probably about seventy days. During all this time the paternal nurse does not seem to feed. The large eggs would, if spawned on sandy or shelly bottoms, be quickly destroyed by crabs or by other fish; if laid on a mud bottom (where the breeding fish are caught) their considerable weight would cause them to sink into and be smothered by the mud. This habit is common in estuarine catfish in all tropical and warm temperate regions. These data are based on six summers' work at the Beaufort laboratory of the United States Bureau of Fisheries, in which time scores of male fish carrying eggs and larvae have been captured and autopsied.

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MAMMALS OF AUSTRALIA IN THE ZOOLOGICAL PARK

Illustrated with photographs by the Author and Elwin R. Sanborn

By W. H. D. LE SOUEF,
Director Zoological Gardens, Melbourne.
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PREFACE

DIRECTOR LE SOUEF AND THE AUSTRALIAN FAUNA.

In length and breadth of departure from the recognized standards of mammalian anatomy and physiology, the mammals of Australia are, per capita, the most odd and remarkable of any continental group. With the exception of the dingo, a few rodents and bats, all those species that do not lay eggs are marsupials, and carry in the abdominal pouch the astoundingly minute newly-born young until it grows to a size fit to take a small place in the outer world. A newly-born kangaroo cannot possibly be appreciated by a stranger until it is seen.

The Australian marsupials display a remarkable line of radiating development that is quite inexplicable to zoologists. This relates to the production of forms within an order, that strikingly parallel in external appearance the characteristic forms of members of various orders of mammals. It would appear as if the scheme of evolution among the Australasian marsupials tended to produce an aggregation of pouched mammals that in form and habits would cover the strange absence of other orders. The Tasmanian "wolf" may be cited as an example and the ant-eating echidna, with its porcupine-like quills, as another. There are carnivorous, fox-like phalangers, marsupial "mice," the wombat—in form and habits like a gigantic woodchuck, and the flying phalanger, which latter animal is precisely like a flying squirrel in form and actions. Yet more remarkable is a marsupial mole.

The New York Zoological Park always has been rather strong in Australian mammals. They are so universally interesting as to be irresistible. Our Australian collection is now very rich. As a contribution to public interest in these strange creatures from the continent wherein Nature has done everything differently, the distinguished Director of the Melbourne Zoological Gardens has been prevailed upon to write a series of short, popular sketches of the Australian species now or recently exhibited here, and illustrate many of them with photographs taken by him in Australia.

Mr. Le Souef is a man of charming personality and successful habit. He visited and lectured in America about eight years ago, and thereby greatly strengthened the bonds of interest between the zoologists of his country and ours. He is the author of books on the wild life of Australia that are at once deeply interesting and thoroughly reliable. The titles of those best known are "Wild Life in Australia" (London, 1907), and "The Animals of Australia," by A. H. S. Lucas and W. H. Dudley Le Souef (London, 1909).

W. T. HORNADAY.

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Photograph by W. H. D. LeSouef

FIG. 32. A TYPICAL FOREST IN THE PROVINCE OF VICTORIA, AUSTRALIA

This home of the beautiful Tree Fern is also the favorite haunt of the now rare Lyre Bird, the Black-Tailed Wallaby, Yellow-Breasted and Rose-Breasted Robins, Giant Kingfisher and Giant Earthworm. "Fern gullies always are delightful places to visit on a hot day."

MAMMALS OF AUSTRALIA IN THE ZOOLOGICAL PARK

By W. H. D. Le Souef,

Director Zoological Gardens, Melbourne.

Author "The Animals of Australia," "Wild Life in Australia."

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Introduction.

Australia is a large country, approximately 2,000 miles square, and is very sparsely populated, therefore, although good laws exist for the protection of native game, it is very difficult to see that they are enforced in the thinly populated districts. For example, Queensland has an area of 670,000 square miles, but its population is only about 190,000 whites, and approximately 9,000 aborigines. New South Wales is better, having an area of 309,460 square miles and a population of 1,847,214. Victoria has an area of only 87,884 square miles, but has a population of 1,397,977, so is considerably more dense than the other States. South Australia consists of 380,070 square miles and has 433,616 people, but Western Australia had the large area of 975,920 square miles and a population of only 308,806.

The Northern Territory, also is a large district, consisting of 523,620 square miles, and inhabited by only 4,767 people, excluding natives. The island of Tasmania has 26,215 square miles, with a population of 199,925.

In glancing over these figures one can easily realize the difficulty in fully enforcing game laws. The only way that native animals surely can be preserved for those that come after us is, to form Reserves in various types of country. This is being done in many of the States, but only to a limited degree at present, because the subject is a difficult one. Introduced foxes and domestic cats that have gone wild, to say nothing of rabbits, cannot well be kept out of these Reserves. The foxes and cats prey on the protected game, and the rabbits destroy the native grass and shrubs that it is sought to preserve. Of course, these animals are not all over Australia yet, but they certainly will be in course of time, despite fences, and we cannot possibly estimate the havoc they will play with the ground game and water fowl. It is quite possible that some species will become extinct before we realize it.

Then again, parts of Australia are subject to severe droughts, and thousands of small animals, as well as birds and kangaroos, perish, and emus cannot migrate as they used to do, on account of fences and settlements. The sheep and cattle help to denude the country and drain the waterholes. Therefore, in some districts where certain forms of life formerly were in evidence, none are seen now. Take as an example about fifty miles inland from Rockhampton in Queensland: there the beautiful parrakeet, (*Psephotus pulcherrimus*) was fairly plentiful, but since the drought in 1896 not a bird has been seen in the whole district. The pig-footed bandicoot was comparatively common in the southern districts of Australia, but now one is rarely, if ever, found.

Gilbert's rat-kangaroo, (*Potorous gilberti*), of southwest Australia, apparently is extinct. The so-called native cat, (*Dasyurus*) was exceedingly plentiful in Victoria, but now they are just as scarce as they once were plentiful. It is difficult to say why these various animals have almost disappeared. Of course the settlements and what they bring with them might account for a good deal, but certainly not for all. We really know little as to the unaccountable disappearance of small mammals in districts where they were numerous, and when we wake up to the fact that they have gone, it is usually too late to take measures of protection. Probably the same thing occurs in America, and elsewhere.

The introduction of foxes into Australia by private persons is bound to cause the destruction, and possibly, extinction of certain ground game. Inasmuch as much of the country has been cleared of scrub, the game does not have the same cover that it had formerly. The animals that live in burrows probably will hold their own longer than those that make their nests on the surface. Tasmania being of comparatively small area, is sure to lose the marsupial wolf or thylacine before long, as the dense bush is cleared and the country becomes more thickly

FIG. 33. AUSTRALIA: GREAT BRITAIN'S SOUTEASTERN EMPIRE

The development of Australia outruns the imagination. How many Americans know that a great transcontinental railway now links Brisbane, Sidney and Victoria with far-distant Perth and Western Australia? Notwithstanding her tremendous outpouring of men, munitions, ships and money for the war, Australia is vigorously maintaining her chain of zoological gardens, and a remarkable series of sanctuaries for the preservation of wild life.

settled. Even now it is scarce, and the settlers snare and destroy it whenever they get the opportunity. The Government has lately established a large Reserve for it near Hobart.

In Queensland there are ninety-two Honorary Rangers, and that State is trying to protect its animal life, but having so much sparsely populated country it is difficult. In the near future, they probably will convert more Crown Land into Reserves. So far only four have been made for animals and fifty-two for birds. It is now under consideration to take up the subject of the exportation of the skins of Australian native wild animals, and to place this important matter on a proper basis. It probably will be under the control of the Commonwealth Government, and further efforts then will be made to preserve our fast disappearing fauna. In every country there are what are popularly called "game hogs," heedless men as well as thoughtless boys, who seek to destroy the fauna of the country for their own individual benefit, and with no thought for posterity, or whether they are exterminating the fauna or not. Simply for what they call "sport," they carelessly destroy all they can, making little use of what they do kill. Persons of this class always are with us, more or less.

THE MAMMALS OF AUSTRALIA.

DINGO.

The Dingo, (*Canis dingo*) is found over the whole of Australia, but curiously enough not in Tasmania or the adjacent islands to the north. It probably is one of the most ancient of wild dogs, and its anatomy shows it to be an intermediate form between the wild dogs of South America and those of the old world. It is a true wild dog.

These animals are usually met with singly or in pairs and only occasionally in small packs, and then they probably would be parents and young. They never attack a human being. They usually hunt at night, but their scent is so keen that they frequently capture ground birds by stalking them and then catching them as they rise on the wing from the ground. They are the size of a sheep dog, and the ears are short and erect. The fur on the under part of the body is gray, the longer hairs, which give the body coloring, are reddish-yellow to much darker shades and in some specimens the saddle is almost black. The Western Australian dogs are, as a rule, darker than those in Victoria. The feet and tip of the tail are usually white.

Albinos sometimes occur and as these often breed true, a white race could easily be established. The females always seem to predominate. They are fleet and strong and can overturn a sheep or calf with ease, should the mother of the latter be absent. However tame they may appear in captivity, they cannot resist the temptation of killing a fowl, should they get an opportunity. They bite with a snap like a wolf, and animals bitten by them seldom recover.

In the open country these dogs can be ridden down by a good horse and despatched with a stirrup iron or waddy, or even caught if necessary. They are readily poisoned with strychnine. When the aboriginals of Australia found Dingo pups they used to rear them with care, tame them partially, share their bed and food with them, and the dogs then would only follow their owners. They were never struck by the natives, but these partially tamed dingoes often joined their wild comrades in the bush and did not return. The natives used them for hunting, but they apparently only followed their master. These animals breed freely with European dogs and consequently it is now difficult to obtain a pure bred Dingo. They never bark, but can howl dismally.

The fossil bones of these animals have been found in several parts of Australia in a formation that is considered to be Pliocene, so that apparently they were in existence in Australia long before human beings.

WATER RAT.

The Water Rat, (*Hydromys chrysogaster*). This is a large, handsome rodent fully twenty inches long from nose to tip of the tail. They are dark buff above, a rich orange-brown below, and the tail is white toward the end. These animals are still fairly plentiful, but being nocturnal are seen rarely. They are purely aquatic and frequent inlets of the sea as well as rivers and lakes, where they feed on the shell-fish, crustaceans and vegetation. They are found in all parts of Australia and Tasmania. The western species is slightly darker than those found in the eastern side of Australia and the amount of white on the tail also varies. A small rat, dark grey on the back, called Thomas' Rat, (*Xeromys myoides*) is found in Queensland. Its body is only four and one-half inches long and its tail three and one-half inches.

RATS.

Due to their remarkable fecundity, rats are very plentiful in Australia, as in other parts of the world, both in species and individuals. Both rats and mice occasionally increase during an unusually good season, when food and cover are plentiful, to almost incredible numbers. During the year of 1917, there was an abundance of rain in southern Australia throughout the summer which produced a great growth of grass and other vegetation. Therefore, as food was plentiful and the vegetation so dense, the rodents were securely hidden from their enemies. They increased so enormously that food became scarce, especially where the grass began to get dry, and they had to migrate in their many millions. They were then preyed on by snakes, carnivorous animals and birds, but despite this, the destruction caused by these little rodents was very great. At the wheat stacks alone at eight railway stations in Victoria, about thirteen tons of mice, representing approximately 892,000 animals, were caught in three days. The same migrations occur in other countries, especially among the lemings in Norway.

MICE.

The members of the genus *Mus* are represented in Australia by twenty-eight species so far known. But this number is certain to be increased later on. As our knowledge of these animals is very incomplete at present, an authentic list cannot well be given. Of our twenty-eight species, only five can be termed mice, although it is difficult to draw a dividing line between the two species. They are met with practically everywhere, increase rapidly, and all burrow more or less. One of the commonest species is the Dusky-Footed Rat, (*Mus fuscipes*), is found in South Australia, the islands of Bass Straits and Tasmania, usually near water or on swampy land. Its body length is about six inches and the tail is about four inches. The fur is conspicuously long.

A closely allied form, (*M. assimilis*) or the Allied Rat having very soft fur, which is light brown above, is found from N. E. Queensland to S. W. Australia, usually in thickly timbered country. They live largely on fruits and seeds. On the Darling Downs in Queensland, the *M. sordidus* is found. It is blackish-brown above and measures about six and one-half inches, with a tail five inches long. Generally in open country, and at the extreme N. E. of Australia, the White-Footed Rat, (*M. terrae-reginae*) is plentiful. Its back is dark brown, with longer black hair and tail with light colored rings. It measures eight and one-quarter inches and the tail seven and one-quarter inches.*

M. gouldi is reddish-yellow in color, with numerous long black hairs above. It measures four and one-half inches and tail three and one-half inches. It is found in south, eastern and central Australia. And *M. greyi* inhabits central and north-eastern Australia and is reddish brown in color with longer dark hairs. It is six inches long and its tail four and three-quarter inches. One small species in Western Australia, *M. nanus,* is only four inches long and its tail three and one-half inches. It is brown in color and has a white patch under the tail. The Pigmy Mouse, (*M. delicatulus*) from Northern Australia is only two and one-half inches and the tail about the same length. It is yellowish-brown in color and the upper parts and the sides of the body are yellow.

The Greyish-White Mouse, (*M. albocinereus*) is found near the seashore in S. W. Australia. Its body is covered with long, soft, light grey hair and the tail and feet are white. The Brown Rat, (*M. decumanus*) and Domestic Mouse, (*M. musculus*) have spread over most of Australia and have become numerous in many districts in the country, as well as in the towns. The

*In a short article like this full descriptions of the various species cannot well be given. (Author.)

former have from two to three litters a year each containing from nine to fourteen young. The European Black Rat is also in evidence, not only in the cities, but chiefly in the country, as they have the habit of building their nests in hollows in trees and are therefore largely arboreal.

JERBOA RATS.

The interesting family of Jerboa Rats of the genus *Conilurus* (*Hapalotis*) is confined to Australia where they are also plentiful in many districts, their long ears and tails making them conspicuous. The fossil specimens that have been found are of great interest as illustrating in the rodents a mode of progression similar to that of the kangaroos. These little animals advance by leaps and bounds like the Jerboas of Africa and Asia and the jumping mice of North America. Fourteen species are known so far, mostly confined to the interior, although some varieties live in the coastal districts of north Queensland.

They have from three to four young, but have no pouch; the young being attached firmly to the nipple and also grasping their parent with their claws. They are strictly nocturnal, resting during the day in nests of dried leaves and grass in hollow fallen branches. The largest varieties, *C. boweri* and *C. hirsutus* are nearly two feet in length and are found in north Queensland.

The White-Footed, (*C. albipes*) is found in the southeastern districts. This animal is greyish-brown, black around the eyes, and has a body length of ten inches and a tail nine and one-half inches. The nest-building Jerboa Rat, (*C. canditor*) from the interior of eastern Australia is only six inches long, and its tail five inches. They combine together and make large nests of grass, sticks and bits of bark sometimes over three and one-half feet high, usually around a small bush, the branches of which help to strengthen the structure. One family or more may occupy a nest and each family has its own compartment, which is connected with the others by passages that put one very much in mind of a beaver's lodge. This animal is greyish-brown and is darker on the center of the back and head.

The Long-Tailed Jerboa, (*C. longicaudatus*) inhabits Western Australia and is seven inches long, with a tail nine inches. It is pale buff on the back and the end of the tail is white. It is usually found in scrub-covered country. The Fawn-Colored Jerboa, (*C. cervinus*) is four and one-half inches long and the tail five and one-half inches long. It is found in the central districts of South Australia. The large ears of this delicate looking little animal are much lighter in color than its back and are very conspicuous. It is all white below. A rat named the Dusky Broad-Toothed (*Mastacomys fuscus*) is found in Tasmania. It is only five and one-half inches long and is dark greyish-brown in color.

GIANT RATS.

The largest rat in Australia, the Giant Rat, (*Uromys macropus*) is found from northeastern Australia to the Arnheim Islands. It is fourteen inches long with a tail about the same length, and rarely is seen in captivity. It is reddish-grey above and white below and is probably destructive to birds' eggs and young during the nesting season. The Buff-Footed Rat, (*U. cervinipes*) found in Western Australia only, is but six inches long with a tail a little over five inches. It is light brown above, with buff-colored feet. The scales on the tails of these animals do not overlap but are set edge to edge.

MUSK RATS.

We now come to the animals that are strictly marsupial, and in Australia they are naturally numerous. The Australian Musk Rat, (*Hypsiprymnodon moschatus*) usually found in the scrub-covered country of the coastal districts of Queensland, is a graceful little animal, with soft and orange-grey colored fur, diurnal in habit and living on insects, snails, fruit and seeds. It has two young at a time in its pouch, and its length is about ten inches and tail six and one-half inches. It is rarely seen and the perfume of musk easily identifies it.

KANGAROOS.

All kangaroos have more or less the same habits and are usually found in small companies in country where they are not disturbed. They are protected for the whole year in Victoria and soon increase if undisturbed. Partial protection is given to them in New South Wales, but not in Queensland, except in certain districts. The number of skins annually sent to other countries from Australia, especially from Queensland, runs into many thousands. Of this number, the United States receives a large share; sometimes over 80,000 in one year.

Many men make their living entirely by shooting kangaroos with a rifle; one man I know having shot over 400 last year (1917). This means that in the course of comparatively a few years, these interesting animals will become very scarce, as the skins of all species, including wallaby, are used for leather. The introduction of the fox into Australia will not help matters as they are sure to kill some of the young ones. These animals fortunately live and breed freely in confinement, having but one young at birth, although twins have been known to occur occasionally.

They are hunted on horseback with the aid of a large dog of the grey-hound type, known as a kangaroo dog, and if the country should be sufficiently open, they usually are caught and killed. When hard pressed, they often will take refuge in a river or in swamps standing waist deep in the water and awaiting their enemies. Should a dog swim out to them, they will hold it under water with their fore arms and eventually drown the venturesome animal. When attacked on land, the old males that are not as speedy as the females, often stand with their back to a tree ready to fight with the dogs; and they are usually quite a match for any single dog. Young kangaroos are often caught and reared by hand, when their mother has been shot or otherwise killed. Their backs are easily damaged if roughly handled. When leaning forward to feed on short grass, they often rest on the upper part of their paws, as well as on the under part in the ordinary way. When in this position, the young that may be in the pouch, and old enough, can nibble on the grass at the same time.

The Grey Kangaroo, (*Macropus giganteus*) is found across the entire southern part of Australia as well as in Tasmania. The species from that island (*M. fuliginosus*) is now very scarce. It has long, dark fur and the under parts are white. The female is much lighter in color than the male. Those on the western side of the mainland usually are darker, but generally melanism is more pronounced among the animals in the western portion of Australia than in the eastern. These animals are only a little inferior in size to the red kangaroo, and the fur is longer and coarser. The males are a dark grey and the females and young much lighter. They are found in open forest country and frequently are called locally the Forester Kangaroo. The variety from Tasmania and Kangaroo Island (*M. fuliginosus*) is now very scarce. It has long, dark fur, the under parts being white. The female is paler than the male.

The Wallaroo of Euro Kangaroo, (*M. robustus*) have long and coarse fur; the color of the male being dark reddish-grey and that of the females more bluish-grey. Farther north in Queensland, the color is often dark greyish-brown in the males. The exact tint varies considerably. This variety is found in the central districts of Australia, as well as towards the coast. They live only on the rocky ranges and are thickset and strong and adepts at bounding over the often rough country where they are found, and where frequently it is difficult for a dog to follow them.

Several sub-species of this animal, (*M. woodwardi*) from northwest Australia, have been described. The color of the short, close hair of the male is bright red and that of the female, fawn. The head and body measures four feet and the tail three feet. The fur of *M. alligatoris* from north Australia is also short and the color more or less rufous, with the neck, arms and fore-back, fawn. Another sub-species from southwestern Australia, *M. cervinus,* is lighter in color, and lastly *M. isabellinus* from Barrow Island off west Australia, has a dark rufous back with the front of the neck white. In the southern districts of Australia, in the drier and frequently sandy country where the mallee eucalyptus grows, is found a darker and more slender variety of kangaroo, the Black-Faced, (*M. melanops*). However,

Photograph by W. H. D. LeSouef

FIG. 34. YOUNG GRAY KANGAROO, *M. gigantus*

Immature specimen just born and placed in the pouch. Beside it is the the nipple to which it would have been fastened about life size.

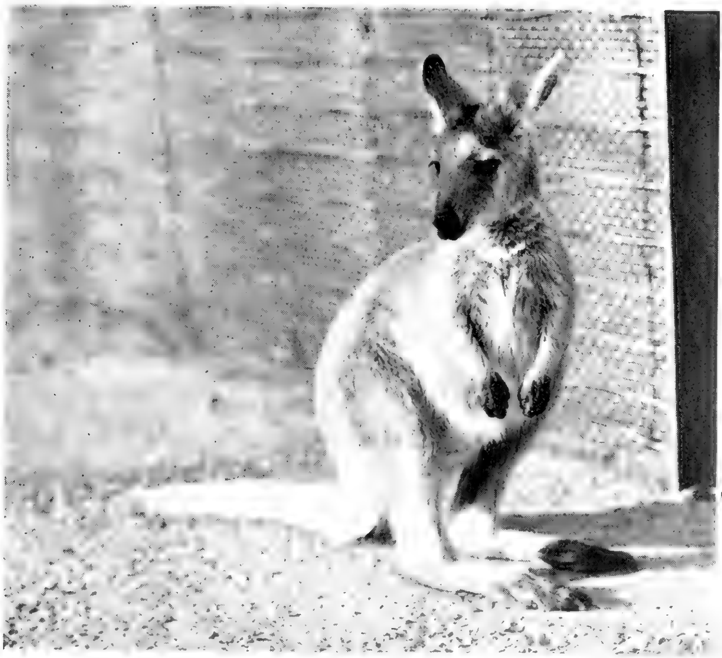


FIG. 35. WALLAROO OR EURO KANGAROO

New York Zoological Park.

Photograph by E. R. Sanborn

FIG. 36. WOODWARD KANGAROO

New York Zoological Park.

Photograph by E. R. Sanborn

FIG. 37. BLACK-FACED KANGAROO

New York Zoological Park

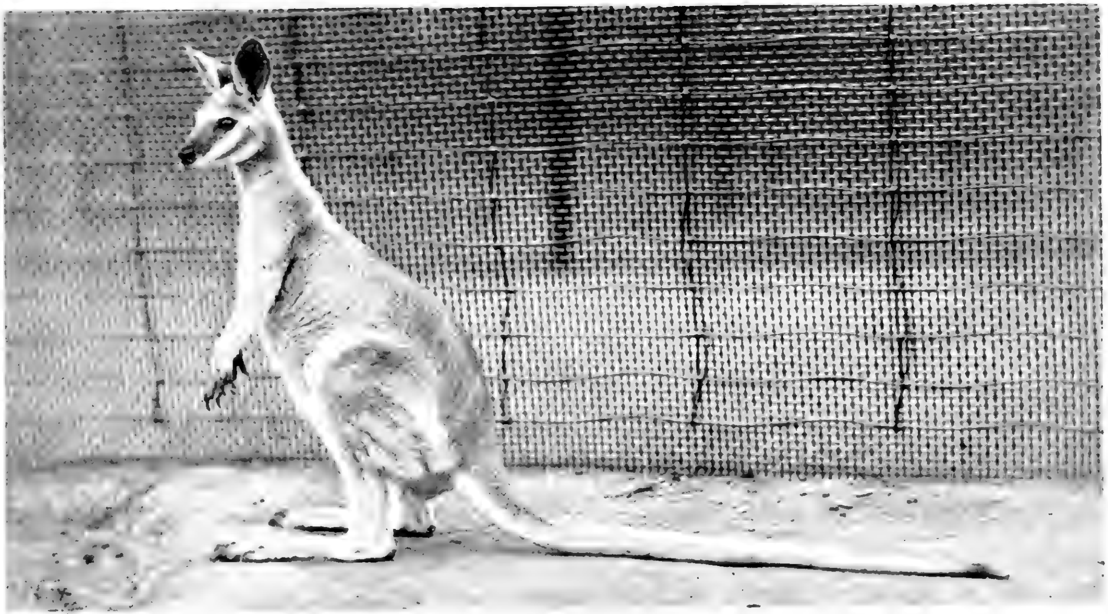


FIG. 38. PARRY KANGAROO
New York Zoological Park.

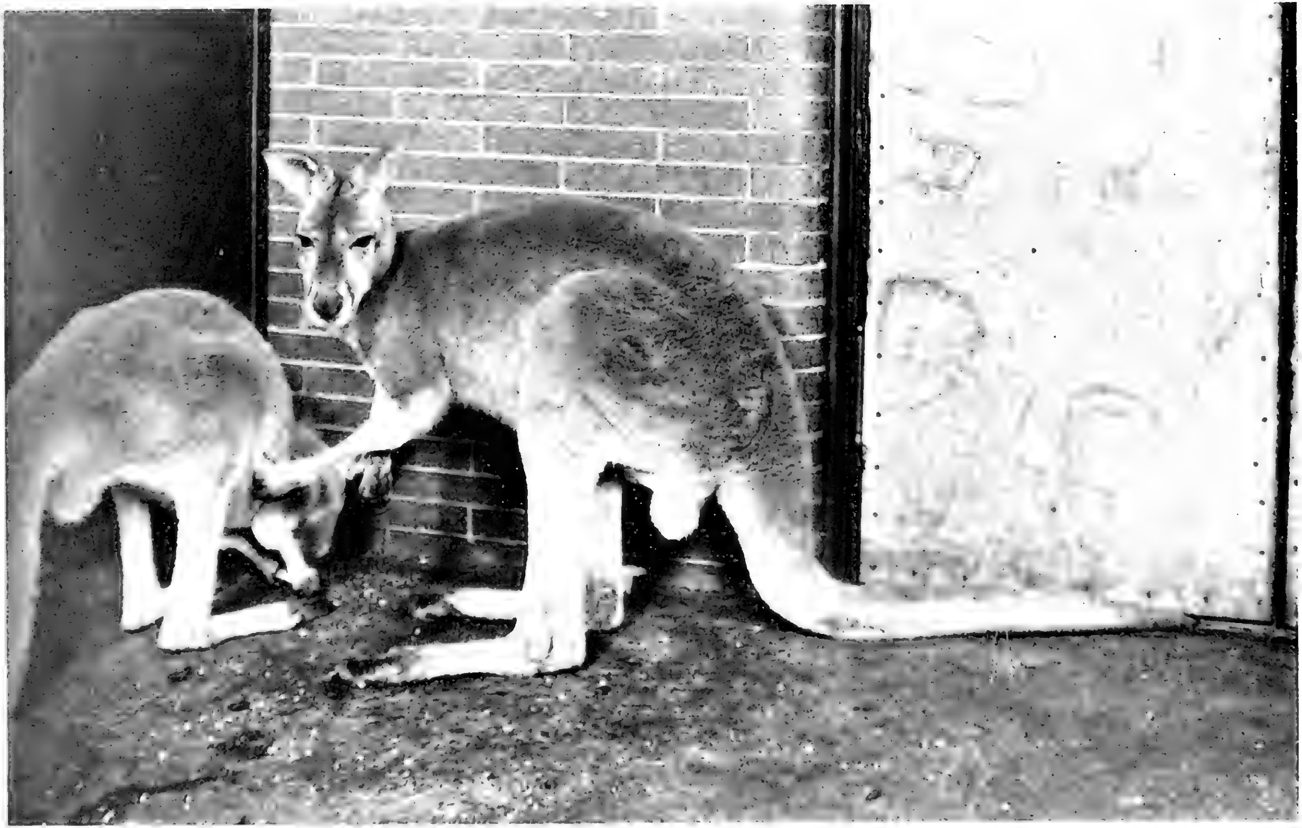
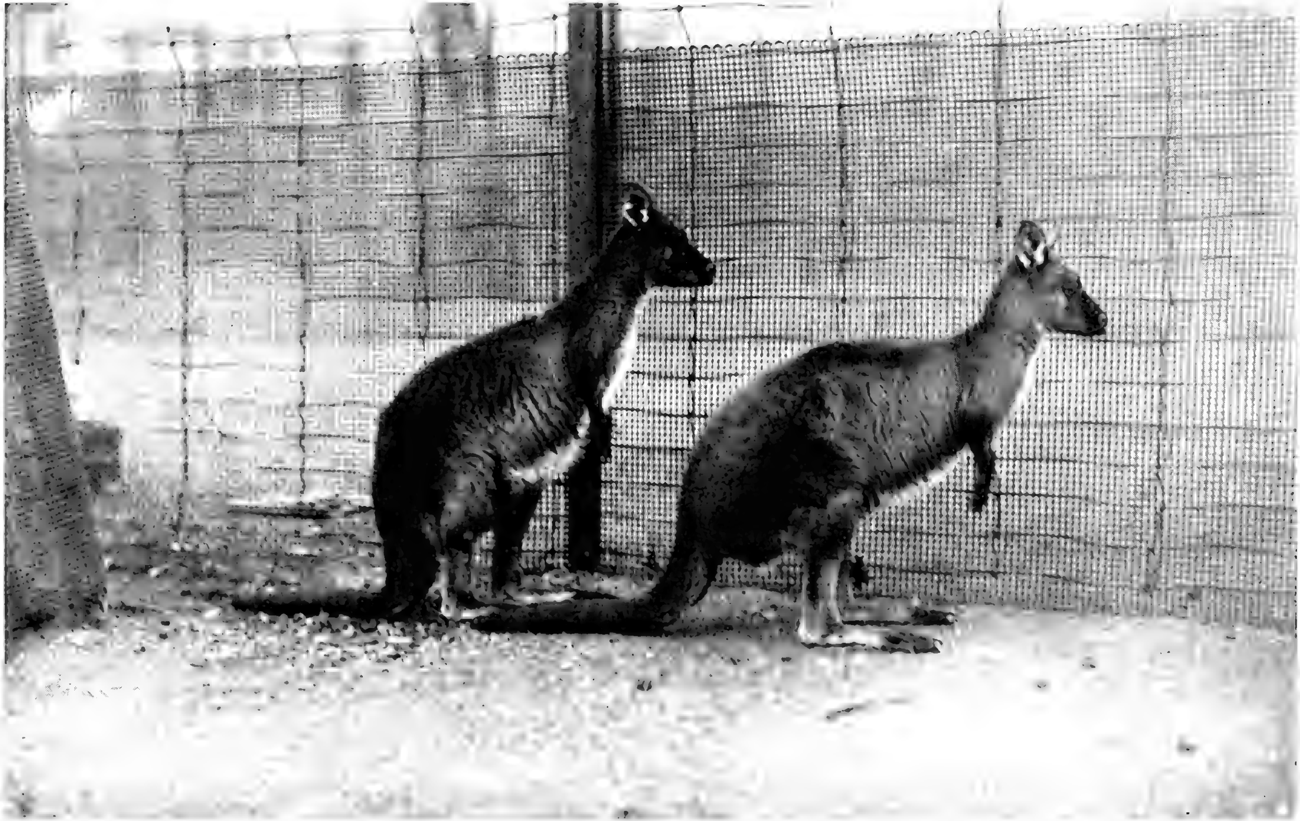


FIG. 39. GIANT RED KANGAROO

New York Zoological Park.



Photograph by E. R. Sanborn

FIG. 40. KANGAROO ISLAND KANGAROOS

New York Zoological Park.

Photograph by E. R. Sanborn

FIG. 41. BENNETT TREE KANGAROO

The tail is not prehensile, but is used in balancing. The forefeet are adept in grasping. These animals sometimes leap to the ground from a height of fifty feet.

New York Zoological Park.

FIG. 42. BENNETT TREE KANGAROO
They both climb and nimbly jump from branch to branch.

FIG. 43. CAPTIVE TREE KANGAROOS
In the Zoological Gardens at Melbourne, Australia.

FIG. 44. RUFOUS-NECKED WALLABY
New York Zoological Park.

Photograph by W. H. D. LeSouef

FIG. 45. BRUSH-TAILED PHASCOGALE

Young attached to nipple.

Photograph by W. H. D. LeSouef

FIG. 46. BENNETT TREE KANGAROO, *D. bennettianus*

Showing pads on the hind feet.

Photograph by W. H. D. LeSouef

FIG. 47. ALBINO RED KANGAROOS

Melbourne Zoological Gardens

Photograph by W. H. D. LeSouef

FIG. 48. ALBINO RED-BELLIED WALLABY

Tasmania

FIG. 49. RING-TAILED WALLABY
New York Zoological Park.

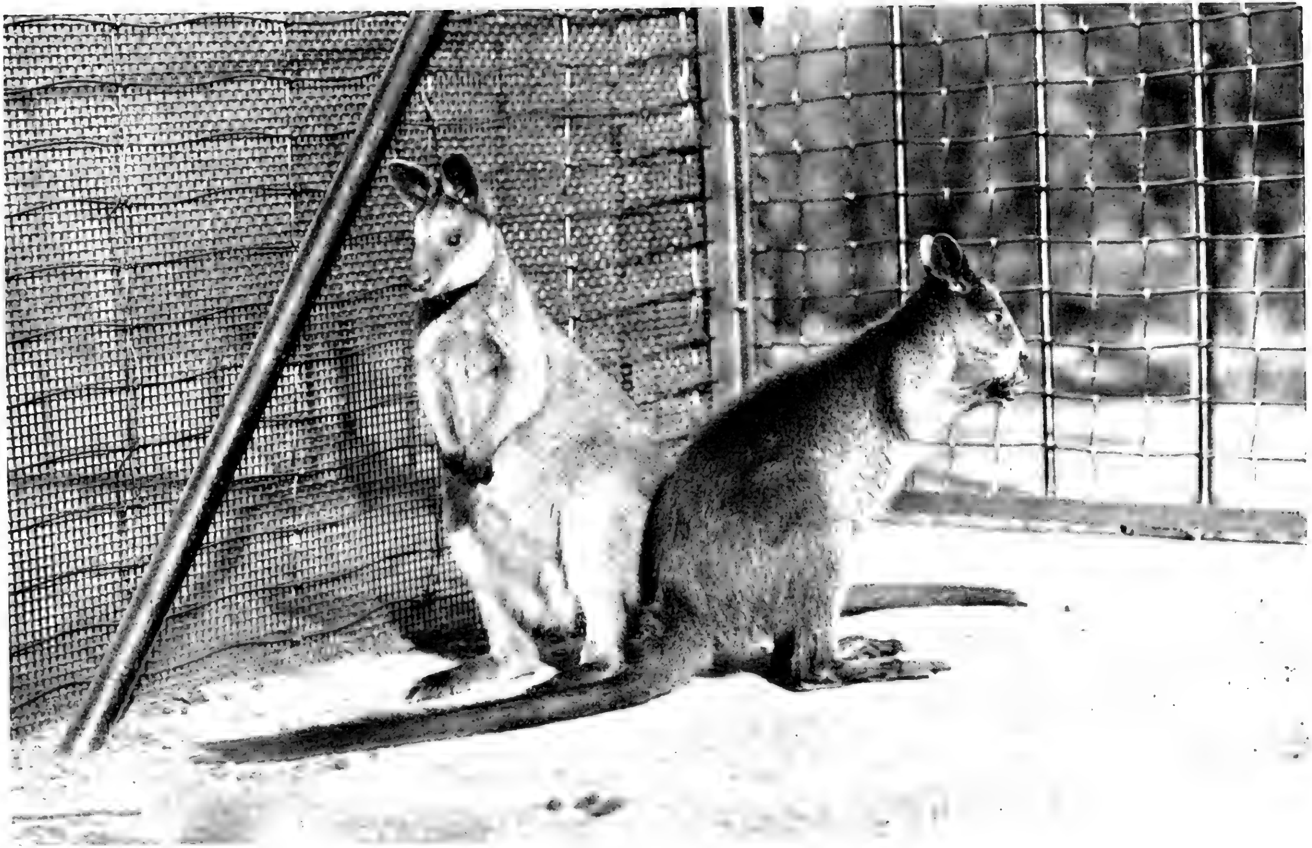


FIG. 50. BUSH-TAILED WALLABIES
New York Zoological Park.

Photograph by E. R. Sanborn

FIG. 51. BLACK SWAMP-WALLABY

Young kangaroos seek refuge in the mother's pouch until one-third grown. This young specimen was fully weaned, but rushed for the mother upon the slightest disturbance.

New York Zoological Park.

Photograph by E. R. Sanborn

FIG. 52. MALE OF THE SWAMP-WALLABY

The dexterous manipulation of the forefeet is clearly shown.

New York Zoological Park.

FIG. 53. AGILE WALLABY
New York Zoological Park.

as this country is being cleared rapidly for wheat-growing, this animal will become scarce, as it is destroyed by the farmers.

Kangaroos are diligently sought for their skins, and although they are well protected in Victoria, and to a certain extent in other parts of Australia, their numbers are diminishing. A small, slender species, Parry's Kangaroo, (*M. parryii*) is found in the hilly coastal districts of Queensland and northern parts of New South Wales. The short, soft and light bluish-grey fur marked with a white line on each side of its face as well as on the neck, and the long, thin tail, have suggested its local names, the Pretty-Face or Whip-Tail Kangaroo. It usually frequents scrubby country and often may be seen in the Darling Downs district from railway carriages when one is travelling from Brisbane to Sydney, or vice-versa. It is three feet in height and its tail is two and one-half feet in length. The Red Kangaroo, (*Macropus rufus*) is probably the largest of the kangaroos. The short, woolly fur is red in color in the male and bluish grey in the female. When standing upright, practically on its hind toes, and resting the weight of its body on the end portion of the tail, it measures about six and one-half feet; otherwise four to five and a half feet.

Old males get very pugnacious and frequently fight one another. They do so by scratching, if possible, with their fore paws, and also by leaning back and resting the weight of their body on the extreme end of their tail, only about six inches, and striking forward with the hind feet. The claws are sharp and although they do not often do much damage to each other, they can easily rip up an unwary dog should one tackle them. These animals live on the plain country of New South Wales and southern Queensland, generally remaining during the heat of the day under the shade of the trees that fringe the plains. They can easily travel at the rate of twenty miles an hour when pursued, and exceed that speed when pressed. They cover about twelve feet at a jump and can clear a fence eight to ten feet high. Occasionally they are pursued on the plains with motor cars, although I hardly think that is a fair way to get them, as they have no chance, unless they get into a belt of timbered or rough country. However, the sport is not destined to be very popular as motoring over the plains at over twenty miles an hour is usually a very bumpy experience. A female kangaroo when hard pressed in flight if she should be carrying a heavy young one, or *joey* in her pouch, will take the young one out and conceal it under a bush, coming back when all danger is over, should she have a chance.

The only safe way to hold a kangaroo is by the tail, and it takes a strong man to hold one. The young are born in the ordinary way, but in a very immature state. They are about an inch long, the fore feet are twice the size of the hind feet and the tail very small. It is placed on the nipple in the marsupium by the mother and the pressure of the milk forms a small bulb at the end of the nipple at the back of the mouth. This swelling being larger than the entrance to the mouth of the young one, holds it on. If the young kangaroo is pulled off at an early stage it cannot be replaced.

The Antilopine Kangaroo, (*M. antilopinus*) is found in the Coburg Peninsula in north Australia, and very little is known of this animal. It is of a heavy build with short fur, rufous in color with underparts white. The female is smaller and of a fawn color. The head and body are four and one-half feet and the tail two feet long.

THE TREE WALLABY.

These interesting animals are found in the mountain ranges near the coast of northern Queensland as well as in New Guinea. Two varieties inhabit Australia, namely Lumholtz's, (*Dendrolagus lumholtzi*) and Bennett's, (*D. bennettianus*). The former which has long yellowish-brown fur with a black chin and white chest is found in the more southern districts near Cardwell, and the latter which has long dark brown fur, further north near Cooktown. Like most of the other grazing Australian animals, they rest during the day and feed chiefly at night. They live almost exclusively in trees or on the tops of granite boulders that are covered with vegetation. I once saw one of these animals that I disturbed when in the latter situation, jump to a rock

Photograph by W. H. D. LeSouef

FIG. 54. THE HOME OF THE TREE WALLABY
Queensland

below, a distance of about forty-five feet. It is wonderful the way they are able to jump from bough to bough and rarely make any miscalculation. Their long tail is not prehensile and is used for balancing only, and the soles of their hind feet are serrated and that prevents them from slipping.

The natives obtain them by going to the upper portions of the scrub-covered ranges in the early morning with their dogs, and the latter are frequently able to pick up the scent of a kangaroo that has gone from one tree to another or to track it to the tree in which it is feeding. Some of the natives then climb any tree in proximity to the one that shelters the wallaby. to prevent it escaping into it, while another of their number climbs the tree that harbors the animal, and either catches it by the tail or forces it to jump to the ground in its endeavors to escape. The other natives with the dogs are there on the lookout for it and generally secure it.

The wallabies frequently get from one bough to another by going along towards the end of a branch, and clinging to it with their fore paws, as it bends they are enabled to get a foothold on one at a lower level. They can also jump a considerable distance from one bough to another. As a rule, when they are on the ground they lean well forward and keep their tail clear of the soil. In ascending a tree, they do so by clinging with their fore paws round a creeper and moving both hind feet up at the same time; and they go up very quickly. They cannot ascend an ordinary trunk of a tree, but as the forests in the districts where they are found abound with creepers, practically every tree having one or more, they have no difficulty in climbing. They also can climb an ordinary two or three-inch rope with ease, or even a gas or water pipe; their serrated pads enabling them to get a secure hold. Should one escape on board a vessel, it quickly climbs the ropes and easily gets to the mast-head. These animals in their native state are more or less infected with two or three kinds of parasites and often have sore places caused by them. As their food consists of leaves of various shrubs, they live well in captivity.

WALLABIES.

There is little difference between kangaroos and wallabies. The members of the genus *Macropus* whose head and body are over four feet in length are called kangaroos, and those three feet and under, usually wallabies. One of the largest of the latter is the Black-Tailed, (*Macropus nalabatus*) measuring just under three feet and the tail two feet. This animal, which is of rather a heavy build, and not nearly so active as many of the smaller kinds, is always found in scrubby country. Its color is very dark brown or reddish-grey and light rufous underneath. They formerly existed in countless numbers in the densely timbered portions of the coastal districts of New South Wales and Victoria, and hundreds of thousands of their skins have been exported. But trappers and settlements have so reduced their numbers that they are now protected in Victoria. During the day they usually remain well hidden, coming out in the evening to feed. A very closely allied variety, (*M. apicalis*) is found in the same class of country in the coastal districts of Queensland. It has shorter fur and the rufous color is more intense. Probably the largest of these animals is the Red-Necked Wallaby. It is of more slender build than the preceding species, is greyish-fawn in color, with a reddish neck and rump, and measures three and one-half feet and its tail two and one-half feet. It is found in the eastern parts of Australia from southern Queensland to Victoria where it usually inhabits the open forest country.

The Tasmanian form of this wallaby, (*M. bennettii*) has thicker and longer fur and is slightly darker in shade. Its neck and rump are dull brown instead of red. It also is found in southern Victoria and on the islands in Bass Strait. Formerly it was very plentiful, especially in the Islands, but now the hunters with their dogs have completely exterminated them also, except in Tasmania, where they still hold their own in the rough parts. In captivity they easily become tame and do not knock themselves about in the way other species often do. In Victoria and South Australia, Grey's Wallaby, (*M. greyi*) is found. It is a slender animal and can travel very fast. The color is greyish-fawn with a rufous tinge on the neck. It measures about two and one-half feet in length and its tail slightly under. Another fine wallaby, the Black Striped, (*M. dorsalis*) is found in the inland districts of New South Wales and southern Queensland. The general color is grey with a reddish tinge on the forequarters, and it is readily distinguished by a narrow black line down the center of its back. It measures slightly over two and one-half feet and its tail two feet.

The Black Gloved Wallaby, (*M. irma*) from southwestern Australia is a well-marked animal, with soft fur of a bluish-grey above, white below the chin, cheeks stripes also of the same color, and another white stripe on the neck, edged with darker color. They measure about three feet and tail two and one-half feet, thrive well in captivity and make very docile pets. The Agile Wallaby, (*M. agilis*) is a heavier animal with short, coarse dark sandy-colored fur, very short ears and a long tail that easily distinguishes it. The habitat of this species is southeast New Guinea, as well as in the northeastern portion of Australia. The Cape York Wallaby, (*M. coxeni*), another species from northeast Australia, is also a dark sandy color, darker on the back with white underparts and a white hip-stripe. These animals are small, being only twenty-eight inches long and their tail fourteen inches.

The Branded Wallaby, (*M. stigmaticus*) is found also in northeast Queensland, but usually further south than the beforementioned species. It is of slender build, the fur is short, of a bright reddish-grey color, with less red on the neck and forequarters. There is also a pale cheek-stripe, the hip-stripe is yellowish and prominent, and the underparts white. It measures twenty-nine inches in length and its tail fourteen inches. The Red-Legged Wallaby, (*M. wilcoxi*) is very similar to the preceding one, but the color is duller, and the hip-stripe hardly visible. It is found in the southern districts of Queensland and the northern parts of New South Wales.

The Pademelon Wallaby, (*M. thetidis*), found in eastern Australia from southern Queensland to Victoria, is a light, graceful little animal, grey in color, reddish on the neck and white below. Its ears are long, and the hip-stripe is very faint. It measures twenty-six inches and its tail sixteen inches. The Dama Wallaby, (*M. eugenii*) from West Australia, the islands off that coast and South Australia, has thick, dark grey fur with reddish shoulders and a pale cheek-stripe. This little animal is about the same size as the preceding one.

The Parma Wallaby, (*M. parma*), very closely allied to the former species, has an even reddish-grey color with a distinct cheek-stripe and a white front. It is found in eastern New South Wales. The Rufous-Bellied Wallaby, (*M. billardieri*) used to be exceedingly numerous in Victoria and especially on the islands in Bass Straits, as well as in Tasmania, but those on the islands have been nearly cleared out. The hunters with packs of kangaroo dogs, used to burn the thick patches of scrub in which they knew the wallabies had taken refuge during the day and their dogs caught the unfortunate animals as they ran out. Their habitat is in the dense scrub and although their runs are very numerous in such places, they are fairly safe under ordinary circumstances. Many hundreds of thousands of their skins have been exported. These animals are of stout build, have thick, soft fur of a dark greyish-brown color, face and head olive-grey and no face markings. The body measures twenty-seven inches and the tail which is very short, only fourteen inches.

The Short-Tailed Wallaby, (*M. brachyurus*) from Western Australia is the smallest of the wallabies. Its body measures twenty-three inches and its tail ten inches. Its fur is long and coarse and is a uniform greyish-brown. The ears are small and rounded. Its habits are identical with those of the rufous-bellied wallaby.

The Rock Wallabies, (*Petrogale*) are found all over Australia, but not in Tasmania. As their name implies they live only in rough rocky country, whereas the members of the family *Macropus* are usually found in the more level districts. The Rock Wallabies lean well forward, using their long, bushy tails only for balancing and not as a third support, as do the Macropus family, especially the larger forms. The underside of the toes are covered thickly with small tubercles that prevent the animals from slipping on the rocks, especially when they are wet. They usually take refuge during the day in caves or under rocks, coming out to feed in the evening and at night. The wonderful way that they can bound freely and without hesitation from rock to rock, sometimes onto excrescences that can hardly be seen, is extraordinary. A dog naturally and fortunately has little chance of catching them. In the many runs among the rocks that have been used by countless numbers of these animals for many years past, the rocks are perfectly polished and shiny. No ordinary fence will stop this active animal, and, should they escape from captivity they seem to enjoy hopping about the roofs of buildings, apparently quite at home and where they cannot well be followed.

The largest of the group is the Yellow-Footed, (*P. xanthopus*). The body measures thirty-two inches and the tail twenty-four inches. The fur is long, soft and grey in color. It has a prominent white cheek-stripe, an orange spot above each eye, and long ears. A black line extends from the head to the middle of the back, there is a brown patch behind the elbow and a white lateral line that runs to the hip. On top of the knee there is another brown patch, and alongside of it a patch of white, and the arms, bands, legs and feet are yellow. The tail is marked above with alternate bands of dark brown and pale yellow. This handsome animal lives in South Australia.

Another variety, the Brush-Tailed, (*P. penicillata*) found in the eastern coastal districts of Australia, is a thick set animal with long, coarse brown fur, a light cheek-stripe and short ears. It measures thirty inches long and the tail, usually tipped with yellow, is twenty-four inches.

The Western Australian form, (*P. lateralis*) is smaller in size. The body being two feet long and its tail one and one-half feet. The fur which is light grey, is long and soft and its cheek-stripe yellowish. It also has a dark line on the center of the upper part of the back, a dark brown patch just behind the elbow, and a prominent white stripe running down to the hip. The latter half of its tail is black.

Another form from the northwest coastal districts of Australia is the Short-Eared, (*P. brachyotis*). This little animal is also slender, with short greyish-brown fur, has practically no face markings, the body markings only just visible and is greyish-white below. The body measures twenty-two inches and the tail sixteen inches.

There are three wallabies belonging to the genus *Onychogale* (Nail-Tailed). They are well marked animals having fairly long tails, crested at the ends and provided with spurs. These are the only marsupials that have such an excrescence. Among mammals, the lion is the only one that has a similar spur. The Nailed-Tailed Wallaby, (*O. unguifera*) from northwest and north-central Australia is a slender and graceful fawn-colored animal, with a darker medium band, and white hip-stripes and under parts. The body measures twenty-six and the tail twenty-eight inches. The tail is long and white on the upper side with a few, faint brown rings showing towards the end, which is black. The spur is flattened laterally and hidden in the long hairs.

Another variety, the Bridled, (*O. frenata*) is found in the eastern districts of Australia from South Queensland to Victoria. These slender little animals having a body length of but twenty-three inches and tail of eighteen inches, make charming pets and when hopping along have the habit of holding their fore paws straight out in front of them. Their grey fur is soft and thick. The cheek-stripe is indistinct, the center of the back of the neck is black, and there is a white shoulder-stripe and a very indistinct hip-stripe.

The West and South Australian form, Cresent, (*O. lunata*) is very similar to the preceding species. The fur is a soft dark grey, and the neck is rufous. The white shoulder-stripe is prominent and there is a faint stripe above the hip. It measures twenty-one inches and the tail fifteen inches.

The Hare-Wallabies, (*Lagorchestes*) of which three varieties are known, form another interesting group of these animals. The name was given because of the likeness in form, size and habits to the hare. They are found usually in plains country, can travel at great speed and are adepts at dodging any dog that may be chasing them. The Spectacled Wallaby, (*L. conspicillatus*) is found on the islands off the west coast of Australia. On the mainland, the closely allied variety of this species has been named *L. leichhardti.* Their color is yellowish-grey with a reddish band round the eye and two light lateral bands. They measure about twenty-one inches and tail eighteen inches. The colors of the mainland form are brighter and the bands and under parts are white.

The common Hare-Wallaby (*L. leporoides*) is found in the interior districts of New South Wales and South Australia. It is light in structure and its general color is like that of the common hare, with the exception of a black patch on the elbow and also the reddish band round the eye. It measures about twenty inches and the tail about thirteen inches. The last variety is the Rufous, (*L. hirsutus*). It is found in the more southern districts of West Australia and is greyish in color, with a reddish tinge behind, and no black patch on the elbow. It measures eighteen inches and the tail fifteen inches.

In the same part of Australia, the graceful Banded Wallaby, (*Lagostophus fasciatus*) is found. It usually lives in thick, scrubby country and is still plentiful in places. It is greyish-brown in color and has three sets of fur. First, grey under-fur, then grey, coarser hair and then long well separated piles projecting well beyond the others. It has no marks on its face or flanks. The lower part of the back has dark and light transverse bands that identify this little animal readily.

KANGAROO RATS.

We now come to the Rat-Kangaroos, or as they are called in Australia, Kangaroo Rats. They formerly were exceedingly plentiful, but dogs and foxes have taken a heavy toll of them and in the settled districts they have almost disappeared. They are about eighteen inches in length with a tail fourteen inches, and are of a sandy-grey color. They usually sleep coiled up in their nests during the day, coming out to feed in the evening and at night. The largest of them, readily distinguished by its reddish-grey color, the Rufous, (*Aepyplymnus rufescens*) is found only in New South Wales, and is twenty-one inches long with a tail fifteen inches. It has an indistinct stripe in front of the hips.

There is another family of these active little animals, namely the Bettongs, (*Bettongia*), characterized by the fact that they are the only ground animals having prehensile tails, which they use for carrying bundles of grass for the construction of their nests. A hollow is first scraped out in the ground and in it a dome-shaped nest of grass is built; the top being about level with the surface of the ground. The animal upon entering the nest draws a bunch of grass after him, and closes the entrance so perfectly that the nest cannot be observed, easily. A fox or dog, however, can readily detect the presence of the owner; if he happens to be at home. If he should be, there is little hope, for the intruder simply pounces down on the nest and usually secures the owner. The varieties of these animals are closely allied externally and are difficult to identify without knowing the locality from which they came. The Tasmanian variety, (*B. cuniculus*) is slightly the largest and has white feet instead of brownish, as in the others. The underparts are white and, generally, there is a white tip on its tail. The New South Wales variety, (*B. gaimardi*) has hair of a more woolly texture than the others and white hind paws; also a few white hairs at the tip of the tail. The Brush-Tailed Rat-Kangaroo, (*B. penicillata*) is found all over southern and central Australia and has a body length of fourteen inches. The tail which is twelve inches long has a black crest along the upper surface of the lower portion, but not white hairs at the tip. The phinarium is bare of fur as in the other species. This is the variety that is usually seen in captivity.

The West and South Australian variety, (*B. lesueuri*), also found on some of the islands off the coast of West Australia, has a tail twelve inches long. Some specimens have a light stripe across the hip, and a white tip on the tail. The Plains Rat-Kangaroo of which there is but one species, (*Caloprymnus campestris*) found in the plains country of South Australia, is a slender animal with a broad face, and sandy-colored, thick, soft fur, which is darker on the back. The feet are white, and the middle of the chest usually has a bare patch. It is very quick in its movements when chased, and dodges about so cleverly that it is difficult to catch.

Probably, the rat-kangaroo that has the widest range is the Common, (*Potorous tridactylus*). It is found all over southeastern Australia and Tasmania. There are only three varieties of this family. The hind feet are short, and the tail short and tapering. When travelling fast, they use their fore feet as well as their hind ones. They never kick with their hind feet as the other rat-kangaroos do. The head of the Common is narrow and long, and is larger than the other two varieties. It measures seventeen inches and its tail nine and one-half inches, but the size varies; those found in Tasmania probably being the largest. The fur is long, coarse and greyish-brown in color, and the ears short and rounded, and the tail usually is tipped with white.

Gilbert's Rat-Kangaroo, (*P. gilberti*) is found in the southern districts of West Australia and is smaller than the aforementioned; otherwise externally identical. The other form, (*P. platyops*) is also from southwestern Australia and is still smaller, measuring only eleven and one-quarter inches, and tail seven and one-half inches. It is called the Broad-Faced; which characteristic is very noticeable. It is otherwise externally the same as the others. An interesting little animal *Hypsiprymnodon moschatus* has been described from the tropical scrubs in northern Queensland. In size and form like a large rat, it is reddish-grey in color, and the large ears are bare as are also the fingers. It is seen but rarely in captivity, as the animal is hard to detect and capture. It hops like a bandicoot and lives on insect life, as well as fruit and vegetation. It has two young.

PHALANGER OR AUSTRALIAN OPOSSUM.

The Australian Phalangers, locally mis-called opossums, are not carnivorous like the American opossum, but feed entirely on vegetation; eucalyptus leaves forming the principal part. They live entirely in trees, and are nocturnal in their habits, sleeping during the day in some hollow or in their domed nest. They once existed in very large numbers, despite having formed the principal article of food of the aboriginals in days gone by, but as their fur is of value for rugs they have been shot and trapped unmercifully and practically cleared out of many districts; over a million skins sometimes being exported annually from Australia. Foxes are now taking their toll of them in southeast Australia;

catching them as they pass on the ground from one tree to another. They climb the trees by jumping quickly upwards with all feet at once; the sharp claws being extended to their fullest extent and thus securing a firm hold in the bark. They choose the upper side of a tree, should it be reclining in any way, and a defined track will be made on the bark of the one that is much used, which serves to guide the natives in finding the hollow in which the opossums are coiled up asleep. They usually are caught by placing a long, thick branch of stick against the tree, and the animal will always ascend by this in preference to going up the straight trunk. In descending the branch, the animal advances head first, thrusts its head through a wire noose that has been placed on the stick, and thereby meets its fate. Many are shot; a moonlight night being chosen for the purpose, as the animals then can be distinguished against the face of the moon. The skins from the animals that have been shot are not as valuable as those that have been snared.

The smaller race of phalangers, called the Ring-Tailed, (*Pseudochirus*) is found in Tasmania, Australia and New Guinea. They also construct bulky, domed nests of sticks and leaves near the top of some thickly growing shrub, on which their tracks are not easily seen. They have from two to three young at birth which, on leaving their mother's pouch, hang to her back for some weeks, by clinging with their claws to her fur, and are carried about until they are able to look after themselves. As their tail is prehensile and frequently used for clinging, the underpart of the end of it is rough and bare. Sometimes when shot and badly wounded they will hang on by their tails before life leaves them, and remain in that position after death for a considerable time; frequently a day. The end of the tail is usually white. In the Herbert River district in Queensland, a small lemur-like variety, (*P. lemuroides*) is found. The soft, woolly brownish-grey fur is darker on the shoulders and lighter on the hips, and the head is brown and the tail black. It measures fifteen inches and tail twelve inches.

Another closely allied form, *P. herbertensis,* is found in the same district. It is dark brown in color, without markings, and is about the same size, but has a longer tail. Some specimens have white rings round their limbs. The common Ring-Tailed Phalanger, (*P. peregrinus*) has a wide range, being found from eastern Queensland to the southern parts of South Australia. They still are very plentiful in places, even near the large cities, where they find refuge in private gardens, and frequently are seen in captivity where they soon become very tame. I often have seen them walking along the thin telephone wires in the grounds of the Melbourne Zoo. They use their tails as a balance, moving them quickly from side to side as necessary, and if knocked over they will continue their progress by hanging on by their claws. These animals do not live on eucalyptus leaves like the large kind, but eat almost any vegetation and fruit and are fond of rose vines and other leaves in flower gardens. Their fur is short and its color varies; being varying shades of dark rufous-grey with a patch of white on the edge of the ear. They measure about fourteen inches and their tail about twelve inches.

The form in Western Australia is closely allied but has no rufous shade and the underparts are whiter, and usually there is more white on the end of the tail. There is also little difference in the Tasmanian form, (*P. cooki*). Its thick fur is more woolly in texture and dark rufous-brown in color with more white on the ears. The Yellow Ring-Tailed is found in the coastal districts of central Queensland. Its color of yellowish-green and white below renders it, therefore, easily distinguished. Four forms are found in New Guinea, namely, *P. albertisi* and *P. schlegeli* from the Anfak Mountains, *P. canescens* from Pamoi, and *P. forbesi* from Sogere. The large Phalanger, or as it is universally called in Australia, the opossum, belongs to the genus *Trichosurus*. The species feed chiefly on the leaves of the eucalyptus, resting during the day in hollows in these trees. It is the skins of this phalanger that have been exported in such quantities and are so largely used for fur rugs, etc. The variety that is by far the most plentiful, *T. vulpecula*, is found over the whole of Australia, except on the extreme northeast. Although formerly so abundant, in many districts they have been almost completely exterminated; but when afforded protection, which they now have in many places, and especially in Victoria, they soon increase. They are easily tamed and would be kept as pets more often if they did not sleep coiled up all day long and become lively only at night. Their thick, woolly fur is grey in color, the under parts whitish, the end of the bushy tail is black and bare on the under side, and there always is a reddish patch on the chest. In making rugs, the bare part of the tail is usually cut off and the backs only used. The ears are long and the body measures eighteen inches and the tail eleven inches.

The Tasmanian variety, *T. fuliginosus,* is larger and has longer fur. Many specimens are dark grey, tinged with rufous, but others are a dark rufous-brown with a black tail. The skins of this latter handsome variety are of considerable value, and the animal has to be rigorously protected to prevent its extermination. In the heavily timbered uplands of Victoria and New South Wales is fonud the Short-Eared Phalanger, (*T. caninus*). Its beautiful fur is very thick and of a dark grey color, although in some specimens it is dark reddish-brown. The short, rounded ears, about one-half the length of the other varieties, render it easily distinguished. This animal is closely allied to the Tasmanian form.

A black form of *caninus,* (*T. c. nigrans*) is found in the coastal scrubland of New South Wales and Queensland. The interesting point is, that the underparts are just as dark as the upper surface. During the summer, however, there frequently is a rufous shade.

KOALA OR NATIVE BEAR.

The Koala, or Native Bear as it is always called, of which there is but one species, (*Phascolarctus cinereus*) is found in all the eastern districts of Australia. They are strictly arboreal, living in the eucalyptus trees, and sitting during the day in a coiled-up position in a fork, where they are more secure. On account of this habit they are therefore easily shot, or killed by the heavy bush-fires. Like phalangers, the young cling to the back of the parent when they become too large for the pouch. The querelous, high-pitched note of the little ones is exactly like the crying of a child, but the old animals utter a prolonged, deep bass note. These animals are grey with white feet, and have thick, woolly fur. They do not possess a tail. An interesting little animal, *Tarsipes rostratus,* that is not often seen in captivity is found in Western Australia. It is only thirty-one inches in length, and its tail three and one-half inches. The color is grey, striped dorsally with dark brown. Its principal food is insects and it also sucks honey from the flowers.

FLYING-PHALANGER.

Australia possesses several forms of Flying-Phalangers, or as they are popularly called, Flying-Squirrels. When the Phalangers stretch the feet well out, the loose skin that acts as a parachute holds the air sufficiently to allow the animal to glide from the higher branches of one tree to the lower trunk of another; the long, furry tail acting as a rudder. As they alight, a quick upward movement is made, the sharp claws enabling them to hold on to the bark, when they quickly can ascend the tree again and repeat the performance. All the species have beautiful long, soft fur.

The Pigmy Flying-Phalanger, (*Acrobates pygmaeus*), well distributed over the eastern parts of Australia, is a delicate looking little creature, three inches long and with a tail three and one-half inches. The soft, silky fur is greyish-brown, the undersurface is white and the edge of the parachute is tipped with the same color. They usually have four young. On the timbered ranges of the coastal districts of Victoria and New South Wales, a large form of flying-phalanger is found, called the Yellow-Bellied, (*Petaurus australis*). Their color is greyish-brown, but varies in shade. The claws are strong and much curved, to enable them to get a good hold of the tree trunk when alighting. The body length of the species measures eleven and one-half inches and the very long and bushy tail is sixteen and one-half inches. The Squirrel Flying-Phalanger, (*P. sciureus*), a much smaller form measuring only ten inches and tail ten and one-half inches, is light grey with a dark line on the crown. They are easily tamed and make interesting pets. They are found in eastern Australia.

A still smaller form, found in the same districts, namely the Lesser, (*P. breviceps*) is only seven inches in length and its tail slightly longer. It also is light grey and can be distinguished from *P. sciureus* only by its smaller size. The Papuan form, (*P. papuanus*) is also closely allied, even in markings, but has shorter fur and usually yellowish underneath and is smaller in its measurements. It is found in the Papuan sub-region of New Guinea, as well as on the adjacent islands.

The Striped Phalanger, (*M. dactylopsila trivirgata*), a striking animal with a white body marked by dark, longitudinal stripes and a long bushy tail with a black line on its upper surface, is found from northern Queensland to New Guinea and on the Aru Islands. In the eastern districts of Australia, from southern Queensland to Victoria, is found the Taguan Flying-Phalanger, (*Petauroides volans*). It measures seventeen and one-half inches and the tail slightly longer. The ears are also very large. The fur, generally white below, is dark ashy grey, but it varies much in shade, some being lighter and others again nearly black. The Queensland form is usually smaller and has been named *P. minor*. Probably one form gradually runs into the other.

A small, mouse-like animal, the Dormouse-Phalanger, (*Domicia*) is closely allied to the flying-phalangers, but has no flying-membrane. Two forms are found in Tasmania. One, *D. lepida* measuring only three inches with a tail of the same length, is a graceful little animal, light fawn in color with fine, soft fur like all the others, numerous long whiskers and large ears. The other form, *D. nana*, fawn in color, but with the legs usually grey, also found in Victoria and New South Wales, is slightly larger, measuring four inches and its tail slightly longer. They have four young at a time. These little animals often have fatty accumulations on the body. The Long-Tailed, (*D. caudata*), which is the larger of the genus, comes from northwest New Guinea. It measures four inches in length, tail five and three-quarter inches and the general color is rufous, with two dark lines on each side of the face.

The smallest form, the Lesser, (*D. concinna*), found in South and West Australia, only measures three and one-half inches, with the tail slightly longer. Their color is fawn, and the underparts white. These little animals live well in captivity. Another genus, *Gymnobelideus leadbeateri* has been described from the mountainous districts of southeast Australia (Gipps-

FIG. 55. SHORT-TAILED WALLABY
New York Zoological Park.

Photograph by E. R. Sanborn

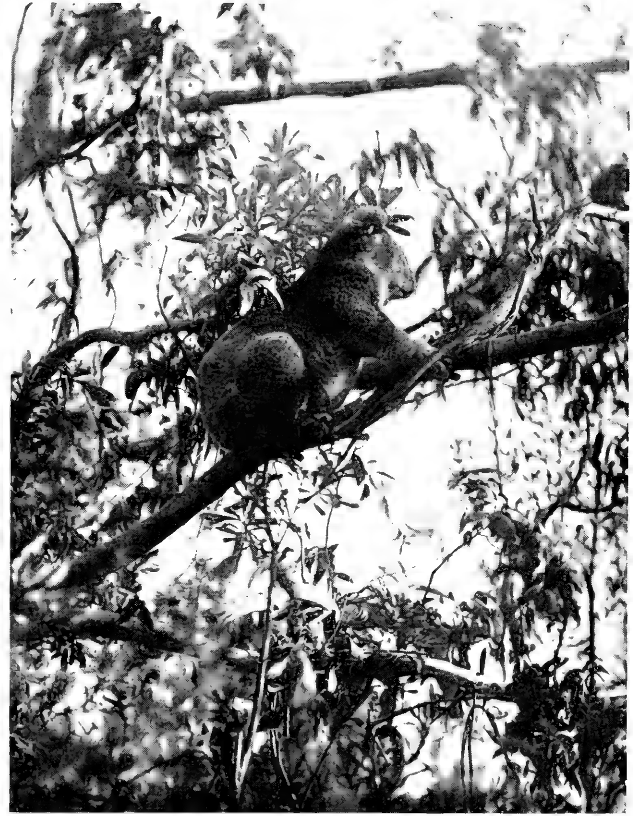
FIG. 56. RAT-KANGAROO
New York Zoological Park.

Photograph by E. R. Sanborn

FIG. 57. AUSTRALIAN GRAY PHALANGER
New York Zoological Park.

FIG. 58. KOALA OR NATIVE BEAR

Phascolarctus cinereus



Photograph by W. H. D. LeSouef

FIG. 59. KOALA IN ITS TREE-TOP HAUNT

An old native bear photographed wild in the bush in Victoria.

Photograph by E. R. Sanborn

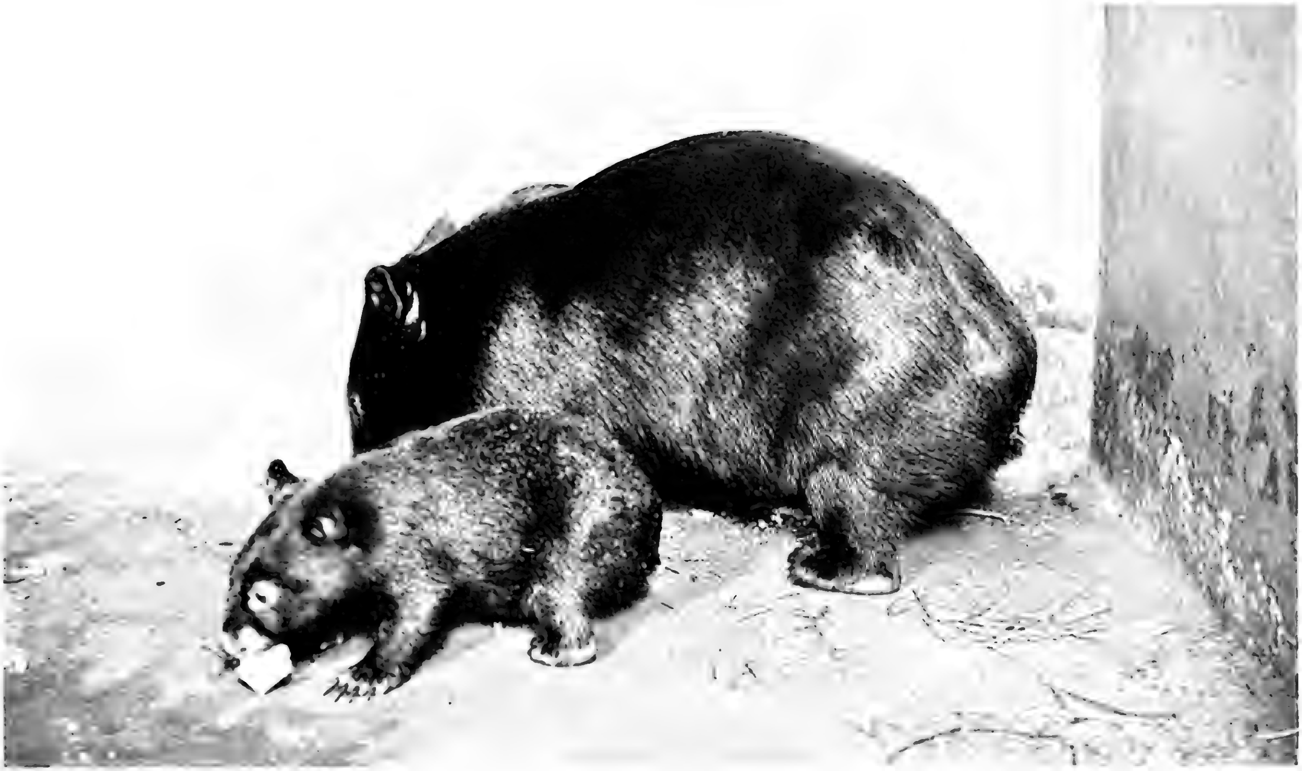
FIG. 60. FAT-TAILED OPOSSUM MOUSE

FIG. 61. FLYING-PHALANGER

New York Zoological Park.

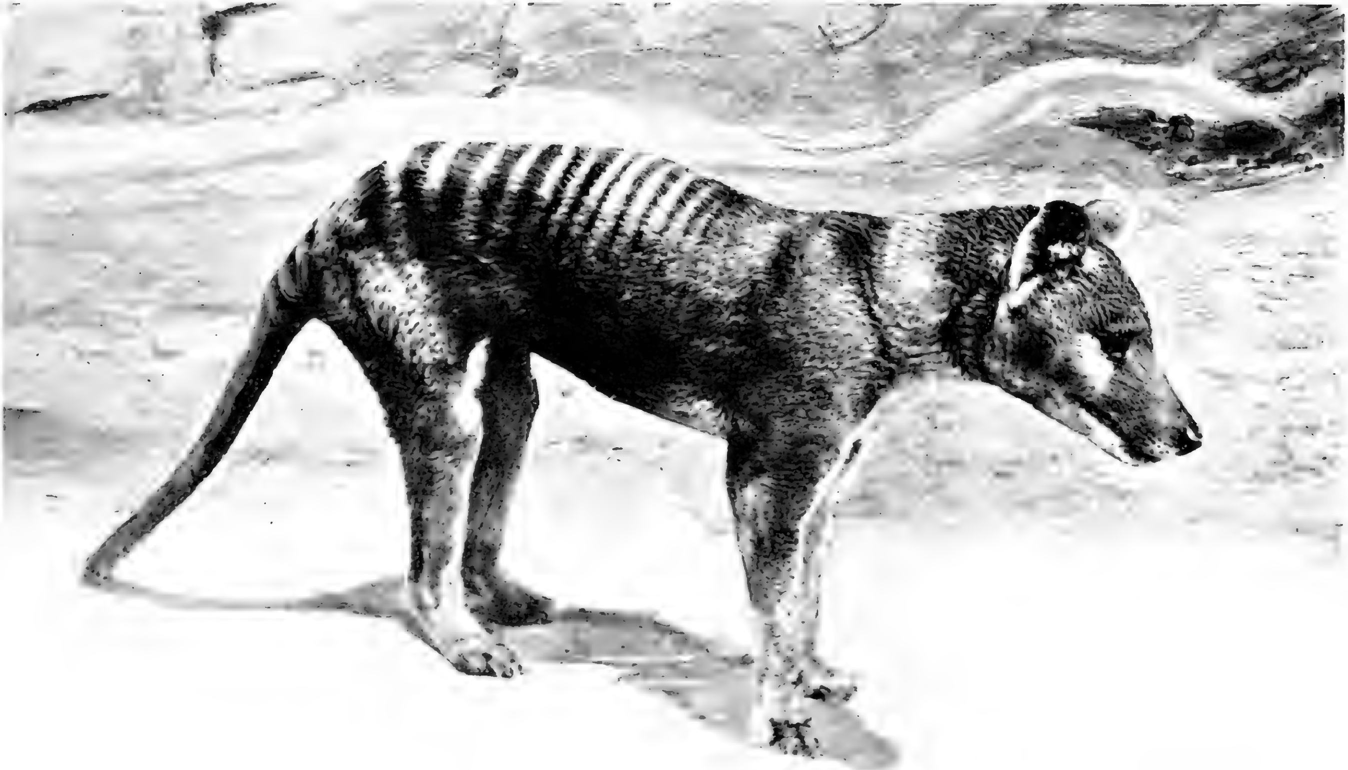
Photograph by E. R. Sanborn

FIG. 62. RABBIT-EARED BANDICOOT
New York Zoological Park.



Photograph by E. R. Sanborn

FIG. 63. WOMBAT AND YOUNG
New York Zoological Park.



Photograph by E. R. Sanborn

FIG. 64. TASMANIAN WOLF; MARSUPIAL WOLF
New York Zoological Park.

land), and is very rarely found. It is five and three-quarter inches long, tail a little longer, and the color of the body is grey with a dark line on the top of its head.

CUSCUS.

The Cuscus (Phalanger family), widely distributed over the islands in the Southern Pacific, are large and arboreal. They subsist on leaves and other vegetation. The Spotted Cuscus, (*P. maculatus*), the only one that is found in Australia, and that, only in the extreme north near Cape York, is also found in the Moluccas, Wai, Amboina, Ceram, Aru, and New Guinea as well as on some of the smaller islands. They live fairly well in captivity.

The fur of these animals is thick and woolly and the general color mottled white, black and red in various combinations. The females are generally dark grey and black without any white, but the markings vary, some color predominating more than others in different individuals. The Grey Cuscus, (*P. orientalis*) is found in Bourn, Amboina, Ceram, Waigin, Aru Islands and New Guinea. The males of these species are sometimes quite white, but the color of individuals varies much in shade. The Short-Eared variety, (*P. breviceps*), slightly smaller and darker than the Grey Cuscus, comes from Duke of York, Solomons, San Christoval and other small adjacent islands, and the Ornate Cuscus, (*P. ornatus*), which is smaller and lighter than the Grey Cuscus, is found in Morty, Ternate and Batchian Islands. In the Celebes and adjacent islands of Sanghir is found another form of Grey Cuscus, (*P. celebensis*).

THE BANDICOOTS.

The Rabbit Bandicoot, (*Peragale lagotis*), from southwest Australia, is about the size of a rabbit. The fawn-grey fur is long and silky, head and ears are long, an indistinct dark line runs vertically from the back on the sides of the rump, the underparts are white and the tail towards the end is also white and crested. Bandicoots are destroyed chiefly by dogs and cats, and were far more plentiful in the days gone by than they now are. They are nocturnal; resting during the day in burrows, and feeding at night upon insects, grubs, earthworms, fungus and roots. They are marsupial and the pouch opens backwards. Their general color is olive-grey, with bars across the lower part of the back. The smaller Bandicoots belong to another species, namely *Perameles*. The Short-Nosed, (*P. obesula*) is the most widely distributed, being found all over southern Australia and Tasmania. It is fourteen inches long and the short, coarse fur is grizzled-yellow and black, the underparts are white and the ears short and broad. They are usually found in swampy localities where the vegetation is very dense. The North Australia Bandicoot, (*P. macrura*) is closely allied to the former, but it is larger and darker in color and its tail is longer. The Long-Nosed Bandicoot (*P. nasuta*), found in the central districts of eastern Australia, also is larger than the Short-Nosed, has very coarse hair and is brown in color without any markings. The ears are long and pointed, the underparts are white, and it measures fifteen and one-half inches and its tail five inches. Gunn's Bandicoot, (*P. gunni*) is about the same size as the last mentioned, but has soft fur, yellowish-brown in color and with bands across the rump.

The form in West Australia is the Striped Bandicoot, (*P. bongainvillei*) is of small size being only nine inches long and has coarse olive-brown fur. Another form, (*P. fasciata*) in southeast Australia is closely allied to the former, but the stripes are very conspicuous and the tails are white. The Pig-Footed Bandicoot, (*Cheropus castanotis*), now becoming rare in places, is a small species measuring ten inches, and tail four inches. The name indicates its identity.

THE WOMBATS.

Wombats, (*Phascolomys*) are still fairly plentiful in southeastern Australia and Tasmania. They dig deep burrows and are safe there from foxes and dogs, as they are quite able to defend themselves. Their length averages about forty-four inches. They prefer scrubby, mountainous country and their food is entirely vegetable. They are nocturnal, resting during the day in their burrows. They have no tail.

The common variety, (*P. mitchelli*) is found in Victoria and New South Wales. They vary in color from dark yellowish-grey to black. The Tasmanian, (*P. tasmaniensis*) is smaller and usually of a dark greyish-brown color, and the Flinders Island form, (*P. ursinus*), the form originally but incorrectly described as from Tasmania, is yet smaller, being thirty-six inches in length. The Hairy-Nosed (*P. latifrons*), grey in color with the end of its muzzle white, is found only in South Australia. They are not as uniformly colored as the other varieties. These animals are very strong and burrow with great rapidity with their powerful claws; a habit that makes them very troublesome to settlers, as they dig under and damage wire-netting fencing. In walking, they shuffle along in a clumsy manner. They live well in captivity, but are very subject to skin disorders.

TASMANIAN WOLF.

The Marsupial Wolf, (*Thylacinus cynocephalus*). These rare animals probably will become extinct before very long, as the settlers are prejudiced against them on account of their destruction of sheep and other stock. The dark marks across the back are so very striking and distinctive, that the animal is usually called locally the Tasmanian Tiger. They utter a peculiar coughing bark, rapidly repeated and something like that of the kangaroo. They have a fair sized pouch which opens backwards and usually bear from one to two young at a time.

These animals resemble in form some of the short-legged wolves, but have short, close hair. During the day they generally sleep in hollow logs, holes, under rocks, and pursue their prey in the evening and at night. They are not very fleet of foot but have a keen scent and usually spring on their prey, which consists, besides the stock of settlers, of wallabies, rat-kangaroo's and other ground game. They swim well and readily cross rivers in pursuit of their prey, one having been recently observed swimming a river after a wallaby; quickly overtaking it. They are now found only in Tasmania, but their bones have been found in Australia. Why they disappeared from the mainland, it is difficult to say.

TASMANIAN DEVIL.

The Tasmanian Devil, (*Sarcophilus ursinus*) is strictly terrestrial and is now found only in Tasmania, although formerly it was plentiful in the southern districts of Victoria, judging by the remains found. But these animals were apparently extinct before the arrival of Europeans. They are strong but sluggish beasts and, having powerful canine teeth, are a match for any ordinary dog. They are carnivorous and can bite severely, while the molar teeth enable them to crush bones with ease. As the Tasmanian Devil is comparatively slow of movement, it usually catches its prey by a sudden spring, afterward devouring it greedily bones and all. It utters a disagreeable kind of snort. The three to four young, when too large to remain in their mother's pouch, generally cling to her back. They lie up in hollow logs or burrows during the day, coming out at night to catch their prey. They are destructive to poultry and lambs, consequently have few friends and are being killed out of all settled districts. Their color is jet black with a white horse-shoe mark on the chest, but they often have patches of white on other parts of the body. So far I have not seen an albino specimen such as one finds among the kangaroos and wallabies.

SPOTTED DASYURE.

The Spotted Dasyure or, as it is popularly called in Australia, the Native Cat, formerly used to exist in thousands in South Australia, but from some unknown cause these pretty little animals have now disappeared from many districts. There are three varieties, namely, the North Australian, (*Dasyurus hallucatus*), which is small, only measuring eleven inches and its tail eight inches; the Black-Tailed, (*D. geoffroyi*) from all Australia except the extreme north and the coastal districts of the southeast, and the Common, (*D. viverrinus*) from eastern New South Wales, Victoria, South Australia and Tasmania. These animals are marsupial, having about six young ones at birth. They are usually of a reddish-grey color, but also often black and are well marked with white spots, but not on the tail which is usually white at the tip. They measure about seventeen inches and their tail ten inches. A larger variety, the Spotted-Tail, (*D.*

Photograph by E. T. Luke

FIG. 65. A FAMILY OF TASMANIAN DEVILS
Melbourne Zoological Gardens

Apparently this rather forbidding animal has received its name partly from its color, and partly from its savage temper and strength of jaw. It breeds in captivity and frequently is seen in collections of living animals.

maculatus) found from eastern Queensland to Tasmania, is more than twice the size of the other species. These animals can climb well although they are mostly terrestrial, taking refuge during the day in hollow logs and among rocks, etc. If several are kept in the same compartment in captivity, they are liable to turn cannibals; the stronger eating the weaker. They are carnivorous, taking birds and their eggs, mice, rats, bandicoots, and other game, and are very destructive to poultry. Consequently, they are not spared by the settlers. They are plentiful in Tasmania; more so than on the mainland.

MARSUPIAL MICE.

A form of Pouched Mouse with habits the same as the others, is the genus *Phascogale.* Their pouch is hardly visible. They bear from six to ten young ones at birth, living principally in holes in trees and lining their nests with grass and leaves. Nine species have been described, namely: the Crest-Tailed, (*P. cristicardata*), which measures about five and one-half inches with a tail three and one-half inches much thicker at the base, is found in central and southern Australia; *P. macdonnellensi* from central Australia has an abnormally thickened tail at the base. The Lesser Brush-Tailed Pouch Mouse, (*P. calura*), also found in southern and central Australia, is five inches long and has a tail six inches. *P. penicillata* or Greater Brush-Tailed Mouse is ten inches long and tail nine inches, is the largest of this genus. They are found all over Australia except at the extreme north, and live almost entirely in trees, making their nests in the hollows of the branches. They have thick tails and the end is covered with long, black hair, forming a brush. There is a very small variety named *P. minutissima,* found in southern Queensland and New South Wales, that is only three inches long. The Yellow-Footed, (*P. flavipes*) with yellow legs and feet, as its name indicates, ranges from eastern Australia to New Guinea. In Tasmania and the adjacent islands, a small variety is found, *P. minima,* or Little Pouched Mouse, with a body length of five inches, and tail three and one-half inches, and in Queensland a still smaller form is *P. minutissima* or Pigmy Pouched Mouse, only three inches long and tail two and one-half inches. Tasmania and southern

Victoria has still another variety, *P. swainsoni* which has long soft fur. In West Australia is found the Freckled, (*P. apicalis*), which is freckled, reddish-grey above. Australia is well off for Marsupial Mice, and other varieties certainly will be found, as these little animals are easily overlooked. Insects form a large part of their food.

Marsupial or Pouched Mice, (*Sminthopis*) are slender and active little animals, from three to four inches long, with large ears and a well developed pouch in which they carry the three to four young they have at birth. They are terrestrial, insectivorous and do not often burrow. Their grey fur is soft and fine. Six species have been described, *S. larapinta,* from Central Australia near the Finke River and the Fat-Tailed, (*S. crassicaudata*), which is found all over Australia except the north. Both of these little animals have the basal portion of their tail much thickened. The Common, (*S. murina*) is found over the southern and central portions of the continent. *S. psammophila* lives near Lake Amadeus in Central Australia, among the sand hills covered with tussocks of porcupine grass. The White-Footed, (*S. leucopus*) extends over eastern Australia from Cape York to Tasmania and is plentiful in certain localities. *S. virginiae* is known only in eastern Queensland. It is five inches long.

An interesting animal found in southwestern and southern Australia, of which but one species is known, is the Marsupial Anteater, (*Myrmecobius fasciatus*). It frequents both the ground and hollows in the trees and its food consists of insects, generally. The fur is short and strong, of a general rufous color which darkens to black toward the tail, with prominent bands of white. It therefore is distinguished readily. The underparts are light yellowish. The females have no pouch, the young adhering to the nipples. It leaps along the ground like a squirrel with the tail slightly raised. They make charming pets and never attempt to bite. It measures ten inches long and its bushy tail seven inches.

THE ECHIDNA.

Of these most interesting animals, the Echidnas, or as they usually are called in Australia the Porcupine Anteater, there are

Photograph by E. R. Sanborn

FIG. 66. UNDER SURFACE OF THE ECHIDNA
New York Zoological Park.

Photograph by E. R. Sanborn

FIG. 67. ECHIDNA IN NORMAL ATTITUDE
New York Zoological Park.

three varieties, namely, that found in New Guinea, (*Echidna lawesii*), about fourteen inches in length, which has short spines; the Brown Echidna, (*E. setosa*) from Tasmania, with long hair almost concealing the spines, and the Australian form, (*E. aculeata*) which is slightly larger than the New Guinea variety, being about seventeen inches long and without as much hair as the Tasmanian species. These animals live entirely on the ground and their food consists of small insects, and, especially termites and ants, which they easily can obtain by digging with their powerful claws into the ant's nests or termites mounds. The tongue which is covered with sticky saliva is then protruded and when covered with ants is drawn back into the mouth. In captivity they are fed on finely chopped raw meat, eggs and milk. They have no true teeth, but have small spines at the back of the tongue. Their tail is rudimentary and the feet short and strong. When in danger, the animal rolls itself up something like a hedgehog. The sharp spines not only are presented to its enemy, but also are stuck into the ground, making it harder to lift up. The only way it can be carried conveniently is by grasping it by its hind feet, so that its head hangs down. It can dig in any hard soil by the aid of the spines as well as by the strong claws, and it is remarkable how quickly it seems to sink into the ground. It also can hold so tightly to the soil that it is only with difficulty that it can be raised, even by the aid of a spade or strong stick. It also is very difficult to dislodge from the corner of a room, and can climb over almost any wire fence and also out of any ordinary box at the corners, and unless the lid is very firmly nailed on, will push it off, and get through a very small aperture. The strength of the animal is astonishing and even if tightly fastened by a cord around one of its hind legs, is almost certain to get it off. These animals generally hibernate during the winter; usually under the surface of the ground, and frequently by a rock or rising ground. It is at this time that the egg is laid and the young hatched. The shell of the egg is soft and not calcified, and measures about half an inch. The mother by rolling herself up helps to protect the young which are in her pouch, and as the female has no nipples the young one when hatched has to lick the milk from the folds in the pouch. The young Echidna leaves the pouch just as the spines begin to appear and when it is a little over three inches long. The pouch then gradually disappears until the next breeding season. Like the kangaroo, it is very rarely that two young are born. These animals are more or less nocturnal, as are nearly all the Australian animals.

PLATYPUS.

The Duck-Billed Platypus, (*Ornithorhynchus anatinus*) is of great interest. Like the Echidna it belongs to the genus *Monotremata,* but passes its time in water and not on land, except when coiled up in its burrow with its tail tucked underneath, which usually is most of the day. It seeks its food generally in the evening or sometimes during the day in some very sheltered spot, feeding on earthworms, shell-fish, crustaceans and water insects, generally; a certain amount of which it can store in its cheek pouches. Although the young have rudimentary teeth, they have none when they reach an adult stage; horny plates developing in the place of them which enables the animals to masticate their food, which they usually do when lying on the surface of the water. The fur, which looks very much like that of a seal when the longer hairs are removed, is of two kinds; the longer being shiny and crisp and the under fur soft and short. The bill is soft and leathery, but shrinks considerably when dry, as in museum specimens. The underparts are lighter in color, usually greyish white. The tail is broad and flat and of a dark color above. The underpart is usually devoid of hair, especially in the older animals. Their eyes are very small, but as their bill is usually sensitive, they generally can find their insect prey by a sense of touch.

Being unable to raise the body high from the ground like ordinary animals they can only shuffle along in an awkward manner. It is a burrowing animal and makes a long upward tunnel in the river banks, sometimes thirty feet in length, usually starting at the roots of a tree that grows to the water, with the entrance generally under the surface of the water. At the end is a small chamber lined with leaves and grass, generally not so far from the surface of the ground, so that the natives frequently can tell where the nest is by striking the surface of

FIG. 68. THE PLATYPUS, OR DUCK-BILL

We regret to say that owing to the food habits of this most remarkable animal, it is never seen alive outside of Australia. There is little ground for hope that a living platypus can be brought to New York and shown in captivity.

the ground above and listening for the echo. When swimming, the claws and web are stretched out to their full extent, but on land the extended web is always doubled up underneath; the end of the claws then coming in contact with the ground. In nearly all specimens in museums, the web is expanded beyond the claws, although the animal is represented as being in the ground. But that is incorrect. These animals are very timid, and though they possess no external ears, they are very quick at hearing, and any suspicious sound makes them dive out of sight. The male measures about eighteen inches, tail six inches. The spur on its heel is larger than that on the female. The latter animal is about fourteen inches in length. The shell of the egg is of a tough, leathery texture, and from two to four eggs are laid at a time. As the mother has no pouch, she practically makes one by rolling herself up in her nesting chamber. She has no nipples, but the mammery glands which are in two groups, are underlying the skin on the underside, and the milk is pressed out by a contraction of the muscles and the young takes its food by applying its flat face and tongue to the lacteal surface. These animals are found in the rivers of Tasmania and eastern Australia, except the extreme north.

MOLE.

Australia possesses a marsupial mole, (*Notoryctes typhlops*) found in central and western Australia, but, naturally it never is seen in captivity. As a matter of fact they will not live in captivity. It is about six inches long, with a curious ringed tail about an inch in length, and much thickened at the base. The nose has a hard shield. The fur is soft with an irredescent effect, and varies in color from a yellowish tint to chestnut-brown. They have two young at birth, live underground entirely, are without eyes and subsist on insect food.

ZOOLOGICA

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By William Beebe
Director, Tropical Research Station

In the course of recent studies of neotropical vertebrates, with reference to future ecological work in the field at the Tropical Research Station of the New York Zoological Society, I have been in constant need of lists of the Vertebrata of British Guiana.[1]

Finding no résumé available of the Amphibia, Reptilia and Mammalia of this colony, I have gone through the literature at hand and made my own lists. These I offer as a preliminary enumeration of the species thus far recorded in literature, or in my own collections, from this British Colony. They form a tangible basis for future increments—the many new species and the radical extension of present known distributions which intensive study of these phyla in British Guiana is certain to achieve. Check-lists of mere names such as these are wholly foreign to the future zoological work of the Tropical Station, but they are absolutely necessary as a basis for identification and investigation, and it is in this spirit that this preliminary work has been undertaken.

I have made no attempt at a thorough search of literature for priority or for confirmation of names or other similar phases of taxonomy, deeming this the special province of the literary systematist. I have merely sought to utilize the most recently accepted names of herpetologists and mammalogists. In general I have followed the classification of Gadow in the Cambridge Natural History, Volume

[1]A preliminary survey of the fishes has been made by Prof. C. H. Eigenmann in his "Freshwater Fishes of British Guiana," and lists of the birds are available in Brabourne and Chubb's "The Birds of South America," in Chubb's unfinished "Birds of British Guiana," and in my "Tropical Wild Life," published by the Zoological Society in 1917.

VIII, for Amphibia and Reptilia, and that of Osborn in "The Age of Mammals" for Mammalia. Dr. J. A. Allen has kindly criticized the mammalian names, and to John Tee-Van, a member of my Tropical Station staff, I am indebted for untiring search through many scores of volumes for British Guiana records.

The lists of names are unannotated, and in each case I have given one authentic record for British Guiana, not necessarily the first in published priority. An asterisk before a name indicates that the species has been collected within a radius of ten miles of the Zoological Society's Research Station in Bartica District. This locality is indicated on the adjoining map.

The total number of species is as follows:

		British Guiana	Bartica District
I.	Class **AMPHIBIA** (Coecilians, Frogs and Toads)	52	35
II.	Class **REPTILIA**	112	54
	CHELONIA (Turtles and Tortoises)	11	5
	CROCODILIA (Crocodiles)	4	1
	LACERTILIA (Lizards)	34	21
	OPHIDIA (Snakes)	63	27
III.	Class **MAMMALIA**	119	48
	MARSUPIALIA (Opossums)	10	5
	CHIROPTERA (Bats)	36	3
	CARNIVORA (Jackals, Raccoons, Otters and Cats)	16	12
	RODENTIA (Agoutis, Porcupines, Rats and Mice)	27	8
	EDENTATA (Sloths, Anteaters and Armadillos)	8	8
	PRIMATES (Monkeys)	9	5
	ARTIODACTYLA (Peccaries and Deer)	8	4
	PERISSODACTYLA (Tapirs)	1	1
	SIRENIA (Sea-cows)	1	1
	ODONTOCETI (Dolphins and Whales)	3	1

CLASS: AMPHIBIA

Order APODA; **Limbless, Burrowing Coecilians**

Family Coecilidae

Coecilia gracilis Shaw
Boul. Cat. Batr. Brit. Mus. 1882.

Siphonops annulatus (Mikan.)
Beebe Coll. Bartica Dist. 1916.

Order ANURA; **Frogs and Toads**

Family Pipidae

*__Pipa americana__ Laur.
Boul. Cat. Batr. Brit. Mus. 1882, p. 459

Family Bufonidae

Bufo guttatus Schneid.
Boul. Cat. Batr. Brit. Mus. 1882, p. 291

*__Bufo molitor__ Tschudi
Beebe Coll. Bartica Dist. 1916

*__Bufo marinus__ (Linné)
Boul. Cat. Batr. Brit. Mus. 1882, p. 316

*__Bufo typhonius__ (Linné)
Beebe Coll. Bartica Dist. 1916

*__Bufo sternosignatus__ Keferst.
Beebe Coll. Bartica Dist. 1916

Family Hylidae

*__Hyla maxima__ (Laur.)
Boul. Cat. Batr. Brit. Mus. 1882, p. 349

*__Hyla crepitans__ Wied
Boul. Cat. Batr. Brit. Mus. 1882, p. 352

*__Hyla indris__ (Cope)
Boul. Cat. Batr. Brit. Mus. 1882, p. 353

*__Hyla pardalis__ Spix
Beebe Coll. Bartica Dist. 1916

Hyla albomarginata Spix
Boul. Trans. Linn. Soc. London, (2) VIII, 1900, p. 56

*__Hyla punctata__ (Schneid.)
Beebe Coll. Bartica Dist. 1916

Hyla granosa Boul.
Boul. Cat. Batr. Brit. Mus. 1882, p. 358

Hyla fasciata (Cope)
Schomb. Reise Brit. Guiana, III, 1848, p. 660

*__Hyla boans__ Daud.
Beebe Coll. Bartica Dist. 1909

Hyla leprieurii Dum. & Bibr.
Boul. Cat. Batr. Brit. Mus. 1882, p. 362

Hyla taurina (Steindachn.)
Boul. Cat. Batr. Brit. Mus. 1882, p. 363

Hyla venulosa (Laur.)
Boul. Cat. Batr. Brit. Mus. 1882, p. 365

Hyla aurantiaca Daud.
Boul. Cat. Batr. Brit. Mus. 1882, p. 388

Hyla acuminata Cope
Boul. Cat. Batr. Brit. Mus. 1882, p. 403

*__Hyla rubra__ Daud.
Boul. Cat. Batr. Brit. Mus. 1882, p. 404

*__Hyla lineomaculata__ Werner
Beebe Coll. Bartica Dist. 1909

Hyla evansi Boul.
Proc. Zool. Soc. London, 1904, II, p. 106

Phyllomedusa bicolor (Boddaert)
Boul. Cat. Batr. Brit. Mus. 1882, p. 427

Phyllomedusa hypochondrialis Daud.
Boul. Cat. Batr. Brit. Mus. 1882, p. 430

Family Cystignathidae

*__Pseudis paradoxa__ (Linné)
Boul. Cat. Batr. Brit. Mus. 1882, p. 186

*__Ceratophrys cornuta__ (Linné)
Beebe Coll. Bartica Dist. 1909

Eleutherodactylus marmoratus (Boul.)
Boul. Trans. Linn. Soc. London, (2) VII, 1900, p. 56

*__Leptodactylus lineatus__ (Schneid.)
Boul. Cat. Batr. Brit. Mus. 1882, p. 207

Leptodactylus hylaedactylus (Cope)
Boul. Cat. Batr. Brit. Mus. 1882, p. 240

***Leptodactylus longirostris** Boul.
Beebe Coll. Bartica Dist. 1916

***Leptodactylus pentadactylus** (Laur.)
Boul. Cat. Batr. Brit. Mus. 1882, p. 242

***Leptodactylus poecilochilus** (Cope)
Boul. Cat. Batr. Brit. Mus. 1882, p. 244

***Leptodactylus typhonius** (Daud.)
Beebe Coll. Bartica Dist. 1916

***Leptodactylus ocellatus** (Linné)
Beebe Coll. Bartica Dist. 1909

***Leptodactylus caliginosus** Girard
Beebe Coll. Bartica Dist. 1916

***Leptodactylus gaudichaudii** (Dum. & Bibr.)
Beebe Coll. Bartica Dist. 1916

Family Engystomatidae

Oreophrynella Quelchii Boul.
Boul. Ann. Mag. Nat. Hist. (6) XV, 1895, p. 522.

Oreophrynella Macconnelli Boul.
Boul. Trans. Linn. Soc. London, (2) VIII, 1900, p. 55

***Otophryne Robusta** Boul.
Boul. Trans. Linn. Soc. London, (2) VIII, 1900, p. 56

***Atelopus Proboscideus** Boul.
Beebe Coll. Bartica Dist. 1916

***Atelopus varius** (Stannius)
Beebe Coll. Bartica Dist. 1916

***Atelopus flavescens** (Dum. & Bibr.)
Boul. Cat. Batr. Brit. Mus. 1882, p. 154

***Atelopus pulcher** Boul.
Beebe Coll. Bartica Dist. 1916

***Engystoma microps** Dum. & Bibr.
Boul. Cat. Batr. Brit. Mus. 1882, p. 163

Family Ranidae

***Prostherapis inguinalis** Cope
Boul. Cat. Batr. Brit. Mus. 1882, p. 139

***Prostherapis trinitatus** (Garman)
Beebe Coll. Bartica Dist. 1916

***Dendrobates tinctorius** (Schneid.)
Beebe Coll. Bartica Dist. 1916

***Dendrobates trivittatus** (Spix)
Boul. Cat. Batr. Brit. Mus. 1882, p. 144

***Rana palmipes** Spix
Beebe Coll. Bartica Dist. 1916

CLASS: REPTILIA

Order CHELONIA; Turtles and Tortoises

Suborder Cryptodira

Family Cinosternidae

***Cinosternum scorpioides** (Linné)
Beebe Coll. Bartica Dist. 1916

Family Testudinidae

***Nicoria punctularia** (Daud.)
Boul. Cat. Chel. Brit. Mus. 1889, p. 124

***Testudo tabulata** Walb.
Beebe Coll. Bartica Dist. 1916

Family Chelonidae

Chelonia mydas (Linné)
Leechman; Handbook Brit. Guiana, 1913, p. 134

Suborder Pleurodira

Family Pelomedusidae

Podocnemis unifilis Trosch.
Schomb. Reise Brit. Guiana, III, 1848, p. 647

***Podocnemis expansa** (Schwigg.)
Beebe Coll. Bartica Dist. 1916

Podocnemis tracaxa (Spix)
Schomb. Reise Brit. Guiana, III, 1848, p. 646

Family Chelydidae

***Chelys fimbriata** (Schneid.)
Schomb. Reise Brit. Guiana, III, 1848

Hydraspis tuberosa (Peters)
Boul. Cat. Chel. Brit. Mus. 1889, p. 223

Hydraspis gibba (Schweigg.)
Boul. Cat. Chel. Brit. Mus. 1889, p. 224

Platemys platycephala (Schneid.)
Boul. Cat. Chel. Brit. Mus. 1889, p. 228

Order CROCODILIA; **Crocodiles**

Family Crocodilidae

Caiman niger Spix
Schomb. Reise Brit. Guiana, III, 1848, p. 647

*__Caiman sclerops__ (Schneid.)
Schomb. Reise Brit. Guiana, III, 1848, p. 648

Caiman trigonatus (Schneid.)
Boul. Cat. Croc. Brit. Mus. 1889, p. 296

Caiman palpebrosus (Cuv.)
Schomb. Reise Brit. Guiana III, 1848, p. 648

Order LACERTILIA; **Lizards**

Family Geckonidae

Gonatodes annularis Boul.
Boul. P. Z. S. 1887, p. 153

*__Thecadactylus rapicaudus__ (Houtt.)
Boul. Cat. Liz. Brit. Mus. I, 1885, p. 112

*__Hemidactylus mabouia__ (de Jonnès)
Beebe Coll. Bartica Dist. 1916

Family Iguanidae

Anolis alligator Dum. & Bibr.
Boul. Cat. Liz. Brit. Mus. III, 1887, p. 500

*__Anolis sagrae__ Dum. & Bibr.
Beebe Coll. Bartica Dist. 1916

*__Anolis fusco-auratus__ D'Orb.
Beebe Coll. Bartica Dist. 1916

*__Anolis ortonii__ Cope
Beebe Coll. Bartica Dist. 1916

Anolis punctatus Daud.
Boul. P. Z. S. 1887, p. 153

*__Anolis chrysolepis__ Dum. & Bibr.
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 90.

Norops auratus (Daud.)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 96

*__Polychrus marmoratus__ (Linné)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 99

Ophryoessa superciliosa (Linné)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 112

Tropidurus torquatus (Wied)
Schomb. Reise Brit. Guiana III, p. 650

*__Plica umbra__ (Linné)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 180

*__Plica plica__ (Linné)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 181

Urocentron azureum (Linné)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 183

*__Iguana iguana__ (Linné)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 190

Family Teiidae

Tupinambis teguixin (Linné)
Schomb. Reise Brit. Guiana III, p. 65

*__Tupinambis nigropunctatus__ Spix
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 337

*__Centropyx intermedius__ (Schleg.)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 341

*__Centropyx calcaratus__ (Spix)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 342

*__Ameiva surinamensis__ (Laur.)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 353

*__Ameiva punctata__ Gray
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 360

*__Cnemidophorus murinus__ (Laur.)
Beebe Coll. Bartica Dist. 1916

*__Cnemidophorus lemniscatus lemniscatus__ (Daud.)
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 364

Crocidilurus lacertinus (Daud.)
Schomb. Reise Brit. Guiana III, p. 650

*__Prionodactylus oshaughnessyi__ Boul.
Beebe Coll. Bartica Dist. 1916

*__Cophias flavescens__ (Bonnat.)
Boul. P. Z. S. 1887, p. 153

Iphisa elegans Gray
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 425

Calliscinopus agilis Ruthven
Ruth. Occ. Papers Univ. Mich. No. 22, 1916, p. 3

Family Amphisbaenidae

*__Amphisbena fuliginosa__ Linné
Boul. Cat. Liz. Brit. Mus. II, 1885, p. 438

Family Scincidae

Mabuia punctata (Gray)
Boul. Cat. Liz. Brit. Mus. III, 1885, p. 161

*__Mabuia aurata__ (Schneid.)
Boul. Cat. Liz. Brit. Mus. III, 1885, p. 190

Mabuia agilis (Raddi)
Boul. Cat. Liz. Brit. Mus. III, 1885, p. 191

Order OPHIDIA ; **Snakes**

Family Typhlopidae

*__Typhlops reticulatus__ (Linné)
Boul. Cat. Snakes Brit. Mus. I, 1893, p. 28

Typhlops lumbricalis (Linné)
Boul. Cat. Snakes Brit. Mus. I, 1893, p. 31

Family Boidae

*__Epicrates cenchris__ (Linné)
Boul. Cat. Snakes Brit. Mus. I, 1893, p. 95

Corallus cookii Gray
Boul. Cat. Snakes Brit. Mus. I, 1893, p. 100

*__Corallus hortulanus__ (Linné)
Boul. Cat. Snakes Brit. Mus. I, 1893, p. 102

*__Corallus caninus__ (Linné)
Boul. Cat. Snakes Brit. Mus. I, 1893, p. 103

*__Eunectes murinus__ (Linné)
Boul. Cat. Snakes Brit. Mus. I, 1893, p. 115

*__Boa constrictor__ (Linné)
Beebe Coll. Bartica Dist. 1916

Family Ilysiidae

*__Ilysia scytale__ (Linné)
Boul. Cat. Snakes Brit. Mus. I, 1893, p. 134

Family Colubridae

*__Helicops angulatus__ (Linné)
Boul. Cat. Snakes Brit. Mus. I, 1893, p. 279

Drymobius boddaertii (Sentzen)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 13

*__Phrynonax sulphureus__ (Wagl.)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 19

Phrynonax fasciatus (Peters)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 22

Spilotes pullatus (Linné)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 23

*__Coluber corais__ Boie
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 32

*__Herpetodryas sexcarinatus__ (Wagl.)
Beebe Coll. Bartica Dist. 1916

*__Herpetodryas carinatus__ (Linné)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 74

*__Herpetodryas fuscus__ (Linné)
Boul. Cat. Snakes Brit. Mus. 11, 1894, p. 75

*__Leptophis liocercus__ (Wied)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 114

Liophis typhlus (Linné)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 136

Liophis reginae (Linné)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 138

*__Xenedon colubrinus__ Günther
Beebe Coll. Bartica Dist. 1916

*__Xenedon severus__ (Linné)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 149

*__Xenedon merremii__ (Wagl.)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 150

Aporophis lineatus (Linné)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 158

Rhadinaea cobella (Linné)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 167

Rhadinaea purpurans (Dum. & Bibr.)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 168

Urotheca bicincta (Hermann)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 184

Dimades plicatilis (Linné)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 186

Hydrops triangularis (Wagl.)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 187

Petalognathus nebulatus (Linné)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 294

Atractus torquatus (Dum. & Bibr.)
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 309

Atractus trilineatus Wagl.
Boul. Cat. Snakes Brit. Mus. II, 1894, p. 312

*__Lycognathus cervinus__ (Laur.)
Beebe Coll. Bartica Dist. 1916

Trypanurgos compressus (Daud.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 59

Himantodes cenchoa (Linné)
Schomb. Reise Brit. Guiana III,

*__Leptodeira albofusca__ (Lacép.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 96

Oxyrhopus petolarius (Linné)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 102

Oxyrhopus trigeminus Dum. & Bibr.
Boul. Cat. Snakes Brit Mus. III, 1896, p. 104

Oxyrhopus cloelia (Daud.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 109

Oxyrhopus coronatus (Schneid.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 112

Rhinostoma guianense (Trosch)
Schomb. Reise. Brit. Guiana, III, 1848, p. 653

Thamnodynastes nattereri (Mikan.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 117

Thamnodynastes punctatissimus (Wagl.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 117

Philodryas viridissimus (Linné)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 129

Oxybelis fulgidus (Daud.)
Schomb. Reise. Brit. Guiana III, 1848

*__Oxybelis acuminatus__ (Wied)
Beebe Coll. Bartica Dist. 1916

Erythrolamprus aesculapii (Linné)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 202

***Tantilla melanocephala** (Linné)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 216

Apostolepis quinquelineata Boul.
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 235

Family Elapidae

Micrurus surinamensis (Cuv.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 414

***Micrurus psyches** (Daud.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 427

Micrurus marcgravii (Wied)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 429

Micrurus lemniscatus (Linné)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 430

Family Amblycephalidae

Leptognathus catesbyi (Sentzen)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 449

Leptognathus pavonina (Schleg.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 450

Leptognathus variegata Dum. & Bibr.
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 451

Leptognathus leucomelas Boul.
Beebe Coll. Bartica Dist. 1917

***Dipsas bucephala** (Shaw)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 462

Family Crotalidae

***Lachesis mutus** (Linné)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 534

***Lachesis lanceolatus** (Lacép.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 536

***Lachesis atrox** (Linné)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 539

***Crotalus terrificus** (Laur.)
Boul. Cat. Snakes Brit. Mus. III, 1896, p. 575

CLASS: MAMMALIA

Order MARSUPIALIA; **Opossums**

Family Didelphidae

*__Didelphis marsupialis marsupialis__ Linné
Linnaeus Guiana Opossum; Crab-eating Yawarri
Thomas, Cat. Mar. Brit. Mus. 1888, p. 327

*__Metachirus opossum opossum__ (Linné)
White-faced Opossum; Quica
Thomas, Cat. Mar. Brit. Mus. 1888, p. 332

Metachirus nudicaudatus nudicaudatus (E. Geoff.)
Bare-tailed Opossum
Quelch, Animal Life in Brit. Guiana, 1901, p. 79

Lutreolina crassicaudata (Desm.)
Thick-tailed Opossum
Thomas, Cat. Mar. Brit. Mus. 1888, p. 336

Caluromys philander (Linné)
Woolly Opossum
Thomas, Cat. Mar. Brit. Mus. 1888, p. 338

*__Marmosa murina murina__ (Linné)
Linnaeus Mouse Opossum; Little Yawarri
Thomas, Cat. Mar. Brit. Mus. 1888, p. 346

Marmosa chloe Thomas
Chloe's Opossum
Thomas, Ann. Mag. Nat. Hist. (7) XX, p. 167

Marmosa cinerea demerarae Thomas
Demerara Ashy Opossum
Thomas, Ann. Mag. Nat. Hist. (7) XVI, p. 313

*__Peramys brevicaudatus__ (Erxl.)
Short-tailed Opossum
Quelch, Animal Life Brit. Guiana, 1901, p. 80

*__Chironectes minimus__ (Zimm.)
Water Opossum; Yapock
Thomas, Cat. Mar. Brit. Mus. 1888, p. 370

Order CHIROPTERA; **Bats**

Family Emballonuridae

Rhynchincus naso (Wied)
Guiana River Bat
Dobson, Cat. Chir. Brit. Mus. 1878, p. 369

*__Saccopteryx leptura__ (Schr.)
Young, Timehri, (2) X, 1896, p. 44

Saccopteryx bilineata (Temm.)
Thomas, Ann. Mag. Nat. Hist. (7) VIII, 1901, p. 140

Peropteryx canina (Wied)
Thomas, Ann. Mag. Nat. Hist. (7) VIII, 1901, p. 140

Cyttarops alecto Thomas
Thomas, Ann. Mag. Nat. Hist. (8) XI, 1913, p. 136

Family Noctilionidae

Noctilio leporinus leporinus (Linné)
Dobson, Cat. Chir. Brit. Mus. 1878, p. 416

Dirias albiventer (Spix)
Young, Timehri, (2) X, 1896, p. 45

Family Phyllostomidae

Micronycteris megalotis megalotis Gray
Thomas, Ann. Mag. Nat. Hist. (7) VIII, 1901, p. 142

Dolichophyllum macrophyllum Wied
Quelch, Timehri, (2) VI, 1892, p. 97

Phyllostomus hastatus hastatus (Pallas)
Dobson, Cat. Chir. Brit. Mus. 1878, p. 486

Phyllostomus discolor Wagner
Young, Timehri, (2) X, 1896, p. 45

Phyllostomus elongatus Geoff.
Young, Timehri, (2) X, 1896, p. 45

Phyllostomus latifolius Thomas
Thomas, Ann. Mag. Nat. Hist. (7) VIII, 1901, p. 142

Vampyrus spectrum (Linné)
False Vampire
Dobson, Cat. Chir. Brit. Mus. 1878, p. 471

Glossophaga soricina (Pallas)
Quelch, Timehri, (2) VI, 1892, p. 97.

Hemiderma perspicillatum (Linné)
Thomas, Ann. Mag. Nat. His. (7) VIII, 1901, p. 143

Rhinophylla pumilio Peters
Young, Timehri, (2) X, 1896, p. 46

Uroderma bilobatum Peters
Quelch, Timehri, (2) VI, 1892, p. 97

Artibeus planirostris fallax Peters
Anderson, Proc. Zool. Soc. 1908, p. 243

Artibeus cinereus cinereus (Gervais)
Anderson, Proc. Zool. Soc. 1908, p. 291

Artibeus quadrivittatus Peters
Young, Timehri, (2) X, 1896, p. 46

Family Desmodontidae

****Desmodus rotundus** (Geoff.)
Common Vampire; Colony-Doctor
Quelch, Timehri, (2) VI, 1892, p. 97

Diaemus youngi (Jent.)
Young's Vampire
Young, Timehri, (2) X, 1896, p. 46

Family Natalidae

Natalus stramineus Gray
Young, Timehri, (2) X, 1896, p. 44

Family Furipteridae

Furipterus horrens (F. Cuv.)
Thomas, Proc. Zool. Soc. 1887, p. 151

Family Thyroptidae

Thyroptera tricolor Spix
Quelch, Timehri, (2) VI, 1892, p. 97

Family Vespertilionidae

Myotis nigricans (Wied)
Young, Timehri, (2) X, 1896, p. 44

Eptesicus hillarii (Geoff.)
Thomas, Proc. Zool. Soc. 1887, p. 151

Lasiurus borealis borealis (Müll)
Quelch, Timehri, (2) VI, 1892, p. 97

Dasypterus intermedius (H. Allen)
Young, Timehri, (2) X, 1896, p. 44

Dasypterus ega ega (Gerv.)
Quelch, Timehri, (2) VI, 1892, p. 97

Family Molossidae

*__Molossops planirostris__ Peters
Dobson, Cat. Chir. Brit. Mus. 1878, p. 409

Eumops abrasus (Temm.)
Dobson, Cat. Chir. Brit. Mus. 1878, p. 416

Eumops maurus (Thomas)
Thomas, Ann. Mag. Nat. Hist. (7) VIII, 1901, p. 141

Molossus rufus Geoff.
Young, Timehri, (2) X, 1896, p. 45

Molossus obscurus Geoff.
Quelch, Timehri, (2) VI, 1892, p. 97

Order CARNIVORA; **Dogs, Raccoons, Otters and Cats**

Family Canidae

*__Cerdocyon thous thous__ (Linné)
Guiana Jungle Jackal; Rough Fox; Crab-dog
Quelch, Animal Life Brit. Guiana, 1901, p. 43

Cerdocyon thous savannarum Thomas
Savanna Jackal
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 146

Icticyon venaticus Lund.
Guiana Hunting Dog; Bush-dog; Warracabra Tiger
Quelch, Animal Life Brit. Guiana, 1901, p. 42

Family Procyonidae

*__Procyon cancrivorus__ (G. Cuvier)
Crab-eating Raccoon; Crab-dog
Quelch, Animal Life Brit. Guiana, 1901, p. 45

*__Nasua nasua nasua__ (Linné)
Black Coati; Kibihee; Quashi
Quelch, Animal Life Brit. Guiana, 1901, p. 46

*__Nasua rufa__ (Ill.)
Red Coati; Kibihee
Quelch, Animal Life Brit. Guiana, 1901, p. 45

*__Potos flavus flavus__ (Schreber)
Guiana Kinkajou; Potto; Night Monkey
Quelch, Animal Life Brit. Guiana, 1901, p. 46

Family Mustelidae

*__Tayra barbara barbara__ (Linné)
Guiana Tayra; Galictis; Hacka
Quelch, Animal Life Brit. Guiana, 1901, p. 47

*__Grison allamandi__ (Bell)
Guiana Grison
Quelch, Animal Life Brit. Guiana, 1901, p. 47

*__Pteronura brasiliensis__ (Zimm.)
Fin-tailed Otter; Water-dog
Quelch, Animal Life Brit. Guiana, 1901, p. 49

Family Felidae

*__Panthera onca__ (Linné)
Jaguar; Tiger; Black Tiger; Maipurie Tiger
Quelch, Animal Life Brit. Guiana, 1901, p. 32

*__Felis couguar__ Kerr
Puma; Deer Tiger
Quelch, Animal Life Brit. Guiana, 1901, p. 36

*__Herpailurus jaguarondi unicolor__ (Traill)
Guiana Jaguarondi; Hacka Tiger; Eyra
Quelch, Animal Life Brit. Guiana, 1901, p. 38

*__Leopardus pardalis tumtumari__ (Allen)
Guiana Ocelot; Tiger Cat; Labba Tiger
Allen, Bull. Am. Mus. Nat. Hist. 34, 1915, p. 632

Margay tigrina tigrina (Schreber)
Margay Cat; Wild Cat
Quelch, Animal Life Brit. Guiana, 1901, p. 41

Family Viverridae

Mungos mungo (Gmelin)
Mongoose
[Introduced] Beebe Coll. Georgetown, 1916

Order RODENTIA; Agoutis, Porcupines, Rats and Mice

Family Hydrochaeridae

*__Hydrochaerus hydrochaerus__ Linné
Capybara; Waterhaas; Waterhare
Quelch, Animal Life Brit. Guiana, 1901, p. 28

Family Caviidae

Cavia porcellus guianae Thomas
Guiana Guinea Pig
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 152

Family Dasyproctidae

*__Dasyprocta croconota prymnolopha__ (Wagl.)
Agouti; Accourie
Quelch, Animal Life Brit. Guiana, 1901, p. 27

*__Agouti paca paca__ (Linné)
Paca; Labba
Quelch, Animal Life Brit. Guiana, 1901, p. 26

*__Myoprocta acouchy__ (Erxl.)
Pigmy Agouti; Adourie
Quelch, Animal Life Brit. Guiana, 1901, p. 28

Family Erethizontidae

*__Coendou prehensilis__ (Linné)
Common Tree Porcupine
Quelch, Animal Life Brit. Guiana, 1901, p. 31

Coendou melanurus (Wagner)
Black-tailed Tree Porcupine
Quelch, Animal Life Brit. Guiana, 1901, p. 31

Family Octodontidae

*__Proechimys cayennensis__ Desm.
Cayenne Spiny Rat
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 152

Loncheres guianae Thomas
Guiana Spiny Rat
Quelch, Animal Life Brit. Guiana, 1901, p. 31

Family Muridae

Mus musculus musculus Linné
Common House Mouse
[Introduced] Beebe Coll. Georgetown, 1916

Epimys rattus alexandrinus (Geoff.)
Black Rat
[Introduced] Beebe Coll. Georgetown, 1916

Rhipidomys sclateri Thomas
Thomas, Proc. Zool. Soc. 1887, p. 152

Rhipidomys macconnelli de Winton
De Winton, Trans. Linn. Soc. (2), VIII, 1900, p. 52

Rhipidomys nitela Thomas
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 148

Rhipidomys milleri Allen
Allen, Bull. Am. Mus. Nat. Hist. XXXII, 1913, p. 602

Holochilus guianae Thomas
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 149

Nectomys squamipes Brandt
Thomas, Proc. Zool. Soc. 1887, p. 151

Sigmomys savannarum Thomas
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 150

Oryzomys navus messorius Thomas
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 151

Zygodontomys stellae Thomas
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 152

Oecomys rex Thomas
Thomas, Ann. Mag. Nat. Hist. (8), VI, 1910, p. 504

Oecomys nitedulus Thomas
Thomas, Ann. Mag. Nat. Hist. (8), VI, 1910, p. 505

Family Sciuridae

***Sciurillus pusillus pusillus** (Desm.)
Common Dwarf Squirrel
Allen, Bull. Am. Mus. Nat. Hist. XXXIV, 1915, p. 197

Sciurillus pusillus glaucinus Thomas
Grayish Dwarf Squirrel
Thomas, Ann. Mag. Nat. Hist. (8), XIII, 1914, p. 575

***Guerlinguetus aestuans aestuans** (Linné)
Common Jungle Squirrel
Allen, Bull. Am. Mus. Nat. Hist. XXXIV, 1915, p. 257

Guerlinguetus aestuans macconnelli (Thomas)
Macconnell's Jungle Squirrel
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 148

Guerlinguetus aestuans quelchii (Thomas)
Quelch's Jungle Squirrel
Thomas, Ann. Mag. Nat. Hist. (7), VIII, 1901, p. 147

Order EDENTATA; **Sloths, Anteaters and Armadillos**

Family Bradypodidae

*__Bradypus tridactylus__ Linné
Three-toed Sloth; Gray Sloth; Ai
Quelch, Animal Life Brit. Guiana, 1901, p. 64

*__Choloepus didactylus__ (Linné)
Two-toed Sloth; Brown Sloth; Unau
Quelch, Animal Life Brit. Guiana, 1901, p. 67

Family Myrmecophagidae

*__Myrmecophaga tridactyla tridactyla__ Linné
Guiana Great Anteater; Antbear; Tamanoir
Quelch, Animal Life Brit. Guiana, 1901, p. 73

*__Tamandua tetradactyla tetradactyla__ (Linné)
Guiana Tamandua; Lesser Anteater
Quelch, Animal Life Brit. Guiana, 1901, p. 74

*__Cyclopes didactylus didactylus__ (Linné)
Guiana Silky Anteater; Two-fingered Anteater
Quelch, Animal Life Brit. Guiana, 1901, p. 75

Family Dasypodidae

*__Priodontes giganteus__ (Geoffr.)
Giant Armadillo
Quelch, Animal Life Brit. Guiana, 1901, p. 70

*__Dasypus novemcinctus__ Linné
Lesser Armadillo; Nine-banded Armadillo; Yesi
Quelch, Animal Life Brit. Guiana, 1901, p. 72

Tatoua unicinetus (Linné)
Small Armadillo; Tatouay
Quelch, Animal Life Brit. Guiana, 1901, p. 71

Order PRIMATES; **Monkeys**

Family Callitrichidae

***Cercopithecus midas** (Linné)
Midas Marmoset
Elliot, Mon. of Prim. I, 1913, p. 191

Family Cebidae

***Alouatta seniculus macconnelli** Elliot
Guiana Howling Monkey; Red Howler; Baboon
Elliot, Mon. of Prim. I, 1913, p. 281

Pithecia pithecia (Linné)
White-headed Saki; Red-bellied Saki
Elliot, Mon. of Prim. I, 1913, p. 294

Pithecia satanas (Hoff.)
Black Saki
Elliot, Mon. of Prim. I, 1913, p. 297

Pithecia chiropotes (Humb.)
Red-backed Saki; White-faced Beesa
Elliot, Mon. of Prim. I, 1913, p. 298

***Saimiri sciureus** (Linné)
Squirrel Monkey; Sackiwinki
Elliot, Mon. of Prim. I, 1913, p. 310

Aotus trivirgatus (Humb.)
Night Monkey
Elliot, Mon. of Prim. II, 1913, p. 16

***Ateleus paniscus** (Linné)
Red-faced Spider Monkey; Quata
Elliot, Mon. of Prim. II, 1913, p. 28

***Cebus apella apella** (Linné)
Guiana Ring-tailed Capuchin
Elliot, Mon. of Prim. II, 1913, p. 80

Order ARTIODACTYLA; **Peccaries and Deer**

Family Tayassuidae

Tayassu pecari pecari Fischer
White-lipped Peccary; Bush-hog; Kairuni
Lydekker, Cat. Ung. Mam. Brit. Mus. IV. 1915, p. 377

***Pecari tajacu** (Linné) subsp.?
Collared Peccary; Black Bush-hog; Abouyah
Lydekker, Cat. Ung. Mam. Brit. Mus. IV, 1915, p. 381

Family Cervidae

Odocoileus virginianus gymnotis (Wieg.)
Orinoco Virginia Deer
Lydekker, Cat. Ung. Mam. Brit. Mus. IV, 1915, p. 174

Odocoileus virginianus spinosus (Gay & Gerv.)
Guiana Virginia Deer
Lydekker, Cat. Ung. Mam. Brit. Mus. IV, 1915, p. 175

Mazama americana americana (Erxl.)
Guiana Red Brocket
Lydekker, Cat. Ung. Mam. Brit. Mus. IV, 1915, p. 202

*__Mazama americana tumatumari__ Allen
Tumatumari Red Brocket
Allen, Bull. Amer. Mus. XXXIV, 1915, p. 536

*__Mazama simplicicornis simplicicornis__ (Ill.)
Guiana Brown Brocket; Wellibicirie
Lydekker, Cat. Ung. Mam. Brit. Mus. IV, 1915, p. 211

Blastocerus dichotomus (Ill.)
Marsh Deer; Guazu
Quelch, Timehri, (2) VI, 1892, p. 171

Order PERISSODACTYLA; **Tapirs**

Family Tapiridae

*__Tapirus terrestris terrestris__ (Linné)
Guiana Tapir; Bush Cow; Maipurie
Lydekker, Cat. Ung. Mam. Brit. Mus. V, 1916, p. 42

Order SIRENIA; **Sea-cows**

Family Trichechidae

*__Trichechus manatus__ Linné
Manatee; Water Cow; Water Mama
Quelch, Animal Life Brit. Guiana, 1901, p. 58

Order ODONTOCETI; **Dolphins and Whales**

Family Delphinidae

*__Delphinus delphis__ Linné
Common Dolphin
Quelch, Animal Life Brit. Guiana, 1901, p. 62

Family Platanistidae

Inia geoffroyensis (Blainville)
Guiana Fresh-water Dolphin
Quelch, Animal Life Brit. Guiana, 1901, p. 62

Family Balaenidae

Eubalaena australis (Desm.)
Southern Right Whale
Quelch, Animal Life Brit. Guiana, 1901, p. 62

BIRDS OF BARTICA DISTRICT

ADDITIONAL LIST

At the time of publication of Volume I of "Tropical Wild Life"* the list of birds observed by ourselves or collected by Whitely in Bartica District numbered three hundred and fifty-one forms.

Since then a considerable addition to this list has accumulated from various sources, and these seventy-five new names I now present, bringing the total to the really remarkable number of four hundred and twenty-six different species of birds, all occurring within a radius of ten miles of our Research Station. These lists are, of course, to be considered as merely convenient check-lists, preliminary to the ultimate elaboration of the life histories of the various species.

The number preceding the name corresponds to that in Brabourne and Chubb's "List of the Birds of South America."

183 **Claravis pretiosa pretiosa** (Ferrari-Perez)
Blue Ground Dove

189a **Leptotila verreauxi macconnelli** Chubb
Guiana Rusty Dove

228 **Aramides axillaris** Laur.
Venezuelan Woodrail

238 **Porzana carolina** (Linné)
Sora Rail

255 **Gallinula galeata galeata** (Licht.)
Florida Gallinule

258 **Ionornis martinicus** (Linné)
Purple Gallinule

267 **Heliornis fulica** (Bodd.)
Finfoot

323 **Sterna hirundo** Linné
Common Tern

330 **Sterna superciliaris** Vieill.
Least Tern

*New York Zoological Society, New York, 1917.

375 **Pluvialis dominicus dominicus** (P. L. S. Müll)
American Golden Plover

479 **Tigrisoma lineatum** (Bodd.)
Lined Tiger Bittern

549 **Phalacrocorax vigua vigua** (Vieill.)
Guiana Cormorant

585 **Micrastur brachypterus** (Temm.)
Pied Hawk

586 **Micrastur mirandollei** (Schl.)
Mirandolle's Hawk

591 **Geranospizias caerulescens** (Vieill.)
South American Blue Hawk

597 **Nisus superciliosus** (Linné)
Eye-browed Sparrow Hawk

732 **Ara ararauna** (Linné)
Blue and Yellow Macaw

743 **Orthopsittaca manilata** (Bodd.)
Red-bellied Macaw

869 **Deroptyus accipitrinus accipitrinus** (Linné)
Hawk-headed Parrot

928 **Chordeiles acutipennis acutipennis** (Bodd.)
South American Nighthawk

946 **Hydropsalis schomburgki** Sclater
Schomburgk's Nighthawk

960 **Antiurus maculicaudatus** (Lawr.)
Spotted-tailed Nighthawk

987 **Reinarda squamata** (Cassin)
Fork-tailed Palm Swift

988 **Panyptila cayanensis** (Gmelin)
Cayenne Swift

1001 **Glaucis hirsuta hirsuta** (Gmelin)
Hairy Hermit

1055 **Campylopterous hyperythrus** Cab.
Rufous-breasted Sabre-wing

1082 **Agyrtrina fimbriata fimbriata** (Gmelin)
Lesson's Emerald

1125 **Hylocharis cyanus viridiventris** (Berlep.)
Green-bellied Sapphire

1199 **Chrysolampis elatus** (Linné)
Ruby and Topaz Hummingbird

1288 **Vestipedes vestitus vestitus** (Lesson)
Glowing Puff-leg

1449 **Discosura longicauda** (Gmelin)
Racket-tail

1544 **Pteroglossus acarari atricollis** (P. L. S. Müll.)
Roraima Aracari

1586 **Galbula ruficauda ruficauda** Cuvier
Rufous-tailed Jacamar

1631 **Malacoptila fusca** (Gmelin)
White-breasted Puffbird

1703 **Melanerpes cruentatus** (Bodd.)
Little Black Woodpecker

1749 **Celeus undatus** (Linné)
Waved Woodpecker

1784 **Picumnus spilogaster** Sunde.
Sundevall's Picilet

1799 **Picumnus buffoni undulatus** Harg.
Undulated Piculet

1867 **Taraba major major** (Vieill.)
Great Bush-shrike

1900 **Hypolophus canadensis canadensis** (Linné)
Black-crested Bush-shrike

1992 **Myrmotherula behni** Berl. & Lever.
Behn's Antbird

2096 **Sclateria naevia naevia** (Gmelin)
Surinam Ant-creeper

2493 **Xenops rutilus heterurus** (Cab. & Hein.)
Red-tailed Recurved-bill

2540 **Xiphorhynchus guttatus sororius** (Berl. & Hart.)
Venezuelan Woodhewer

2678 **Mecocerculus leucophrys setaphagoides** (Bonap.)
Bonaparte's Chat-tyrant

2715a **Colonia leuconota poecilonota** (Cab.)
Northern Long-tailed Tyrant

2747 **Platyrhynchus saturatus** Sal. & God.
Guiana Flatbill

2767 **Rhynchocyclus poliocephalus sclateri** Hellm.
Sclater's Flatbill

2829 **Perissotriccus ecaudatus** (d'Orb. & Lafr.)
Short-tailed Pygmy Tyrant

2927 **Tyrannulus elatus elatus** (Lath.)
Yellow-crowned Tyrantlet

2934 **Tyranniscus gracilipes** Scl. & Sal.
Slender-footed Flycatcher

3080 **Myiarchus tyrannulus tyrannulus** (P. L. S. Müll.)
Rusty-tailed Flycatcher

3095 **Myiarchus nigriceps** Scl.
Black-headed Flycatcher

3104 **Tyrannus melancholicus satrapa** (Cab. & Hein.)
Lesser Yellow-breasted Kingbird

3160 **Chiroprion pareola pareola** (Linné)
Blue-backed Manakin

3191 **Scotothorus chrysocephalus** (Pelz.)
Golden-crowned Manakin

3221 **Pachyrhamphus rufus** (Bodd.)
Cinerous Thickbill

3227 **Pachyrhamphus niger cinereiventris** (Scl.)
Grey-bellied Thickbill

3263 **Attila thamnophiloides** Spix
Spix's Attila

3390 **Thryophilus albipectus albipectus** (Cab.)
Schomburgk's White-faced Wren

3498 **Donacobius atricapillus atricapillus** (Linné)
Black-capped Mocking-thrush

3573 **Pachysylvia pectoralis** (Scl.)
Cinereous-headed Woodbird

3617 **Compsothlypis pitiayumi pitiayumi** (Vieill.)
Olive-backed Warbler

3641 **Geothlypis aequinoctialis aequinoctialis** (Gmelin)
Equinoctial Warbler

3645 **Granatellus pelzelni pelzelni** Scl.
Pelzeln's Red-throated Chat

3648 **Setophaga ruticilla** (Linné)
American Redstart

3659 **Myioborus castaneicapillus** (Cab.)
British Guiana Redstart

3678 **Basileuterus roraimae** Sharpe
Roraima Warbler

3713 **Cyanocompsa cyanoides rothschildii** (Bart.)
Rothschild's Blue Grosbeak

3760 **Sporophila americana** (Gmelin)
Gmelin's Seedeater

4076 **Dacnis bicolor** (Vieill.)
Blue-grey Honey-creeper

4138 **Tanagrella velia velia** (Linné)
Blue-bellied Tanager

4281 **Thraupis palmarum melanoptera** (Scl.)
Western Palm Tanager

4361 **Nemosia pileata pileata** (Bodd.)
Hooded Tanager

4437 **Schistochlamys atra atra** (Gmelin)
Black-faced Grey Tanager

The various sources of these additions are as follows:

A—Collected by William Beebe near Kalacoon in 1909 during the expedition described in the volume "Our Search for a Wilderness;"* Numbers 479, 549, 591, 732, 1586, 1631, 1703, and 1784.

B—Collected at Bartica, in Chubb's account of McConnell's collection, "The Birds of British Guiana," Vol. I., together with a manuscript list of these to be published in Vol. II; Numbers 16, 183, 189, 228, 238, 255, 258, 267, 585, 586, 597, 743, 869, 946, 1001, 1055, 1082, 1125, 1199, 1544, 1992, 2096, 2493, 2540, 2678, 2715, 2747, 2767, 2829, 2927, 2934, 3080, 3095, 3104, 3160, 3191, 3221, 3227, 3263, 3390, 3498, 3573, 3617, 3641, 3645, 3648, 3659, 4678, 3713, 3760, 4076, 4138, 4281, 4361 and 4437.

C—Recently identified specimens collected in Bartica District in 1916; 928, 960, 987, 1449, 1749, 1867, 1900, 2715, 3191, 3617, 3645, 3659, 3678, and 4361.

D—Additions made during the short visit to the District in 1917; 323, 330, 375, 629, 836, 988, 1288, 1799, 2927.

Volume II, Number 9

LIZARDS OF THE GENUS *AMEIVA* IN BARTICA DISTRICT

NOTES ON THEIR COLOR AND PATTERN VARIATION

Preparatory to intensive studies of the ontogenetic and phylogenetic evolution of color and pattern among neotropical birds, many notes have been made of the remarkable variations found among lizards, especially in such abundant forms as *Ameiva.* While reserving the publication of these until another season's work will have made them more complete, I make mention here of the bearing which color and pattern variation have on the present classification of certain *Ameiva.*

"A Revision of the Lizards of the Genus *Ameiva*" is the title of a very excellent and thorough paper by Thomas Barbour and G. Kingsley Noble.* I wish especially to speak of the forms which the authors recognize as *Ameiva ameiva ameiva, A. a. bilineata, A. a. melanocephala,* and *A. a. petersii.*

The following quotations have to do with these subspecies:

KEY TO THE SPECIES

i[1] Dorsal surface with heavy confluent spots of black. j[1] Throat sprinkled with a few black spots . . . . *ameiva ameiva*

j[2] Throat smoky. k[1] Brahchials in three rows of subequal scales . . . . *atrigularis*

k[2] Brachials in one row of very large scales and three rows of smaller ones *ameiva melanocephala*

i[2] Dorsal surface with a few black spots not confluent. j[1] A broad lateral band of brown on each side of the adult . . . . *ameiva bilineata*

j[2] Lateral stripe indistinct or wanting . . . . *ameiva petersii*

HABITAT

Ameiva a. ameiva. Widely distributed over the northeastern part of South America from the Demerara River in British Guiana as far south as Bahia, Brazil, inland along the Amazon to as far west as the Madeira River.

Ameiva a. bilineata. Apparently confined to the region between the Demerara and Orinoco Rivers.

Ameiva a. melanocephala. Probably widely distributed throughout Venezuela.

Ameiva a. petersii. Found along the upper Amazon from the Madeira River westward.

*Bull. Mus. Comp. Zool. Harv. LIX. No. 6, 1915, pp. 417-479.

As regards the two subspecies inhabiting British Guiana, the conclusions are based on six specimens, one from Tumatumari and five from Dunoon. The detailed descriptions are from individuals measuring from one hundred and six to one hundred and sixty-two millimeters in length—individuals which I should hardly be inclined to call fully adult. The average of a half hundred specimens collected in one locality I have found to be almost twice this length, while extreme individuals reach over five hundred millimeters.

By a minor geographic error the ranges of the two British Guiana forms are made to overlap, as Tumatumari, the locality for *Ameiva*, is a cataract on the Potaro, a western tributary of the Essequibo, far west of the Demerara and hence well within the indicated range of *bilineata*, "between the Demerara and Orinoco Rivers." Dunoon is on the Demerara River.

The main point I wish to make is that within an area of about five hundred yards around the Research Station of Kalacoon, and within a period of one week, I have collected several score of perfectly typical specimens of *ameiva*, *bilineatus*, *melanocephala* and *petersii;* and others which, judged by still more extreme variation of color and pattern, deserve still further subspecific differentiation. A certain proportion of this remarkable variation is due to age—to ontogenetic pigmental and pattern changes, but, on the other hand, all the forms are represented in my collection by fully adult lizards, that is, by individuals three hundred millimeters or more in length. This extremely local variation would seem to indicate either that all four forms were only intermediate variations, or, rather improbably, that Bartica District is a meeting place for a quartet or more of geographic subspecies. This collection of several score specimens from one locality opens up most interesting questions, and the correlation of observations carried on more widely, should quickly solve these rather superficial problems of diagnostic characters of color and pattern.

The ontogenetic phase can be certainly demonstrated. Young specimens of Bartica *ameiva* averaging one hundred and fifty millimeters in length are almost invariably of an extreme *bilineatus* type, exceeding the description of that form as given by Barbour, in concentration of pigment as much as it in turn is said to differ from *ameiva*. The dorsal and ventral surfaces are immaculate, while a broad black band begins at the snout and extends back to the thigh, narrowly bordered above and below with blue or white. In about ten per cent. of these small specimens the black body bands are broken up by vertical rows of faint dots.

A second, larger stage, averaging about two hundred and fifty millimetres in length shows black spotting on the throat, and a more decided penetration of the black body bands by the rows of dots. But a new pattern in this phase is a double dorsal series of large black spots, which is found neither in larger nor in smaller forms of this lizard. In my notes I have distinguished this as *bipunctata*.

Passing through larger stages we find a typical lizard of four hundred millimetres in length with much of the upper surface covered with large confluent blotches, and the black lateral bands practically gone, the bluish-white vertical rows of dots of great size, and furnishing the dominant color and pattern note. It has changed from a brown, banded lizard to a green, spotted one. It is nearer to the description of typical *ameiva* than anything else, but lacking such relatively immature characters as the white flank stripe, and the lateral, black, caudal stripe.

Finally, we find a few big bluish-green giants over five hundred millimetres in length, dotted rather than blotched above, and with the lateral green spots large, isolated and framed in black—this framing being all that is left of the broad solid bands which form such a dominant feature in many smaller specimens.

While much more material is needed and will be secured in the near future, yet even in this collection, a hint of still another problem is presented. In all the sizes and color patterns we find occasional individuals which appear melanistic—either in part or as a whole. Thus a specimen which will pass as extreme *melanocephala*, has the entire sides of the head, lower jaw, chin, throat and lower neck to between the forelegs, jet black. This anterior concentration of pigment seems to have been directly at the expense of the dark pigment in other parts of the body. The dorsal and lateral regions are quite green, with the isolated pale lateral dots lacking even their black frame, so drained are all the posterior parts of the animal of their black pigment. It has had a rush of melanism to the head, giving the superficial appearance of a very remarkable pigmented mutation.

A second and more abundant melanistic form goes farther, and while above presenting a dull *ameiva* or *petersii* color and pattern, is quite uniformly smoky black below. For purposes of record I have called this *melanoventer*.

Studies of the color and pattern variations in living and recently killed specimens; recording of sexual characters in hundreds of individuals, especially of mating pairs; scrutiny of the variations within a single brood of these lizards; uninterrupted observation of ontogenetic changes in individuals from the egg to the five hundred millimetre stage; all these will surely contribute to the solution of such intensely interesting problems as the following:

(a) Are *ameiva, bilineata, petersii, bipunctata, melanocephala* and *melanoventer* recognizable geographic subspecies or variations, which meet and live close together within a few yards radius.

(b) Are they ontogenetic phases of one or more species?

(c) Is it possible that in different localities they combine in part both *a* and *b*; a paedogenetic acceleration or retardation such as we find in Axolotl?

(d) Are these characters environmental or hereditary?

(e) Are the similar variations which Gadow* has so well demonstrated in Mexican *Cnemidophorus* to be considered as parallel or convergent when compared with those of *Ameiva*, in addition perhaps to being a striking instance of orthogenesis?

*A Contribution to the Study of Evolution Based Upon the Mexican Species of *Cnemidophorus*, Proc. Zool. Soc., London, 1906, I, p. 277.

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AS OBSERVED IN SOUTHEASTERN OREGON IN MAY, 1918

BY R. BRUCE HORSFALL

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FIG. 69. SAGE GROUSE DISPLAYING AND STRUTTING AT SUNRISE
Painted from Life by R. Bruce Horsfall

ZOOLOGICA
SCIENTIFIC CONTRIBUTIONS OF THE
NEW YORK ZOOLOGICAL SOCIETY

VOLUME II, NUMBER 10

REMARKABLE HABITS OF THE SAGE GROUSE

AS OBSERVED IN SOUTHEASTERN OREGON IN MAY, 1918

BY R. BRUCE HORSFALL

With Illustrations Drawn from Life by the Author

PUBLISHED BY THE SOCIETY
THE ZOOLOGICAL PARK, NEW YORK

APRIL, 1920

FIGURES

REMARKABLE HABITS OF THE SAGE GROUSE

AS OBSERVED IN SOUTHEASTERN OREGON IN MAY, 1918

By R. Bruce Horsfall

With Illustrations Drawn from Life by the Author

Stealthily and carefully we picked our way along the mud-flat road to the high gate in the lava-rock ranch fence, and peered through the bars.

"There they are!" burst from our lips in an excited whisper, as we caught the glint of white spots a few hundred yards beyond.

Cautiously we clambered over the irregular loose rocks and, like Indians on the warpath, crawled, squirmed and wriggled our way to a low outcropping of volcanic rock. From this vantage point we had an unobstructed view of the broad and bare flood-plain before us.

Cramped and strained in every muscle and bone, we remained hidden among those rocks till supper time, loath to leave the wonderful sight.

In the open at intervals of from twenty-five to fifty feet were sixty magnificent sage cocks strutting around with puffed-out chests and tails spread like miniature turkey gobblers, making noises for all the world like the popping of corks on the pier at Atlantic City, a sound which took me back in memory to the hotel in Colombo, Ceylon, where a hundred guests were served soda water at every meal, and the bottles were always opened at the tables.

Evidently these rocks had been a favorite place for Indians in years gone by, for all about us in the sand were obsidian chips and charcoal, with bits of arrow and spear heads. We afterwards picked up many perfect specimens on the open flat.

Here the Klamath Indian had lurked at evening to secure, with his twanging bow and bits of flying glass, a sage cock for the morrow's dinner, making arrow heads in the middle of the day when no birds were about. To the Indian a strutting sage cock was but an easy mark and a quick lunch. His stolid nature probably did not marvel at the wondrous performance, and no question entered his mind as to how and why.

To us, however, it was a sight which satisfied a great hunger; not the hunger of the body, but of the mind. We had spent days and nights in travel to see that phase of nature, to gain that scrap of knowledge; and we feasted to a great content, though many questions remain unsatisfied as to the how and the why.

The opportunity for these observations had come after two years' delay, and we were accordingly appreciative to the utmost.

In the summer of 1915, we had been viewing the Klamath Lake Pelican Colonies with the game warden, Mr. J. J. Turber, and had gone on to Laird's Landing, at the foot of the lake, to remain over night. While we were there Mr. Laird told us of sage grouse coming down on the flat at the eastern end of the pasture every spring to do their courting, but at that date, May 31st, they had stopped for the season.

It was now May, 1917, and we were to have our opportunity to observe and picture the birds in action.

Mr. Turber had brought William L. Furley, Stanley G. Jewett and the writer from Klamath Falls to Mr. Laird's place. It was afternoon when we rounded the lower end of the lake, and a few grouse were on the open alkali flat. We cached our camera and blind, and went on to the house to arrange for beds and board, leaving as soon as possible for our first close view of the birds. After supper that evening we set up our blind near the grassy slope reaching from the sage-covered hill at the eastern side of "the wash."

The waters that had formed this flood plain came down from the forest-capped Van Brimmer mountain away off to the south. Westward of this wash lay hillocks and ridges of dark lava rock. About eight level acres, near the shore of the lake, were bare of vegetation, and it was there that the sage cocks came from miles around to dance and strut—and "plop."

The strut was made up of four movements. First, the filling of the air pouch, accompanied by a grunting sound; second, a short stiff-legged run in which neither pouch nor wings touched the ground; third, the bird stopped suddenly, spread his tail as it raised to the perpendicular, threw back his head and with a forward movement of the wings pushed the air-filled pouch well up on the chest; fourth, there was a sudden upward throw, followed by a more vigorous and snappy toss, and the tightened pouch came down again on the extended chest with a rubbery "plop." This plop was repeated three times, then the bird eased down for another rumbling gurgle and another run.

Mr. Laird assured us that these antics take place from early March till the first of June; in fact, through the mating season. However, it was evident that this was not a courting action; because when in the course of the morning or evening performance, two or three hens meandered through the throng no notice whatever was taken of them. A real courting performance of a different character may take place in the daytime, far from the watering place, on the sage covered hills.

Each bird appears to have a private spot on which no other dares to trespass. In reaching those proprietary spots, collisions sometimes occurred, and quiet cock-fights took place much after the manner of China pheasants. With rump feathers erect, lowered heads and tails, and dragging pouches, the birds sidled around and struck with their wings; all the while scolding in a trumpeting, gurgling grunt, as the owner actually pushed the intruder off his domain. A few feet one way or another, the belligerents would separate and go on plopping as before.

Some birds began to perform well up in the sage brush, and plopped all the way out to the dancing spot; others walked quietly into their respective claims before beginning to show off.

An examination of the pouch of the sage grouse discloses a peculiar development. In front are two yellowish-green bare spots separated and surrounded by short stiff feathers, shortest and stiffest immediately surrounding the bare area. Probably it is these spots which make the sounding plop, after the manner of a wet drum-head. In the fall, when new, these feathers are soft and exceedingly friable, and by the time the birds are ready for strutting, have broken away to stiff, sharp bristles

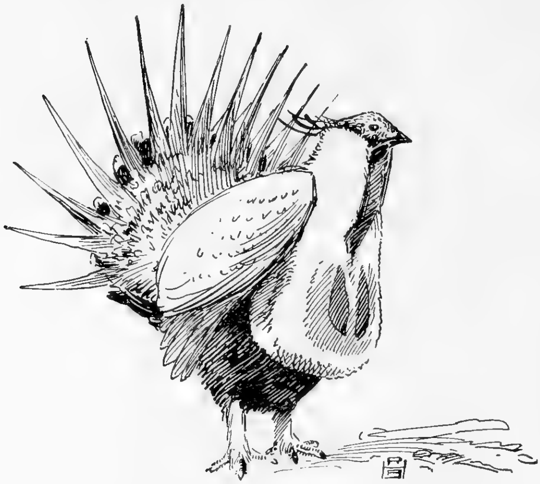

FIG. 70. FILLING POUCH WITH AIR

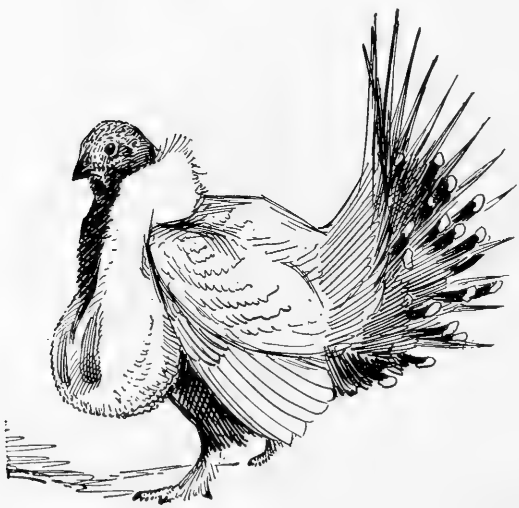

FIG. 71. STIFF-LEGGED RUN AFTER FILLING THE POUCH

STUDIES FROM LIFE OF SAGE GROUSE DANCE
Pen Drawings by R. Bruce Horsfall

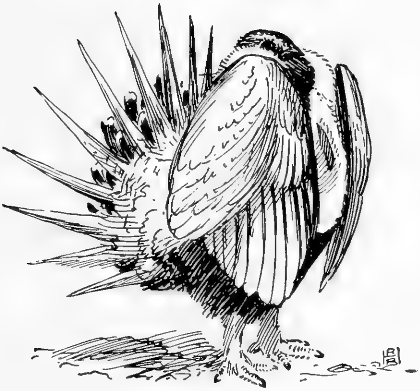

Fig. 72. Lifting Pouch with the Wings

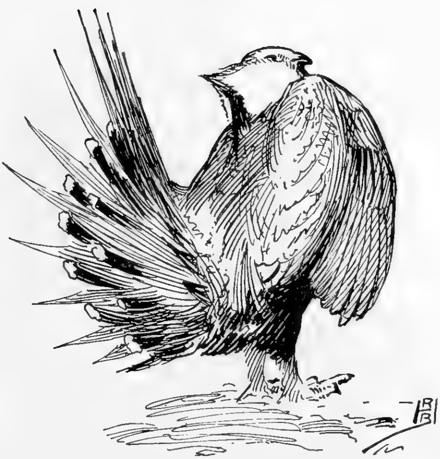

Fig. 73. Side View of Lift of the Pouch

STUDIES FROM LIFE OF SAGE GROUSE DANCE
Pen Drawings by R. Bruce Horsfall

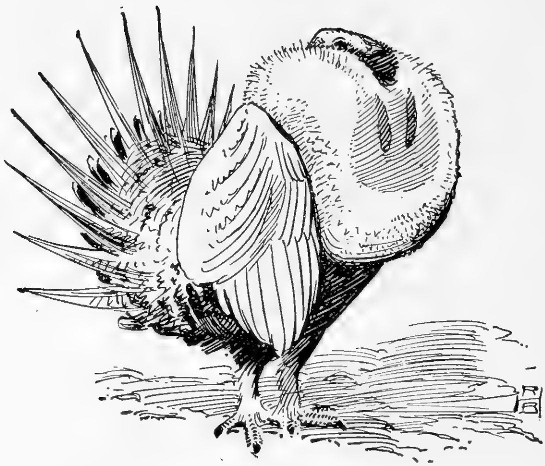

FIG. 74. EXTREME OF THROW OF THE POUCH

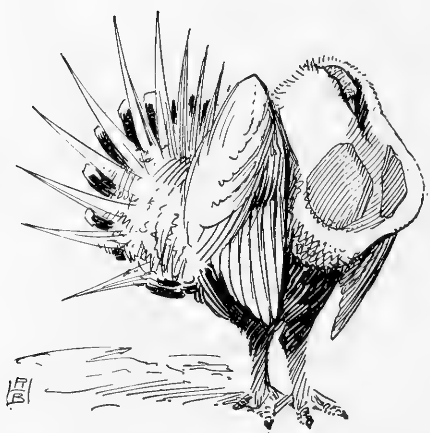

FIG. 75. SLAP DOWN OF POUCH ON CHEST SHOWING DISTENDED BARE SPOTS

STUDIES FROM LIFE OF SAGE GROUSE DANCE
Pen Drawings by R. Bruce Horsfall

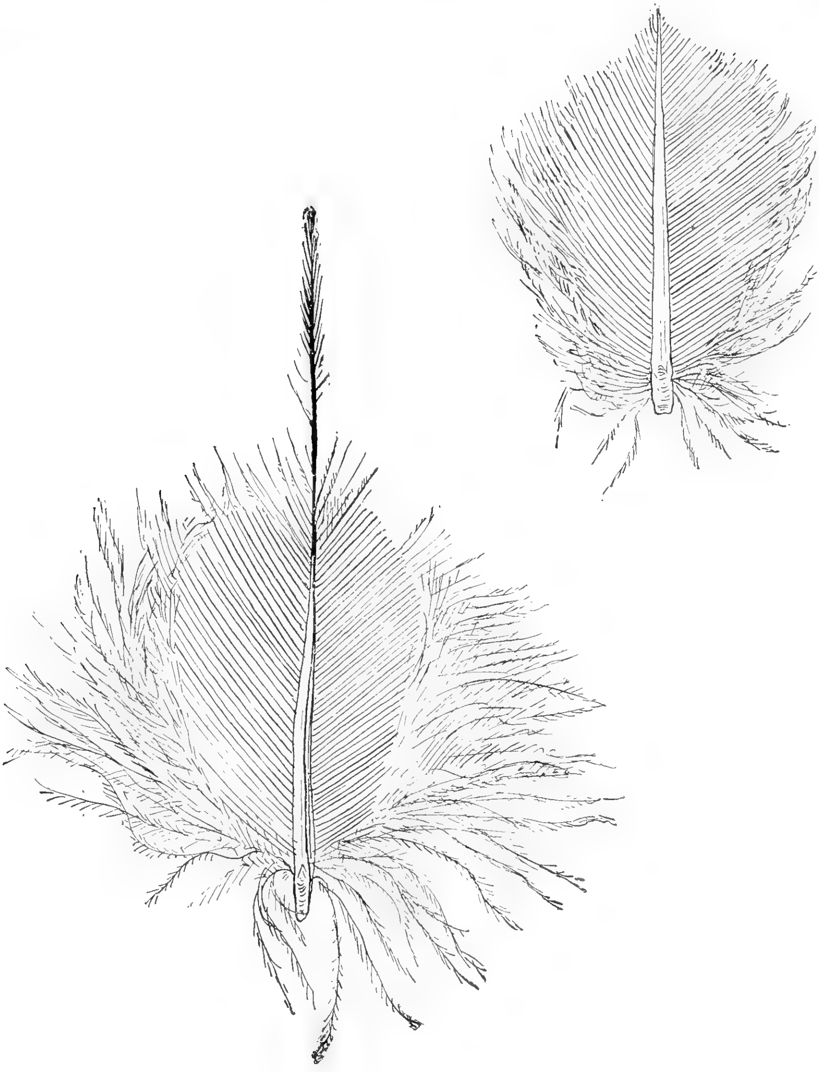

FIG. 76. SAGE GROUSE (MALE) NECK FEATHERS

September feather of loose structure which accounts for the wear on the spring feather. *Upper*—Taken from near bare spots on the pouch. *Lower*—Feather from breast beneath pouch

Pen Drawings by R. Bruce Horsfall

which will in no way interfere with the vigor of the snap, as soft feathers would do.

The morning after our arrival, the 11th of May, no birds came near enough to the blind for photographing. At nine o'clock it began to rain, and we spent the remainder of the morning searching for nests on the adjacent hillside. We found two from which the young had hatched, and one that had been rifled of its contents, probably by a coyote. In the afternoon the birds came in too late for pictures.

On May 11, no birds came near the blind, so we moved it to another spot. The afternoon was windy and stormy, and only a few birds came in at four o'clock.

On the 13th of May, we arose at three A. M. and after a hurried breakfast, stumbled and wabbled along the ruts of the road. No wind was stirring; which was a very unusual thing for this high plateau region. A heavy cloud hung over us, as only clouds in an arid region can hang, black as night, but the faint yellowish light of dawn was slowly brightening as we crept into the blind, at four o'clock. Dark as it was, a few birds were already there, and by five-fifteen we were able to make the first exposure. As usual, there were about sixty birds in the field. Actual counts of birds within our range of vision at various times were 51, 52, 51 and 54. By seven o'clock all had left for the sage-brush hills; but we had had several birds within thirty feet of us most of the time.

We returned to the blind at 4:15 A. M. A few birds were on the shore when we arrived and by seven o'clock, the usual time for the birds to scatter, we had secured moving and still pictures of every action from birds within twenty-five feet of us.

As we left, a lone coyote yapped to us a long farewell.

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VOLUME II, NUMBER 11

ECLIPSE PLUMAGE IN DOMESTIC FOWL

BY

LEE S. CRANDALL
CURATOR OF BIRDS

PUBLISHED BY THE SOCIETY
THE ZOOLOGICAL PARK, NEW YORK

OCTOBER 15, 1920

FIG. 77. GAME COCK, SHOWING HACKLE IN ECLIPSE

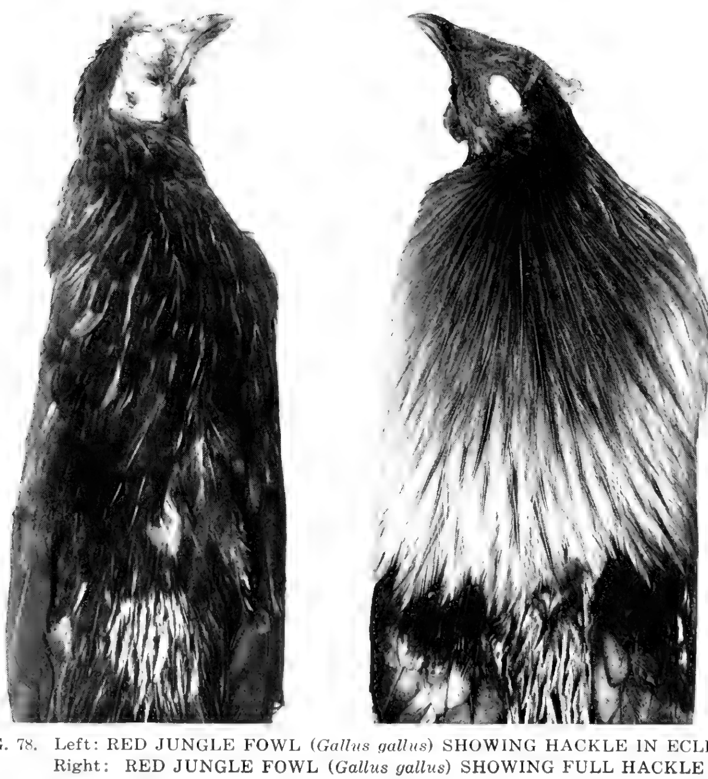

FIG. 78. Left: RED JUNGLE FOWL (*Gallus gallus*) SHOWING HACKLE IN ECLIPSE
Right: RED JUNGLE FOWL (*Gallus gallus*) SHOWING FULL HACKLE

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By Lee S. Crandall
Curator of Birds.

From the time of Darwin, ornithologists almost unanimously have agreed that the Red Jungle Fowl (*Gallus gallus*) of India, the Malay Peninsula, Indo-China and the neighboring islands, is the sole ancestor of domestic fowls. Practical poultrymen, on the other hand, are equally sure that certain breeds, especially of the groups known as Asiatics and Oriental games, must have come from some unknown, gigantic ancestor. There are some, also, who feel that the case of the Red Jungle Fowl's ancestral relation to breeds other than these Eastern types, is not fully established. While it is not the purpose of the present paper to enter fully into this discussion, it is felt that the facts herein presented have a strong bearing in this seemingly interminable controversy.

On October 22, 1916, the New York Zoological Park received, through the medium of Ansel W. Robinson, of San Francisco, a pair of Red Jungle Fowl. They were young birds but the male was in full color, with flowing hackle and saddle feathers. The pair had been obtained in the Philippine Islands, where the species is believed to have been introduced by man. Both specimens were typical, which is more than can be said for most of the Red Jungle Fowl seen in captivity. They were very wild when first received but gradually became tamer, though they never would allow themselves to be handled or even touched.

The birds were kept in warm quarters during the winter months, and by spring were in very good feather and condition. In June, the cock began to shed his long neck hackles and dropped the sickle feathers of the tail at the same time.

Close watch was kept on the bird during this period and it was found that he was going through the oft-mentioned but seldom described eclipse which is typical of the species. As the red, black-centered, pointed hackle feathers dropped out, they were replaced by short, round-tipped black ones. Those in the upper portions of the neck were broadly margined with orange, but as they approached the neck, they became wholly black.

Late in July, the cock caught a sudden cold, and died on August 2, 1917. The eclipse was not quite complete, the small feathers on the head, just behind the comb, not having been molted. It is quite possible that this is as far as the normal eclipse goes. The new tail sickles had not yet begun to grow. This individual seems to correspond in general with Ogilvie-Grant's* designation of June-September as the eclipse period.

This eclipse plumage of the male Red Jungle Fowl, while not generally well known, has always proved a stumbling block to those who maintain that the species is the sole ancestor of our domestic fowl. It has been difficult to explain the absence of the eclipse in domestic birds, since it is so characteristic of their wild progenitors.

There seems to be no record of eclipse plumage in domestic cocks, though in the light of the present evidence, this seems due rather to oversight than to lack of occurrence.

In the autumn of 1919, Mr. Prescott Van Wyck, of Summit, New Jersey, brought to the Zoological Park, a Black-breasted Red Pit Game cock, for the writer's inspection. The bird was a yearling, in his first adult molt. Examination showed that the sickle feathers of the tail had been cast and that the neck was in eclipse plumage, exactly as in the Red Jungle Fowl. This is all the more interesting, as, in color, the Black-breasted Red game fowl is an almost perfect counterpart of the Red Jungle Fowl. The eclipse feathers of the game cock were orange, with broad black margins, exactly the opposite of the colors in the Jungle Fowl eclipse. To complete the comparison, the short, red, pointed feathers of the head, as in the Jungle Fowl, had not been replaced.

Unfortunately, this cock was not the property of Mr. Van Wyck, and could not be left for observation. However, a photograph was made, showing the hackle in eclipse. In the foreground of the photograph, which is presented herewith, a single unmolted hackle feather may be seen.

A few months later, the change to full plumage had been accomplished, and specimens of the normal hackle feathers were obtained, which may be compared with those of the eclipse.

It seems reasonable to suppose that this example of the eclipse plumage in domestic fowls, is not unique but that its occurrence has been overlooked. Careful examination of molting cocks, particularly game fowl, no doubt would reveal total or partial eclipse plumage as at least fairly common.

*Ogilvie-Grant, W. R. A Hand-book of the Game Birds, 1897, Vol. II, pp. 48-9.

FIG. 79. Above: FEATHERS FROM ECLIPSE HACKLE OF GAME COCK
Below: NORMAL HACKLE FEATHERS FROM SAME BIRD

ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS OF THE
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VOLUME II. NUMBER 12

(Papers from the New York Aquarium)
(Contribution Number 5)

A CONTRIBUTION TO THE LIFE HISTORY OF THE PUFFER, *SPHEROIDES MACULATUS* (SCHNEIDER)

By W. W. WELSH
United States Bureau of Fisheries

AND

C. M. BREDER, JR.
New York Aquarium

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JANUARY, 1922

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Corrected to January, 1922.

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By W. W. Welsh
United States Bureau of Fisheries
AND
C. M. Breder, Jr.
New York Aquarium

PUBLISHED BY THE SOCIETY
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January, 1922

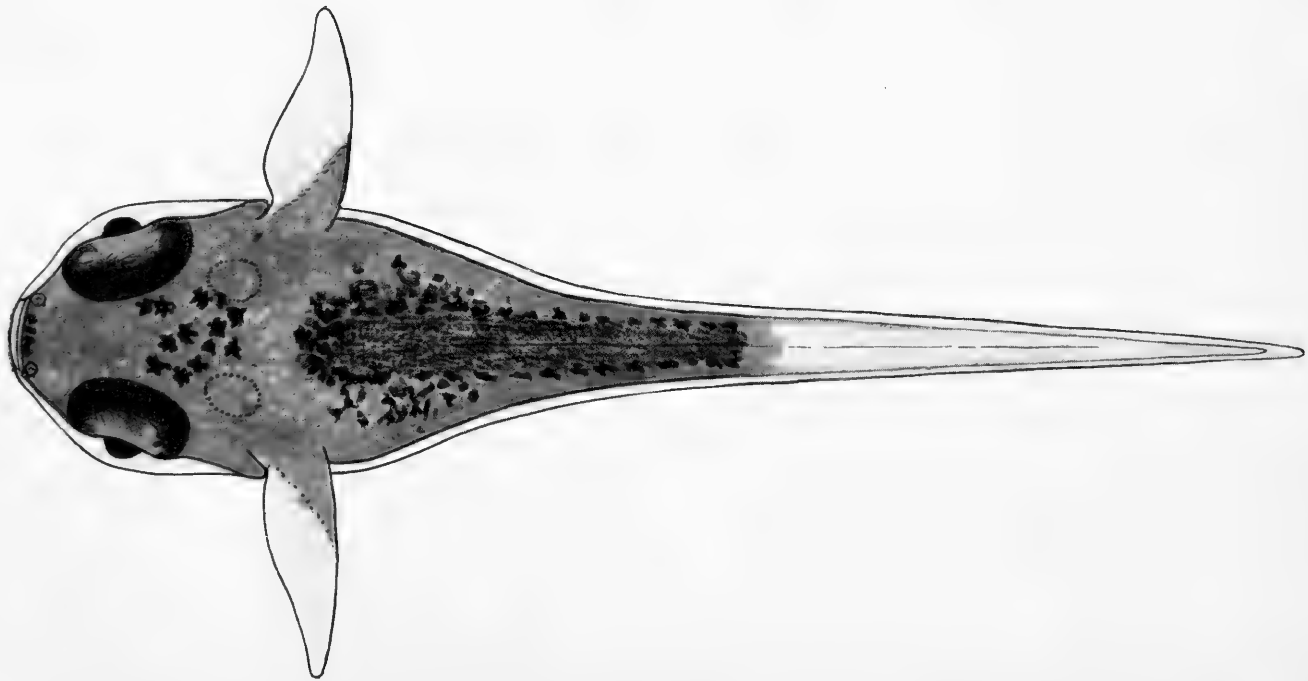

FIG. 80. LARVA FIVE DAYS AFTER HATCHING
Actual length, 2.55 mm.

Volume II, Number 12

A CONTRIBUTION TO THE LIFE HISTORY OF THE PUFFER, *SPHEROIDES MACULATUS* (SCHNEIDER)[1]

By W. W. Welsh
United States Bureau of Fisheries

C. M. Breder, Jr.
New York Aquarium

Introduction.

The present paper embodies the results of studies on *Spheroides maculatus* (Schneider), carried out at Atlantic City, New Jersey, chiefly during the month of August, 1920, where a temporary field laboratory was established on Young's Million Dollar Pier through the courtesy of Captain E. L. Young. All material for study was obtained from the two pound-nets operated upon this pier.

The temperature of the water during this season was abnormally low, being comparable to that normally encountered below the five fathom line in this region. Although conditions in general were rather unsatisfactory for this type of work, no difficulty was encountered in securing adequate material for the study of this species.

The drawings of the eggs and larvae were made from living material by means of the camera lucida. In most cases a small quantity of chlorotone was added to the sea water containing the larvae, to quiet them. All illustrations, excepting Fig. 87 have been executed by the junior author.

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[1] Published by permission of the United States Commissioner of Fisheries.

Ontogeny.

Spawning.—Ripe females of this species were taken from July 30 to August 27, which were the first and last dates on which specimens were examined. There seemed to be no increase or decrease in the proportionate number of ripe fish, which fact suggests that the peak of their sexual activity extends well over the period in this region. Hard and spent individuals were constantly taken with the ripe ones. The ova passed freely on the application of very slight pressure, issuing forth in a stream about 3 mm. in diameter. Ripe males were frequently taken, but equal success in fertilization was obtained by macerating the testes of fish from which milt would not flow. The sexes were present in approximately equal numbers.

Eggs.—The eggs are transparent, spherical, and invested with a smooth adhesive covering which is irregular in outline. They are demersal and readily become attached to any submerged object, or caked in a mass, owing to their adhesive nature. Where numbers adhere to a side of the container, close together and in a single layer, the adhesive envelope assumes a somewhat hexagonal appearance. The surfaces of the eggs are finely reticulated, rather resembling crepe paper. The eggs average about 0.874 mm. in diameter, varying from .85 to .91 mm., while the enveloping adhesive coat increases the diameter to an average of about .954 mm. A large number of colorless oil globules of low refractive index are present in a foamy cluster, which averages about .34 mm. in diameter, and a very faint yellowish olive tinge can be detected in the area in which the blastoderm is to develop. Fig. 81, A represents the unfertilized egg.

Embryology.—The eggs, of which the development was studied, were incubated in small bowls, with a daily change of water, at a temperature which averaged about 67°F. At fifteen minutes after fertilization no great change was apparent, but within the following two hours the first cleavage had been completed (Fig. 81, B), and by sixteen hours after fertilization the blastodisc had commenced to indicate the approaching differentiation (Fig. 81, C). By twenty-four hours the embryo was quite

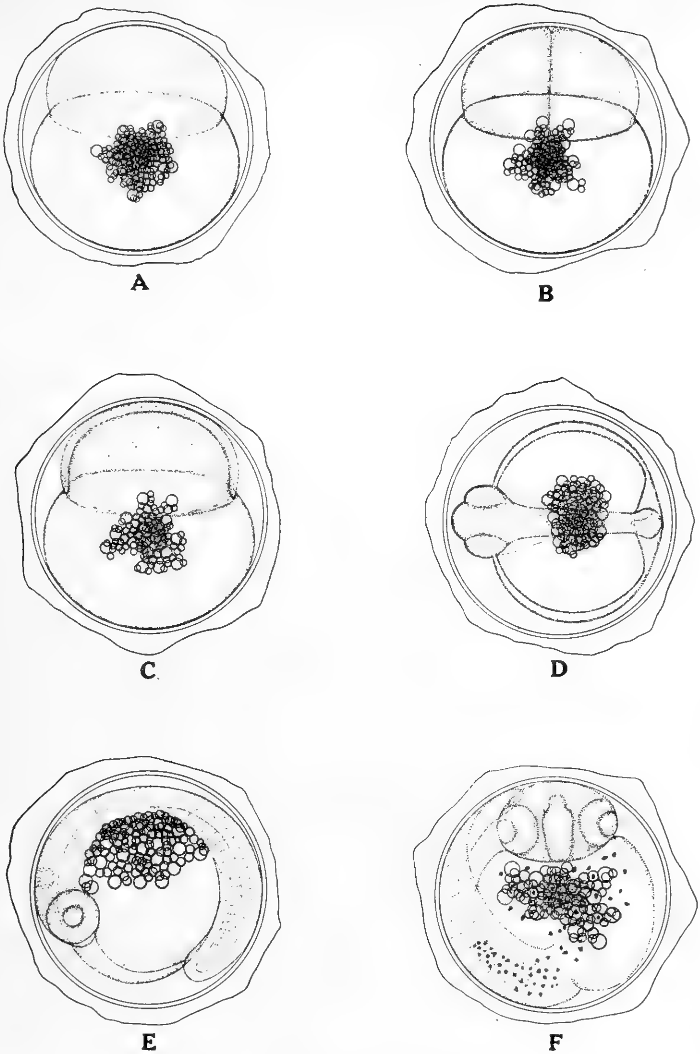

FIG. 81. MAGNIFICATION 36 X.

A—Unfertilized egg. B—Egg with blastoderm of two cells. Two and one-half hours after fertilization. C—Egg showing early stage in the differentiation of the embryo. Sixteen and one-half hours after fertilization. D—Egg showing a moderately advanced stage of differentiation of the embryo. Forty hours after fertilization. E—Egg with moderately advanced embryo. Seventy hours after fertilization. F—Egg with advanced embryo. Ninety hours after fertilization.

distinct and in the succeeding twenty it had reached more than half way around the yolk (Fig. 81, D) At seventy hours the tail was free at its tip, vertebral somites were visible, and convulsive squirmings had commenced. Scattered black chromatophores had appeared along each side and the eyes were quite distinct. The oil globules were chiefly located in the dorsal half of the yolk (Fig. 81, E). At ninety hours, in addition to the black chromatophores, red and orange ones were scattered along the sides. The anterior ventral surface of the yolk was well covered with large black chromatophores, rather dendritic, and there was a suggestion of the oil globules consolidating into a somewhat lesser number of larger spheres. A few small black chromatophores and punctulations were located in the posterior part of the iris and on the tip of the snout (Fig. 81, F). At this stage the tip of the tail overlapped the head and the embryo exhibited much activity. The eggs began hatching at about one-hundred and twelve hours after fertilization. At this time they were steadily increasing in pigment content. The pigmentation terminated posteriorly in abrupt fashion about midway between the vent and the tip of the tail, and at this point a brilliant opaque chrome yellow spot was apparent on the dorsal surface. Numbers hatched however before the chrome yellow spot appeared (Fig. 82). Most of the larvae emerged from the egg tail first, although in a few cases the head came first. Both the eggs and larvae were decidedly variable during the entire period they were under observation, especially in the matter of pigmentation.

The frontispiece (Fig. 80) represents the typical coloration of the fry at the age of five days. Various shadings have been used in the text figures in an attempt to represent the very striking coloration exhibited by this species. Red has been represented by large closely placed dots, yellow by small ones, and the various green, orange, and purple markings by short lines, the location of each being explained in the text. By comparing the line drawings with the colored plate, a fair idea of the pigmentation at each stage may be gained, since, while the amounts of pigment present in the various stages differ, the actual colors shown by the chromatophores differ little from those represented in the plate.

Larval development.—The newly hatched larvae averaged about 2.41 mm. in length. The yolk sac was small and still contained oil globules. The head was somewhat deflected and the eyes, the pupils of which were not yet dark, were directed a trifle forward and downward. The pectoral fins were difficult to see, owing to the heavy pigment lying beneath them. The coloration was brilliant; red, orange, yellow and black chromatophores being thickly distributed over the body. Deep purplish black chromatophores invested the anterior end of the yolk sac and some were scattered through the iris, which also contained a cluster of heavy black ones in the dorsal and posterior quadrant. Numerous minute tubercles were present over practically the entire body. The newly hatched larvae were very active and possessed considerable vitality. Fig. 88 shows a detailed profile of the head at this age.

As development advanced the red pigment became relatively reduced, the orange and yellow coming more into prominence. About twenty-four hours after hatching the pupil became black, the nostrils were plainly visible, the pectorals more distinct, and what seemed to be beginnings of lateral line organs had appeared. Seven pairs of these organs were observed in a two day old specimen, and probably more were present but not distinguishable from the surrounding tissue. Three pairs have their origin over the eyes, a small and a large pair are posterior to the pectorals and another small pair over the vent, as well as a pair somewhat forward of that point (Fig. 83). On treating one specimen with chlorotone a secretion appeared to exude from these bodies, which indicated their glandular nature. Fig. 89 shows in detail the vent and location of the two posterior glands, and Fig. 90 represents the appearance, in profile, of the large one just behind the left pectoral in a specimen seven days old.

At two days the vent and mouth were open, and in addition to the other pigments, various green markings had appeared, especially in the iris. The yolk was materially reduced and at three days the mouth was functioning. Viewed by reflected light the colors were brilliant and metallic. The fry were active and decidedly heliotropic. The chrome yellow caudal spot, pre-

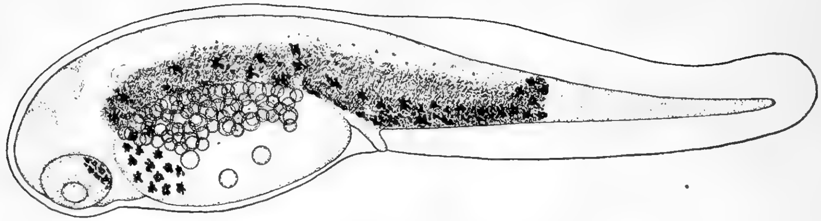

FIG. 82. NEWLY HATCHED FISH.
Actual length, 2.41 mm.

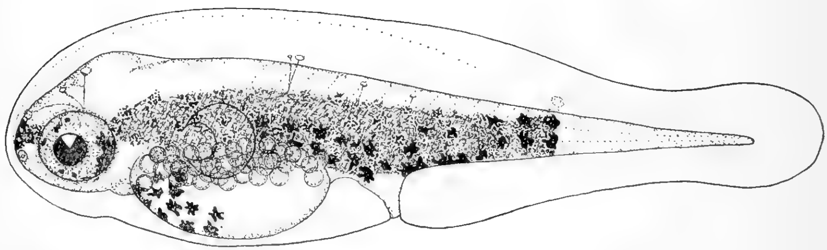

FIG. 83. LARVAL FISH ONE DAY AFTER HATCHING.
Actual length, 2.50 mm.

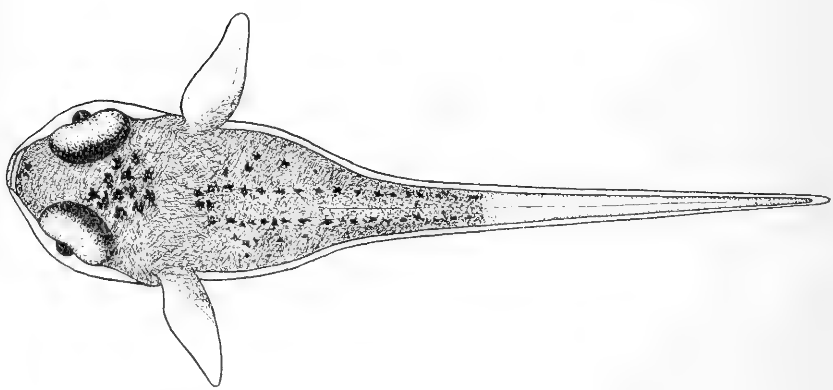

FIG. 84. LARVAL FISH FIVE DAYS AFTER HATCHING.
Actual length, 2.55 mm.

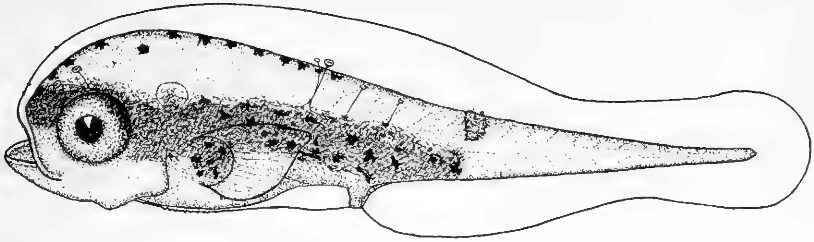

FIG. 85. LARVAL FISH SEVEN DAYS AFTER HATCHING.
Actual length, 2.62 mm.

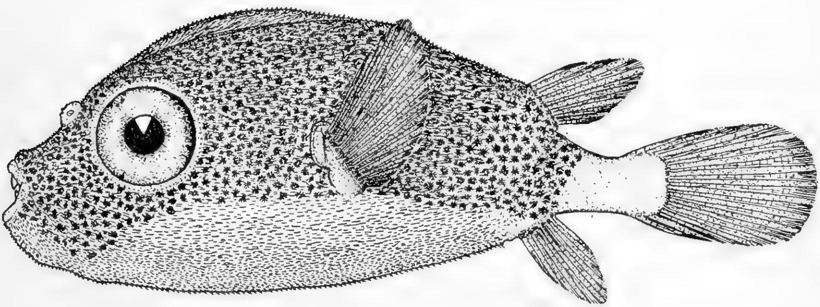

FIG. 86. POST LARVAL FISH.
Actual length, 7.35 mm.

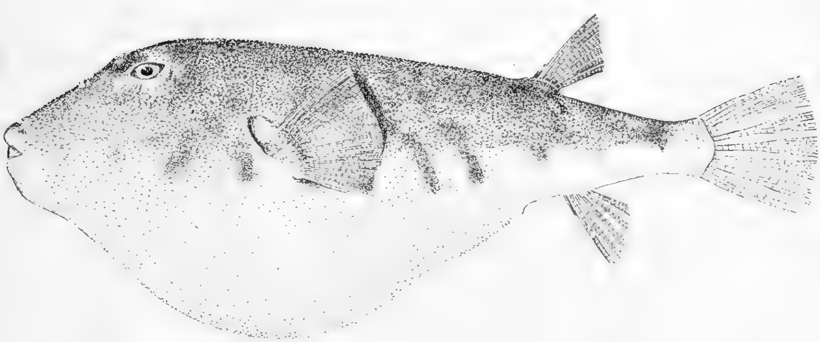

FIG. 87. ADULT FISH, PARTLY INFLATED.
Actual length, 200 mm.

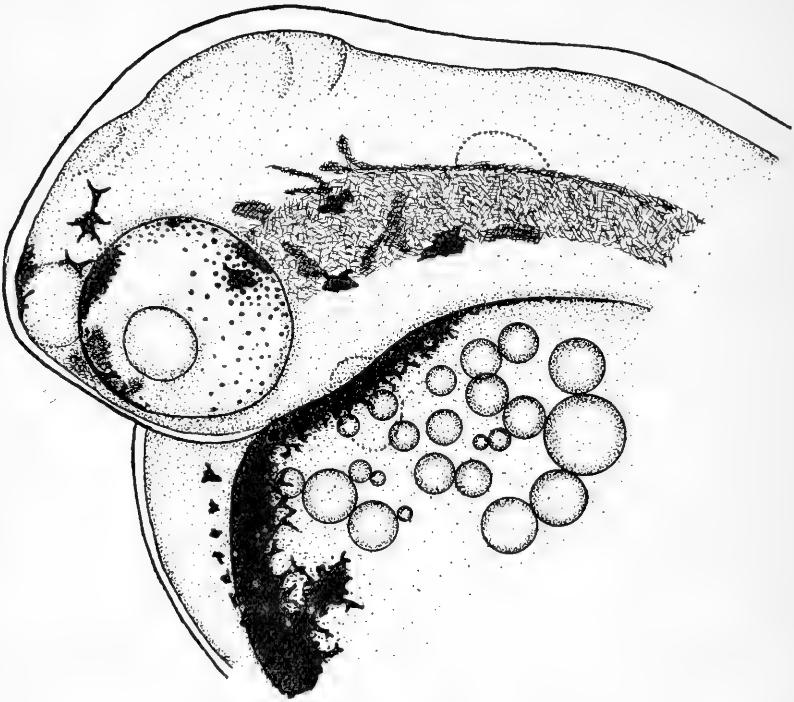

FIG. 88. DETAIL OF HEAD OF NEWLY HATCHED LARVA.
Actual length of entire fish nearly 2.40 mm.

viously noted, and a few black ones on the head constituted the only dorsal pigments.

On the fifth day numerous tubercles of considerable size were observed on the ventral surface. The eyes were coming into a more nearly lateral position and a small spine was developing on the operculum. The black chromatophores on the abdominal region (the yolk being practically absorbed and the oil globules gone) were decidedly dendritic. The pectoral was assuming a less spatulate shape, a rather pronounced point appearing near the upper margin, and the maxillary was well formed and prominent (Fig. 84). The tip of the tail, shown by Fig. 91, indicates the tuberculated appearance of the body in a six day old specimen. At this age the otoliths were becoming

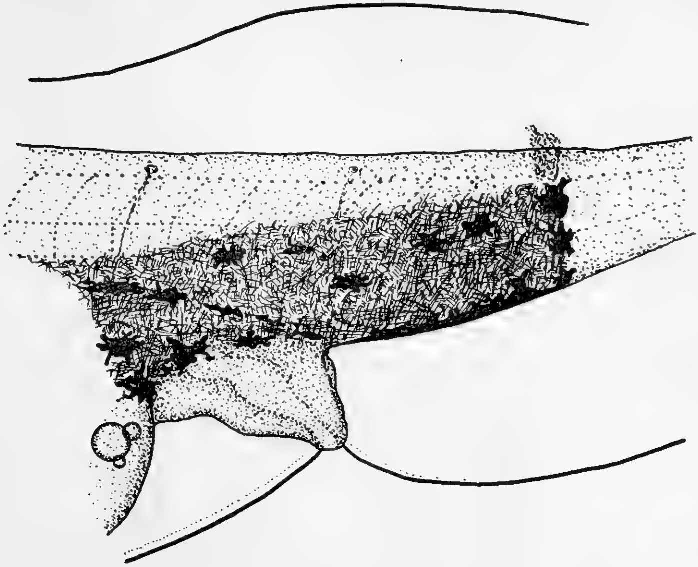

FIG. 89. DETAIL OF VENT OF TWO DAY OLD LARVA.
Actual length of entire fish nearly 2.52 mm.

more complicated in conformation and the body was becoming opaque. At seven days, (Fig. 85), little further change in appearance could be observed. The tubercles, especially on the ventral surface steadily increased in size, and the maceration of some from that location disclosed small barbed hooks as shown in Fig. 92. At ten days the larvae were all dead or dying, the largest having reached a length of 2.65 mm.

It is believed that these eggs and larvae would prove exceptionally satisfactory for detailed studies of embryology and larval development; the eggs, because of extreme hardihood, transparency, and possession of an adhesive coat maintaining them in a definite position; and the larvae because of the large and varied chromatophores that develop so strikingly, and their great tenacity to life.

Fig. 86 was drawn from a specimen 7.35 mm. long taken by the U. S. S. Grampus July 31, 1913, station No. 10081, over a depth of eleven fathoms off the New Jersey coast near Barnegat, the net haul being from ten fathoms to the surface. At this stage most of the diagnostic characters of the adult have been

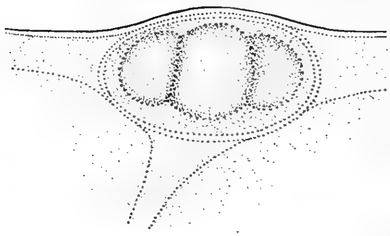

FIG. 90. PROFILE OF LATERAL ORGAN, POSTERIOR OF LEFT PECTORAL FIN, FROM A SEVEN DAY OLD LARVA.

Magnification nearly 360 X.

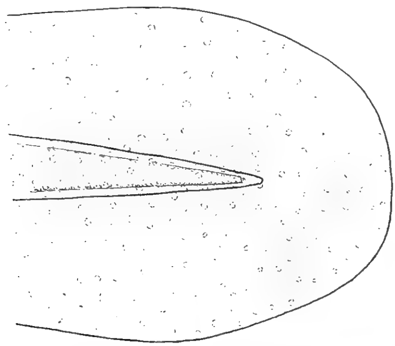

FIG. 91. TIP OF TAIL OF SIX DAY OLD LARVA SHOWING TUBERCLES.

Magnification nearly 104 X.

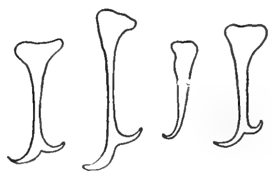

FIG. 92. SPINES FROM VENTRAL SURFACE OF TEN DAY OLD LARVA.

Magnification nearly 360 X.

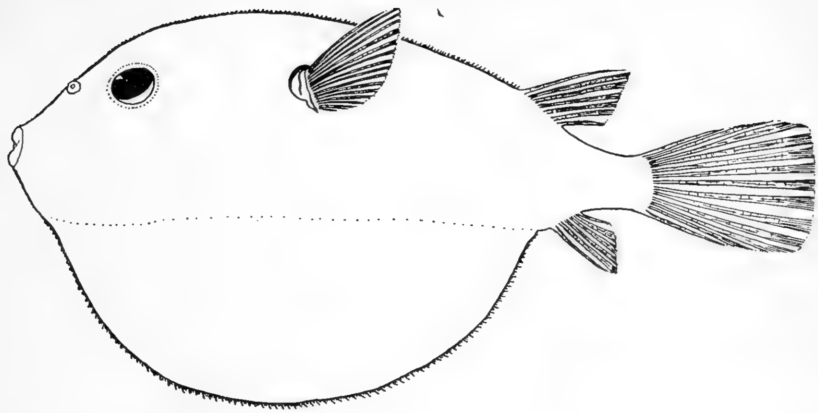

FIG. 93. OUTLINE OF A SPECIMEN 22.5 MM. LONG, SHOWING PROPORTIONS ASSUMED ON INFLATION BY THE POST LARVAL FISH.

From United States National Museum collection. Aug. 11, 1892, Quissett Harbor, Mass.

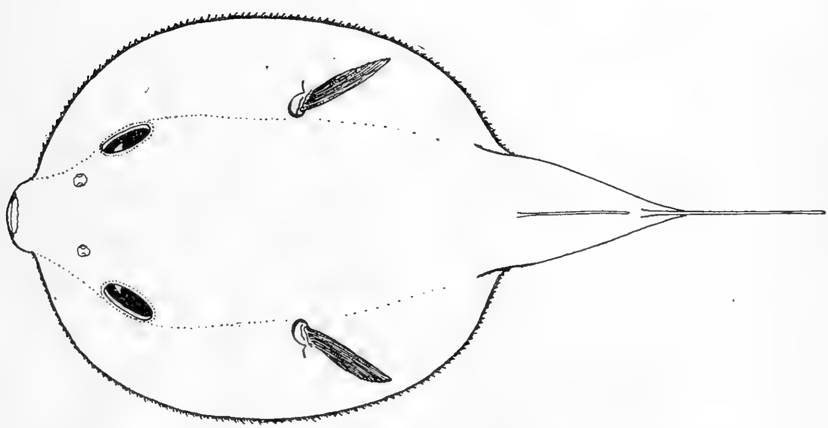

FIG. 94. DORSAL VIEW OF SPECIMEN SHOWN IN FIGURE 93.

acquired, although the skin surrounding the body is more distensible than in the mature fish. The transparent membranes covering the eyes move away from them on inflation, adding to the grotesqueness of appearance. The skin is literally turned inside out over the caudal, dorsal and anal fins, the fish inflating to such an extent that these fins are buried in furrows in the distended skin. In preserved specimens the dorsal outline over the eye is extended by a fold of this expansive membrane, which shows in the deflated specimen illustrated by Fig. 86. The projecting pectorals are practically the only prominences of note on the otherwise spherical surface of an inflated specimen. As shown in Figs. 93 and 94, by the time the species attains a length of 22.5 mm. their inflatibility does not exceed that of the adults. The entire skin, however, is still loose, and upon inflation, as the drawing indicates, the membrane covering the eye becomes pulled down to a certain extent.

Latham, 1916[2], reports having seen specimens 2.5 to 7.5 cm. at Orient, Long Island, during November and the early part of December. It may be inferred that the smaller ones at least must have been hatched that same year, when it is considered that specimens of over 7 mm. were taken in July by the Grampus. This, together with the fact that specimens in graduated sizes from a few mm. in length to adult size have been taken at most diverse seasons, indicates a long spawning season.

Preserved material.—Examples of all stages studied were preserved in strong formalin. The most notable change in the younger eggs was the change of the oil globules to a decidedly amber color, and their migration from the interior of the yolk to its outside wall, at which surface they mostly adhered. The blastodisc and the early embryos became white and opaque. All chromatophores lost their color and were difficult to differentiate, excepting the black ones. The prominent chrome yellow spot nearly disappeared, and the lateral glands were almost indistinguishable. Staining with alizerin red failed to aid much in bringing out these details.

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[2] Latham, Roy—Migration notes of fishes from Orient, Long Island. Copeia, March 24, 1916, No. 41, p. 22.

Food.

The stomachs of 102 specimens taken between July 30 and August 4 were examined immediately on capture. The range of total lengths was from 14 to 24 cm. Some individuals were spawned out, others still hard, although the majority were ripe. No variation in diet could be correlated with size, sex or condition. The males were fifty-nine in number and the females forty-three.

The accompanying table indicates the number of stomachs containing each constituent of their food.

Material	Number of stomachs.
Small crabs	14
Unidentified crustaceans	2
Mussels	7
Univalves	1
Unidentified	82
Empty	16

The crabs were all of small non-commercial species. The unidentified material consisted largely of matter reduced to an offensive blue or yellowish paste. The apparent discrepancy in numbers is accounted for by the fact that some specimens partook of more than one kind of food.

Linton, 1905[3], found on examining fifteen specimens during July and August at Beaufort, N. C., that their food included fragments of oysters, scallops, mussels, razor-clams, gasteropods, barnacles, crabs, shrimp, sea-urchins, worms, ascidians, bryozoans, and watermelon seed, which gives the species a much more varied diet than found in the present investigation.

Relative Size of the Sexes.

The females of this species average somewhat larger than the males. Inspection of Fig. 95 shows that there is a difference of 3 cm. between the modal lengths of the two sexes. The

[3] Linton, Edwin.—Parasites of the fishes of Beaufort, N. C. In Bulletin, U. S. Bureau of Fisheries, Vol. XXIV, 1904, p. 402.

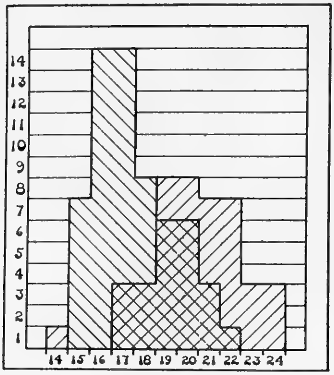

FIG. 95.

Horizontal index—Total lengths in centimeters. Vertical index—Number of individuals. Males represented by hatching from upper left to lower right corner. Females represented by hatching from upper right to lower left corner.

difference of the averages is slightly less, being about 2.85 cm. The 102 specimens examined for food determination were measured for plotting this graph. It is evident that fish more than 22 cm. long are almost surely females, while those less than 17 cm. are nearly all males. The sole female of 14 cm. length was probably a large specimen of a younger group, the remainder of which probably passed through the meshes of the net or were chiefly located in another area.

This knowledge proved very useful when dissecting the fish for eggs and milt, as by simply selecting the largest and smallest examples of a catch, both sexes could be had with almost entire certainty.

While both gonads were functioning in ripe fish, in all cases the left one was considerably larger than the right.

The Relation of Length to Weight.

The total lengths and weights of the 102 specimens of both sexes formed the basis of Fig. 96 which is arranged to show the weight of a fish of any given length or vice versa. These are plotted against each other, the larger circles indicating the points obtained by averaging the weights of all specimens in their respective length groups, which are in steps of 1 cm. The small circles on either side of the large ones indicate the high-

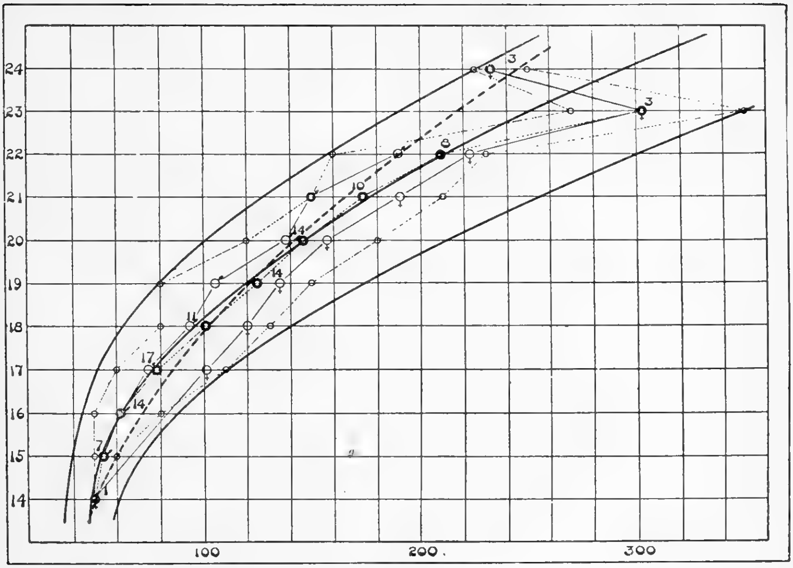

FIG. 96.

Horizontal index—Weights in grams. Vertical index—Total lengths in centimeters. Large circles—Average weight of corresponding length group. Small circles—Extremes in weight for corresponding length group. Numbers near large circles—Number of specimens making up average. Sex symbols—Average weight of sex indicated for corresponding length group. Center heavy curve—Line of average weights, smoothed. Outer heavy curves—Lines of extreme variation of weights. Heavy dashed curve—Line of formula, $w=l^3/56$.

est and lowest weights found in the individual groups. The central heavy curved line is the theoretical curve obtained by smoothing the dotted line connecting the large circles. It graphically represents the change in relation of length and weight as growth increases. The two outer heavy curved lines represent the limit of individual variation as established by the plotted points. The sex symbols connected by light solid lines shows the average weight for the indicated sex in each length group. This shows well the fact that males weigh considerably less than females of a given length. The modal weight of the males is about eighty-two grams less than that of the females, while the difference of the average weights is about eighty-seven grams.

It is evident that having the length or weight of a fish of this species, the other may be had by inspection of the curve, the central lines giving the probable measurement, while the outer two limit the known variation in the breeding season. If the specimen in question is a male its weight will in all probability fall between the central line and the left hand outer one, while if it is a female it will probably be located on the other side of the central line.

On the assumption that the weights of fish of this species vary as the cube of their length multiplied by some constant, as is usual in fishes, the formula $w = l^3/56$ was calculated in which w = weight in grams, l = length in cm., and 56 = the constant. The heavy dashed curve was plotted from this equation. While it does not follow the smoothed curve perfectly it keeps well within the limitations required and the small discrepancies can be accounted for by the fact that the specimens weighed varied in sex, development of the gonads, and amount of material present in the alimentary tract.

SUMMARY.

1. *Spheroides maculatus* has a long spawning season, probably lasting all through the warmer months.

2. Artificial fertilization is readily accomplished and owing to the transparency, adhesive nature, and hardihood of the ova, as well as the vitality of the larvae, the species is ideally suited for studies of early development.

3. Incubation occupies about three days and ten hours at an average temperature of 67°F.

4. The critical period for the larvae of this species appears to be on or about the tenth day after hatching.

5. Preservation in formulin destroys the finer details but fails to make the eggs or larvae unidentifiable.

6. The food of *Spheroides* does not include organisms of any considerable commercial value.

7. The females average larger than the males.

8. In specimens of equal length the females are somewhat heavier than the males, at least in the breeding season, although this is irrespective of the condition of the gonads.

9. The relation of length to weight in this species is approximated by the formula $w = l^3/56$.

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HERMAPHRODITISM OF A CROAKER, *MICROPOGON UNDULATUS* (LINNAEUS)

By C. M. BREDER, JR.
New York Aquarium

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JANUARY, 1922

HERMAPHRODITISM OF A CROAKER,[1] *MICROPOGON UNDULATUS* (LINNAEUS)

By C. M. Breder, Jr.
New York Aquarium

During the months of July and August, 1920, a large number of croakers, *Micropogon undulatus* (Linnaeus), were taken in the pound nets operated at Young's Million Dollar Pier, Atlantic City, New Jersey. They appeared to be approaching the spawning season rapidly and some males were found from which milt would flow. No females were taken with ripe eggs however, so on August 9, when what appeared to be a female turgid with eggs was taken, considerable interest was aroused. Its proportions were as follows:

Total length	32 cm.
Standard length	27 cm.
Body depth	9.5 cm.

Externally it appeared to be normal in all respects and when it was found that stripping was not possible, curiosity prompted dissection. The explanation of its great body depth was apparent when it was seen that perfect sets of both ovaries and testes were present. The testes lay dorsal of the ovaries, but in all other respects the internal anatomy was of the usual character.

In the accompanying semi-diagramatic sketch of the ventral aspect of the dissected specimen all fatty tissue and mesentary membranes have been omitted. Only the digestive tract and sexual organs have been shown in detail. The stomach appears as a very small appendage, but that is the normal

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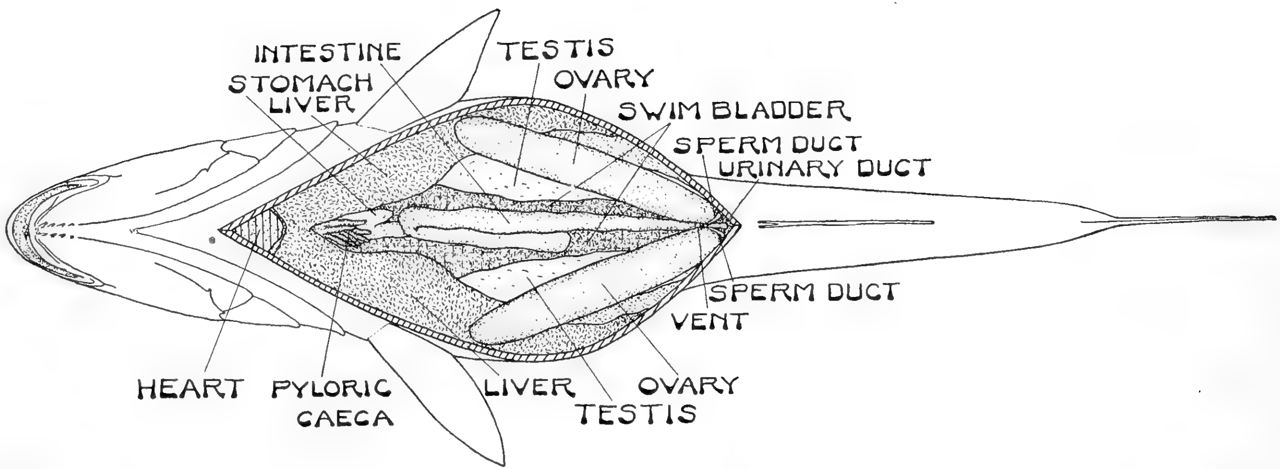
INTESTINE
STOMACH
LIVER
TESTIS
OVARY
SWIM BLADDER
SPERM DUCT
URINARY DUCT
SPERM DUCT
VENT
HEART
PYLORIC
CAECA
LIVER
OVARY
TESTIS

FIG. 97.

condition of the organ when the individual has not been feeding.

The only displacement of the viscera, other than that caused by the spreading due to opening the fish, is that of moving the anterior ends of the ovaries outward so as to show the testes lying dorsally of them. Before this separation, the ovaries were nearly parallel to each other and appressed against either side of the intestine. The paired fins indicated are the ventrals, the pectorals not being shown as the open flaps of body wall hide them completely.

The junction of the ova, sperm and urinary ducts appeared to be at the genital pore. This is shown in the diagram just posterior to the vent. The spermatic ducts can be seen passing around the rear end of the distended ovaries, which extend backward past the genital pore. The urinary duct passes between the posterior ends of the ovaries as it descends from the kidneys lying dorsally of the swim bladder, and is flexed forward to the external opening.

Both sets of gonads seemed well developed and in the state most frequently found in normal individuals of this species taken about the same time as this sportive example. The testes were soft and flocculent, and easily ruptured, the milt streaming out from such injuries, but they were not quite ripe enough to strip, and the ovaries were also a little too green for that operation.

Most previous records of hermaphroditism in fishes tell of one set being much in advance of the other in regard to development, but this specimen suggests speculation on the possibility of self-fertilization, which mechanically, at least, appears to be entirely possible. Scale examination and size indicate that this fish was about five years old and has therefore passed through at least one spawning season. The age of the fish together with the fact that the gonads were normal in themselves, strongly suggests that this is a case of functional hermaphroditism of which we have three possible methods of function: that is, self fertilization, and mating with other fish, either as the male or female element or alternately, as first one and then the other.

To the best of the writer's knowledge bi-sexuality in teleosts has been recorded only from the following families and orders; *Cyprinidae, Clupeidae, Salmonidae, Esocidae, Poeciliidae, Gasterosteidae, Mugilidae, Percidae, Serranidae, Sparidae, Scombridae, Labridae, Squamipinnes, Gadidae* and *Pleuronectidae.*[2]

It is believed that no additions have been made to the above list up to the present time, so this notice stands as record of the addition of the *Sciaenidae* to it.

C. Stewart, in the Journal of the London Linnean Society (Zool.) 24 pp. 70-71, mentions the most nearly similar case, which is among the *Scombridae.* This is apparently the only other record in which the abnormality has approached symmetry; but even in the case of the mackerel the organs failed to reach the degree of symmetry found in the present specimen.

This example of abnormal hermaphroditism is now deposited in the U. S. National Museum, number 66140.

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[2]This list, excepting the *Poeciliidae* and *Serranidae* was recorded by James E. Gemmill in his publication, "The Teratology of Fishes", 1912, James Maclehase & Sons, Glasgow, Pub. The occurrence of this type of monstrosity among the *Poeciliidae* was recorded by H. H. Newman, 1908 "A Significant case of Hermaphoditism in fish", Biol. Bull. Woods Hole, Mass., pp. 207-214. This reference however was listed in Gemmill's bibliography. The *Serranidae* are included in this list on D. S. Jordan's authority. In his "Guide to the Study of Fishes" 1905, p. 124, Holt & Co., N. Y., Pub., he states that *Serranus* is "sometimes truly hermaphroditic."

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ZOOLOGICA

SCIENTIFIC CONTRIBUTIONS OF THE NEW YORK ZOOLOGICAL SOCIETY

VOLUME II. NUMBER 14

THE FOOD OF CERTAIN MINNOWS

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BY C. M. BREDER, JR.
New York Aquarium

AND

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INTRODUCTION

The smaller members of the family Cyprinidæ although often neglected, are without doubt the most important of the small fishes which inhabit our fresh waters. To the practical fish culturist they are of greater importance than is usually recognized since they represent the food of many game and food fishes, while their diversity of species and habits, together with their interesting ecological relations, and availability, make them of considerable interest to the scientific student. A study of their intimate relationships and habits, therefore, is at once important from an economic and scientific standpoint. With these considerations in mind, this study of the food and feeding habits was essayed, since they are undoubtedly among the chief factors in the lives of these fishes.

FISH CULTURAL VALUE

The fact of primary importance to fish culture is that these minnows enter largely into the diets of the larger game fishes. At least twenty-three different predatory fishes are known to subsist largely upon various cyprinoids. They are as follows:

Lepidosteus osseus (Linnæus)................Long-nosed Gar or Billfish
Hiodon alosoides (Rafinesque)...............Golden-eye or Northern Moon-eye
Hiodon tergisus Le Sueur....................Golden-eye or Moon-eye
Pomolobus chrysochloris Rafinesque...........Skipjack
Salmo sebago (Girard)......................Sebago Salmon

Cristovomer namaycush (Walbaum)	Lake Trout
Esox americanus (Gmelin)	Little or Bonded Pickerel
Esox reticulatus (Le Sueur)	Pickerel or Pike
Esox lucius Linnæus	Pike
Esox masquinongy Mitchill	Muskallunge
Aphredoderus sayanus (Gilliams)	Pirate Perch
Pomoxis annularis Rafinesque	Crappie or Croppie
Pomoxis sparoides (Lacépède)	Black Crappie or Calico Bass
Ambloplites rupestris (Rafinesque)	Rock Bass
Chaenobryttus gulosus (Cuvier and Valenciennes)	Warmouth
Micropterus dolomieu Lacépède	Small Mouthed Black Bass
Micropterus salmoides (Lacépède)	Large Mouthed Black Bass
Stizostedion vitreum (Mitchill)	Wall Eyed Pike
Stizostedion canadense (De Kay)	Gray Pike or Sauger
Perca flavescens (Mitchill)	Yellow Perch
Roccus chrysops (Rafinesque)	White Bass
Roccus lineatus (Bloch)	Striped Bass
Morone americana (Gmelin)	White Perch

After listing a number of species (included above), Forbes and Richardson ('08), add: "That th's list might be considerably enlarged by more extensive studies of the food of fishes is beyond a doubt, and it is safe to say that no fish-eating fish would, if hungry for fish, refuse a minnow of any kind unless it seemed too small to be worth the trouble capturing. . . . Moreover, by their great numbers, by their various adaptations and corresponding ecological d'stribution, and by their permanently small size, the minnows must distract in great measure the attention of carnivorous fishes from the young of the larger species, upon which, without them, the adults of these larger species would fall with the full force of their voracious appetites. . . . It is not too much to say, consequently, that the number of game fishes which any waters can maintain is largely conditioned upon its permanent stock of minnows."

Since the successful stocking of any stream with game fishes depends upon the food supply, it is essential to know how this important item may be maintained. As Forbes ('83) remarked, "Really intelligent fish-culture on any large scale, implies a full acquaintance with the food of the native species."

Fortunately, most of our streams east of the Rocky Mountains seem to be plentifully supplied with Cyprinoids, numerous species being found frequently in one stream. The availability of these fishes as a staple food for larger fishes depends upon their abundance, which, in turn, depends upon the abundance of their food. It is important, therefore, to know what these minnows eat at various seasons of the year. For this reason a considerable portion of this paper is devoted to the analysis of the stomach contents of specimens taken at various seasons.

Scientific Value

Ecologically and taxonomically the Cyprinidæ form a puzzling group. A study of the affinities of the various species is needed, both with reference to anatomical details and environmental conditions. In this connection, a knowledge of the food of the group throughout the seasons is of prime necessity and the results embodied in this paper, it is hoped, may be of value to other workers.

Minor Values

This group of fishes furnishes a large per cent of the bait to fishermen, sport for many a small boy, and a few of the larger species are used for human consumption.

Any or all of the different species of suitable size may be used as bait, many being hardy as live bait, but *Notropis cornutus* is probably the favorite among most of the fishermen. *Semotilus bullaris* is a wary fish and in some localities, at least, it is regarded as a minor sport fish.

Lastly, many of the species, in fact all of those which were collected in connection with this work, are attractive aquarium fishes, most of them becoming adapted to balanced aquaria, although they become adapted more readily to conditions in an aquarium supplied with running water.

Field Methods

In order to determine the nature of their food, collections were made of six of the common species of cyprinoids occuring in the District of Columbia.

A small stream known as Oxon Run was chosen for this purpose because of its accessibility and various physical features which will be subsequently described. It was decided that collections should be made once a month for one entire year. This plan was followed, except that no collection was made in August, but the collecting dates were so arranged that the greatest gap be-

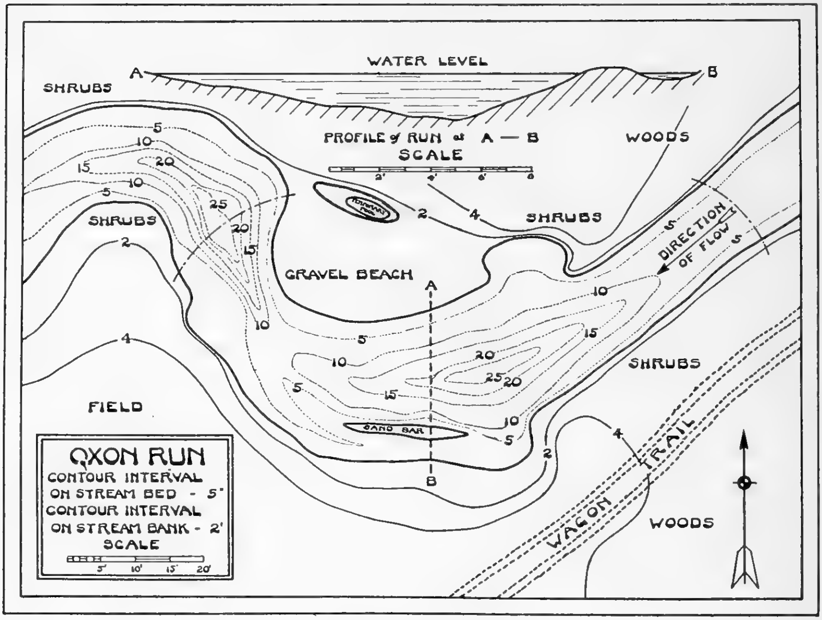

FIG. 98. MAP OF COLLECTING SITE

The two curved lines crossing the stream mark the limits of the area in which the collections were made. This locality is indicated on the Washington Biological Society's Map (MacAtee '18) as S. E. G. 12.

tween any two was only 49 days, which period spanned that month.

Oxon Run is about 7.5 miles long and flows into the Potomac River near the southeast boundary of the District, opposite Alexandria, Va. In every way it is a typical steam such as found in the coastal plain region of Virginia and Maryland. It was observed that there was a considerable fluctuation in the amount of flow, depending on the amount of rainfall, and consequently, the turbidity varied accordingly. These changes were not detrimental to the work, although the swift current increased the difficulty of hauling the seine. The location shown on the map (Fig. 98) is about 2¼ miles above the mouth and was chosen because there is a rather deep eddy, on one side of which is a small beach providing an ideal place for hauling out the seine. The bank opposite this beach is rather high with overhanging shrubs, grasses and other plants. Upstream, the channel is nearly flat and has a gravelly

TABLE NO. I

PHYSIOGRAPHICAL CONDITIONS AT OXON RUN DURING 1920

Date	Temp. (Fahr.) Air	Water	Condition of Water Turbidity, Etc.	Depth	Weather Conditions
Jan. 1	48	37	Rather swift, fairly clear	12 inches	Partly cloudy
Feb. 1	29	32	2 inch ice over area seined	Greatest, 36 inches	Snow flurries. Cloudy
March 14	42.5	38	Slightly murky	Evidence of previous high water	Fair and windy
April 11	59	58			Fair
May 23	..	63			Partly cloudy; warm
June 13	89	71	Clear	Quite low	Partly cloudy
July 17	80	74	Very roily from children swimming		Sunny; hot
Sept. 4	83	66	Very clear	Low	Clear or partly cloudy
Oct. 4	75	57	Very clear	Very low	Fair
Nov. 7	61	48	Clear	Low	Cloudy
Dec. 5	65.5	49	Turbid, swift	Highest noted	

bottom that slopes gently, the water being about six inches deep at the low water stages. Down stream there are deeper places which were found unsuitable for seining. The table of physiographic conditions (Table No. I.) shows the general conditions and seasonal variations under which the collections were made.

All of our collections were made within the limits shown on the map by means of a ten-foot seine of one-quarter inch mesh. The bottom was quite free from snags and weeds of any kind and the only cover provided for the fishes was such debris as dead leaves and other materials which may have collected in the eddy. Even when the water was clear, few fishes were to be seen, yet the number of specimens collected gives some evidence as to their abundance. No definite number of hauls was made, since the catch each time was found to vary considerably, collecting being continued until a sufficient number of specimens had been secured, or until the site had been exhausted temporarily of fish. The specimens were placed immediately into formal alcohol and sorted later in the laboratory. Formal alcohol was found to be an efficient killing fluid since it acted quickly thus preventing further digestion of the stomach contents and hardened the specimens without perceptible shrinkage.

Laboratory Methods

After the specimens were brought to the laboratory, the solution of formal alcohol was poured off and 75 per cent. alcohol substituted for permanent preservation. Each species was preserved in a separate bottle and the different monthly collections were also segregated. Each fish was measured, the standard length being recorded because this measurement was used in constructing curves of growth which are discussed further on. Since this is the only measurement referred to throughout the paper it is mentioned subsequently simply as length. Each specimen was provided with a paper tag numbered serially to provide a ready reference to each specimen. In all, there were 1554 specimens including six species.

The entire digestive tract of each specimen was removed and the contents pressed out on a glass slide. The material was examined with a low power of the compound microscope supplemented by higher powers when necessary. Pierce's method (Pierce '15)[1] was used to estimate the various quantities of food present. It is apparent that such a method can yield only a rough estimate, but none other was found to be feasible on account of the time required to make more accurate volumetric determinations. It is pointed out that frequently only small quantities of food, such as the leg of a beetle or wing of a fly, would be found yet such material had to be listed as 100 per cent. coleopterous, or dipterous remains, as the case might be, since there was no evidence of other food having been eaten. However, these errors would be naturally compensating rather than cumulative and in the tables we present giving the averages of each collection, they lose significance.

[1] Briefly, in this method the contents of each example is considered as unity, the various items being expressed in terms of percentage by volume as estimated by inspection.

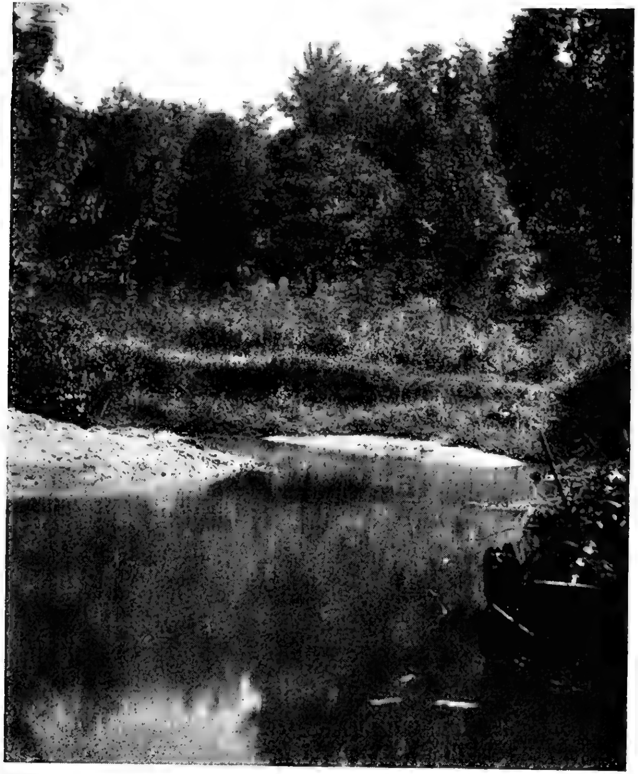

FIG. 99. VIEW LOOKING UP STREAM

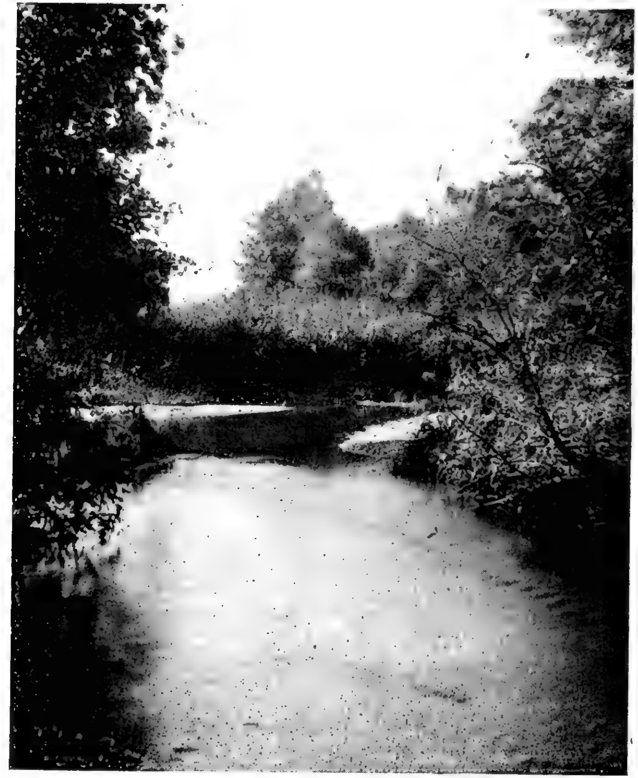

FIG. 100. VIEW LOOKING DOWN STREAM

In taking these photos the camera was located a little beyond the upper and lower limits, respectively, of the area in which the collections were made. Taken in early October. See Map, page 290.

FIG. 101. ENTIRE CONTENTS OF THE STOMACH AND INTESTINE OF A SPECIMEN OF *NOTROPIS CORNUTUS* 7.3 CM. IN LENGTH TAKEN IN DECEMBER. 4X

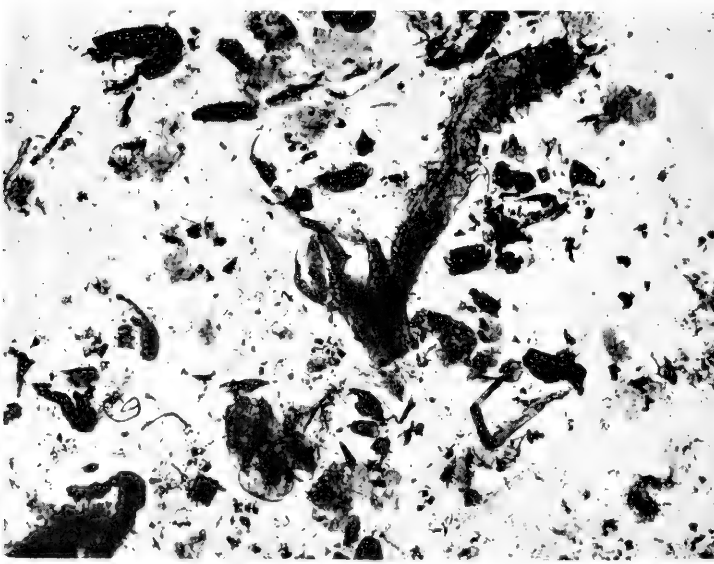

FIG. 102. ENTIRE CONTENTS OF THE STOMACH AND INTESTINE OF A SPECIMEN OF *NOTROPIS CORNUTUS* 5.7 CM IN LENGTH TAKEN IN DECEMBER. 4X

Photomicrographs showing the degree to which the food was usually found to be macerated.

The food was found to be masticated usually beyond the possibility of positive identification, as illustrated by figs. 101 and 102. This condition, doubtless, was caused by the action of the raptorial pharyngeal teeth possessed by these species. However, it was possible to distinguish insect remains from those of other organisms and often the various orders of insects such as Coleoptera, Diptera, etc., could be separated.

Our thanks are due Mr. J. T. Nichols, of the American Museum of Natural History at whose suggestion the problem was undertaken, to Dr. W. C. Kendall, of the U. S. Bureau of Fisheries, for determining the identity of certain specimens, and to Dr. R. E. Coker, for his kindness in allowing the use of the facilities of the Division of Inquiry of the latter institution. All illustrations have been made by the senior author.

Observations

Arrangement of Treatment by Species.—Complete statements and tables of the stomach contents of the six species on which this paper is based follow. A few general notes are followed by a discussion of the analysis of the data obtained. Following this, is the table of foods given in volumetric percentage by months. Opposite each date of collection is given the number of specimens which contained food and the number which were found to be empty. The modal, maximum and minimum lengths in millimeters are given next to convey a general idea of the size of the specimens examined. In cases in which no modal length is given the specimens were so scattered or few in number that no distinct mode was discernable from the frequency graph. Of course, in other cases the significance of the mode is directly proportional to the number of variants measured. In plotting these on graphic paper groupings of 4.0 mm. each were used throughout, beginning with 0 to 4 as the first group.

The body of the table in which the various organic substances are arranged in systematic order follows next, with the unidentified materials placed last. The figures for any one month indicate the averages for that collection. They have been reduced in practically all cases to whole numbers because figures closer than 0.5 per cent. have no particular significance, owing to the variation of the estimates and other uncontrollable factors. All such materials present in quantities of less than 0.5 per cent. are indicated simply by a plus sign indicating a mere trace. The general average for the whole year differs slightly from that which would be obtained by averaging the monthly numbers since the original calculations with all their fractional parts have been used because frequently the aggregate number of plus signs was sufficient to form a whole number. This grand average then also was smoothed in a similar manner to the method used for the monthly averages. Here, also, the value of the results is directly proportional to the number of specimens.

The table is followed in each case by a list of annotations amplifying and explaining certain features not expressed in the table itself or its preceding analysis.

Semotilus bullaris (Rafinesque) FALLFISH

Examples of *Semotilus bullaris* ranging from 1.6 to 12.2 cm. in length were taken. Those of the larger size were at once distinguished from *S. atromaculatus* of which a considerable number were taken also, by the black spot at the base of the anterior rays of the dorsal fin, from which the species takes its name. The very small specimens, however, were extremely difficult since most of the adult charactertistics had not yet appeared, and it was only after considerable study that they were separated to our satisfaction. *S. bullaris* is separated from *S. atromaculatus* chiefly by its larger scales and the crowded conditions of the anterior costal scales of the latter which is not apparent in very small specimens of *S. bullaris*. Most of the specimens taken were immature. None below 4.0 cm. were mature while most of those of greater length were sexually developed. Graphs were constructed plotting the lengths with their frequencies. Those below 4.0 cm., which formed the majority, composed a well-defined group forming a single mode as is indicated in Table No. II. No second mode was formed since the larger specimens were too few in number to show any tendency in that direction. The small number of mature individuals suggests that probably the adults run up the stream to spawn. This would be in accordance with observations of this species in various lakes where it is known that the adults spawn in the streams. Fowler ('08) records this species as reaching a length of eighteen inches which is several times the length of our largest specimen.

Judging from the modal lengths of each collection these fish appeared to be chiefly of two-year classes; that is, most of those collected from January to July inclusive were undoubtedly of the spawning season of 1919. In September those of the 1920 spring began to appear in the collections, being by this time large enough to be unable to escape through the meshes of the seine. During the months of March, June, September, November, and December, a few larger individuals probably of greater age were taken.

Analysis of Stomach Contents:—Reference to the accompanying table plainly shows that this species is decidedly insectivorous, since these invertebrates formed 87 per cent. of the entire food of the 242 fish which were found to have been feeding. The plant remains amounting to only 5 per cent. apparently were taken incidentally. In September these remains were found to be present among the food in their greatest quantity (17 per cent.) but this relatively large amount in no way invalidates the conclusion that they were accidentally ingested, because none of the diatoms or algae were found to be plasmolized which would have been the case if any of them had been acted upon by digestive fluids; or if they had been macerated, the alcohol would have completed that action. This, together with the fact that the unidentified debris also amounted to only 5 per cent., suggests that these fish are not bottom feeders, and as they do not have a superior mouth, (Figs. 103 and 111), the inference is that they captured most of their prey as it fell through the water at some point below the surface. It was observed that specimens in the aquarium usually fed in this manner. Assuming this to be the truth, the lack of diatoms and algae would be explained since in the locality where the collections were made these plants must have been taken from the bottom because of the absence of larger plants, brush, etc., to which such growths could adhere and flourish, while the swiftness of the current precludes the existence of pelagic forms. Some of what they took might well have been broken fragments drifting down stream from above which were snapped up in passing. Additional evidence that this species indulged in bottom feeding to only a slight extent is furnished by the fact that not a single grain of sand was found

Table No. II *Semotilus bullaris* Tabulation of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	101	6	22	24	34	12	4	24	2	2	11	242
Number of Empty Specimens	13	12	23	3	0	0	1	0	0	0	4	56
Modal Length (mm)	30	22	30	32	34	38	...	26	...	...	...	Aver-
Maximum Length	44	36	88	52	48	52	56	44	48	122	72	ages
Minimum Length	16	16	24	20	24	36	44	20	36	28	28	
Diatoms	...	...	...	...	14	...	...	16	...	...	...	02
Filamentous Algæ	...	...	...	...	...	...	...	01	...	...	...	+
Unidentified Plant Remains	...	08	...	...	...	09	...	...	...	...	...	02
Total Vegetable Matter	...	*08*	...	...	*14*	*09*	...	*17*	...	...	...	*05*
Chætopoda	11	...	04	...	05	...	...	...	...	...	...	01
Decapoda	01	...	04	...	...	...	...	...	...	...	...	01
Diplopoda	...	...	...	04	...	...	...	...	...	...	...	01
Larval Ephemeroptera	08	...	...	...	...	...	...	...	...	...	...	01
Larval Plecoptera	11	...	04	...	...	...	...	...	...	...	14	02
Larval Coleoptera	01	...	...	...	...	...	...	...	...	...	...	+
Adult Coleoptera	06	17	39	24	45	33	50	16	100	...	...	30
Larval Lepidoptera	05	...	...	...	...	...	...	...	...	...	...	01
Crysilid of Lepidoptera	01	...	...	...	...	...	...	...	...	...	...	+
Larval Diptera	...	...	...	08	...	...	...	...	...	...	...	01
Adult Diptera	...	...	...	04	01	25	...	...	...	...	36	06
Adult Hymenoptera	...	...	...	10	12	...	...	16	...	...	...	03
Unidentified Insect	30	58	41	50	21	33	50	48	...	100	50	43
Total Insect Remains	*62*	*75*	*84*	*96*	*79*	*91*	*100*	*80*	*100*	*100*	*100*	*87*
Fish	...	...	04	...	...	...	...	...	...	...	...	+
Unidentified Debris	26	17	04	...	02	...	...	03	...	...	...	05

Jan. 1. The crustacean remains consisted of the chela of a *Cambarus* of small size. Among the debris was found a partly digested ctenoid scale, probably from a ***Boleosoma***, the only abundant fish of this locality bearing such scales. All the Chætopods were small annelids, allies of ***Tubifex***, etc. March 14. The crustacean remains consisted of the eye of a *Cambarus*. The fish had eaten a hydrophylid beetle, and a magot-like larva was among the unidentified insect remains. April. 11. Diplopods were represented by a fragment of a millepede. May 23. One individual had eaten a buffalo fly, two had taken ground beetles and four contained a white paste, together with the hard parts of beetles. The former was presumably the partly digested soft parts of these insects. Sept. 4. An ant was present among the Hymenoptera.

in any stomach, although in several of the other species sand was found quite commonly.

No correlation of feeding habits and size was discerned in any case since all sizes fed on essentially the same types of organisms. The few exceptions noted are attributable simply to mechanical differences due to size. As an example, in March a *Boleosoma* was eaten by a fish 86.5 mm. in length. It is obvious that some of the smaller specimens could not have eaten a *Boleosoma* since many were smaller than the Darter itself. It may be noted here that not a single case of cannibalism was observed in any of the six species studied.

The tabulations of the number of fish found to be empty plainly shows that these fish feed considerably less during the cold months. On February 1, the coldest day on which a collection was made, when ice two inches thick was broken in order to operate the seine, twice as many of the stomachs were found to be empty as those which contained food and of the latter, two-thirds contained very little food.

This species appeared to be nearly free of intestinal parasites and no other kinds were noted among the entire series of 298 specimens. Only ten contained parasitic worms in the alimentary tract. These parasites were distributed as follows:—January, 4; February, 1; March, 4; April, 1. None was found in any succeeding months.

All foods other than insect were present in such small quantities that they cannot be considered important.

It should be noted here also that such bottom forms as the larval Plecoptera and Ephemeroptera were taken only in the colder months when fewer terrestrial insects were available, and the fish were naturally seeking deeper water on account of low temperature at the surface.

Incidentally fourteen specimens of *S. atromaculatus* were examined and it was found that they had partaken of food practically identical to that taken by *S. bullaris*.

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	31	0	8	81	56	10	19	45	23	11	0	284
Number of Empty Specimens	3	0	0	1	1	0	2	0	3	0	0	10
Modal Length (mm)	58,30	...	...	48,30	52,34	34	42	42,30	34	38	...	Aver-
Maximum Length	64	...	54	64	60	52	56	56	56	56	...	ages
Minimum Length	20	...	30	20	20	24	32	20	28	32	...	
Diatoms	...	...	...	...	...	...	01	01	...	...	...	+
Filamentous Algæ	...	...	...	...	...	...	03	...	...	...	...	+
Total Vegetable Matter	...	...	...	...	...	...	*04*	*01*	...	...	...	+
Chætopoda	...	...	...	01	...	...	...	...	...	...	...	+
Decapoda	...	...	...	01	...	...	...	...	...	...	...	+
Adult Thysanura	01	...	...	...	...	...	...	...	...	...	...	+
Larval Ephemeroptera	28	...	24	...	...	...	...	...	...	...	...	06
Nymph of Odonata	...	...	...	...	...	...	...	01	...	...	...	+
Larval Plecoptera	16	...	...	...	...	...	...	...	...	...	...	02
Larval Trichoptera	...	...	...	...	02	...	...	...	...	...	...	+
Adult Orthoptera	...	...	...	...	01	...	...	...	...	...	...	+
Larval Coleoptera	02	...	08	...	...	...	...	...	...	...	...	02
Adult Coleoptera	13	...	...	38	77	...	21	27	08	...	...	20
Larval Lepidoptera	03	...	...	01	...	...	...	...	...	...	...	+
Adult Diptera	03	...	...	05	...	...	...	...	14	32	...	07
Adult Hymenoptera	...	...	19	02	02	30	05	04	04	04	...	08
Unidentified Insect	33	...	32	51	16	70	70	67	74	64	...	53
Total Insect Remains	*99*	...	*83*	*97*	*98*	*100*	*96*	*99*	*100*	*100*	...	*98*
Arachnida	...	...	05	01	...	...	...	...	...	...	...	+
Mollusca	01	...	...	...	...	...	...	...	...	...	...	+
Unidentified Debris	...	...	12	...	02	...	...	...	...	...	...	02

Jan. 1. A partly digested planarian was found among the debris. The molluscan remains consisted of a single specimen of *Limax*, sp. Among the remains of larval coleoptera was found a Parnid beetle. April 11. The decapod remains consisted of the chela of a crayfish. One specimen had eaten an ant. A single representative of each of the following families was found: Hydrophilidæ, Syrphidæ, and Chalcidæ. May 23. The following families of terrestrial beetles were found in many stomachs: Carabidæ, Elateridæ and Chrysomelidæ, the former two of which were represented by individuals small enough to be swallowed entire, but had suffered from subsequent maceration. Much of the unidentified insect was also very probably the remains of beetles. The Orthoptera was represented by a single small grasshopper. June 13. Most of the Hymenoptera were chalcid flies. July 17. Four maggots were found in one stomach. Sept. 4. Several kinds of insects were present among those entered as unidentified.

Leuciscus vandoisulus Cuvier and Valenciennes
Rosy-sided Dace

The specimens of *Leuciscus vandoisulus* that were collected for this study appeared to be of normal size. Fowler ('08) gives a length of from 1¾ to 3 3/16 inches which compares well with our maximum and minimum of 6.4 and 2.0 cm., (2.11 and 1.27 inches). This species has been recorded as having a maximum length of 5.0 inches. Our series which of course included very young fish, did not include any which reached Fowler's largest. There was no particular difficulty experienced in identifying the mature specimens because of the beautiful rose red streak on the sides brought out in the preservative both on the males and females. The young which did not have this distinctive mark were easily identified by their large gape of mouth and a certain dark pigment along one of the lateral fascia which showed through the skin and scales as a diagonal dark streak from shoulder to tail. (Breder, '20, b). This well served to separate this species from the other twenty-three taken at this locality. Ripe fish about to spawn were taken in May.

At least four of the collections show two distinct modes in the frequency graphs which clearly divides the fishes into two year-classes (Breder '20, a). The group of smaller specimens represents those which hatched in the spring or summer of 1919, while that of the larger fishes were mostly of the 1918 season, a few possibly being referable to 1917. In September, examples of fish hatched in the spring of 1920, entered the collections but so far overlapped those of 1919 as to merely shift the mode a trifle and lower the minimum lengths.

No correlation appeared to exist between size and feeding habits of this species, mechanical limitations alone entering.

Analysis of Stomach Contents:—The food of this species is practically identical with that of the preceding differing only in very minor details. In this species the insects amounted to 88 per cent. and the vegetable content to only a trace, reaching only 4 per cent. in the month of its greatest amount. In these fish the diatoms and algæ also were found in an unplasmolized condition, and the unidentified debris averaged only 2 per cent.

Table No. IV *Notropis procne* Tabulation of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	26	5	37	40	61	28	27	28	9	16	7	284
Number of Empty Specimens	7	7	33	6	1	0	0	0	0	1	0	55
Modal Length (mm)	38,18	22	38	38,22	38	42,26	42,34	42	42	46,38	42	Averages
Maximum Length	52	48	52	48	52	52	48	44	44	48	48	
Minimum Length	16	16	28	20	32	24	32	32	28	32	40	
Diatoms	...	...	...	20	91	71	58	66	61	59	...	39
Filamentous algæ	...	...	...	...	01	...	26	33	01	01	...	06
Unidentified Plant Remains	...	20	...	...	...	...	...	...	...	...	...	02
Total Vegetable Matter	...	*20*	...	*20*	*92*	*71*	*84*	*99*	*62*	*60*	...	*47*
Unsegmented Worms	...	...	...	00½	01	01	...	...	...	...	...	+
Chætopoda	25	...	31	02	...	02	...	...	...	...	64	13
Larval Ephemeroptera	05	...	03	...	...	...	...	...	...	...	14	02
Nymph of Odonata	...	...	...	01	...	...	...	...	...	...	...	+
Larval Plecoptera	10	...	...	...	...	...	...	...	...	...	08	01
Larval Coleoptera	04	...	...	...	...	...	...	...	...	...	...	+
Adult Coleoptera	...	...	10	13	02	08	12	...	...	...	...	04
Larval Lepidoptera	11	...	...	...	...	...	...	...	...	...	...	01
Unidentified Insect	20	80	56	34	04	14	04	01	38	40	14	28
Total Insect Remains	*50*	*80*	*69*	*48*	*06*	*22*	*16*	*01*	*38*	*40*	*36*	*36*
Acarida	...	...	...	00½	...	...	...	...	...	...	...	+
Unidentified Debris	25	...	...	29	01	04	...	...	...	...	...	04

Jan. 1. Five fish contained parasitic worms. Feb. 1. Five specimens contained very little food, two had taken larval insects and one what appeared to be weed seed. March 14. Seven specimens held very little, one an insect larva and one was fairly full of food. The Chætopods were probably near allies of *Tubifex*. April 11. Five contained very little food, one a staphylinid beetle, while some of the worms eaten were very small. Two fish were the hosts of parasitic worms. The Acarida were represented by a few water mites in one stomach. May 23. Four specimens contained very little, one had an insect larva while two had two and three worms, respectively. Probably some of the algæ was *Voucheria*. One specimen contained sand and silt with what was probably vegetable debris. Many fish were very full. June 13. One had eaten very little. The debris was probably mostly of vegetable origin. July 17. Some of the algal remains were probably *Spirogyra*. Sept. 4. Eight specimens had ingested considerable sand. Most of the algæ was *Spirogyra*. Oct. 4. Two specimens contained sand grains.

The strongly oblique and capacious gape, (Figs. 104, 105, and 112,) suggests that this species is inclined to feed from the surface. This is well borne out by the table of foods, since in all probability the Thysanura were taken while being supported on the surface film. In aquaria it was noted that this cyprinoid tended to keep nearer to the surface than any of its associates.

In the specimen which had taken a larval caddis fly was found a small amount of detritus which was absent from the remaining specimens, 294 having been examined. This suggests that bottom feeding is only occasional. As in *Semotilus*, it is quite evident that the only regular bottom feeding was performed in the winter months with the exception of the above mentioned caddis fly and a dragon fly nymph taken in September. The low temperature and lack of food at the surface probably caused the descent of this species although some food could, no doubt, have been taken at times as it was released from melting blocks of ice as they drifted down stream.

Lighter feeding in winter is not indicated by the number of empty stomachs or their distribution in time, although if this species had been taken in February and December such a condition might have been suggested. Attention is called to the possibility of a semi-hibernation or dormancy, because no specimens were taken on the two collecting days which were most cold.

Notropis procne (Cope) DELAWARE MINNOW

The examples of *Notropis procne* which were collected ranged in length from 1.6 to 5.2 cm. Fowler ('08) gives their lengths as reaching up to 2 11/16 inches which is a little in excess of what our maximum examples showed. It was easily distinguished from any of the other species which we took. However, we carefully scrutinized each specimen in order to exclude *N. bifernatus* which has not been recorded from this region, but has been taken in Maryland, just north of the District.

Five collections show what appears to be a double mode but the overlapping of the extremes is so great that it quite obscures any attempt to read the age of the various groups from such data alone. There is no differentiation of food with the advance in size.

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	10	0	53	43	28	41	46	12	12	10	10	265
Number of Empty Specimens	1	0	20	5	0	0	0	0	0	0	0	26
Modal Length (mm)	54	...	54,30	26	38	54,34	38	42	42,30	58,30	...	Aver-
Maximum Length	60	...	84	56	56	56	64	60	52	68	96	ages
Minimum Length	28	...	20	20	24	28	32	24	24	24	36	
Diatoms	...	...	...	...	94	05	15	77	33	29	...	25
Filamentous Algæ	...	...	...	...	...	...	27	08	+	38	...	07
Unidentified Plant Remains	...	...	...	...	...	03	06	...	...	...	04	01
Total Vegetable Matter	...	...	...	...	*94*	*08*	*48*	*85*	*33*	*67*	*04*	*33*
Unsegmented Worms	...	...	...	...	+	...	...	...	...	...	...	+
Chætopoda	08	...	01	01	...	...	...	...	...	...	04	02
Larval Ephemeroptera	42	...	06	...	...	...	...	...	...	...	21	07
Odonata Nympth	...	...	05	...	...	...	...	...	...	...	...	+
Larval Plecoptera	10	...	08	...	...	...	...	...	...	...	...	02
Larval Coleoptera	...	...	...	...	...	...	...	...	...	...	02	+
Adult Coleoptera	...	...	04	...	04	30	16	...	21	...	07	08
Larval Diptera	...	...	...	...	...	...	...	...	...	...	02	+
Adult Hymenoptera	...	...	04	...	...	03	02	...	04	...	...	01
Unidentified Insect	40	...	70	36	01	59	32	15	42	33	60	39
Total Insect Remains	*92*	...	*97*	*36*	*05*	*92*	*50*	*15*	*67*	*33*	*92*	*57*
Acarida	...	...	...	...	01	...	...	...	...	...	...	+
Unidentified Debris	...	...	02	63	...	...	02	...	...	...	...	08

Jan. 1. No correlation between size and food eaten could be found in this month's series, or in any of the others. Feb. 14. Very little had been eaten by fourteen specimens, three had taken gomphid nymphs, three had eaten ants, and one contained an unidentified insect larva. April 11. One had taken very little food. Most of the food was found in the posterior part of the intestine; which suggests that it had not been feeding recently, the time of collecting being 1:45 to 5:30 P. M. on a cloudy day. May 23. One specimen had taken very little. Three families of beetles were recognized: Staphylinidæ, Scarabaeidæ, and Chrysomelidæ. A single specimen of Rhynchophora was present. In several cases the chlorophyl from the plants ingested was visible through the thin body walls of small specimens. June 13. One specimen was extremely distended with food. Five contained parasitic worms; two some sand and mud, and one a single specimen of some species of Ichneumonidæ. July 17. One specimen had taken very little and two held three parasitic worms each. Some of the algæ was probably *Spirogyra*. Oct. 4. One held two parasitic worms and another some sand grains. Nov. 7. Three had taken very little food. Dec. 5. Four had eaten very little and one had four parasitic worms. The larval Coleoptera remains consisted of one parnid beetle.

Analysis of the Stomach Contents:—It may be seen at a glance that the feeding habits of this species are somewhat different from those of the two preceding forms. Here the vegetable remains exceed those of the insect, the respective percentages being 47 and 36. Also, the comparatively large amount of sand indicates a bottom feeding habit. In aquaria this was not observed to be especially noticeable, since most of the specimens kept well up in the middle water. The rather subterminal mouth does not suggest that these fish are bottom feeders to a much greater extent than *Semotilus,* although the food points strongly to that conclusion.

The number of empty stomachs and the months in which they were found indicates that this species also feeds less heavily in the winter than at other times.

Notropis cornutus (Mitchill) REDFIN

Our specimens of this species varied in length from 2.0 to 9.6 cm. According to Fowler ('08) this species appears to reach a length of about twice that of our largest. Many of our larger specimens were breeding fish. All above 4.0 cm. were mature while all those of less length were juvenile. In the frequency graph this point coincides with the gap or point of greatest depression between two modes when such were distinctly present. Collections in which only one mode was evident a few scattering specimens were always to be found on the other side of this line of demarcation. Obviously there were two year-classes represented here, and the group of smaller specimens was evidently from the spawning of the previous year, while the mature fish had passed through two or more winters. Here we have the same length of time required to reach maturity as was found necessary for *Leuciscus.* Ripe fish about to spawn were taken in May.

No correlation between size and the food taken could be found.

Analysis of Stomach Contents:—This species feeds upon about twice as much insect as vegetable matter. Judging from specimens in aquaria, they seem to be given to rather promiscuous feeding. As observed in captivity, they were noted to rise to the surface with both the force and grace of a trout although they seemed also to be quite adept at securing food from the bottom.

Table No. VI *Rhinichthys atronasus* Tabulation of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	31	1	7	25	18	4	24	16	21	37	7	191
Number of Empty Specimens	15	1	7	23	2	3	4	0	6	1	4	66
Modal Length (mm)	42, 22	...	...	42, 22	...	...	38	38	38	26	42	Aver-
Maximum Length	48	28	56	48	48	44	44	48	44	48	48	ages
Minimum Length	16	20	16	16	24	24	28	24	20	20	20	
Diatoms	...	...	...	...	55	...	01	90	57	40	...	22
Filamentous Algæ	...	...	...	...	01	...	01	...	01	17	...	02
Unidentified Plant Remains	...	...	...	...	...	...	01	...	...	...	...	+
Total Vegetable Matter	...	...	...	...	*56*	...	*03*	*90*	*58*	*57*	...	*24*
Chætopoda	10	...	...	...	...	...	...	...	...	22	04	04
Larval Ephemeroptera	03	...	...	...	...	...	...	...	...	...	...	+
Larval Plecoptera	11	...	28	...	...	...	...	...	...	...	14	05
Larval Trichoptera	...	...	...	16	...	...	...	...	...	...	14	02
Larval Coleoptera	...	...	...	...	...	...	...	...	...	...	10	01
Adult Coleoptera	02	...	...	04	22	...	...	09	04	...	...	04
Larval Lepidoptera	...	...	22	...	...	...	...	...	...	...	...	02
Adult Diptera	...	...	...	04	...	...	...	...	...	...	...	+
Adult Hymenoptera	01	...	...	...	...	...	...	...	...	...	...	+
Unidentified Insect	53	...	35	64	22	100	86	01	33	21	58	43
Total Insect Remains	*70*	...	*85*	*88*	*44*	*100*	*86*	*10*	*37*	*21*	*96*	*57*
Arichnida	01	...	...	...	...	...	...	...	...	...	...	+
Unidentified Debris	19	100	15	12	...	...	11	...	05	...	...	15

Jan. 1. Three contained unidentified insect larvæ and among the debris was a worm which evidently was not an annelid. March 14. Two specimens contained parasitic worms and one sand grains. April 1. Eight specimens contained very little; one an aquatic beetle; five contained parasitic worms; two unidentified insect larvæ. One fish was blind in the left eye. May 23. One contained very little; five contained parasitic worms; among the diatomaceous remains were noted a very few desmids. (Not listed in the table.) June 13. One contained very little food. July 17. Six contained very little food and two contained parasitic worms. Sept. 4. Six contained parasitic worms; one very little food; one sand grains. Oct. 4. One held parasitic worms and four unidentified insect larvæ, and three held sand grains. Nov. 7. Three contained sand grains. Dec. 5. One contained very little and one contained parasitic worms. Some of the unidentified insect remains was probably Coleoptera.

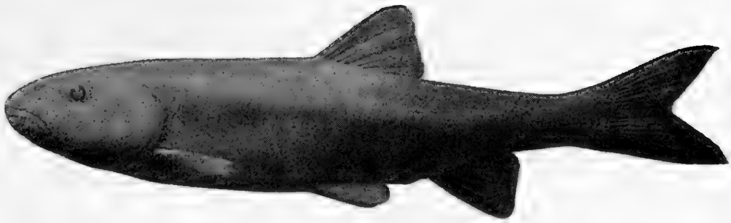

FIG. 103. *SEMOTILUS BULLARIS*
Standard length 12.0 cm.

FIG. 104. *LEUCISCUS VANDOISULUS*
Standard length 6.3 cm.

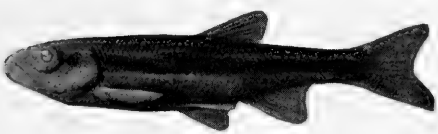

FIG 105. *LEUCISCUS VANDOISULUS,* imm.
Standard length 3.8 cm.

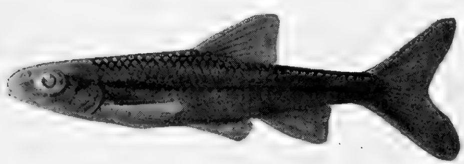

FIG. 106. *NOTROPIS PROCNE*
Standard length 4.6 cm.

FIGS. 103-106. FISHES FROM OXON RUN

FIG. 107. *NOTROPIS CORNUTUS*
Standard length 9.0 cm.

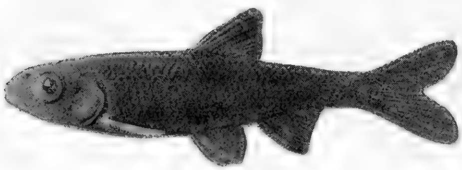

FIG. 108. *NOTROPIS CORNUTUS*, imm.
Standard length 5.3 cm.

FIG. 109. *RHINICHTHYS ATRONASUS*
Standard length 3.9 cm.

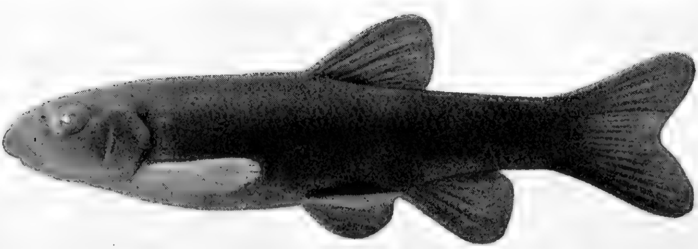

FIG. 110. *EXOGLOSSUM MAXILLINGUA*
Standard length 6.3 cm.

FIGS. 107-110. FISHES FROM OXON RUN

The percentage of empty stomachs and the months in which they occurred, in this case also, indicates a cessation of active metabolism during the cold season.

Rhinichthys atronasus (*Mitchill*) BLACK-NOSED DACE

This readily recognized species required close examination only to prevent the possibility of confusing it with *R. cateractæ,* which, however, was not taken in any of our collections. Our specimens varied in length from 1.6 to 5.6 cm. Fowler ('08) found his maximum to be 3½ inches, which is somewhat larger than ours. The smallest mature fish had a length of 3.0 cm. although a few above that size were immature. The two collections showing double modes on the frequency graphs presented the point of greatest depression between them at approximately the 3.0 cm. point. However, the overlapping of the year-classes was so great that very little information could be deduced therefrom. Nothing except the fact that more than one year-class was present could be satisfactorily determined.

Analysis of Stomach Contents:—This species appears to be intermediate in feeding habits between *Semotilus* and *Leuciscus* on one hand and the two species of *Notropis* on the other, the vegetable and insect remains appearing as 24 and 61 per cent. respectively. The unidentified debris amounted to a considerable quantity, constituting the remaining 15 per cent.

The number of fish which were not feeding before the time of capture roughly suggests a lighter feeding in the colder months.

This species was the most heavily infested with intestinal parasites, although the fish seemed to show no ill effects from the presence of these worms since they were uniformly fat and healthy in appearance. In all, 22 examples out of the 257 specimens that were examined contained one or more parasites.

The vegetable remains were found to be almost exclusively in an unplasmolized state.

Specimens in the aquarium appeared to feed almost indifferently from either the bottom or middle of the tank, and occasionally rose to the surface.

Table No. VII *Exoglossum maxillingua* Table of Stomach Contents

Date Taken	Jan. 1	Feb. 1	Mar. 14	Apr. 11	May 23	June 13	July 17	Sept. 4	Oct. 4	Nov. 7	Dec. 5	Totals
Number of Full Specimens	0	0	2	3	9	20	9	4	1	9	2	59
Number of Empty Specimens	3	0	6	1	1	2	0	1	0	1	1	16
Modal Lengths (mm)	...	...	...	...	30	30	38	38	...	42	...	Aver-
Maximum Length	44	...	52	52	48	58	56	44	25	60	64	ages
Minimum Length	28	...	24	20	24	28	32	36	...	24	36	——
Diatoms	...	...	...	...	26	05	11	37	...	...	...	08
Filamentous Algæ	...	...	...	...	+	...	...	...	...	...	...	+
Unidentified Plant Remains	...	...	...	...	...	...	55	...	...	...	...	07
Total Vegetable Matter	...	...	...	...	*26*	*05*	*66*	*37*	...	...	...	*15*
Chætopoda	...	...	50	...	22	57	...	13	...	23	100	30
Adult Coleoptera	...	...	...	...	08	...	...	...	...	...	...	01
Unidentified Insect	...	...	50	67	22	33	12	50	...	77	...	34
Total Insect Remains	...	...	*50*	*67*	*30*	*33*	*12*	*50*	...	*77*	...	*35*
Fish Ova	...	...	...	...	...	05	...	...	...	...	...	+
Unidentified Debris	...	...	...	33	22	+	22	...	100	...	...	20

March 14. Two specimens contained parasitic worms. The annelids were possibly *Tubifex,* or an allied species.

June 13. The fish eggs were represented by the ova of some small fish, probably a cyprinoid. In the same stomach were also several other ovate bodies, which were probably parasitic cysts. Two other stomachs contained parasitic worms. Some of the unidentified debris was probably of vegetable origin and some of the unidentified insect remains was probably Coleoptera.

July 17. One contained very little food. Some of the debris was probably of vegetable origin. In two stomachs there was sand in quantity equal to that of the food.

Sept. 4. Three contained sand.

Nov. 7. A larva was among the unidentified insect remains.

Dec. 5. One of the worms was a *Lumbricus.*

Judging from the relative frequency of Chætopods, Mayfly, and Stonefly larvæ, these fish feed more frequently from the bottom in the colder months, in a manner comparable to the behavior of the other species.

Exoglossum maxillingua (Le Sueur) Cut-lips

This unique and striking species presented no difficulty to identification in any way, the peculiar three-lobed mandible being entirely sufficient to at once isolate the species. The lengths of the specimens of our series varied from 2.0 to 6.4 cm. Fowler's ('08) maximum or 4⅞ inches (12.38 cm.) was about twice that of ours, although many of the latter were adult and in breeding condition. This cyprinoid has been recorded as reaching a length of 6.0 inches (15.24 cm.). The smallest mature fish was 4.3 cm. and the largest immature specimen was 5.8 cm. This excessive overlapping of the year-classes together with the unfortunate paucity of the collection precluded drawing of any conclusions as to age.

Analysis of Stomach Contents:—Something decidedly different in the food of this species might be expected judging from the peculiar formation of the lips, (Figs. 110 and 116). However, this was not found to be so, as practically all of the food of this species was similar to that taken by the others. The large amount of debris and vegetable matter suggests that these fish were primarily bottom feeders. In the aquarium, this was observed to be the case, the specimens for the most part poking around in little nooks and crannies among the rocks and negotiating with difficulty all but the smallest particles of food. However, they were seen to rise occasionally to the surface as small particles of food were descending through the water.

In this case, also, feeding was less heavy during the winter season. In those specimens which contained diatoms, the diatoms appeared partly digested.

Discussion

Comparison of Foods:—Table No. VIII shows the foods of each species for the year side by side to facilitate comparisons.

Table No. VIII

Showing averages of foods taken by each species for entire collection
(Comparison by percentage)

FOOD	*Semotilus*	*Leuciscus*	*N. procne*	*N. cornutus*	*Rhinichthys*	*Exoglossum*
Diatoms	02	+	39	25	22	08
Filamentous algæ	+	+	06	07	02	+
Unidentified plant remains	02	—	02	01	+	07
Total vegetable matter	*05*	+	*47*	*33*	*24*	*15*
Unsegmented worms	—	—	+	+	—	—
Chætopoda	01	+	13	02	04	30
Decapoda	01	+	—	—	—	—
Diplopoda	01	—	—	—	—	—
Adult Thysanura	—	+	—	—	—	—
Larval Ephemeroptera	01	06	02	07	+	—
Odonata nymph	—	+	+	+	—	—
Larval Plecoptera	02	02	01	02	05	—
Larval Trichoptera	—	+	—	—	02	—
Adult Orthoptera	—	+	—	—	—	—
Larval Coleoptera	+	02	+	+	01	—
Adult Coleoptera	30	20	04	08	04	01
Larval Lepidoptera	01	+	01	—	02	—
Crysilid Lepidoptera	+	—	—	—	—	—
Larval Diptera	01	—	—	+	—	—
Adult Diptera	06	07	—	—	+	—
Adult Hymenoptera	03	08	—	01	+	—
Unidentified insect	43	53	28	39	43	34
Total insect	*87*	*98*	*36*	*57*	*57*	*35*
Acarida	—	—	+	+	—	—
Arachnida	—	+	—	—	+	—
Mollusca	—	+	—	—	—	—
Fish	+	—	—	—	—	—
Fish ova	—	—	—	—	—	+
Unidentified debris	05	02	04	08	15	20

The table clearly indicates that all of the species are rather insectivorous. Hymenoptera and Diptera were represented mostly by various minute chalcid flies and midges. Lepidoptera were represented by the larvæ of Geometridæ. All of the insects with few prominent exceptions were terrestrial species which evidently had fallen into the water.

Table No. IX shows in still more epitomized form to what degree each species was carnivorous. The species have been arranged in this table with the most carnivorous coming first. A superficial examination of this table no doubt would suggest to

Table No. IX

Showing degree to which each species is carnivorous
(Comparison by percentage)

SPECIES	Animal	Vegetable plus debris	Insect	Other animal	Vegetable	Debris
Leuciscus	98	02	98	trace	trace	02
Semotilus	90	10	87	03	05	05
Exoglossum	65	35	35	30	15	20
Rhinichthys	61	39	57	04	24	15
N. cornutus	59	41	57	02	33	08
N. procne	49	51	36	13	47	04

the reader that *N. procne* was decidedly vegetarian, the others somewhat so, but to a lesser degree, progressing upward toward *Leuciscus* which shows only 2 per cent. of vegetable matter and debris combined, for the whole year.

However, since most of the vegetable matter was found to have been undigested and all of these species have a short digestive tract and decidedly raptorial pharyngeal teeth, it seems unlikely that *N. Procne* or any of the other species are intentionally vegetarian. It must be noted, however, that in the case of *N. procne* the pharyngeal teeth present a greater grinding surface than in any of the other species, a few of the teeth being simply obliquely truncated cylinders. (Fig. 119).

The lack of vegetable matter in *Leuciscus* and *Semotilus* is easily explained by assuming that they feed above the bottom, as was pointed out in the individual treatments, pages 301 and 295 respectively. Also, the presence of considerable vegetation in the stomachs of *Exoglossum* and *Rhinichthys* may be explained by their known habit of nosing around near the bottom. All considerations point respectively to such habits of these four species: the food, the structure of the mouth, and the habits as observed in the aquarium.

However, in the case of *N. cornutus* and *N. procne* it is another matter. The trout-like grace of *N. cornutus* in no way suggested a typical bottom feeding fish, although a relatively large amount of plant and vegetable debris was found in this species.

Table No. X

Specimens containing no food by months
(Comparison by percentage)

SPECIES	January	February	March	April	May	June	July	September	October	November	December
Semotilus	11	66	51	11	00	00	20	00	00	00	25
Leuciscus	09	—	00	01	02	00	09	00	11	00	—
N. procne	22	58	47	13	02	00	00	00	00	06	00
N. cornutus	09	—	27	10	00	00	00	00	00	00	00
Rhinichthys	32	50	50	46	10	43	14	00	22	03	36
Exoglossum	100	—	75	25	10	09	00	05	00	10	33

In the case of *N. procne,* the only suggestions of bottom feeding were the very slightly inferior mouth and the rather prominent grinding surfaces of the pharyngeal teeth.

These considerations taken as a whole are not convincing that these fish are partly vegetarian. The impression left by this study was that most if not all of the vegetable matter was ingested accidentally along with the invertebrates which are usually associated with diatoms and filamentous algæ. The presence of these plants in such quantities can be explained by the fact that peristalsis in these fishes depends largely upon the mechanical action of forcing the food backwards as more food is eaten and consequently digestion is rather a slow process. Owing to this, the presence of the silicon and cellulose covered cells, of diatoms and algæ, for a more or less protracted period would be expected. Furthermore even the chitonous parts of insects can be discerned at times even in the excrement of these fishes.

In view of the fact that none of the vegetable matter seemed to have been acted upon by digestive juices, with the possible exception of diatoms in some specimens of *Exoglossum* previously noted (page 307), it seems to be an unwarranted conclusion from the examination of the stomachs of these fishes that they are vegetarian, or derive any perceptible amount of nourishment from vegetation ingested.

These fishes appear to be very adaptable to changing conditions of food and feeding. In an aquarium they take anything and everything that is given to them, living or dead, both the food which might possibly have been taken in their native haunts and that which it would have been impossible for them to secure under ordinary conditions, i.e., unnatural foods, such as boiled egg, shredded wheat, cooked meat, boiled potatoes, et cetera.

It is easily demonstrated by means of simple experiments that these minnows will snap at any small particle alighting upon the surface of the water, or settling to the bottom. Whether or not the particle is ingested seems to depend upon its physical properties. To the fish it seemed to be immaterial whether one kind of food or another was presented provided it was of proper size.

"It seems likely to be a general rule," Forbes has written, ('80), "that a fish makes no more than a *mechanical* selection from the particles of food accessible to it, taking almost indifferently whatever edible things the water contains which its habitual range and its peculiar alimentary apparatus enables it to appropriate, and eating of these in about the ratio of their relative abundance and ease with which they can be appropriated at any time and place." The positive identification, therefore, of the different constituents of the food is of small importance when carried beyond a certain point.

The following tabulation seems to include all factors directly concerned with the act of taking food.

EXTRA ORAL

I. Habitat of food.

A. Geographical distribution.
The *ranges* of the food and feeder must overlap. This is necessary for "B" to be possible.

B. Exact, or local position.
The exact local habitats of the food and feeder must overlap and finally the individual feeder, and food unit must be in proximity.

II. Size and condition of food.

A. Limitations.

Upper. Too large to be swallowed and unsuitable for nibbling into small pieces.

Lower. Too small, or well concealed to be perceived by any of the sense organs.

INTRA ORAL

I. Tactile and taste reactions.

A. Tactile limitations.

Upper. Hard, sharp, rough, unmasticatable.

Lower. Soft, flocculent, "melting in mouth." Such food is not rejected intentionally, but most of it usually escapes through the operculum.

B. Taste seems to be unimportant since strongly medicated food only is rejected, and then not always.

Table No. X showing the percentages of empty stomachs for the various months, which by comparison with Table No. I demonstrates lighter feeding for all species during the three coldest months, January, February, and March. In February, only three of the species were represented in our collections which suggests hibernation or a secretive habit during the extreme cold weather. There appears to be no cessation of feeding in any case during the spawning season which in all species was indicated as extending from sometime in April to well into the summer.

Little can be said of the high percentage of empty stomachs in the series of *Rhinichthys* in June since it was composed of only seven specimens.

The general feeding habits of these six species appears to be remarkably similar even as much, or more so, than their anatomical structures. It is rather striking that so many members of the same family of fishes should become suitably adapted for survival in the same localities and still retain their specific identity, although in many cases the young were difficult to differentiate. It seems that all fill practically the same ecological niche and very likely we have here a case of intra-family convergence, rather than divergence from a recent common prototype.

Comparison of Alimentary Tracts

On the whole, there is no vast difference between the alimentary structures of the six species under consideration. However, the minor details vary considerably as shown by the dissections, (Figs. 111-116).

In making these dissections, the body wall of the left side was removed by cutting it through along a median line from the vent forward to a point just posterior to the cardiac cavity, from whence it was passed diagonally upward to a point dorsal of the pharingeals, thence following back just ventrally of the gonads to the vent. In this way, only the visceral cavity was laid open, the heart, gonads and air bladder and kidneys remaining hidden. Two perpendicular cuts were made; one above, and one below the oral cavity extending from the snout to the opened visceral cavity. Between these two cuts, all substance was removed down to the median plane, thus showing the mouth and pharynx in true cross section. In making the semi-diagramatic sketches all unnecessary detail was omitted for the sake of clarity. Thus the structures above and below the buccal cavity are indicated simply by conventional cross-hatching, as is likewise the pelvic girdle.

The intestine, in all cases a simple tube containing a single sigmoid flexure, was spread out somewhat. That is, the forward arm was drawn down and the posterior one upward. By simply swinging them up and down respectively to a nearly horizontal position and allowing their distal ends to act as fulcra, the normal location of the parts can be found. The forward arm would thus lie to the right and the posterior two to the left, one above the other. The liver with its two lobes drops curtain-like to either side of the intestine. Their derangement has been trivial, but slightly different in most of the sketches in order to show the parts to their best advantage.

The representation of all mesentary membranes and fat has been omitted in order that the details which the drawings were designed to show might not be obscured. Lettering of the parts also has been omitted since the shape and locations of the organs together with the descriptive text following is sufficient explanation.

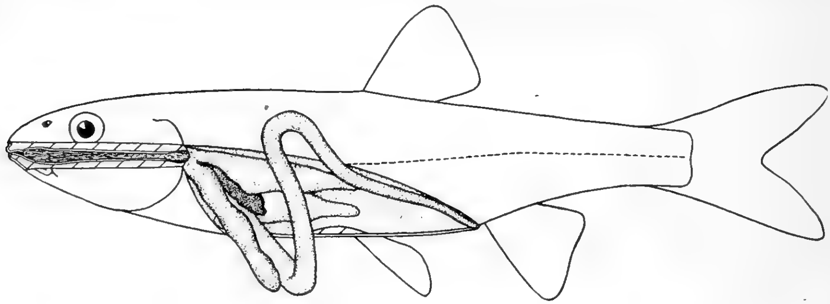

FIG. 111. *SEMOTILUS BULLARIS*
Standard length 12.0 cm.

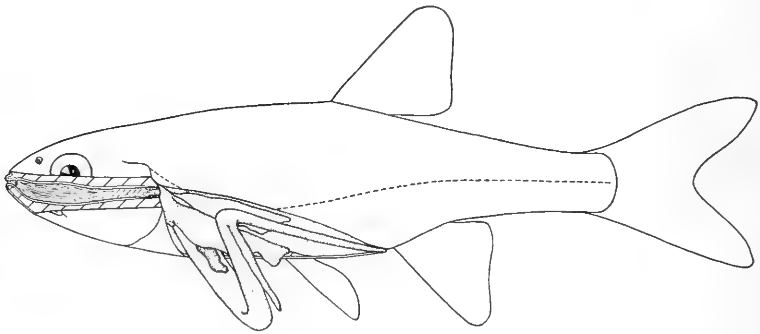

FIG. 112. *LEUCISCUS VANDOISULUS*
Standard length 6.3 cm.

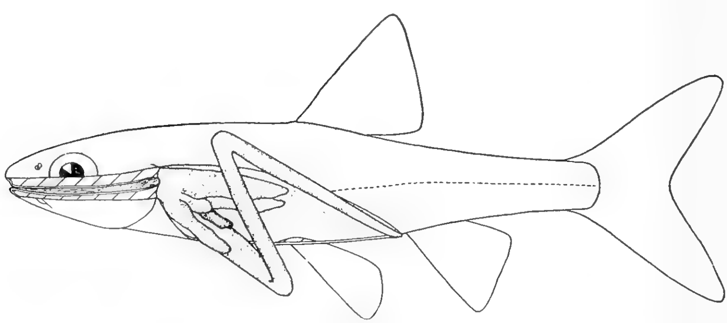

FIG. 113. *NOTROPIS PROCNE*
Standard length 4.6 cm.

FIG. 111-113. VISCERAL DISSECTIONS

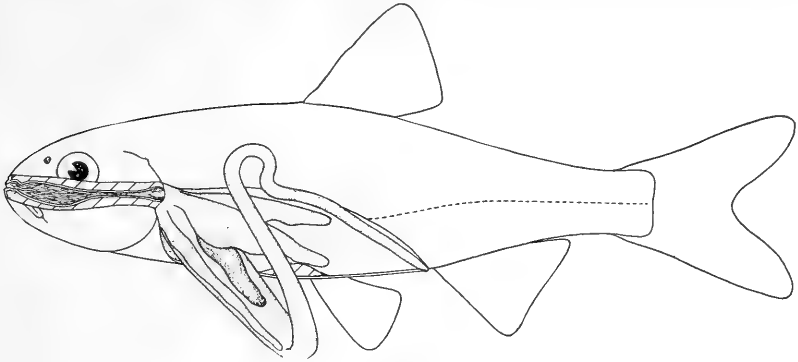

FIG. 114. *NOTROPIS CORNUTUS*
Standard length 9.0 cm.

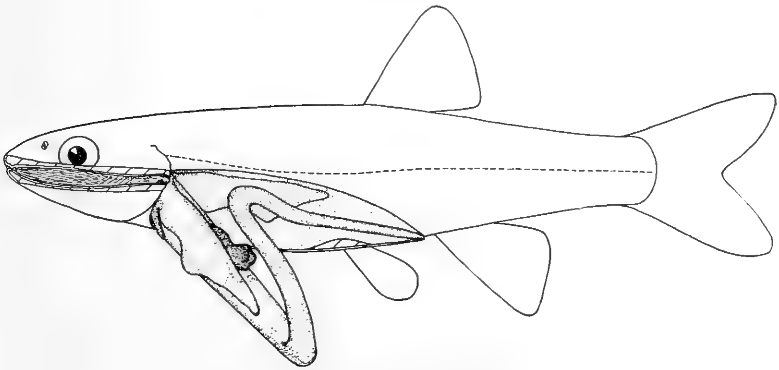

FIG. 115. *RHINICHTHYS ATRONASUS*
Standard length 3.9 cm.

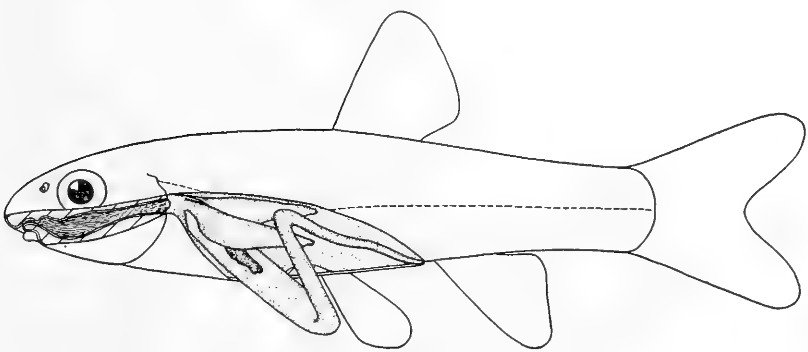

FIG.116. *EXOGLOSSUM MAXILLINGUA*
Standard length 6.3 cm.

FIGS. 114-116. VISCERAL DISSECTIONS

For those readers who are not familiar with the internal anatomy of this group of fishes, it should be mentioned that the stomach is simply the widened anterior arm of the tube extending from gullet to vent, while the posterior portions are considered as intestine. The two-lobed liver (shown by light stippling) is attached to the anterior end of the stomach and the spleen, in all cases a small body (shown by dark stippling) is attached further back. The gall bladder is embedded in the liver and not shown. The pancreas in all cases (also shown in light stippling) lies ventrally to the stomach and it is bound to it with mesentary and is so embedded in fatty tissue that it is hard to differentiate. In all cases, except one, the point of attachment to the stomach wall was at its forward end. In *Leuciscus,* it was apparently attached at the first bend of the sigmoid flexure. However, this is a debateable point and in reality it may have been attached similarly to the others, although the drawing was made as shown only after many specimens were opened.

The structure of the mouth, its inclination and general conformation, are here, as in many other groups of animals, a very fair index to the food and feeding habits. The only species in which the mouth can be considered properly other than terminal are *Exoglossum, Rhinichthys* and *Notropis procne.* However, in the latter two, the mouths are very nearly terminal. The buccal cavity is much alike in all of them, being lined with an epithelium of the same general structure throughout. The most pronounced variation in this respect is in the odd formation of the mandible of *Exoglossum* which is so modified that it is divided into three lobes, the central one alone pressing firmly to the upper jaw. (Fig. 116).

There is some similarity in the pharyngeal teeth in all of the species. The comparative drawings show that the greatest difference in number of teeth between any two species is three. Most of the teeth are decidedly raptorial, with small grinding surfaces. The greatest variation is seen in *N. procne* in which some of the teeth are blunt and flat across the end with a fairly well developed grinding surface.

It should be noted here that the teeth were held in various positions to show the shape and number of teeth to the best


FIG. 117. *SEMOTILUS BULLARIS*
Standard length 5.5 cm.


FIG. 118. *LEUCISCUS VANDIOSULUS*
Standard length 5.7 cm.


FIG. 119. *NOTROPIS PROCNE*
Standard length 4.9 cm.


FIG. 120. *NOTROPIS CORNUTUS*
Standard length 7.6 cm.


FIG. 121. *RHINICHTHYS ATRONASUS*
Standard length 4.4 cm.


FIG. 122. *EXOGLOSSUM MAXILLINGUA*
Standard length 3.9 cm.

FIGS. 117-122. PHYRANGEAL TEETH
Diameter of black disc = 1. cm.

FIG. 123. *SEMOTILUS BULLARIS*
Standard length 4.2 cm.

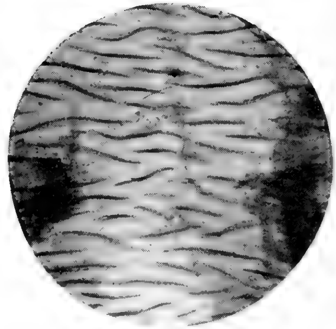

FIG. 124. *LEUCISCUS VANDIOSULUS*
Standard length 4.0 cm.

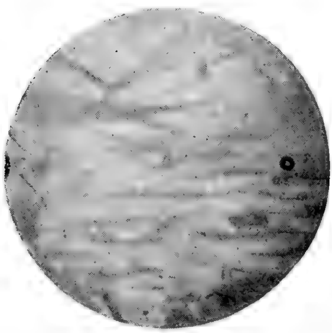

FIG. 125. *NOTROPIS PROCNE*
Standard length 39 cm.

FIG. 126. *NOTROPIS CORNUTUS*
Standard length 4.0 cm.

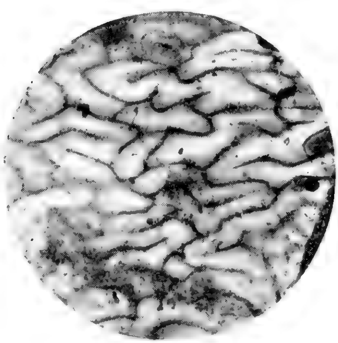

FIG. 127. RHINICHTHYS ATRONASUS
Standard length 4.0 cm.

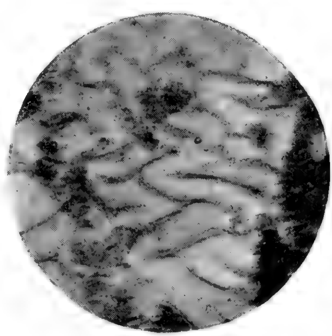

FIG. 128. *EXOGLOSSUM MAXILLINGUA*
Standard length 4.0 cm.

FIGS. 123-128. INTESTINAL WALLS. 28X

advantage in each case.[2] This causes foreshortenings of the supporting pharyngeal bones in various ways, depending upon the angle from which they were viewed. In all cases the pharyngeal bones must bear the same relation to each other in order to accomplish their purpose of masticating the food, but their shapes depend upon the correlated differences of other related anatomical parts.

The stomach, or first arm of the digestive tract, is very similar in all cases, being a simple, nearly straight tube capable of considerable distention, and normally extending to a point slightly past the pelvic girdle. At its anterior end, the liver and pancreas are attached, except in *Leuciscus* in which the latter appears to be attached to the second flexure of the tube, as previously noted, although when the disarranged viscera are re-assembled it seems probable that this organ may be attached to either or both points since they are appressed closely in life. In this position, what appears to be the free end of the pancreas is brought in apposition to a possible point of attachment similar to that of the organ in the other species. In *Rhinichthys* and *Exoglossum* the pancreas appears to be reduced to a small, almost indistinguishable mass. The liver on the left side extends forward of the digestive tract in life and infolds it. The spleen is practically identical in all of the species, except for size and shape, both of which seem to be quite variable in individuals.

The differences in length of the alimentary tracts are too small to be used as an index of food habits. However, the two species of the single genus *Notropis* have the longest tracts. In the case of *N. cornutus* the tube has various curves and bends while that of *N. procne* is made up of three rectilinear sections. *Semotilus* and *Rhinichthys* follow in the order named and *Leuciscus* and *Exoglossum* possess the shortest digestive tracts. The lengths of all are characteristic of carnivorous fishes.

Heinrich Rathke ('24) recognized folds on the intestinal walls of certain European Cyprinoids similar in a general way to those of these species, illustrated by (Figs. 123-128). His list includes *Cyprinus gobio, C. jesus, C. aspius, C. vimba,* and *C. caras-*

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[2] The accompanying wash drawings were modified from line drawings made through the camera lucida applied to a low power microscope. The teeth were removed carefully and cleansed, after which they were placed on a block of black parafin, which held them in any desired position and formed a contrastive background.

sius. Our figures of the intestinal walls of *Leuciscus, N. cornutus,* and *N. procne* appear to represent one type of folds which under low magnification give an effect somewhat similar to that of the herring-bone weave of cloth. These evidently are the "Zickzack falten" of Rathke. *Rhinichthys* and *Exoglossum* represent another type in which the folds anastomose to a great extent. These folds can be traced for a considerable distance along the top of the ridges without coming to a blind end. This is markedly different from the short, straight, or curved folds of the former three. *Semotilus* represents a still different formation. Here the ridges for the most part are short and heavy, and in many instances they are branched but are not anastomosing in any sense of the word. While these absorptive folds fall into three general groupings, each is distinctive and would serve as a character separating at least these six species.

Each of the figures[3] (123-128) represents a small piece of the intestinal wall taken from a point just posterior to the second angle in the modified sigmoid flexure of the intestinal tract. All of these sections were taken from as nearly similar places as possible and from specimens of about the same size in order to make as close comparisons as desirable.

Thus it is seen that the similarity of these six species extends to their alimentary structures and food. This fact, as previously pointed out, furnishes an illustration of the well-known principle that organisms living in the same environment and under similar conditions tend to develop similar habits and converge in details of their anatomical structures. It seems unlikely that this similarity is due to a divergence from a single ancestral type since these fishes are coexistant in the same locality and subject to the same conditions.

Fish Cultural Significance of These Cyprinoids

By study of the accompanying tables, listing the foods of the six species dealt with in this paper, the conclusion is drawn that these species, at least while they are young, will not destroy the

[3] The photographs are not all that could be desired, since it was found to be impracticable to thoroughly remove the mucus without destroying the ridges. However, the usefulness of the illustrations is not impaired. Alcoholic specimens were used. After the material had been cleansed as well as possible the pieces were immersed in glycerine to clear the tissue a trifle. The photomicrographs were taken with the aid of an Edinger projector, owned by the Bureau of Fisheries.

young of important food and game fishes. However, it is pointed out that insects and other small animals enter into the diet of all small fishes to a certain extent, and in so far as they do, therefore, these minnows must compete with all other fishes of a similar size and habitat. Nevertheless, it is difficult to overestimate the importance of these cyprinoids to fish culture. No doubt continued success in the cultivation of basses, crappies, and other species in ponds might be greater if suitable food could be provided for the growing fish and thus check their well-known cannibalistic tendencies. Similar difficulties in stocking streams with the various salmonoids might be overcome to a large extent by providing them with minnows for food.

All of these cyprinoids are not of equal value in practice and due regard for their variations in habit must be taken into consideration. For instance, if a stream is found to be suitable in every way for the introduction of trout, except that it is deficient in natural food, the deficiency might be overcome by introducing some of the smaller species of cyprinoids, such as *Exoglossum maxillingua,* or *Rhinichthys atronasus,* which are found in clear, rather swift streams. Other species are better adapted to a lacustrine habitat, such as *Semotilus bullaris,* or *S. atromaculatus.* In view of the fact that *S. bullaris* is predatory and sometimes reaches a length of thirteen inches and a weight of a pound or more, this species should be introduced with caution.

Since very little has been recorded concerning the rate of growth of these cyprinoids, success in propagating them in large quantities for fish food is problematical. It is known that some of the species will spawn in aquaria and that the young when reared with small tropical fishes will become adapted to the warm water conditions necessary for the latter. This suggests a method of procedure in stocking a pond with minnows, but the details of the experiment must be worked out for each species under local conditions.

There is no reasonable doubt that a pond may be stocked successfully with minnows provided that they are suitable. Brood stocks should be available in many places since these minnows are widely distributed and generally easily captured with a small seine. The suitability of a species selected for introduction will depend, of course, upon the similarity of its natural habitat to

Table No. XI

List of Species Taken at Oxon Run During 1920

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Sept.	Oct.	Nov.	Dec.	Totals
1. *Lampetra wilderi*, J. & E. ..... (s)	0	1	0	0	0	0	1	0	0	0	1	3
2. *Catostomus commersonii* (Lac.) (s)	0	0	2	0	1	17	4	8	0	0	6	37
3. *Catostomus nigricans*, Le S. (m, s)	1	4	1	0	20	0	5	2	4	3	2	16
4. *Erimyzon sucetta oblongus* (Mitch.) (s)	1	1	0	0	2	0	2	0	0	0	1	5
5. *Hybognathus nuchalis*, Agassiz ..	0	0	0	0	0	0	0	0	0	2	0	2
6. *Pimephales notatus* (Raf.)	0	0	0	0	0	0	0	0	0	2	1	3
7. **Semotilus bullaris (Raf.)**.........	114	18	45	27	34	12	5	24	2	2	15	298
8. *Semotilus atromaculatus* (Mitch.)	1	1	6	1	0	0	2	0	1	1	0	13
9. ***Leuciscus vandoisulus*, C. & V....**	33	0	8	82	57	10	21	45	26	11	0	294
10. *Abramis crysoleucas* (Mitch.)	2	0	0	0	0	0	0	0	0	0	0	2
11. **Notropis procne (Cope)**.........	33	12	70	46	62	28	27	28	9	17	7	339
12. *Notropis whipplii* (Girard) ... (s)	1	0	0	0	0	0	0	0	2	0	0	3
13. *Notropis analostanus* (Girard) ...	0	0	4	3	0	1	26	16	10	3	25	88
14. **Notropis cornutus (Mitch.)**.......	11	0	73	48	28	41	46	12	12	10	10	291
15. *Ericymba buccata*, Cope	0	0	0	0	0	0	0	1	1	0	0	2
16. **Rhinichthys atronasus (Mitch.)**...	46	2	14	48	20	7	28	16	27	38	11	257
17. **Exoglossum maxillingua (Le Sueur)**	3	0	8	4	10	22	9	5	1	10	3	75
18. *Anguilla rostrata* (Le Sueur) (s)	0	1	0	0	0	0	0	0	0	0	1	2
19. *Fundulus diaphanus* (Le Sueur) ..	Many specimens seen throughout the year											
20. *Lepomis auritus* (Linn.) ...... (s)	0	0	2	0	0	0	0	1	1	1	1	6
21. *Eupomotis gibbosus* (Linn.) .. (s)	1	2	2	7	8	0	0	0	4	0	0	8
22. *Micropterus salmoides* (Lac.) (s)	0	0	0	0	0	0	2	0	0	0	0	2
23. *Boleosoma olmstedi* (Storer)	Very abundant throughout the year											

(s)—Small examples only. (m)—Medium sized examples. Certain species were counted and part returned to the stream, which accounts for the apparent discrepancy between the sum of the monthly numbers as shown, and the total, because the latter only includes preserved material.

that into which it will be introduced. Success may not be obtained by stocking ponds with species taken from swift, clear streams, unless, as suggested, the young are hatched and reared under pond conditions, or otherwise properly acclimatized.

It seems desirable to know,

(1) the spawning time, habits and place, in order that comparisons can be made between them and those of the species which will subsist on the minnows. It is obviously desirable to arrange conditions in such a way that the young fish under cultivation will find a supply of young minnows at the time when they are most needed; also

(2) how prolific each species of minnows is and length of time required to mature. However, certain factors, such as good protection to the eggs, etc., might compensate for small numbers; and

(3) the natural conditions under which the minnows live, so that these conditions may be reproduced as nearly as possible and thus assure a continuous supply.

No doubt, many natural ponds which have become over-run with chubs or other species of minnows because of their rapid growth, or because they are able to subsist better on the existing food supply to the exclusion of more desirable species, such as brook trout, could be made a valuable asset to the fish culturist if properly manipulated. The young of all of these cyprinoids are excellent and acceptable food for the young of all piscivorous fishes and if economical ways are developed for handling them, another natural resource may be developed. In all cases it is presupposed that all primary factors will be under the control of the fish culturist. If chubs are to be introduced into ponds when young, they should not be left to reach a large size and their introduction therefore, should depend upon the ease with which they may be removed, i.e., small ponds may be found more effective. Minnows seem to thrive best in streams or ponds where the banks are grown with overhanging vegetation which supports an abundance of insect life. If they are introduced into similar places where they will find their natural food in abundance it is unlikely that they will prey upon the eggs or young of other fishes.

Notes on Associated Organisms

In the course of making these collections, as shown by Table No. XI, seventeen other species of fish and fish-like vertebrates were accidentally seined. Two of these are new to the region, namely *Notropis whipplii* (Girard), (Crawford, '21), and *Lamptera wilderi* (Jordan and Evermann), (Breder and Crawford, '22). Up to the present, regional lists of the District of Columbia have shown twenty-three species of cyprinoids. With the addition of N. *whipplii,* the list is now twenty-four which shows that cyprinoids comprise over 25 per cent. of the fishes of this region. The three specimens which we took were small, being not over 5.4 cm. in length.

The only representative of the Petromyzonidæ hitherto known from the District is *Petromyzon marinus* Linnæus, the young of which *Lampetra* resembles. Considerable time and effort was consumed in establishing the status of our specimens which are now deposited in the American Museum of Natural History.

One of the specimens of *Erycimba buccata* presented the only decided abnormality taken in the entire collection, in that it was a fair example of the pugheaded condition which is quite common among other fishes. A few other minor abnormalities were noted, such as notches in the operculum and small irregularities in the fins. As a whole, however, the collection consisted of typically normal individuals.

The eels taken were both small, while two others were seen which we judged to be about 30.0 and 45.0 cm. in length respectively.

Previous to these collections, in September, 1919, several small specimens of *Schilbeodes insignia* were taken at this point and in February, 1921, a larger one was netted a short distance down stream. These records suggest that the number of species occasionally to be found at this collecting site may be considerably greater than our list shows, although collections were consistently made all through one year as well as scattering ones before, after and between the regular dates listed.

When all other organisms living associated with these fish, both vertebrate and invertebrate, are considered the aggregate number is rather surprising. Small aquatic salamanders were found frequently, as well as frogs and their tadpoles. Land turtles visited the place at least occasionally. Kingfishers were seen frequently about and they no doubt preyed upon the fishes of this stream almost entirely. They were, no doubt, summer residents nesting in some sand or clay bank nearby of which there were plenty of suitable size and location. A drowned mole was noted and various bird and mammalian tracks furnished evidence of the presence of these warm-blooded creatures of sizes which varied from that of the song sparrow to man.

Among the invertebrates the crayfish and insects were the most prominent. A representative list of the latter is to be found among the list of foods in Table No. VIII. Many gomphid nymphs were present although but few of our cyprinoids were large enough to negotiate such formidable and sizeable insects. Practically no snails were present although a single specimen of *Physa* was taken from the stomach of a *Boleosoma.* Aquatic vegetation was entirely absent except for the very minute and ubiquitous representatives of algæ, none of which appeared to be particularly plentiful. The nearest approach to the larger aquatics was a very sparse growth of the semi-aquatic *Ludwegia,* which appeared to be gaining a foothold in the little cove just up stream of the beach on which the seine was hauled out. None was noted either above or below our collecting site. Fair growths of *Fontinalis* were noted beyond the limits of the map and seasonal fluctuations in the growth of this plant were observed.

SUMMARY.

1. The six species of cyprinoids treated in this paper are chiefly insectivorous.
2. Vegetable matter ranks second in volume of materials swallowed, but this material appears to have little or no nutritive value since the fish do not seem to be able to digest it.
3. The amount of food taken in the winter months is relatively small.
4. The seasonal abundance of the more prominent items of diet is reflected in the food of the six species.
5. No correlation exists between the size of the fish and the food taken except that which is entirely mechanical.

6. There is apparently no cessation of feeding during the breeding season.
7. A seasonal change from pelagic to benthotic feeding is shown more or less strongly by all species as the cold weather approaches.
8. The fish of this locality appear to be exceptionally free of parasites and abnormalities.
9. The alimentary structures are much alike in the various species.
10. These fishes are recorded as the food of many important food and game fishes.
11. It is believed that, if properly propagated, some of the species discussed in this paper would be of great value to fish culturists as food for other fishes.

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ZOOLOGICA

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BY

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New York Aquarium

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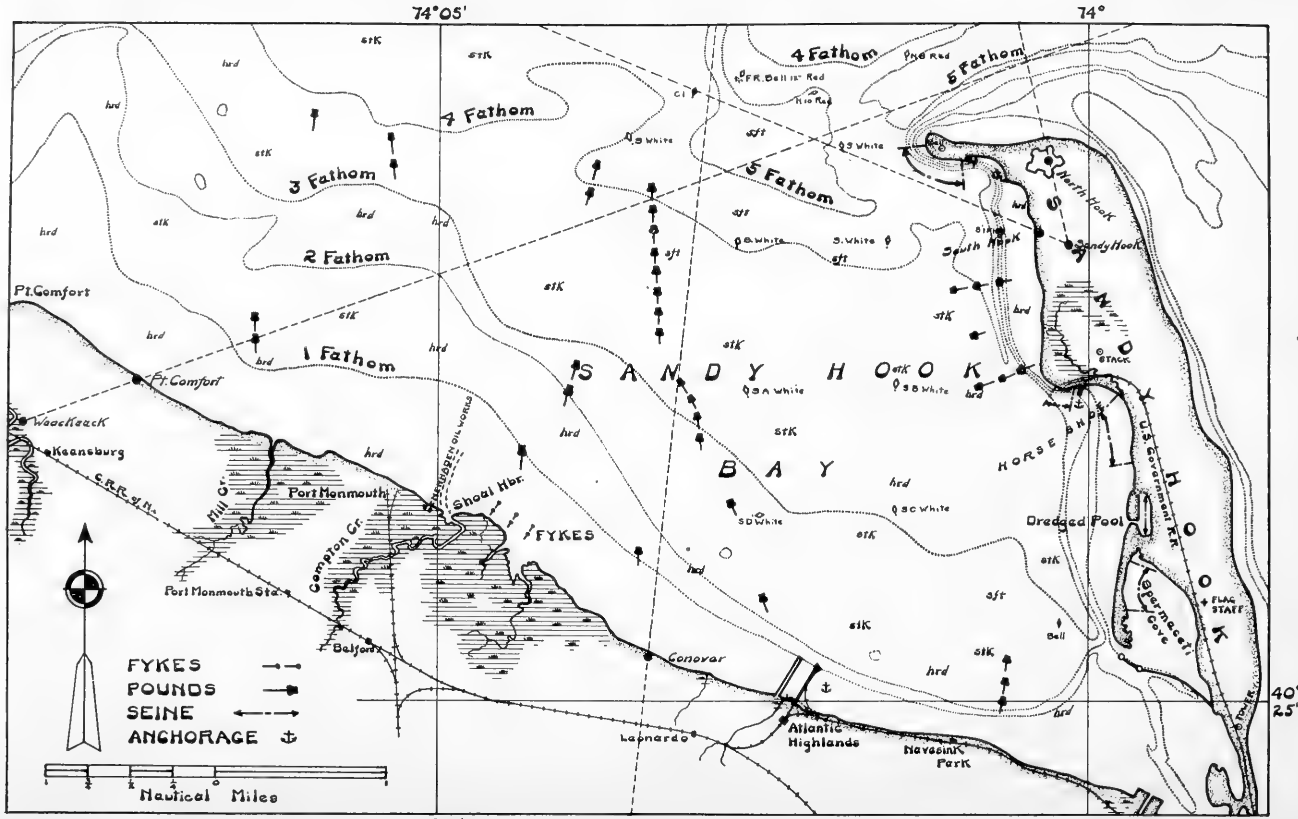

FIG. 129. MAP OF SANDY HOOK BAY

THE FISHES OF SANDY HOOK BAY

By C. M. Breder, Jr.
New York Aquarium

The work of collecting local marine fishes undertaken by the New York Aquarium's wellboat *Seahorse* for the exhibits of that institution has made it possible for the writer to compile an annotated list of the fishes of Sandy Hook Bay during the summer of 1921, which is herewith presented. Much of the material was gathered by visiting the various pound nets at times when the owners were removing their catches. There were thirty-five such traps within the limits of the Bay, and as the accompanying map shows, they were well scattered over the area, in this way intercepting at least a few individuals of practically all species entering the Bay which might be taken in such fishing gear. Late in the season when fykes were set they were likewise visited. They were six in number and located along the shore between Port Monmouth and Atlantic Highlands as indicated on the map. A seine, three hundred feet in length, was frequently used on the Beach of the Government Reservation at Sandy Hook, while less often smaller ones were dragged in tide pools and back waters. The shores along which the seines were operated are so marked on the map. Spermaceti Cove was seined only in 1920 as it was found to contain less material than numerous other places, which were more accessible. The beach at Atlantic Highlands was tried but once during 1921 when it was found to be rather unsatisfactory on account of the many submerged snags there present, upon which the net continually caught.

The first records of 1921 were made on June 1 and the last on October 21, which dates mark the beginning and end of the boat's activity for the year. Between these dates records were made on fifteen trips varying in length from two to five days, the writer accompanying the boat on all except three. On these Mr. S. A. Callisen, of the New York Aquarium, was kind enough to record and report such notes as were of particular interest. Credit is also due him for giving various kinds of assistance in the compilation of this list.

Records relative to 1920 were made by Dr. C. H Townsend, Director of the Aquarium, who has permitted the use of his log book for that year. His notes extend from June 1 to November 8 and consist of data taken on twenty-four trips of from two to four days duration. As the trips were approximately equidistant throughout both seasons the collections and observations so made give a very fair idea of the fishes to be encountered during the summer in these waters. It is unfortunate that it was impossible to make trips before and after the dates mentioned as the seasonal aspect of the Bay for an entire year would be particularly valuable in regard to the study of the migrations of certain forms. However, it is doubtful if many species not mentioned in the list are present in any considerable numbers in winter.

The kindness of Mr. J. T. Nichols, of the American Museum of Natural History, in allowing a perusal of his scrap book of records and notes on local fishes leaves little doubt as to the authenticity of the early and late dates recorded in this list.

The most recent regional paper on the fishes of New Jersey is "A List of the Fishes of New Jersey" by Henry W. Fowler, Proceedings of the Biological Society of Washington, Vol. 33, pp. 139-170, Dec. 30, 1920. This publication gives, under specific captions, the region in which each species is found, by counties. It was rather surprising to find that seventeen species included in the present list have not been recorded,[1] according to Fowler, from Sandy Hook Bay or indeed from any of the waters of Mon-

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[1] A short note on thirteen species found in 1920 has been published in Copeia, No. 91, Feb. 15, 1921, by C. H. Townsend and J. T. Nichols and a non-annotated list of sixty species taken the same year is given in "The Twenty-fifth Annual Report" of the New York Zoological Society, July, 1921. The substance of the former and all species included in the latter have been incorporated in this paper for convenience in reference.

mouth County.[2] When it is considered that Monmouth County has a long coast line on the open sea as well as on small bays, and that it is to the entire county that Fowler refers, the actual lack of accurate knowledge concerning the distribution of the fishes of this region is at once apparent. Notice to Fowler's omissions is given under the respective specific headings. Unfortunately the available regional lists of fishes found near New York City contain little or no information concerning exact geographical locations and are therefore practically impossible to compare.

Fowler, in addition, records about forty other marine species from Monmouth County, not in the present tabulation, but as no definite section is indicated, it is not known exactly how many have been taken in the Bay. This rather formidable looking list of names is made up, however, chiefly of pelagic and southern fishes of which comparatively few are likely to find their way into this body of water. While the writer's enumeration in no way pretends to be complete and is admittedly preliminary in nature, it is hoped that it will form an added step to a better knowledge of New Jersey fishes in which direction Mr. Fowler already has made such splendid advances.

The vernacular name following the technical one is, in each case, the local appellation known to be in actual use by the fishermen engaged in procuring their livelihood from this body of water, except in the cases of those few for which no local name appeared to be in current usage. In these instances the common names applied to the species in question in adjacent territories or proposed by other writers are given in brackets. All measurements given are standard lengths except where otherwise stated and in the case of the sharks where the total length is understood. The metric system is used throughout with the approximate English measure following. The annotation following each specific heading is separated into two parts according to the year in which the data was collected, so that the fauna of the Bay may be compared for two consecutive years and in this way be of aid to students of problems to whom such data might be of service. It is to

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[2] Monmouth County has a coast line extending from a point a few miles south of the mouth of the Raritan River, on Raritan Bay to the mouth of the Manasquan River on the seaward coast.

be understood that the specimens were taken in pound nets if no other type of gear is mentioned.

GALEIDÆ

1—*Mustelus canis* (Mitchill) DOGFISH, DOGGIE

Common practically all season during 1920. In the warmest weather few were taken except in the pounds set in the deepest water near the point of Sandy Hook. During 1921 this species was few in number until October 10, after which time it was abundant, varying in length from about 40 to 102 cm. (16½ to 40 inches) and in weight from about .20 to 3.20 kilograms (½ to 7 pounds). A single specimen was taken in a seine near the point of the Hook. On June 1, several copepods were noted on some examples.

2—*Carcharhinus milberti* (Müller and Henle)
SHARK, SAND SHARK, GRAY SHARK

Some examples upward of 1 meter (about 3 feet), as well as smaller ones were taken in 1920 from July 15 to September 23. In 1921 one small example was taken on each of the following dates: July 8, 15, 27, September 19, and October 19. This last is a late date for the species, being over a month later than any previous record from this region. One specimen of larger size was taken in mid-July. Fowler gives a single record of this species, which he admits as being a questionable identification, from Monmouth County as being made at Perth Amboy, which locality actually is in Middlesex.

SPHYRNIDÆ

3—*Sphyrna zygæna* (Linnæus) HAMMERHEAD

Small examples, less than 60 cm. (about 2 feet), were seen during both years in mid-summer. Fairly common. None seen before July 14 or after August 26, during 1921.

CARCHARIIDÆ

4—*Carcharias taurus* Rafinesque SHARK, SAND SHARK

Thirty or more individuals seen between June 13 and October 4 in 1920, varying in length from about 60 to 214 cm. (2 to 7 feet). One about 121 cm. (4 feet) long was taken on July 28, 1921, and what was apparently another about 153 cm. (5 feet) was seen basking about five miles south of Coney Island on September 29, which position, however, is really outside the confines of the Bay.

SQUALIDÆ

5—*Squalus acanthias* Linnæus SPINED DOG, THORNED DOGFISH

Taken late in fall of 1920 up to November 8. Many small ones, mostly under 30 cm. (about 1 foot) taken between October 17 and 21, 1921.

RAJIDÆ

6—*Raja erinacea* Mitchill SKATE

Taken on June 1 of both years, and on October 13 and later in 1920. A single example was taken on October 10, 1921. Apparently absent from these waters during the summer months.

7—*Raja eglanteria* Bosc SKATE

Fairly common during season of 1920 except in September. During 1921 quite common from June 1 to July 29, and from October 10 to 21. This species, while generally more common than the preceding, tends likewise to absent itself from this locality in the warmest weather. October 21 is a late date for this Skate.

8—*Raja stabuliformis* Garman BARNDOOR SKATE

Taken in November, 1920. One example about three feet in length of disc taken in October, 1921.

DASYATIDÆ

9—*Dasyatis centrura* (Mitchill) STINGER, STINGAREE

Two were taken between June 20 and September 23, 1920. In 1921 a single example was taken on September 16 and another on September 20, both with a length of disc less than 45 cm. (about 18 inches).

MYLIOBATIDÆ

10—*Rhinoptera bonasus* (Mitchill) STINGER, STINGEREE

A few taken between June 13 and September 11, 1920. One example with a disc of more than 60 cm. (about 2 feet) in length, taken on August 4, 1921.

ACIPENSERIDÆ

11—*Acipenser sturio* Linnæus STURGEON

Fairly common in fall of 1920. One example 45 cm. (about 18 inches) long was taken on September 15, 1921. Fishermen reported having taken a few others about this time.

12—*Acipenser brevirostrum* Le Sueur STURGEON

A few small examples were taken in the fall of 1920. Fowler makes no mention of this species being taken in Monmouth County.

ELOPIDÆ

13—*Elops saurus* Linnæus SALMON

One example 20 cm. (about 8 inches) long was taken on October 12, 1921. Fishermen spoke early in the season of taking "Salmon" but the identity of the fish they had in mind could not be determined from their descriptions. Very likely they referred to this species. Cape May is the only New Jersey county Fowler records it from.

CLUPEIDÆ

14—*Etrumeus teres* (De Kay) [ROUND HERRING]

One example of 37 cm. (about 15 inches) was taken in a fyke on September 20, 1921. The fishermen admitted to not having seen this species before and had no name for it. According to Fowler it has not been recorded from Monmouth County before.

15—*Clupea harengus* Linnæus HERRING

A few medium sized examples were taken from June 1 to 23, and one each on July 7 and October 17, 1921. This species is known to be irregular near here, but these observations might be taken to indicate that possibly the Herring is absent from this

Bay in summer. Fowler does not record it as being found in the waters of this county.

16—*Pomolobus pseudoharengus* (Wilson) ALEWIFE, SHADINE

One example of medium size taken on June 1, 1921. Probably a few of this and the following two species were present later, but as it was not always possible to examine each catch in the detail necessary to identify such inconspicuous fish in a boat load of Menhaden it can not be said with certainty.

17—*Pomolobus æstivalis* (Mitchill) SHADINE

From June 1 to July 7, 1921, a few medium sized examples were taken.

18—*Alosa sapidissima* (Wilson) SHAD

Several were taken in 1920 and a few on June 1, 1921.

19—*Opisthonema oglinum* (Le Sueur)
THREAD HERRING, SAW-BELLY

A few were taken in mid-summer in 1920. Medium sized examples were taken from July 7 to 29 and one on October 21, 1921. Very likely they were absent in the interim. Fowler records this species only from Cape May and Atlantic Counties.

20—*Brevoortia tyrannus* (Latrobe)
BUNKER, BANKER, MOSSBUNKER, MENHADEN

Taken at all times during both seasons. Both young and adults abundant, and taken in all gear. As the season of 1921 came to a close their numbers became noticeably less, especially after the middle of September, at which time the Weakfish replaced them to a certain extent. This species forms by far the major part of the pound netters' catch, sometimes to the exclusion of almost everything else. On July 28 a skiff was taken up the "Creek" that has its mouth at the "Horseshoe" on Sandy Hook, and many young Menhaden 10 to 13 cm. (about 4 to 5 inches) long, were seen as far up as it was possible to force the skiff, which was almost a mile, measuring along the bank. This "Creek" is apparently purely salt water, at present, at least, being merely an arm of the Bay. On July 27 and 28 countless numbers of these fish of a similar size were seen in great schools from the pier at Atlantic Highlands. At this point a large sewer empties just below the surface and the water is consequently heavily charged with various kinds of evil smelling debris. These young fish were in the thick of it, stemming the rather forceful current which the flow from the sewer pipe caused. It appeared that they were feeding, either on the finely divided sewage itself, or else on some small organism drawn there by the large amount of decaying organic matter, although it hardly seems possible that a small pelagic invertebrate, minute enough for these fish to engulf could sustain itself in the strong current urging the debris from the pipe.

About the middle of September several decidedly greenish adults were seen which the fishermen say always appear at this season and which they dub "Irish Bunkers." From a casual examination it was seen that they had fed on some green substance and that the internal organs were likewise suffused with the same color.

ENGRAULIDIDÆ

21—*Stolephorus brownii* (Gmelin) [Striped Anchovy]

One example was taken on June 7, 1921, in company with the following species. Not previously recorded from Monmouth County according to Fowler.

22—*Stolephorus mitchilli* (Cuvier and Valenciennes)
[Common Anchovy]

Taken in small numbers on June 7, 29, September 22, October 18 and 21, 1921. Probably present all summer but passing through the meshes of most gear. Large schools of anchovy-like fishes were seen which were very likely composed of this species with a few individuals of the preceding, in proportion to their relative abundance.

ANGUILLIDÆ

23—*Anguilla rostrata* (Le Sueur) Eel

Taken uniformly on practically all trips and in all gear. Both large and small examples were seen.

PŒCILIIDÆ

24—*Fundulus majalis* (Walbaum) KILLY

Taken whenever fished for with small seines in back waters, tide pools, and runs. Especially common in the "Horseshoe." Ripe males and females taken June 1 to 23, 1921. In company with the following species but not as abundant.

25—*Fundulus heteroclitus macrolepidotus* (Walbaum) KILLY

Abundant, especially in back waters and tide pools, particularly so in "Dredged Pool." Taken whenever such places were seined. Ripe examples of both sexes were taken June 1 to 23, 1921.

26—*Cyprinodon variegatus* Lacépède KILLY

Taken only in the large and deep "Dredged Pool" in company with the two preceding species. Males with brilliant coloring seen from June 1 to 23, 1921. Apparently breeding at this time as were the other Pœciliidæ. Specimens apparently spent were taken on July 14 and 22, 1921.

BELONIDÆ

27—*Tylosurus marinus* (Walbaum) BILLFISH

Taken in the late fall of 1920. One example 45 cm. (about 18 inches) long was taken in seine on September 27, 1921 and another in a pound net on October 14, the latter being 60 cm. (about 2 feet) long.

GASTEROSTEIDÆ

28—*Apeltes quadracus* (Mitchill) STICKLEBACK

One small ripe female taken in back water of the "Horseshoe" on June 1, 1921, and a few, of which the condition was not noted, on July 20 in "Dredged Pool." Fowler gives this species as being unrecorded from Monmouth County.

SYNGNATHIDÆ

29—*Syngnathus fuscus* Storer PIPEFISH

Taken in mid-summer of 1920, especially abundant in Spermaceti Cove. Taken between June 23 and October 12, 1921.

Common near the point of Sandy Hook and in the "Horseshoe" in seines. Many males with brood pouches full were observed in mid-summer of this year. At times while riding at anchor in calm weather these fish could be seen swimming or drifting past, a few inches below the surface of the water. On June 21 a post larval example of 13 mm. (about ½ inch) was taken in a bolting cloth tow net at the surface near the mouth of the bay.

30—*Hippocampus hudsonius* De Kay SEAHORSE, HORSEFISH

One specimen taken during 1920. On August 24 and 26, 1921 each, one fair sized example was picked off the leaders of the pound nets by the fishermen. Several others were reported about this time.

ATHERINIDÆ

31—*Menidia menidia notata* (Mitchill) SPEERING, WHITEBAIT

Seined in mid-summer in 1920. Taken in seines from June 21 to September 22, 1921. Very young fry and ripe adults were seen in early part of season, while larger fry and spent adults were seen later.

MUGILIDÆ

32—*Mugil cephalus* Linnæus MULLET, LEAPING MULLET

Common in fall of 1920. A few small examples were taken on June 29, many large ones from July 20 to October 21 during 1921, chiefly in seines and fykes. The adults were exceptionally well nourished and fat. Fowler records this species only from Atlantic and Cape May Counties.

SPHYRÆNIDÆ

33—*Sphyræna borealis* De Kay BARRACUDA

On June 20, 1920, a few very small examples were taken. Three specimens were taken on October 17, 1921 in the seine, two of which measured 16½ and 17 cm. (6½ and 6¾ inches) respectively. Several others of about the same size passed through the meshes at this time.

AMMODYTIDÆ

34—*Ammodytes americanus* De Kay [SAND LANCE, SAND EEL]

A single example, which was probably originally about 5 cm. (2 inches) in length, was taken from the stomach of a small bluefish caught on June 29, 1921. However, it is possible that it was captured at some point outside the Bay. The reason why this common species, abundant at other points close by should be so scarce in this Bay is not clear, although no doubt later in the fall they appear in numbers.

SERRANIDÆ

35—*Roccus lineatus* (Bloch) STRIPED BASS

Fairly common in fall of 1920. One good sized example was taken in seine on June 22, 1921, which was blind, another in a pound net on September 19, and several small and medium ones were taken in fykes between October 17 and 21.

36—*Morone americana* (Gmelin) WHITE PERCH

Common in fall of 1920. Taken in fykes and pounds. A few medium sized examples were taken in fykes between October 17 and 21, 1921.

37—*Centropristes striatus* (Linnæus) SEA BASS

Taken in late fall of 1920, but not common. After their first appearance on September 28, 1921, this species increased in numbers until the close of the season, at which time they were abundant.

LOBOTIDÆ

38—*Lobotes surinamensis* (Bloch) TRIPLE-TAIL, FLASHER

One large, very dark example was taken in one of the outermost pound nets on July 13, 1921.

HÆMULIDÆ

39—*Orthopristes chrysopterus* (Linnæus) PIGFISH

A single individual was taken during 1920.

SPARIDÆ

40—*Stenotomus chrysops* (Linnæus) PORGY, SCUP

A few adults were taken during 1920. Common from June 1 to 23, 1921, males with running milt; spent fish later, July 14 to October 21, decreasing in numbers as the season drew to a close. From October 10 to 21 many small ones of about 3 cm. (1¼ inches) in length were taken in seines and fykes.

41—*Lagodon rhomboides* (Linnæus) SAILOR'S CHOICE

One example was taken during 1920.

KYPHOSIDÆ

42—*Kyphosus sectatrix* (Linnæus) BREAM

One example was taken in 1920. Fowler's list fails to mention this fish as being known from New Jersey waters at all.

SCIÆNIDÆ

43—*Cynoscion regalis* (Bloch and Schneider)
WEAKFISH, BLACKTAIL

Present at all times during both years, increasing in numbers as the menhaden decreased. Sometimes taken in fykes as well as pounds. Many silvery below, while others were more or less golden. The fishermen believe the latter to be visitors from outside waters, while the former are supposed to be residents of the Bay. There was no opportunity to gather accurate data as to the actual cause of the two phases appearing simultaneously, however. Several were examined on June 29, 1921, and a number found to be ripe. Their stomachs contained squid, prawns and the remains of small fish. One example contained what appeared to be a small *Bairdiella chrysura* which in turn held a specimen of *Stolephorus* sp. A few examined on September 14 had fed on menhaden. These weakfish varied in length from 32.5 to 50.5 cm. (13 to 20 inches) and contained fish about 11.5 cm. (4½ inches) long. In most cases three such young menhaden were found in a stomach.

44—*Bairdiella chrysura* (Lacépède) WHITE PERCH

One medium sized example was taken on June 28 and another on September 14, 1921. No distinction is made by the fishermen between this and *Morone americana.*

45—*Sciænops ocellatus* (Linnæus) CHANNEL BASS, RED DRUM

One example 82.5 cm. (2 feet 8½ inches) in length was taken on September 13, 1921.

46—*Leiostomus xanthurus* Lacépède SPOT, LAFAYETTE

Common all season in 1920. Present sparingly all summer in 1921, most plentiful in September, falling off in numbers on either side of that month. Much less common than in the preceding year.

47—*Micropogon undulatus* (Linnæus) CROAKER

Common during 1920, being taken at times by the boat load between June 13 and October 22. One or a few examples were taken on each of the following dates in 1921: June 28, July 7, 28, August 25, September 14, 28, and October 20. Some were of a fair size while some were not over 15 cm. (about 6 inches) in length.

48—*Menticirrhus saxatilis* (Bloch and Schneider) KINGFISH

Only small examples were taken both years, averaging about 15 cm. (6 inches) in length in fykes and seines. Fairly common from July 28 to October 21, 1921.

49—*Pogonias cromis* (Linnæus) DRUMFISH, BLACK DRUM

Two examples were taken in September, 1920. One was about 914 cm. (3 feet) and the other about 1219 cm. (4 feet) in length.

POMATOMIDÆ

50—*Pomatomus saltatrix* (Linnæus)
BLUEFISH (Young—SNAPPER)

Fairly common in 1920. Taken in 1921 from June 21 to October 21. The adults became more common as the season wore on, with a drop in numbers, however, near the end. The young were common, being taken in seines and fykes as well as the pounds. By October 11 most of the fish hatched early in the spring had reached a length averaging 15 cm. (about 6 inches), which was well established by a comparison of the serial collections, showing this species to have an extremely rapid rate of growth.

RACHYCENTRIDÆ

51—*Rachycentron canadum* (Linnæus) CRAB-EATER

One large example was taken in 1920.

STROMATEIDÆ

52—*Peprilus paru* (Linnæus) HARVEST FISH, BUTTERFISH

Taken in mid-summer in 1920. Adults were fairly common from June 28 to September 17, 1921. Fowler fails to mention this species at all in his list. Apparently an oversight, as it is mentioned in a paper[3] of his of 1906, in which he writes "It is known only from the record of Dr. Abbott. It is properly a native of southern waters and can only be said to be a straggler on our shores." Nichols, writing of the fishes within fifty miles of New York City[4] says "The Harvestfish is occasionally common in summer - - - ." The experience of the writer has certainly confirmed the latter statement and it seems remarkable that as late as 1906 only one record of this species had found its way into regional literature.

53—*Poronotus triacanthus* (Peck) BUTTERFISH

Very common during both seasons. Abundant in fall of 1920. Most numerous during the early part of the season of 1921, their numbers falling off prominently after September 28. Adults and juveniles were seen in approximately equal numbers from June 7, which is an early date for the species, to October 21, 1921.

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[3] 1906—The Fishes of New Jersey, by Henry W. Fowler. Report of the New Jersey State Museum, 1905.

[4] Fishes of the Vicinity of New York City, by John Treadwell Nichols. American Museum of Natural History, Handbook Series No. 7, 1918.

CARANGIDÆ

54—*Seriola zonata* (Mitchill) PILOT, PILOTFISH

A few of fair size were taken in 1920, from July 21 to November 8. Only medium sized examples were taken in 1921, mostly less than a foot in length. Seen from July 27 to October 21. Most common in the latter part of August and early September.

55—*Selar crumenophthalmus* (Bloch) [GOGGLE-EYED SCAD]

Two were taken in fall of 1920. A few examples 25.5 cm. (about 10 inches) long were taken on September 14, 1921. Not recorded north of Beesley's Point, Cape May County by Fowler.

56—*Caranx hippos* (Linnæus) JACKFISH, RUNNER

A few were taken in 1920, and several medium sized examples between September 13 and 29, 1921. Recorded from Atlantic and Cape May Counties only by Fowler.

57—*Caranx chrysos* (Mitchill)
YELLOW MACKEREL, RUNNER, GOLDFISH

A few were taken in 1920. Common in 1921, all small and most abundant in September. Taken from August 18 to October 21, 1921.

58—*Alectis ciliaris* (Bloch) THREADFIN, RIBBON FISH

One example was seen on July 29, 1921, and another on August 12, both 10 cm. (about 4 inches) long. Recorded from Cape May County only, by Fowler.

59—*Vomer setipinnis* (Mitchill) MOONFISH, LOOKDOWN

A few small ones were taken in 1920. Two fair sized examples were taken on July 14, 1921, and another one of about 4 cm. ($1\frac{1}{2}$ inches) on October 17. Fowler records this from Cape May County alone.

60—*Selene vomer* (Linnæus) MOONFISH

Recorded in 1920.

61—*Trachinotus carolinus* (Linnæus) POMPANO

Several large examples were taken in fall of 1920 as well as a few small schools of young fish. Many small examples 7.5 to 10 cm. (about 3 to 4 inches) were taken in seines and fykes from September 27 to October 18, 1921. Scattering small individuals were taken from September 27 to October 21, 1921. Much more common than the preceding year.

SCOMBRIDÆ

62—*Scomber scombrus* Linnæus MACKEREL

A few were taken in 1920. A few large and many small examples, 15 to 21.5 cm. (6 to 8 inches) were seen June 7 to July 8, 1921, while from September 18 to October 21, only small ones were observed. Taken in all gear. Small ones 65 to 120 mm. (about 2½ to 4¾ inches) taken on July 7 were found to contain schizopods, copepods, amphipods, *stolephorus* sp. and other mangled small fish.

63—*Scomber colias* Gmelin MACKEREL

Recorded in 1920.

64—*Sarda sarda* (Bloch) BONITO, HORSE MACKEREL

A few dozen examples 914 cm. (about 3 feet) long were taken between September 13 and 17, 1921.

65—*Scomberomorus maculatus* (Mitchill) SPANISH MACKEREL

One medium sized example was seen on August 25, 1921.

LABRIDÆ

66—*Tautogolabrus adspersus* (Walbaum) CUNNER, BERGALL

A few were recorded in 1920. Three small examples were seined in "Dredged Pool" on July 21, 1921.

67—*Tautoga onitis* (Linnæus) BLACKFISH

Fairly common in the fall of 1920. Large and medium examples were taken in pounds in 1921, and by seines in tide pools rather sparingly all season, but becoming more common with the approach of cold weather.

BALISTIDÆ

68—*Balistes carolinensis* Gmelin TRIGGERFISH

Several small examples were taken in 1920. Two fair sized specimens were taken on October 17, 1921, which is a late date for this species.

MONACANTHIDÆ

69—*Stephanolepis hispidus* (Linnæus)
FILEFISH, GRANNY WHALE

Several were taken in 1920. A few small examples were taken from September 13 to October 12, 1921.

70—*Alutera schœpfii* (Walbaum) GRANNY WHALE, HAMBAG

A few large and several small examples were taken in 1920. One large specimen was taken on July 28, 1921, and many small ones, about 20 cm. (8 inches) long, with juvenile markings from then on to October 21. Recorded by Fowler from Atlantic, Cape May and Ocean Counties only.

TETRAODONTIDÆ

71—*Lagocephalus lævigatus* (Linnæus)
RABBITFISH, SMOOTH PUFFER

One dead specimen was seen in the possession of a fisherman on September 15, 1921.

72—*Spheroides maculatus* (Bloch and Schneider)
SWELLFISH, SWELLTOAD, TOADFISH, PUFFER, PUFF-BALL

Common practically all season in 1920, but less so in fall. Common from June 1 to July 15, 1921, becoming scarcer toward the latter date. Many of these fish were nearly ripe and some of the females emitted ova. Later, July 27 to October 21, young were taken in seine from 2.5 to 13 cm. (about 1 to 5 inches) and longer, while adults were irregularly abundant, but all apparently were spent.

DIODONTIDÆ

73—*Chilomycterus schœpfii* (Walbaum)
SPINY PUFFER, BURRFISH, PINCUSHION

Not rare during the fall of 1920, and a single specimen was taken as early as July 27. One large example was reported on July 8, 1921, which is an early date, and small ones fairly common from September 13 to October 21. These latter averaged 10 cm. (about 4 inches) in length.

MOLIDÆ

74—*Mola mola* (Linnæus) HEADFISH, SUNFISH

A few were reported by fishermen in 1920. One small specimen was reported on June 22, 1921, and others were mentioned by fishermen about this time.

COTTIDÆ

75—*Myoxocephalus octodecimspinosus* (Mitchill)
DADDY SCULPIN

A few were taken in the spring and fall of 1920.

TRIGLIDÆ

76—*Prionotus carolinus* (Linnæus) SEA ROBIN

A few were seen occasionally all through both seasons but not as common as the following species; medium and small examples only. In 1920, some as long as 20 cm. (about 8 inches) were seen in the autumn.

77—*Prionotus evolans strigatus* (Cuvier and Valenciennes)
SEA ROBIN

Common both years. Seen from June 21, 1921, to season's end. None above medium size. Small examples, 10 cm. (about 4 inches) in length abundant in latter part of season.

ECHENEIDIDÆ

78—*Echeneis naucrates* Linnæus
SUCKER, SHARK SUCKER, PILOT, FISH SUCKER, SUCKING FISH

One was taken on October 11, 1920, which is a late date. Several medium sized examples were taken from July 7 to 15, and 27 to 29, 1921. It is likely significant that their appearance was made only when *Carcharhinus milberti* was also present during this year.

BATRACHOIDIDÆ

79—*Opsanus tau* (Linnæus) SALLY GROWLER

Medium and small examples were taken in all inshore nets at practically all times both years, but most common in fall. Taken in all gear in 1921, from September 13 to October 21. None of the fishermen encountered knew this species as Toadfish, the appellation generally given it elsewhere.

MERLUCCIIDÆ

80—*Merluccius bilinearis* (Mitchill)
LING, HAKE, SILVER HAKE, SQUIRREL HAKE

Taken in spring and fall of both years. Seen on June 1, 1921, and from October 17 to 21, being absent during warm weather. In spring the specimens were of good size, while in fall they were small, being about 20.5 cm. (8 inches) long. At no time was this species very common.

GADIDÆ

81—*Microgadus tomcod* (Walbaum) TOMCOD, TOMMYCOD

Taken in fall of 1920. One example was taken on July 21, 1921, in "Dredged Pool" and a few in fykes from October 17 to 21. All small fish.

82—*Gadus callarias* Linnæus COD, (Small, up to 2 feet—SCROD)

Taken in lobster pots at mouth of the Bay during November and possibly later in 1921. First reported November 1. Fish 45 cm. (about 18 inches) long. A few taken in the outermost pounds.

83—*Phycis regius* (Walbaum) HAKE, LING

A few were taken in the fall of 1920.

84—*Phycis chuss* (Walbaum) HAKE, LING

Taken in spring and fall of 1920. Taken in spring of 1921. This, like the less common preceding species, disappears in warm weather. One example examined on June 1 was found to be crammed full of large prawns.

PLEURONECTIDÆ

85—*Paralichthys dentatus* (Linnæus) FLUKE

Fairly common at all times both seasons. The largest individual recorded measured 60 cm., 24 inches in standard length, 67.5 cm., 27 inches in total length, and was a spent female. It was seined on June 21, 1921. Small examples 5 to 15 cm. (2 to 6 inches) frequently were taken in the seine, while most of the large ones were met with in the pounds, and occasionally in the fykes.

86—*Pseudopleuronectes americanus* (Walbaum) FLOUNDER

All small examples taken both years, varying from 5 to 20 cm. (about 2 to 8 inches) in length. Taken throughout the season of 1921 and chiefly in seines.

87—*Lophopsetta maculata* (Mitchill) WINDOWPANE

Plentiful both seasons, none seen over 18 cm. (7 inches). Absent in August and September of 1920, but present at all times in 1921. The stomach contents of several examined on June 1, 1921, consisted of crustacean remains, probably schizopods. On August 25, a small example was seined in which the right side was almost as well pigmented as the reverse. Only the under part of the head and abdominal region was white, the remainder duplicating the normal color of the left side. Fowler does not record this species from Monmouth County.

88—*Etropis microstomus* (Gill) [SMALL-MOUTHED FLOUNDER]

One example, 7.5 cm. (about 3 inches) long was taken in a seine on September 28, 1921. This species is not included in Fowler's list as being known from Monmouth County. Deposited in the American Museum of Natural History.

SOLEIDÆ

89—*Achirus fasciatus* Lacépède HOG CHOKER

One example of 15.5 cm. (about 6 inches) in length was taken on July 6, 1921.

LOPHIIDÆ

90—*Lophius piscatorius* Linnæus

CARPET BAGGER, ANGLER, TOADFISH

A few were taken in the fall of 1920. Two examples, each 76 cm. (about 2½ feet) long were taken on October 20, 1921.

In concluding this list a few remarks on general considerations may not be amiss. As might be expected, the pound nets lying nearest to the shore were found to usually capture the smallest specimens as well as the majority of typical shore loving fishes, while those further out most often caught the largest examples and also contained the highest number of pelagic forms. In addition the latter took nearly all the southern representatives, which reach here in the latter part of summer and early autumn. The combination of a large number of factors is responsible for the above mentioned condition, but probably chief among them are, salinity, temperature, and water currents. A through study of these three elements would almost certainly throw considerable light on the problem of the distribution of the fishes of such a small bay as this, besides adding something to the knowledge of the life histories of a number of species.

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THE WEAVING OF THE RED-BILLED WEAVER BIRD IN CAPTIVITY

By HERBERT FRIEDMANN

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INTRODUCTION

It is among the weaver birds that we find the art of nest-building developed to its greatest perfection. Their nests are models of bird architecture and represent the climax of avian effort at home making.

"Instinct and necessity have made these birds wonderful architects. Natives of a land where the rays of a vertical sun alternate with tropical rains; where monkeys, serpents, and all kinds of other enemies abound, the weaver bird has learnt to avoid these manifold dangers for his progeny. . . . In its details the nest of each species of weaver bird varies, but all of them are more or less ball-shaped. The roof is always very thick and substantial enough to keep off the heaviest downpour, as well as to protect the inmates from the tropical sun. The nest is invariably suspended from frail branches or reeds just strong enough to bear its weight, but never strong enough to tempt any predatory animal to climb up. The entrance to the nest is invariably from underneath, a sort of ridge dividing the nest proper from the entrance, and preventing eggs or young from falling out. No bird of prey can therefore possibly see the contents of a weaver bird's nest, much less commit any ravages on a brood." [1]

Review of the Literature

For a long time ornithologists have been interested in the nests of the Ploceidae and while a great deal has been written about them, no one, as far as I have been able to ascertain, has ever described the actual details of the methods of nest construction in any species of weaver birds, or, for that matter, in any species of bird. This may seem to be a hasty statement, but a thorough search in the literature of this subject has failed to produce a single article of the nature sought for, the nearest and best attempts being those conveniently collected by Dr. A. G.

[1] Blackston, W. A., Swaysland, W., and Wiener, A. F. The Book of Canaries and Cage Birds, British and Foreign, p. 404.

Butler in his work on "Foreign Finches in Captivity."[2] But these deal only with the larger features of nest-building. Plenty of good descriptions of these larger features have been published for many of the Ploceidae, notably those just referred to, those in the works of Shelley,[3] Chapin,[4] Stark and Sclater,[5] Bates,[6] etc., to mention just a few of the more important ones. Bartlett's unfinished monograph of the weaver birds does not go into as great detail in the matter of nidification as a monograph might, and, as far as the present paper is concerned, adds nothing to those mentioned above.

As far as the particular species under discussion in this paper, *Quelea quelea* (*Quelea sanguinirostris*), is concerned, good descriptions of its nesting habits have been published by Blackston, Swaysland and Wiener,[7] by Butler, Shelley, and others, but all, as I said before, deal only with the gross aspects of the building process.

In view of the lack of the literature on this point, it may not be amiss to present herein a study of the actual weaving of one of the commonest species of Ploceidae, the Red-billed Weaver.

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[2] Butler, A. G., 1899, Foreign Finches in Captivity.
[3] Shelley, G. E., 1896, Birds of Africa, Vol. IV.
[4] Chapin, J. P., 1917, Classification of the Weaver birds. Bull. A.M.N.H. Vol. XXXVII, Art. IX, pp. 243-280.
[5] Stark and Sclater, Birds of South Africa, Vol. I.
[6] Bates, G. E. Ibis., Jan., 1909, p. 44; Ibis, 1911, p. 589.
[7] See[1] pp. 408-409.

FIG. 130. WEAVING OF WEAVER BIRDS IN THE PERCHING BIRDS' HOUSE IN THE ZOOLOGICAL PARK

1. Nest recently started, showing vertical loop. 2. Completed nest. 3. Part of playground. Photographed two years after the studies were made.

THE WEAVING OF THE RED-BILLED WEAVER BIRD, *QUELEA QUELEA* IN CAPTIVITY

By Herbert Friedmann

1. General Features of Nest-building

The general features of nest construction in this species have been described in more or less detail by several writers referred to above. Therefore I shall pass over this phase of the subject in a hasty manner and, were it not for the fact that in captivity the birds build nests quite unlike those built by the same species in nature, I would scarcely have touched upon it.

Not only did the nests built in the Zoological Park differ from those in nature, but also from those built in the aviaries of Dr. A. G. Bulter in London where, to judge by his descriptions, the nests built in captivity agree with those built in a state of nature. I cannot, and do not attempt any explanation for the discrepancies between the nests in captivity as I found them and those in nature or in the London aviaries.

In nature, the nest of the species is described as a more or less globular nest with an entrance hole on one side. In captivity the nest was really cup-shaped and had an arched roof which was attached to the nest proper at the two ends of the major axis of the slightly elliptical margin of the cup, and free on the sides. If the roof had been adnate to the bowl around its entire edge, the nest would have been truly globular. Mr. Chapin, whose wide field acquaintance with the Ploceidae gives his statements the stamp of authority, writes me that "ordinarily no weaver would leave a part of the roof open as in your sketch. Building is generally begun by weaving an upright ring at about the middle of the nest-to-be, and then adding the back of the nest, and the front, with entrance. So far as I know they never begin by constructing a simple cup-nest like a vireo."

In Reichenow's Vogel Afrikas III, p. 109, von Heuglin is quoted to the effect that while the subspecies *aethiopica* built

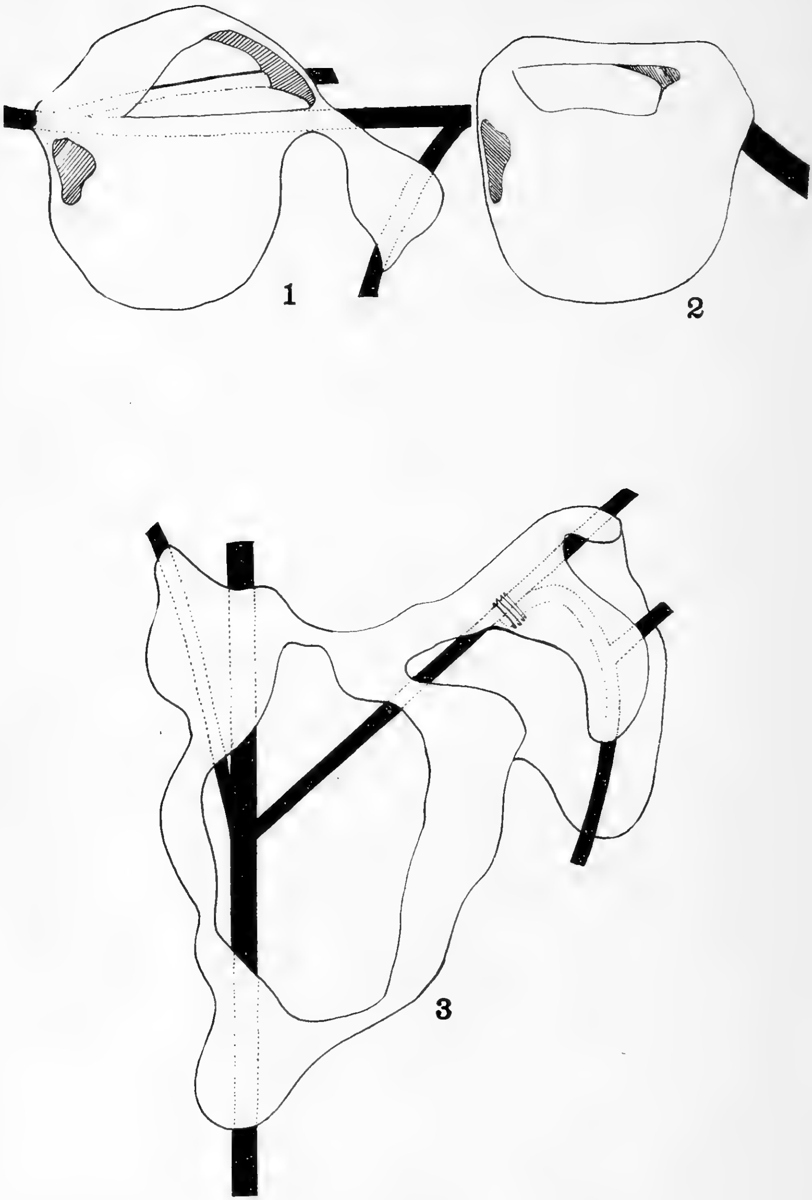

FIG. 131. OUTLINE DRAWINGS OF TWO NESTS AND PART OF A PLAY-GROUND BUILT IN CAPTIVITY.

purse-shaped nests in the Gardens at Khartoum, especially in Parkinsonias, they seemed never to lay in them.

The South African species is said to be parasitic. This is probably an error.

The two nests built by this species in captivity and part of the "playground" are shown in outline sketches (Fig. 131). It will be noticed that the two nests are very dissimilar in the degree of curvature of the roof but that they agree in having the roof partly free on the sides. The "playground" consists of perches, arches and runways, connecting the nests.

When building, *Quelea quelea* usually selects a fork of a branch and weaves a small mass of fiber or whatever material it may have (raffia in this case) right in the crotch of the fork. From this as a basis it forms a hoop nearly vertical as a rule. "From this hoop it works, starting from the bottom and gradually filling in the back, finishing off with the front, in the center of which it leaves a small hole to enter by." [8]

2. Details of Weaving

At the time this study was begun, there were nests already built, and also a large mass of what we may collectively call the "playground." This gave the birds two different types of sites for weaving—the first being the bare twigs around which they might weave, the second being the already existing woven foundations (nests and playground), to which they might add by weaving.

There seemed to be different types of stitches employed by *Quelea quelea* when weaving on a previously woven foundation than when weaving around a branch or twig. In describing stitches, I believe that diagrams are clearer and more eloquent than words, and consequently this text is largely an explanation of the accompanying plates.

When weaving around a twig or branch, *Quelea quelea* used three types of stitches as illustrated (Fig. 132). The arrows indicate the direction of the progress in making the stitch; the

[8] Butler, A. G., 1899. Foreign Finches in Captivity, p. 229.

dotted lines represent the strand of raffia as being on the far side of the twig, i.e., the portion that would be hidden by the twig in this view. (1) shows what seems to be a stitch used chiefly in conjunction with that shown in (2). Here the bird places a strand longitudinally along the branch, pushes one end around the twig, catches it on the other side, carries it up and over, tucks it under the part of the strand lying lengthwise along the branch, pulls it through and then tightens it with jerks of its head, seizing the strand nearer the knot with each jerk, until the knot is tight. In all weaving, the bill is the weaving organ, taking the place of a hand, the feet being used merely to clamp the straw down to the twig and hold it there.

In (2) is illustrated the simplest and most commonly used of all the stitches. The diagram should be self-explanatory, the stitch consisting in merely laying a strand longitudinally along a branch for about half its (the strand's) length and winding the remaining half around and around to hold it there. When the end of the strand is reached it is tucked in as in (1).

A variation of the type shown in (1), is illustrated in (3). This type is apparently rare as it was seen but once out of hundreds of stitches observed. It was used to tuck in the end of the strand at the completion of a stitch of the type shown in (2). All these three types were used when weaving on straight limbs.

When weaving at a fork the birds did one of two things: Generally they wove a solid compact mass of straw on the two arms of the fork before stretching a single strand across. However, they sometimes, though seldom, stretched a strand across before weaving any foundation on either side. They would straddle the fork, one foot on each side, just as far apart as possible. At times the distance between their feet was more than twice the width of the body! Then they would fasten the ends of the strand on either end by a stitch as shown in (2) and (1), Fig. 132. However, when the birds did act as above, they invariably drew the straw down to the crotch of the fork after they were through. Evidently they have no liking for frail suspension bridges.

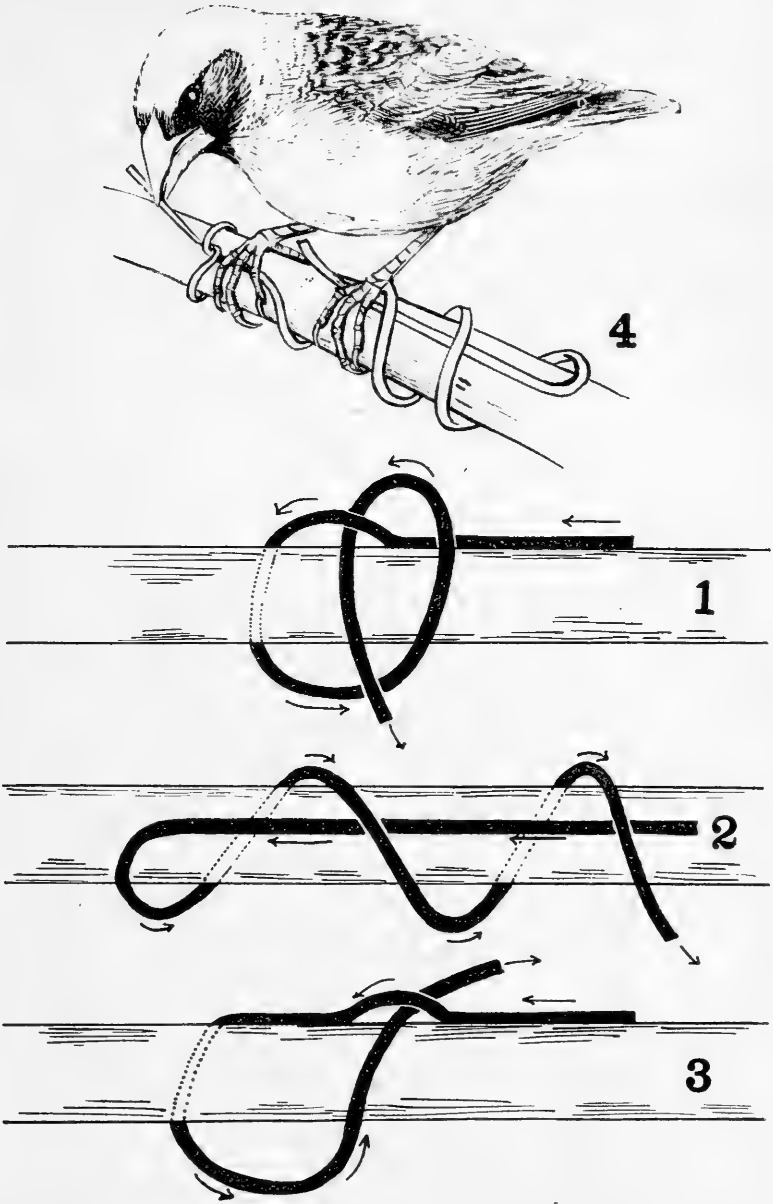

FIG. 132. TYPES OF STITCHES USED BY *Q. QUELEA* WHEN WEAVING AROUND A BRANCH

(4) after drawing by James P. Chapin.

When the birds were weaving on an old foundation of straw previously woven, their stitches were quite different from any of the preceding. In Fig. 133 the stitch is shown in detail in (1 to 10 incl.). The arrows indicate the direction of movement of the straw, dot-and-dash lines represent the straw being pulled through the mass of straw foundation, and dotted lines indicate the straw being on the other side of the mass.

The letter A marks the place in each case where the bill was applied. Briefly, the stitch is as follows: The bird holds a strand near one end in its bill and pushes it through the already existing woven mass (represented in the diagram by the space between the two parallel horizontal lines) as in (1). Bending over, it pulls the strand until one end is through as in (2-4). Then the bird takes the strand around the back of the mass (5-6), and repeats the process (6-9), the next time winding it in front of the mass as in (10). This stitch formed by far the greatest part of all the weaving done by *Quelea quelea.*

Especially interesting are (6′) and (7′) as indicative of the intelligence of these birds. In (6′) the bird made a knot by pulling the strand through the loop. Then on pulling at (A) (6′), to draw the knot tight, the bird evidently noticed that the part of the strand (B) (6′) was being drawn through the woven mass more and more with each tug at (A). The bird then tucked (B) under the loop (C) (7′) and then went back and jerked at (A) without any danger of pulling the strand out!

The weaving done by *Quelea quelea* is not only intricate and beautiful but it is strong and serviceable. I tried to pull down some straw the birds had woven on the wire netting of the cage. In one case the straw was attached only at one end, the other end dangling freely. I pulled with a force that I estimated to be over ten pounds, and the straw broke but the knot did not undo itself! On the contrary it seemed to become tighter.

The speed with which the birds weave is subject to great variation. All the straws used were of approximately equal length (one foot) so that in comparing speed, the comparison was a fair one. The speed varied from forty-eight seconds to

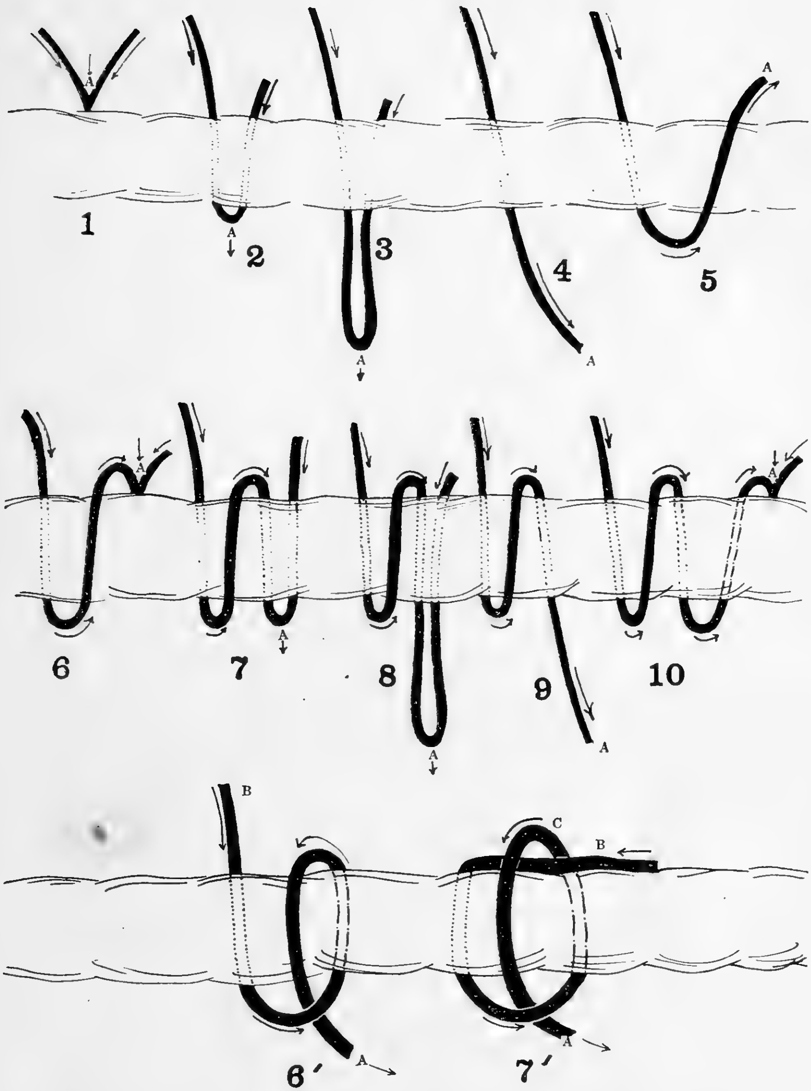

FIG. 133. STITCHES OF WEAVER BIRD OVER AN OLD FOUNDATION.

over thirty minutes per straw. Of course in winding around two twigs it would naturally take less time to use up a straw on a twig of greater diameter than on a smaller twig, there being fewer revolutions necessary in the former case.

The relation between the bill and the feet in weaving is interesting. The birds always pick up the strands with their bills, but invariably hold them down on the twigs or woven masses with their feet. A highly specialized case of correlated action is shown in Fig. 134. The bird pushed the strand underneath its toes as in (1-3). Then it took one end of the strand around the twig as in (4), and tried to push it under between its toes. (4A) shows the same position as (4) but from another view. Then to facilitate matters, the bird raised its middle toe, thereby loosening the straw and allowing the bill to work its way under and make the knot. This was observed but once, so that it is evidently not a general practice with *Quelea quelea,* but nevertheless serves to emphasize the degree of skill and intelligence with which these birds are endowed.

The discrimination shown by these birds in their nest making is little short of amazing. The location for permanent weaving is chosen only after many trials of various places. They are extremely critical of their weaving, often pulling out part of their nests and weaving it over again. In one case a bird pulled the same straw out eight times before it was satisfied with the manner in which it was woven. The general practice was this: A bird would weave in a strand, wipe its bill on the twig and then view its work from all sides. Then if not satisfied, it would try to mend it or pull it out entirely and try again. The weaving had to be compact or it was not satisfactory. Often the birds would pull and pull at a straw, each time jerking their heads back and forth with such force that it was a wonder that they could stand the strain. The discrimination of *Quelea quelea* with regard to color is fully described under Color Preferences. Suffice it to say here that red was the favorite color and orange next, while green, black, blue and violet were not used to any great extent.

The birds also showed considerable discrimination with regard to the width of the straws used. They preferred thin, fine

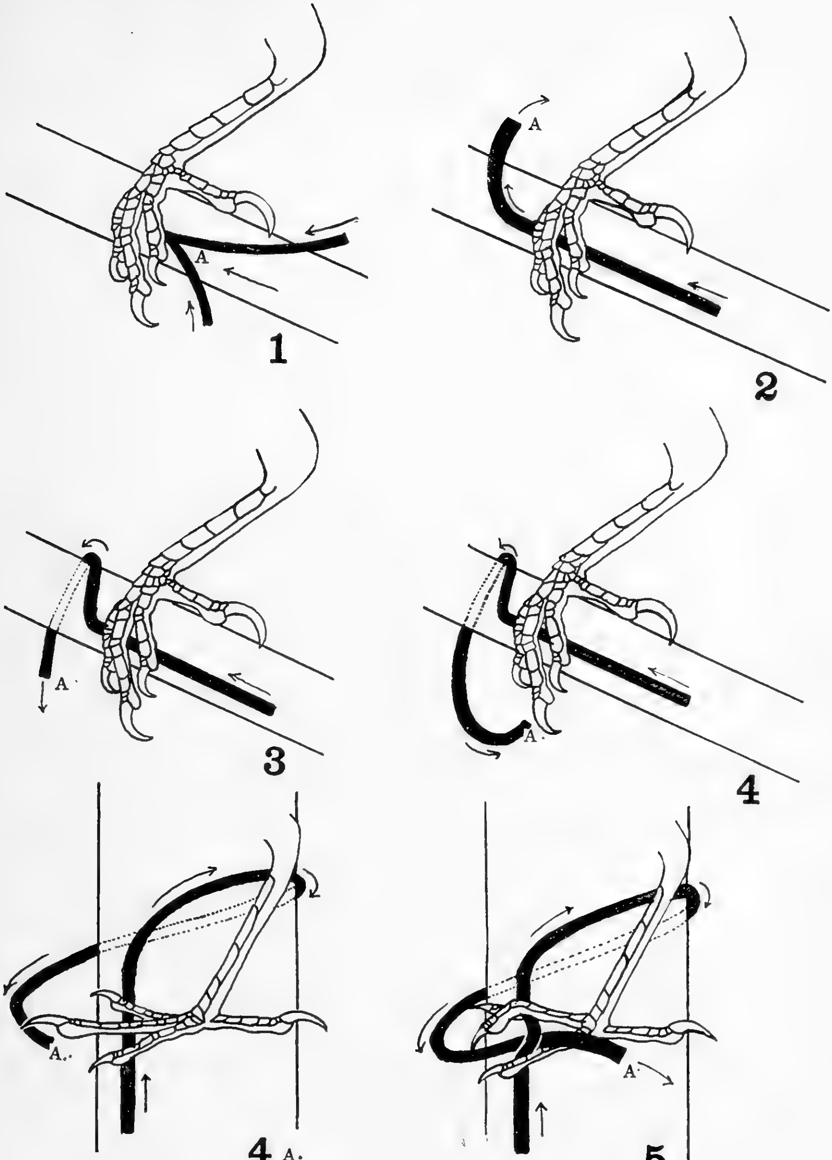

FIG. 134. HIGHLY SPECIALIZED CORRELATED ACTION BETWEEN BEAK AND FEET.

(1-4) Figure of foot after drawings by James P. Chapin.

straws to coarse, heavy ones. In fact, on numerous occasions, after stretching a strand across a fork, a bird would peck at the middle of the strand until the raffia would split longitudinally. Then it would pull on one side, thereby elongating the split until the entire length was divided into two thin strands where there had been but one wide strand. *Quelea quelea* is about as active and tireless a nest builder as one can want. The birds are always building new nests or playgrounds and when they have no building material, they busy themselves with repairing or even tearing down the old nests only to rebuild them and tear them down again. In his activity and "restless anxiety to weave nests, anything comes handy to the Red-beaked Weaver-bird, and a small finch coming near him would at once find himself minus a wing or tail feather, a friendly pecking at the neighbor's plumage being more convenient to the Red-billed Weaver than a search after a bit of fibre."[9]

This restless desire to build seems not to be restricted to *Quelea quelea* for Bates[10] writes of *Ploceus cucullatus* that ". . . . . . tearing down their nests only makes them build the more furiously. They have a perfect mania for building, and when not building new nests are all the time repairing the old ones. They often destroy palm trees by stripping them bare of their leaves."

There was much keen rivalry between birds for straws. If one bird picked up a straw and dropped it, another bird was sure to pick it up in preference to any other straw, regardless of color or width. It was not uncommon to see two birds, one on each end of the same strand pulling in opposite directions. The birds sometimes tried to frighten each other away from their nests by spreading out their wings, somewhat in the style of the intimidation display of the white-breasted nuthatch, as described by Allen[11], lowering the head, opening wide the bill and uttering a harsh scolding note.

[9] Blackston, W. A., Swaysland, W., and Wiener, A. F. Book of Canaries and Cage birds, British and Foreign, p. 404.

[10] Bates, G. L. Ibis, Jan., 1909, p. 44.

[11] Allen, A. A., Bird Lore, Vol. XXI, No. 1.

The presence of crowds of people tended to make the birds more active, as on Sundays when thousands of people watched them during the day. Ordinarily the birds were most active from 10:00 A.M. to 11:00 A.M.; least active, or rather inactive from 11:00 A.M. to 2:00 P.M.; and active again from 2:00 P.M. to 4:00 P.M. If no crowds were present the birds would tend to sleep from 11:00 A.M. to 2:00 P.M., a habit reminiscent of their lives in tropical Africa.

Color Preferences

In studying the stitches used by the birds it was found convenient to use various colors of raffia so that each stitch would be easy to follow through. Incidentally it was found that the birds seemed to have a definite preference for certain colors, chiefly red and orange.

In testing for color preferences, the method used was as follows: Seven colors of raffia were used, the raffia being of exactly the same texture as the raffia the birds had been using for some months previously. The colors used were red, orange, yellow "natural," blue, green, violet and black. There was no noticeable difference between these straws in any respect except as to color. They were tested for taste and no difference in taste was found for any color. They were tested for weight, and found alike. Tests were also made for strength and texture, and all gave similar results. Therefore it was safe to say that the straws were exactly alike except in color. (The term straw as used in this paper refers to a piece of raffia. The term is used merely for convenience.)

Thirty-six equal sized pieces of each color raffia were distributed over the floor of the cage at the end of the day, care being taken to see that the colors were evenly scattered. The birds did not venture to touch the strange material until the next morning. By watching them all the next day (from 10:00 A.M. to 4:00 P.M.), I was able to record just how many pieces of each color each species took, used or rejected. Then, at the end of this day, I added to the raffia previously put in, the same number of pieces of each color as the birds used up during the day.

This was repeated each day for four days. Then the experiment was repeated nineteen days later and carried on for three days. Thus every day the birds had thirty-six pieces of each of the seven colors or two hundred and fifty-two pieces of raffia in all to start with. Therefore, by adding together the results of the different days' tests for each species, I was able to find what colors each preferred and what each disliked. The possibility of the birds using up the colors of their preference and then, through lack of these, having to use other colors was eliminated by starting them off in the beginning with more of each kind than they could use up in a day and by adding each day just what they used up as described above.

All the straws used in the experiments were of equal thickness and about a foot long, this length being chosen because it satisfied two conditions: it was long enough for the birds to use with comfort, and at the same time it was short enough to enable each bird to use quite a few pieces each day. This latter condition was essential if any appreciable number of records were to be obtained.

The experiments were extended not only to include *Quelea quelea*, but also its close relative *Quelea russi*, the Russ masked weaver bird. There were five individuals of the Red-billed Weaver and three of the Russ Masked Weaver under observation. The following table illustrates graphically the substance of the present paragraph:

RED-BILLED WEAVER, *Quelea quelea*
(5 individuals)

	RED	ORANGE	YELLOW	GREEN	BLUE	VIOLET	BLACK
Used	59	27	22	8	11	7	3
Rejected	0	0	3	10	3	5	2
Total	59	27	25	18	14	12	5
Percentage Used	100	100	88	44	78	58	60
Percentage Rejected	0	0	12	56	22	42	40

RUSS MASKED WEAVER, *Quelea russi*
(3 individuals)

	RED	ORANGE	YELLOW	GREEN	BLUE	VIOLET	BLACK
Used	21	20	7	3	1	3	3
Rejected	0	0	0	3	1	0	0
Total	21	20	7	6	2	3	3
Percentage Used	100	100	100	50	50	100	100
Percentage Rejected	0	0	0	50	50	0	0

It will be seen at a glance that in numbers of straws used by *Quelea quelea,* red is more than double orange which, in turn, is greater than yellow, etc. In numbers of straws rejected, that is, picked up by the birds and then voluntarily (apparently) rejected, green leads with ten, while red and orange were never rejected. In this connection I may say that I counted as rejected those straws, the rejection of which appeared to be voluntary on the part of the birds. Several times a bird picked up a straw and was chased by another bird or frightened by some noise, and dropped the straw and flew off to a perch. These cases are not counted here, as they evidently have nothing to do with color rejection. Several red and orange straws were rejected in this way. In view of this it may be that the figures given in the table are not wholly correct but the general results are probably very nearly true. While the preferences may not be as marked as the figures would indicate, we must admit the existence of these preferences. The accompanying graph (Fig. 135) represents the color preference of *Quelea quelea* as interpreted by the number of straws of each color used by that species.

If we add the number of straws used and the number rejected for each color and then find that what not that percent of the total number of each color was used we find the preference to be:

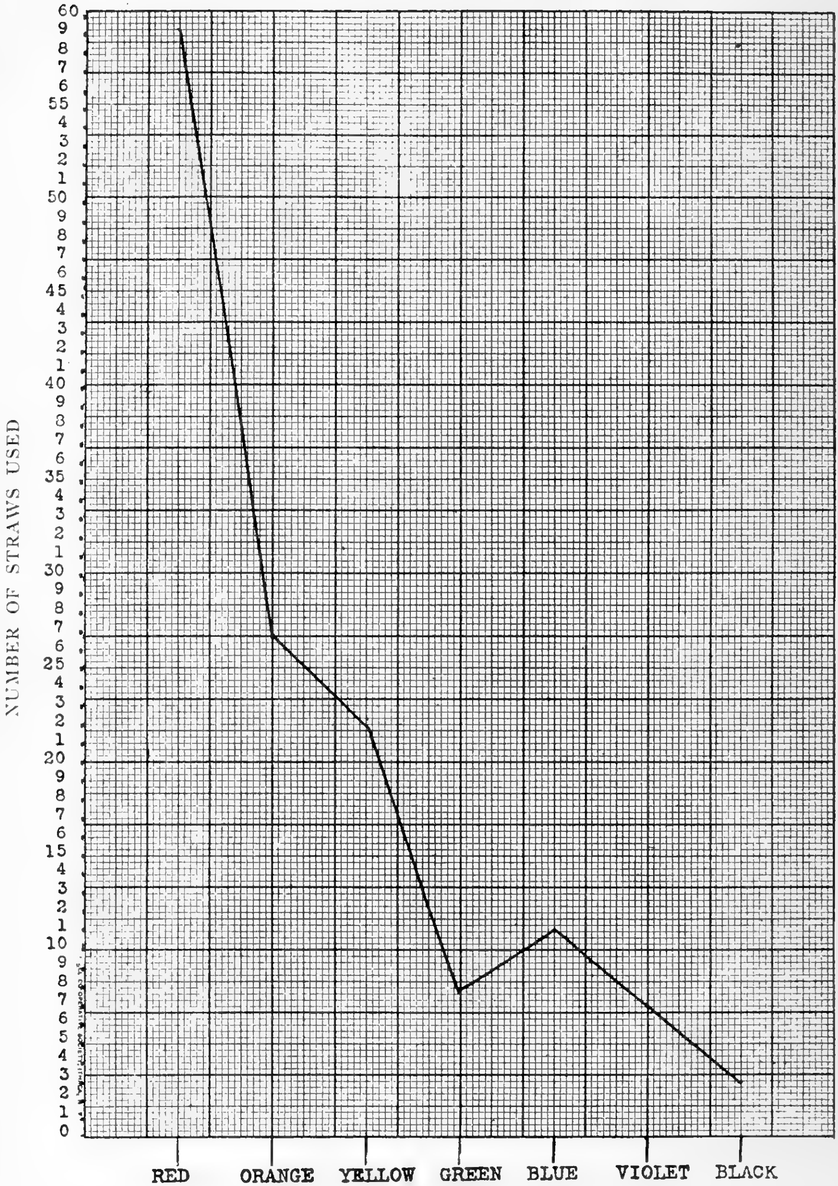

FIG. 135. GRAPH SHOWING COLOR PREFERENCES OF *Q. QUELEA*.

1. *Quelea quelea*—red 100%, orange 100%, yellow 88%, blue 78%, black 60%, violet 58%, green 44%.
2. *Quelea russi*—red 100%, orange 100%, yellow 100%, violet and black 100% (not significant as there were only three straws of each color picked up as compared with twenty-one red and twenty orange), and green 50%, blue 50%.

While there seems to be a fairly well defined color preference for each species, yet there is considerable variation among the individuals of the same species. Thus, one individual of *Quelea quelea* used in one day one red, one orange, one violet, and one blue straw, while another individual of the same species used in the same day three red, three orange, one yellow (and rejected one yellow) and one green straws. Still another individual of this species used on the same day four red, one orange, one yellow, and one blue straws. Yet each individual, of the five used at least one red and no more than one of any other color except orange on that day. Not only is there variation between individuals of the same species, but the same individual may vary from day to day.

Summary and Conclusions

1. In captivity the birds built abnormal nests, but later (two years after), they built normal ones, as shown in Fig. 130.

2. Normally they begin by weaving a vertical hoop, and, beginning at the bottom, fill in the back and then the front, in the middle of which they leave an entrance hole.

3. Different types of stitches were used in weaving on bare twigs and on previously woven masses.

4. In weaving around bare twigs, three types of stitches were used, as shown in Fig. 132. On this plate (2) shows the commonest stitch used.

5. The type of stitch used in weaving on a previously woven mass is shown on Fig. 133 and needs no further mention here.

6. All actual weaving is done with the bill; the toes being used to pick up and hold in place the straws used.

7. A considerable degree of correlation seems to exist between the bill and toes in weaving.

8. The birds exhibit a remarkable amount of discrimination in respect to the color and width of the straws used and in regard to the compactness of the weaving.

9. The birds preferred red and orange to all the other colors used, the colors being taken in the following order:

Red-orange-yellow-green-blue-violet-black.

The last three are not significant due to the paucity of records.

Acknowledgments

The work on which this paper is based was conducted at the New York Zoological Park through the courtesy of Mr. William Beebe and Mr. Lee S. Crandall of the Department of Birds. I take this opportunity of acknowledging my indebtedness to both Mr. Beebe and Mr. Crandall for their many kindnesses and to Professor A. J. Goldfarb of the College of the City of New York for helpful suggestions and criticism. For permission to use the figure of a ploceine foot Fig. 134 (1-4) I am indebted to Mr. James P. Chapin of the American Museum of Natural History, the original of this figure having appeared in his paper on the classification of the weaver birds. Mr. Chapin very kindly has given me also a drawing of a Red-billed Weaver, Fig. 132 (4), for use in this paper.

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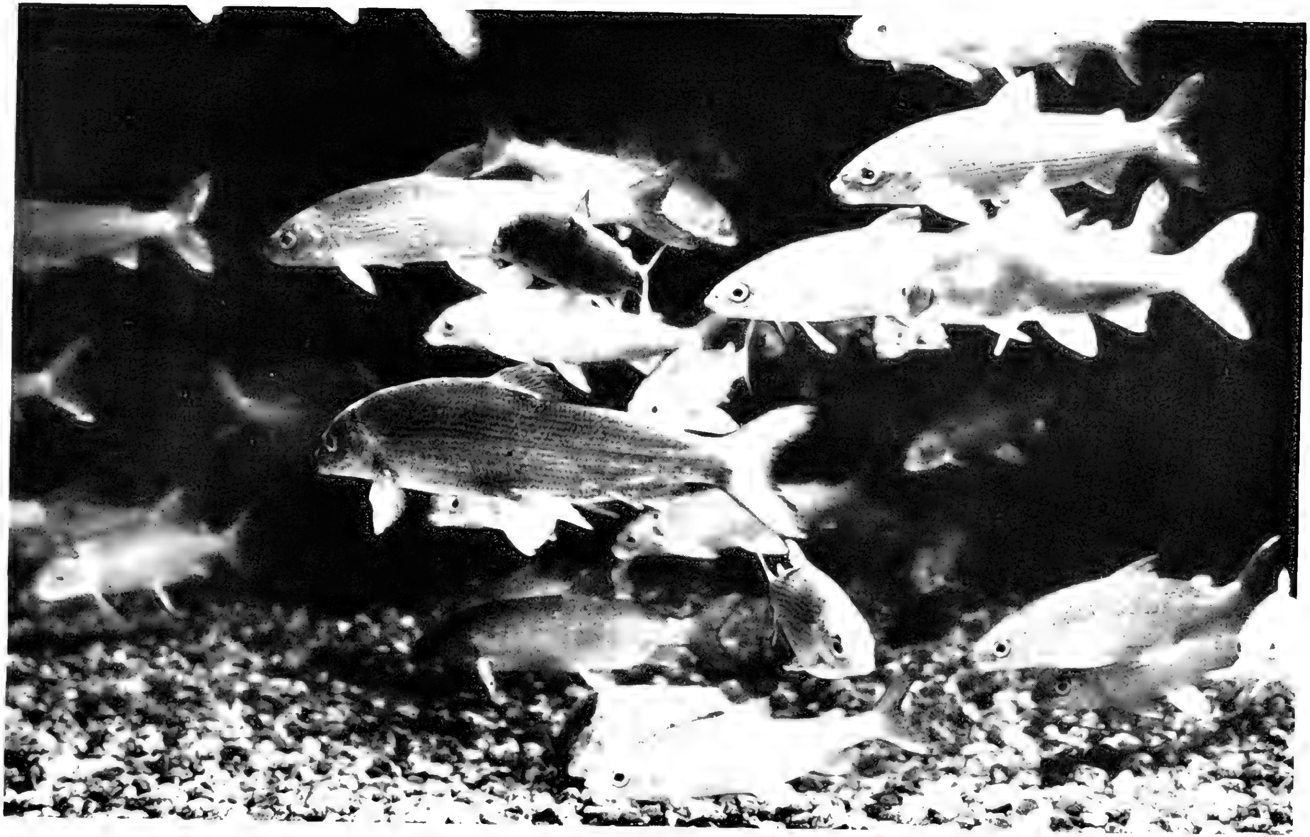

FIG. 136. WHITEFISHES REARED IN THE NEW YORK AQUARIUM
Photograph by Elwin R. Sanborn

Fig. 136—Face Title Page
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(Contribution Number 9)

THE WHITEFISHES

(Coregonus clupeaformis)

WHITEFISHES REARED IN THE NEW YORK AQUARIUM

By Ida M. Mellen
New York Aquarium

A STUDY OF THE SCALES OF WHITEFISHES OF KNOWN AGES

By John Van Oosten
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New York Aquarium

The New York Aquarium is showing a unique exhibit of whitefishes *(Coregonus clupeaformis)* hatched in the Aquarium in January, 1913; unique in that no similar exhibit ever has been seen there or anywhere else. Once or twice whitefishes were reared in the Aquarium to the age of a month, and once to the age of a year; but those now on exhibition—nine years old at the present writing—are the only whitefishes ever reared in captivity from egg to maturity. They are the survivors of a few hundred specimens retained from the fry that hatched out of a consignment of a million eggs received in December, 1912, from the United States Bureau of Fisheries. The eggs came from western Lake Erie waters, and were shipped from the fisheries station at Put-in-Bay, Ohio. The remainder of the fry were distributed to state waters of northern New York and New Jersey.

By checking up our findings with those of other observers, we have learned some interesting facts about whitefishes, the probable age when they arrive at sexual maturity, their longevity, etc. As ours are the only fishes of this species in existence the age of which is positively known, certain biologists engaged in the study of lepidology (the scales of fishes) have been provided with scales from the Aquarium specimens, whitefishes being one of the species in which the age is written in concentric rings on the scales. Of the various kinds of scales in fishes—placoid, ctenoid, cycloid, ganoid or rhomboid, etc.—those which characterize the whitefish are of the cycloid type, *i. e.*, thin, rounded scales, having concentric rings as just described, and with no spiny projections.

A cycloid scale strongly reminds one of a finger print. It has its central whorl, called the focus, which starts the series of concentric rings, called circuli, and there are lines of radiation called radii. But unlike the finger print, groups of the circuli are marked off in definite dark and light bands, two such bands representing one year of the fish's life. That is, there is a large area of light summer bands and a small area of dark winter bands or annuli, growth being more rapid during the months when temperature is higher and food more abundant.

Dr. Jacob Reighard's assistant in the Department of Zoology, University of Michigan, Mr. John Van Oosten, who is also in the employ of the United States Bureau of Fisheries, made a study of whitefish scales from our Aquarium specimens. One dead fish and three scales from a live fish were sent him each month for twelve months, in order that he might observe progressive changes in the scales of specimens the age of which was known, though it was not to be supposed that fishes that had spent all their lives in captivity, with limited swimming space and little variety in their food, would compare favorably in development with wild fishes. The method followed in removing the scales was suggested by Mr. Van Oosten and consisted in segregating two specimens, removing scales from one fish one month and from the other the next, thus giving each fish a rest of two months between operations. The scales were removed with a small forceps.

Whitefishes are so fragile that they are sometimes killed merely by transference from one tank to another, or by an accidental stroke of the brush when their tank is being cleaned. It was therefore with some trepidation that the writer commenced this series of very delicate operations. The first specimen operated on died within fifteen minutes; but this tragedy was never repeated. All subsequent operations were made on specimens held by the head and tail in a shallow pan of water, the gills being kept continually moist, and great care being taken to remove scales not too near the lateral line (in fact, all scales were removed from a spot about half way between the lateral line and the back, the section anterior to the dorsal fin being selected); also to remove them rapidly and apply a strong solution of permanganate of potassium at once to the injured spot, returning the fish quickly to the tank. The operation always exhausted the fish and it would lie quite still while the permanganate was poured on. When returned to the tank it floated on its back, breathing hard for a few minutes, then gradually equilibrated itself and recovered.

Mr. Van Oosten found that the scales of the Aquarium whitefishes revealed the stunted growth of the specimens in the growth of their circuli, but by experience he gradually learned that by selecting scales of a certain shape, he would obtain scales which showed the annuli or year-rings so clearly that any inexperienced person could read them with ease. In fact, he had various such people read the scales though they knew nothing about the age of the fish from which the scales were taken. He found that while the circuli are formed throughout the year, the annulus is truly a winter-band, being formed only during the winter months, *i. e.*, after October. All of which is explained in detail in his paper here published.

So many of these notable whitefishes died in 1921 that it was imagined they might have lived the natural span of their existence; yet they had never been observed to spawn. It was hinted that they must have done so and the eggs had been eaten so fast that no one ever saw them; but Mr. Robert J. Lanier, of the Aquarium staff, to whom belongs the honor of having reared these fishes, has kept watch over them all their lives and was entirely certain that they had never spawned. Was it possible that captivity prevented them from attaining sexual maturity? If so, the case was a unique one.

In January, 1922, when the fishes were exactly nine years old, females were observed swollen with eggs which, however, lacked vitality to such an extent that they could not be fertilized! Were these whitefishes reaching sexual maturity and their natural span of life at the same time? It seemed impossible.

The writer knew of only one way to solve the riddle. Dr. Wilbert A. Clemens, of the Department of Biology, University of Toronto, who had also received some scales from the Aquarium specimens, had studied the scales of wild whitefishes. Perhaps he had found some that were older than ours! We wrote him about the eggs, their lack of vitality, the supposition that nine years might be the natural term of the life of the fish, etc., and asked if he had ever found a wild specimen more than nine years old.

His answer, as the following quotation from it shows, was fraught with interest:

> "I have indeed taken whitefishes much older than those you have at the Aquarium. I spent last summer on Lake Nipigon and according to my records the largest whitefish we took was twenty-one and a quarter inches in length and was at least sixteen years old. I have records of two others about twenty inches in length, which I have recorded provisionally as sixteen and seventeen years old, but possibly eighteen or nineteen.
>
> "We do not know as yet at what age whitefish first spawn. In Lake Erie I suspect it occurs at the end of the fifth or sixth summer. In Lake Nipigon it probably occurs considerably later. On November 11 of last year I received from the spawn-takers on Lake Nipigon four whitefish which they said were the smallest they had taken spawn from. These were scarcely fifteen inches in length and were nine and ten years of age. So it may be that the whitefish in the Aquarium are just reaching the spawning age, and although the eggs are few and weak this year they may be normal or nearly so next year. It will certainly be interesting to see what happens."[1]

Mr. Van Oosten's paper describes the condition in which he found the sex organs of the Aquarium whitefishes.

This species of whitefish normally attains a length of two feet or more, but none of the specimens in the Aquarium measures more than fifteen inches. We have not infrequently observed that fishes and even snails are stunted by captivity. It is known, however, that fishes do not always stop growing when they reach sexual maturity or decline in years, many continuing to grow as long as they live; and we believe that these whitefishes are still growing, though they probably never will be of normal size.

[1] In December, 1922, when the fishes were nearly ten years old, a female was again observed carrying eggs. She was stripped and the eggs fertilized; but they were weak and did not develop beyond the morula stage.

The last time these specimens were counted was in 1919, when they were transferred from one tank to another and numbered two hundred and sixteen. They have dwindled to about eighty-four, and it is hoped that we may some day be able to repeat the remarkable feat of rearing some to maturity from the eggs—a feat many times attempted both at the Aquarium and at Government hatcheries, but only once performed.

Jordan and Evermann (Fishes of North and Middle America) state that the common whitefish *(Coregonus clupeaformis)* "is subject to considerable variations, dependent on food, waters, etc." The food of fishes is indeed a factor of so great importance in their growth and development that breeders of fancy varieties believe the food controls not only the size and health of the fish, but the actual shape and beauty of its fins. Like other vertebrated animals, they require, for perfect development, foods that are both nourishing and bone-building.

In a state of nature infant whitefishes, judging from those in the Aquarium tanks, remain near the surface for a time, their first food consisting of plankton—live floating matter of both vegetable and animal character: protozoa, diatoms, minute crustaceans such as the young of the shrimp *(Gammarus)* and water fleas *(Cyclops, Cypris, Daphnia)*, etc. Later they subsist entirely on minute crustaceans of these and other species. In the earliest period of their lives, after the absorption of the yolk sac, Dr. S. A. Forbes, of Illinois, has observed that the fry are provided with four curved teeth in the lower jaw, which are of no possible service and are subsequently lost.

Gradually they descend to the bottom for food, and there, according to those who have examined the stomach contents of adult wild specimens, they feed on small live invertebrates, principally crustaceans, snails, insect larvae and water beetles.

The crystalline gray-whiteness of mature whitefishes is exceedingly attractive to the eye, and the specimens in the New York Aquarium have long furnished one of its most pleasing exhibits for the casual visitor, as well as one of its most important economic exhibits for the fish culturist. This species of whitefish is not only the largest, but the most delicate in flavor of all the whitefishes of the Great Lakes.

The Aquarium specimens have never known the excitements of wild life, or what it means to hunt or be hunted.

New York Aquarium, April 1922.

THE WHITEFISHES
(Coregonus clupeaformis)

A STUDY OF THE SCALES OF WHITEFISHES OF KNOWN AGES[2]

BY JOHN VAN OOSTEN
Field Assistant, U. S. Bureau of Fisheries.

INTRODUCTION.

During recent years many investigations of scientific and economic importance have been conducted on the age and the rate of growth of fishes as determined from a study of their scales. This has involved the interpretation of certain rings found on the exterior surface of scales.

In order to illustrate clearly the mode of the formation of these rings, Fig. 137 is presented. It represents a typical scale of a whitefish, 197 mm. in length, captured October 22, 1917, at East Tawas, Mich., on Lake Huron. Near the center of the scale is a small, clear area, the focus (F), which represents the original scale in the young specimen. Around this focus are numerous, more or less relieved striations, concentric or nearly so with the margin. These are termed circuli (C) and like the rings in a tree mark successive stages in the growth of the scale. Running from the focus to the periphery of the scale are four more or less conspicuous radiating ridges (AR, PR), which divide the surface of the scale into four roughly triangular areas or fields. When the scale is in position in the fish the area to the right in the figure is directed towards the tail and is therefore designated as the caudal or posterior area (Caudal). The area opposite the caudal is the anterior (Anterior), while the two areas which separate the caudal from the anterior are the lateral or the dorsal (Dorsal) and the ventral (Ventral). The borders of these four areas which form the periphery of the scale are accordingly termed the caudal, anterior, dorsal and ventral

[2] Contribution from the Zoological Laboratory, University of Michigan, published with the permission of the U. S. Commissioner of Fisheries.

borders. The radiating ridges are either antero-lateral (AR) or postero-lateral (PR). The greatest antero-posterior diameter which bisects the caudal area of the scale is its length (L-L).

By careful examination two distinct zones may be seen in this scale, an inner characterized in general by more closely spaced lines and an outer in which the lines are further apart. The two zones are more readily seen when the figure is viewed from such a distance as to somewhat obscure the details. The inner zone represents, according to current theory, the entire growth of the first year, while the outer zone represents the growth of the second summer. If the lines of growth in the lateral field be followed from the center outward and downward along the antero-lateral ridge, it may be seen that the first twenty are complete and uniformly spaced. With occasional breaks and irregularities they may be traced entirely around the scale. The next six are incomplete and the outermost of them ends (or begins) near the antero-lateral ridge. Following this last incomplete line to the anterior field, a region is encountered within which the individual circuli can no longer be traced with certainty, for they are less distinct, much broken, anastomosed and closer together. This zone of faint, approximated and much broken circuli, when contrasted with the preceding and succeeding areas of strong, complete and widely spaced circuli stands out as a rather sharply defined band. This band may be traced around the whole scale and is perhaps better defined in the posterior field where it appears as a lighter zone with very little detail.

To account for these structures, it is contended that the completed and comparatively widely separated circuli are formed during periods of rapid growth, the incomplete lines during periods of decreased growth, and the short, weak, much broken lines during periods when growth has nearly ceased. As the cessation or retardation of growth is thought to occur in the winter, the much broken area is accordingly designated as a winter-band or annulus (A).

When the scale resumes its growth in the spring a complete circulus is again formed which in the process of uniting, as it were, the incomplete lines bends sharply at the antero-lateral ridge. This circulus is considered the limit of the annulus it encloses and is so employed in the measurements of scales.

The twenty-five circuli of the second summer, in this scale, are much more widely separated than those of the first, which indicates a much more rapid growth during the former season.

Of these twenty-five circuli the last five or six at the margin are incomplete, which indicates the occurrence of a retardation in growth. No approximation of the circuli is yet visible, nor is there apparent the area of weak and broken lines. A complete cessation of growth has not yet taken place. This conclusion appears to be reasonable as the specimen was caught in October preceding the period of low temperatures when growth is greatly retarded or ceases altogether.

The foregoing account of the mode of formation of annuli is accepted by the majority of those investigators who make use of scales in determining the lengths and rate of growth of fishes.

The application of the above hypothesis to the study of the life-histories of fishes is a simple matter. By enumerating the annuli on the scales, the age of the individual is determined in years. Thus the specimen whose scale (Fig. 137) illustrated the method of growth is found to be at the end of its second year. The length of an individual at the end of each successive year may also be ascertained from its scales. Given the total length of the fish and of one of its scales and the length of that part of this scale included in an annulus formed during a given year, the total length of the fish at the end of this given year may be computed by the following formula in which the third term is the unknown:

$$\frac{\text{length of scale formed at end of year X}}{\text{total length of scale}} = \frac{\text{length of fish at end of year X}}{\text{length of fish at the time of capture.}}$$

Repeating this formula for each year of the fish's life, the lengths attained at the end of the several years are calculated and by a simple subtraction the increments of growth for each year are determined.

The soundness of the scale method of determining the length of a fish at successive years of its life and its annual growth increments depends on the validity of the following propositions:

1. That the scales remain constant in number and identity throughout the life of the fish.
2. That the annual increment in the length (or some other dimension which must then be used) of the scale maintains throughout the life of the fish a constant ratio with the annual increment in body length.
3. That the annuli are formed yearly and at the same time each year.

Incidentally the following questions are raised, but the validity of the scale method of computation is not affected by them:

4. Whether the annuli represent periods of retarded or arrested growth of the scale.
5. Whether the growth of the fish in length is retarded or arrested at the time of formation of the annuli.
6. What factors are responsible for the arrest or retardation of growth in fish and scales.

Considering now the first three propositions listed above, it is believed that the first two are fairly well established and that the last one forms the crux of the whole problem. If the age of a fish can be determined with certainty, the establishment of the validity of the third proposition becomes a comparatively easy matter in a group of fishes whose scales show growth rings. Indisputable evidence of a correlation between the number of annuli on the scales and that of the years of life of their bearer can only be obtained by observation on fish of known age in the field and in the laboratory. And the value of the results rises with the number of years for which this correlation is found to exist.

An extended review of the literature is reserved for a later paper. Here I indicate briefly the chief differences of viewpoint.

Both Hoffbauer (1898, 1899, 1901) and Walter (1901) believed that the age-hypothesis does not hold for carp older than four years. Likewise Brown (1904) and Tims (1906) contradicting Thomson (1904) held the scale method entirely unreliable as applied to the Gadidae. Even Thomson concludes from his experiment that a well-fed whiting may pass the winter without forming an annulus on its scales. Arwidsson (1910) concludes from his study of a series of salmon, 4 to 36 months old, that the completion of the first annulus does not occur at a definite time of the year nor at a definite age, but only at a definite length of the fish, viz., at 60 mm. Masterman (1913) asserts that it is a well known fact that the otoliths or "ear-stones" often used for age-determinations cease growing in the plaice after 6 or 7 years, and that scales also are unreliable after the first 4 or 5 years, though the latter statement is questioned by Hutton (1914). Likewise Scott (1906) expresses the opinion that otoliths do not show the exact age of their possessors. Many other authors may be quoted as opposing the age-hypothesis, but an overwhelming majority assume the validity of the theory and apply it.

Much diversity of opinion exists as to the relation between the formation of annuli and the growth of scales and body. The majority of students believe that the annuli are due to seasonal variation in body growth, that they correspond to retarded growth; but Cunningham's (1905) observation and Cutler's (1918) experiments contradict this view in part, while Taylor (1916) denies such a correlation entirely.

Much controversy also obtains relative to the factors governing the formation of annuli. According to Hoffbauer (1898, 1899), Thomson (1904), Fraser (1917) and others food is the primary factor and not temperature. Taylor (1916) and Cutler (1918) conclude from their experiments that food is not the factor involved. Fraser (1917) holds that neither salinity nor density nor temperature has any factorial significance, while Cutler (1918) believes that temperature alone is causative. Rich (1920) refers to the factor as "a changed environment," Jacot (1920) calls it "migration," while in the case of some trout and salmon the later annuli correspond to a spawning and consequently are transformed into "spawning-marks."

Masterman (1913) wrote, "Experience shows that each species of fish must be investigated separately by the method best suited to it," implying that the establishment of the validity of the hypothesis for one species does not necessarily make it applicable to other species of fish.

The scales of the whitefish *(C. clupeaformis)* have never been critically studied. During the course of an extended investigation of the scales of the Coregonine fishes of the Great Lakes, the writer was fortunate in obtaining scales of this species of known age—nine years. This material forms the basis of an attempt to test the underlying assumptions of the scale method of computation as applied to this species. It also is believed to throw light on the relation between annuli and rate of growth; while the accompanying data permit a discussion of the environmental factors involved in annulus formation.

Here I wish to present a brief description of the apparatus used for the measurement of scales, as my method differs from those ordinarily employed. The instrument is constructed on the principle of a photomicrographic apparatus in which the image is projected on the ground glass. The apparatus consists of a rectangular wooden frame, 14 inches square and 34 inches long. Into one end of the frame is fitted, flush with the exterior surface of the frame, a piece of ground glass, 12 inches square. A tapering bellows made of ordinary chart cloth painted black is attached to the ground glass end of the frame. The bellows when fully stretched extends about three-fourths the length of the wooden frame. The tapered end of the bellows is attached to a small square wooden frame into which is tightly fitted a wooden block in the center of which a hole large enough for the insertion of the microscope tube is bored. When the apparatus is used in the vertical position the microscope is simply placed beneath and extended into the bellows. It is much easier to use this instrument in the horizontal position. In this case the microscope stand is attached to a board at the base of the wooden frame (the end opposite that into which the ground glass is fitted) and the microscope tube drawn into the horizontal position. The open base of the frame is then covered with a sheet of black paper into which a hole is cut so as to allow the light to enter the condenser of the microscope. A special Bausch and Lomb lamp with a 108-Watt bulb furnishes the illumination and is placed about two feet from the base of the frame. A special aspherical condenser accompanying the special lamp is used in the place of the ordinary condenser. The light concentrated upon the hole in the black paper passes through the condenser, microscope tube and bellows, and projects the scale upon the ground glass.

A mechanical stage is always used. To each adjustment button of the mechanical stage is attached, by means of a universal joint cut from a piece of tin, slender wooden rods which extend a little beyond the ground glass end of the frame. In a similar way another rod is attached to the coarse adjustment screw of the microscope. By means of these rods the scale can be moved into place and properly focused from the ground glass end of the frame. The projected scale is measured with an accurate wooden or transparent millimeter rule which is held in place against the ground glass by two strips of steel, four of which are screwed on the wooden frame, one at each corner. To facilitate the counting of the circuli of each scale an ordinary reading glass is used. The whole apparatus is placed upon a long table and may be covered with a black cloth. No dark room is required as the lamp is strong enough to project a clear image on the ground glass in a room illuminated by electric lights; during the day the curtains of the room must be drawn.

The advantages of this method of scale reading over those which use the camera lucida, ocular micrometer or micrometer eyepiece are many. In the first method the scales can be highly magnified without any part being lost to view as is the case in the microscope tube; the circuli and the distances between the annuli of such highly magnified scales can be more accurately, more quickly, and more easily enumerated and measured; and, if the illumination is properly adjusted, scale work can be done with much less straining of the eyes.

When the apparatus is used in the horizontal position it is necessary that the scales be mounted in a stiff medium. Each scale is therefore cleaned in water with a small bristle brush and mounted in a medium of glycerine to which has been added filtered gelatine and a little carbolic acid. The glycerine and gelatine are mixed in such proportion that the solution will stiffen immediately upon cooling. When in this medium, the scales can be stored as permanent mounts and can also be photographed. The photomicrographs (Figs. 137-142) are of scales mounted in a gelatine-glycerine solution.

I wish to express my appreciation to Dr. Charles H. Townsend, the Director, and to Miss Ida M. Mellen, the secretary and scientific assistant of the New York Aquarium, through whose kindness and efficient cooperation I have been able to obtain the whitefishes and scales for this work. These whitefishes, the only ones known to have been reared in captivity, form a valuable exhibition at the Aquarium so that it has been no small sacrifice to part with even a few of them. I am also indebted to Dr. Walter Koelz of the U. S. Bureau of Fisheries who has kindly given me access to his field data and manuscript on the Coregonine fishes of Lake Huron. I would further express my obligations to Prof. Jacob Reighard, who read the manuscript and generously gave assistance in the course of the work. To Mrs. Alvina M. Woodford, of the University of Michigan Library, I am indebted for many valuable suggestions relative to the photographing of the scales.

NEW YORK AQUARIUM WHITEFISH SCALES

Annuli and Number of Winters of Life

Twenty-seven preserved specimens of the Aquarium whitefish, hatched January, 1913, were received. These had died (or had been killed) at intervals between August 13, 1920, and January 3, 1922, as shown in Table I—a period of sixteen months. The fish received had died (been killed) during every month of the year except November. The lengths of each specimen at the time of death is shown in column K of Table I and is followed by the formula which indicates the sex and the condition of the sex organs (see p. 403). The remaining entries in Table I are calculated values and will be referred to in another place.

Table I—Showing for 27 New York Aquarium Whitefish hatched January, 1913, from eggs from Put-in-Bay Hatchery, the U. of M Museum number, the date of death, the length in mm. (K) at time of death (measured snout to caudal), the sex and condition of sex organs, the lengths in mm. at the end of each winter of life as calculated from the scales (K_1, K_2, K_3, etc.), the annual growth increments in mm. as determined from scales (k_2, k_3, etc.), and the averages of these calculated values for each year of life. Below the calculated averages at the bottom of the columns are given the average lengths and average annual increments for each year of 238 Lake Huron whitefish as determined by actual measurements; the average length of the first year, however, is based on diameter measurements of scales, as no one-year-old whitefish were available.

U. of M. Museum Number	Date of Death	Length in mm. K	Sex and Stage of Organs*	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	k_2	k_3	k_4	k_5	k_6	k_7	k_8	k_9
54505	Aug. 13, 1920	227	♂ D	55	97	110	142	167	190	217		42	13	32	25	23	27	10	
54506	Oct. 26, 1920	245	♂ D	58	136	152	176	206	218	236		78	16	24	30	12	18	9	
54507	Dec. 1, 1920	265	♂ D	65	131	161	183	210	233	256		66	30	22	27	23	23	9	
54508	Dec. 30, 1920	287	♀ A1-2-4E	108	175	199	219	234	256	274		67	24	20	15	22	18	13	
54509	Jan. 28, 1921	219	♀ A1-2-3D-	63	113	127	143	163	190	206		50	14	16	20	27	16	13	
54510	Feb. 28, 1921	334	?eviscerated	112	201	234	255	277	299	314		89	33	21	22	22	15	20	
54511	Mar. 4, 1921	303	♀ A3D-	67	135	156	196	222	253	280		68	21	40	26	31	27	23	
54512	Mar. 28, 1921	286	♀ A4D-	66	156	181	211	229	247	263		90	25	30	18	18	16	23	
54513	Apr. 28, 1921	278	♂ E	70	149	176	202	219	233	250	274	79	27	26	17	14	17	24	4
54514	May 28, 1921	210	♀ A2D-	43	92	109	128	157	179	193	203	49	17	19	29	22	14	10	7
54515	June 25, 1921	275	♀ A2-4D-	49	120	155	189	201	219	241	256	71	35	34	12	18	22	15	19
54516	July 13, 1921	282	♀ A5D	81	136	159	180	198	217	240	259	55	23	21	18	19	23	19	23
54517	July 27, 1921	310	♂ C	69	150	175	208	232	250	270	291	81	25	33	24	18	20	21	19
54518	July 27, 1921	311	♂ E	51	134	182	216	244	262	278	296	83	48	34	28	18	16	18	15
54519	July 28, 1921	256	♂ E	72	120	166	179	205	228	238	248	48	46	13	26	23	10	10	8
54520	July 28, 1921	268	♀ D	67	119	168	188	206	232	245	263	52	49	20	18	26	13	18	5
54521	July 28, 1921	322	♂ C	62	182	199	217	247	271	287	309	120	17	18	30	24	16	22	13
54522	Aug. 3, 1921	287	♀ A3-4-5D+	66	126	149	166	185	204	232	270	60	23	17	19	19	28	38	17
54523	Aug. 3, 1921	339	♂ D	91	116	207	235	261	278	299	319	25	91	28	26	17	21	20	20
54524	Aug. 25, 1921	259	♀ D	51	111	142	175	195	217	232	246	60	31	33	20	22	15	14	13
54525	Sept. 11, 1921	220	♂ C	40	78	114	128	149	163	194	208	38	36	14	21	14	31	14	12
54526	Sept. 18, 1921	275	♀ A6D-	65	113	146	186	199	212	223	247	48	33	40	13	13	11	24	28
54527	Oct. 25, 1921	235	♂ C	71	110	137	168	177	191	214	225	39	27	31	9	14	23	11	10
54528	Dec. 20, 1921	329	♂ A	54	146	205	232	253	271	288	307	92	59	27	21	18	17	19	22
54529	Dec. 20, 1921	320	♀ B	67	131	174	191	213	236	273	295	64	43	17	22	23	37	22	25
54530	Jan. 3, 1922	317	♂ C or A	50	128	183	217	252	265	280	299	78	55	34	35	13	15	19	18
54531	Jan. 3, 1922	347	♀ B	84	154	193	232	256	278	305	332	70	39	39	24	22	27	27	15
	Length and increment averages of N. Y. Aq. whitefish.			67	132	165	191	213	233	253	271	65	33	26	22	20	20	18	
	Length and increment averages of 238 Lake Huron whitefish.			119?	213	268	322	366	412	449		94?	55	54	44	46	37		

*For explanations of the letters denoting the stage of sex organs, see p. 403. Also see Table VII.

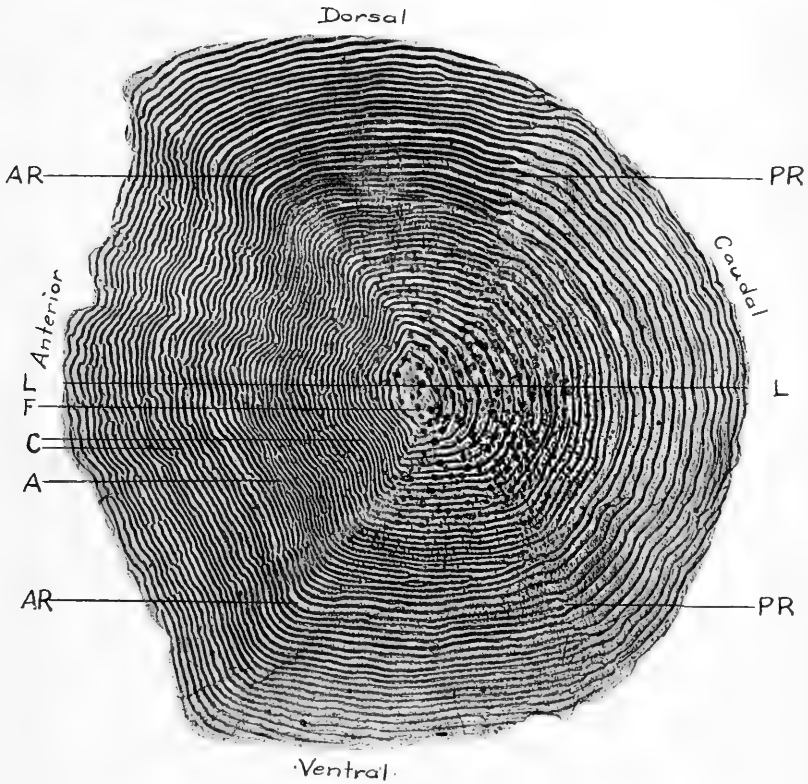

FIG. 137. Typical scale of Lake Huron Whitefish *(Coregonus clupeaformis* Mitchill) from East Tawas, Michigan. Length of fish, 197 mm., captured October 22, 1917. L-L, length of scale; F, focus; C, circuli; A, annulus of first winter; AR, antero-lateral ridges; PR, postero-lateral ridges; Dorsal, Ventral, Anterior, Caudal border and area. X-25.

FIG. 138. Scale of New York Aquarium Whitefish *(C. clupeaformis)* hatched January, 1913; killed December 1, 1920. U. of M. Museum No. 54507; Male, 265 mm. long, 7 years, 10 months old. Scale shows 7 completed annuli and a marginal growth. X-22.

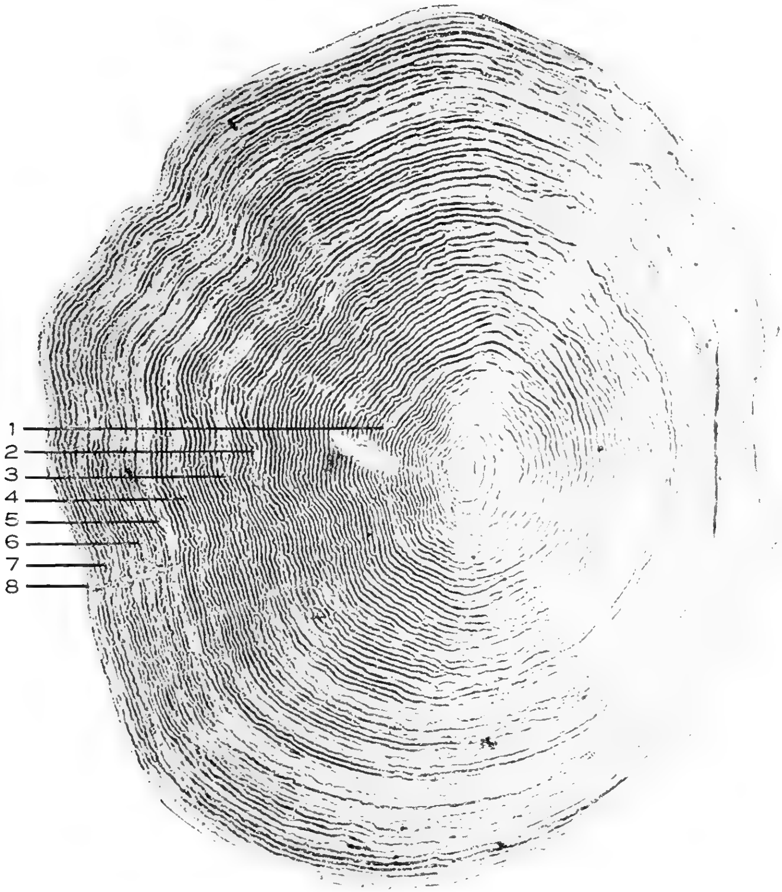

FIG. 139. Scale of New York Aquarium Whitefish *(C. clupeaformis)* hatched January, 1913; killed April 28, 1921. U. of M. Museum No. 54513; Male, 278 mm. long, 8 years, 3 months old. Scale shows 8 completed annuli, the eighth at the margin. X-18.

FIG. 140. Scale of New York Aquarium Whitefish *(C. clupeaformis)* hatched January, 1913; died July 13, 1921. U. of M. Museum, No. 54516; Female, 282 mm. long, 8 years, 5½ months old. Scale shows 8 completed annuli and a marginal growth. X-18.

FIG. 141. Scale of New York Aquarium Whitefish *(C. clupeaformis)* hatched January, 1913; died August 3, 1921. U. of M. Museum No. 54523; Male, 339 mm. long, 8 years, 6 months old. Scale shows 8 completed annuli and a marginal growth. X-16.

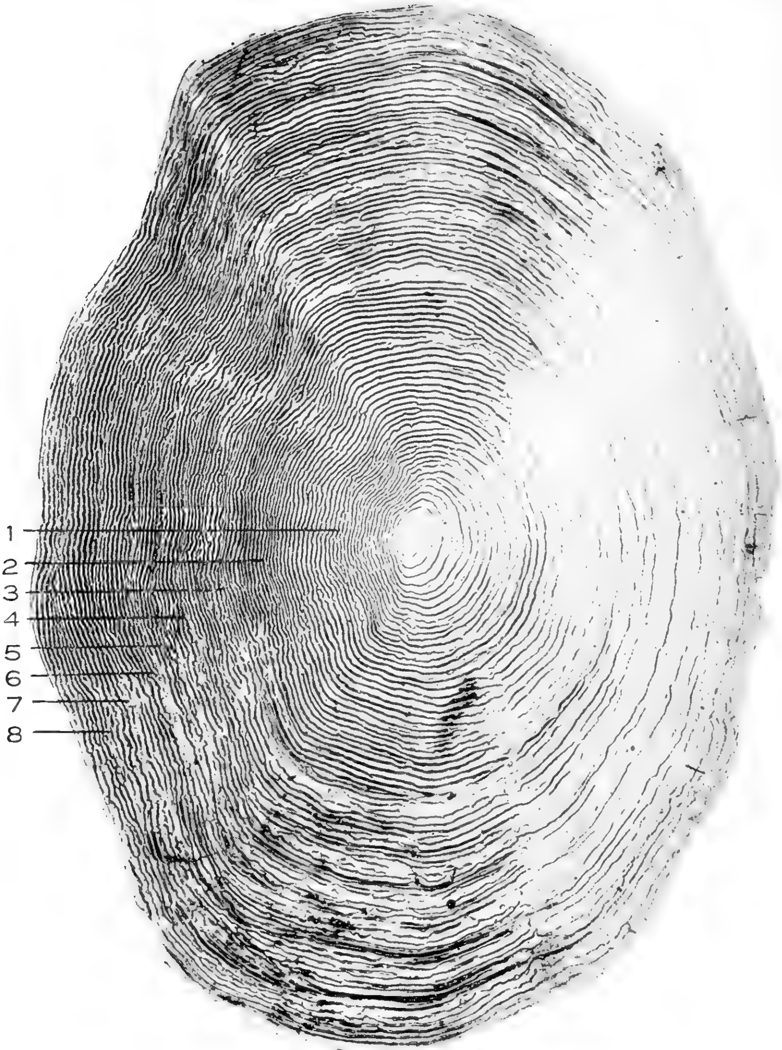

FIG. 142. Scale of New York Aquarium Whitefish *(C. clupeaformis)* hatched January, 1913; died January 3, 1922. U. of M. Museum No. 54531; Female, 347 mm. long, 9 years old. Scale shows 8 completed annuli and a marginal growth. X-19.

Figs. 138-142 are photomicrographs of scales taken from Aquarium fish killed at different ages. On each photograph reference lines have been drawn which indicate the positions of the annuli of the different years. On comparing the scales of these aquarium whitefishes with those of the wild whitefish, it may be seen that the former are much stunted in growth; their circuli are more irregular and crowded together, while their annuli, in some instances, nearly come into contact in the posterior or exposed area of the scale. In some scales the annuli are difficult to observe, but by the use of various magnifications and by the manipulation of the light source they can be determined. In most of the fish several scales are necessary for an age-determination. I gradually discovered, however, that those aquarium scales whose caudal area is longer than its anterior area and whose form approaches the elliptical possess annuli that can be more readily determined than those of scales without these characters. Such scales were usually obtained from the area between the pectoral fin and the lateral line. Those photographed and employed in this study were taken from the left side of the body.

The first specimen died August 13, 1920, at the age of seven years and seven months. Its scales possessed seven annuli with a small amount of marginal growth. The number of annuli, thus, corresponded with the number of years of life of the individual. The next seven specimens received (54506 to 54512, Table I), which ranged from seven years and nine months to eight years and two months in age, also possessed scales with seven completed annuli and various amounts of marginal growth. Fig. 138 represents a photograph of a scale from the specimen killed December 1, 1920, and shows seven annuli with the eighth year increment at the margin. The eighth annulus is completed in April. Fig. 139, a photograph of a scale from the April specimen, shows the eighth annulus situated at the margin. In the remaining eighteen specimens (54514 to 54531, Table I), which ranged from eight years and four months to nine years in age, the eighth annulus is entirely removed from the margin and surrounded with various amounts of the ninth year increment. Figures 140, 141 and 142 are photographs of scales from specimens that died July 13, 1921, August 3, 1921, and January 3, 1922, respectively. Each figure shows eight annuli and, presumably, a completed ninth year's growth.

It thus appears (1) that the specimens received from August, 1920, to March, 1921, which represent ages from seven years and seven months to eight years and two months possessed

Table II—Showing at different dates the average total length in mm. of magnified scales of individuals of whitefish reared in the New York Aquarium; the percentage of the scale length outside the outermost annulus (marginal growth) in the antero-posterior diameter included in the last annulus, the part of this marginal growth percentage formed since the preceding date and the number of scales upon which the averages are based.

U. of M. Museum Number	Name of Fish	Date of Removal of Scale	Date of Death of Fish	V7 or V8 Average Length of Scales at End of 7th or 8th Growth Year	v8 or v9 Average Length of Marginal Growth in 8th or 9th Year	v8/V7 or v9/V8 Percentage Added to Scale Outside Last Annulus	△ Percentage Added Since Preceding Date	Number of Scales on Which Each Average is Based
54507	Crooked-back	Oct. 26, 1920		201	5.8	2.8*	+2.8*	4
		Nov. 26, 1920		167	3.7	2.2	—0.6	3
		Dec. 1, 1920	Dec. 1, 1920	175	5.2	2.9	+0.7	5
54516	Double-crook	Dec. 30, 1920		185	16	8.6*	+8.6*	1
		Feb. 25, 1921		183	16.5	9.0	+0.4	2
		April 26, 1921		220	5	2.2z	+2.2z	2
		June 29, 1921		221	16	7.2	+5.0	3
		July 13, 1921	July 13, 1921	189	14	7.4	+0.2	4
54515	Open-gill	Jan. 26, 1921		175.	12.5	7.1*	+7.1*	2
		March 26, 1921		199	13.3	6.7	—0.4	3
		May 26, 1921		221	15.6	7.0z	+7.0z	3
		June 25, 1921	June 25, 1921	183	16.6	9.0	+2.0	6

* Since March or April, 1920.
z 1921 growth.

scales with seven annuli and various amounts of marginal growth and therefore belong to the same growth year, the eighth, even though the three fish received from February to March actually were in their ninth year of life; (2) that those received from April, 1921, to January, 1922, which vary from eight years and four months to nine years in age possessed scales with eight annuli and different amounts of marginal growth.

The annuli are thus actually proved to be of the same number as that of the winters of the fish's life, if we exclude the first one in which the fish was hatched.

Marginal Growth and Time of Formation of Annuli

Two specimens of the aquarium fish were segregated in the New York Aquarium and kept living with the purpose of taking scales from them at monthly intervals in order to follow the seasonal changes in the scales from November until June. Owing to deaths a total of six fish was employed during this interim, three of which lived for periods of two, six and seven months. In Table II these fish are designated by names indicating slight physical peculiarities and by their museum numbers. The names should not be taken as indicating that the fish were notably deformed. They were the smaller, poorer fish, less desirable for exhibition purposes. Table II shows the average total length in mm. of the magnified scales taken from these fish in different months, the average total length in mm. of the marginal growth, the percentage of its length in the antero-posterior diameter of that part of the scale included in the last annulus, the difference in the percentages of successive months and the number of scales upon which each average is based. The percentages in this table are, however, only approximately correct as they vary with the areas on the body of the fish as well as with the scales taken from the same area. However, as all the scales, except those removed from the dead fish, have been taken from the same area, the variability of the scale values has been reduced to a minimum so that they may be used with confidence in drawing certain conclusions.

The discrepancy in the fall or winter percentages (which seem to show scale absorption) of Crooked-back and Open-gill are presumably due, then, to the variability of their scales. The small difference (+0.4) between the two winter percentages (8.6 and 9.0) of Double-crook which represent a period of two months, likewise may be looked upon as due to this same variability and thus can have no significance. Presumably, then, the percentages in column v8/V7 or v9/V8 remain constant for

Table III—Showing for all New York Aquarium fish of Table I the percentage of the scale increment of the 7th, 8th and 9th year in the total scale length of the 6th, 7th and 8th year respectively and the average for each series of percentages.

Date of Death	v7/V6 Percentage of 7th Year Increment in Scale Length of 6th Year	v8/V7 Percentage of 8th Year Increment in Scale Length of 7th Year	v8/V7 or v9/V8 Percentage of Incompleted 8th or 9th Year Increment in Scale Length of 7th or 8th Year respectively	Number of Scales on Which Percentages Are Based
August 13, 1920	14.5		4.7	2
October 26, 1920	8.2		4.1	2
December 1, 1920	9.8		2.9	5
December 30, 1920	7.4		4.7	2
January 28, 1921	8.8		6.2	2
February 28, 1921	5.2		6.4	2
March 4, 1921	10.9		8.5	2
March 28, 1921	6.6		8.9	2
			5.8a	
April 28, 1921	7.3	9.3	1.6b	1
May 28, 1921	8.1	5.0	3.4	1
June 25, 1921	9.8	6.5	9.0	1
July 13, 1921	10.8	7.6	7.4	1
July 27, 1921	8.9	7.8	6.5	2
July 27, 1921	5.9	6.5	5.2	1
July 28, 1921	4.5	4.3	3.0	1
July 28, 1921	5.6	7.4	2.0	1
July 28, 1921	5.9	7.5	4.3	1
August 3, 1921	13.4	16.3	6.1	1
August 3, 1921	7.3	6.8	5.6	1
August 25, 1921	7.1	5.7	5.4	1
September 11, 1921	18.8	7.3	5.7	1
September 18, 1921	5.2	10.8	11.5	1
October 25, 1921	12.0	4.9	4.6	1
December 20, 1921	6.3	6.8	7.1	1
December 20, 1921	15.8	8.2	8.4	1
January 3, 1922	5.9	6.5	6.1	1
January 3, 1922	9.8	8.9	4.5	1
Average =	8.9	7.6	6.5c	

a—Average for incompleted 8th year, August to March. b—Ninth year increment begins.
c—Average for incompleted 9th year, August to January.

each fish during the fall and winter, *i. e.*, the marginal growth of the scales is arrested during the period from October to March. Marginal growth is resumed sometime in April (or March?). On April 26, 1921, the new marginal growth of Double-crook showed a percentage of 2.2, which value was increased to 7.4% on July 13, two and one-half months later. Similarly, Open-gill showed a new marginal growth of 7.0% on May 26, 1921, which percentage was increased to about 9.0 on June 25, one month later. The percentages of Double-crook and Open-gill are thus entirely consistent with and comparable to each other from April on and show that rapid scale growth is resumed sometime in April (or March?) and is continued at least until July.

In order to show approximately by comparison how much of the new year's growth was completed by Double-crook and Open-gill at the time of death, I computed percentages, similar to those of Table II for the preserved specimens listed in Table I. Table III shows in column v7/V6 the percentage of the scale increment of the seventh year in the total length of the scale included in the sixth annulus, in column v8/V7 the percentage of the scale increment of the eighth year in the total scale length included in the seventh annulus, and in column v8/V7 or v9/V8 the percentage of the incomplete marginal growth of the eighth or ninth year in the total scale length included in the last completed annulus (7th. or 8th.). The average for each series is given at the bottom of each column.

From this table it may be seen that the average percentage of the completed seventh year scale increment in the total scale length of the sixth year for 27 specimens is 8.9 and somewhat less, as is to be expected, for a similar percentage for the next year (7.6) for 19 fish. When these averages (8.9 and 7.6), which represent the completed seventh and eighth growth years are compared with the percentages of Double-crook and Open-gill (7.4 and 9.0) and when it is remembered that the percentage for the ninth year may reasonably be expected to be somewhat less than that for the eighth, it may safely be assumed that the scales of the segregated fish have just about completed their ninth year's growth and certainly would have done so by August or September.

If we now assume that August closes the period of scale growth and compute the average of the percentages of the incomplete ninth year from August to January and compare this average with those of the two preceding completed years and with the percentages of the two segregated fish we may obtain a criterion which ascertains roughly the probability of the correctness of our assumption relative to the time of the cessation of scale growth. Table III shows that such a ninth year average is 6.5%, which compares favorably with those of the two preceding completed years (8.9 and 7.6), and may therefore be considered as representing the average of a completed ninth year. The ninth year average (6.5) thus suggests the completion of scale growth by August not only in the fish of Table II (with 9th year percentages of 7.4 and 9.0), but also in those of Table I. Again, when the average of the percentages of the incomplete eighth year from August to March is compared with that of the completed eighth year, it is found that the former (5.8) compares fairly well with the latter (7.6) when it is remembered that the fish sacrificed first (included in the 5.8 average) were the poorer and less valuable specimens. Thus again scale growth may presumably be considered complete by August. Also, Tables II and III show that the percentages of the incomplete eighth and ninth years show no consistent increase from August and October to April, while those of the ninth year from April to June or July do.

In the light of the preceding discussion it now appears reasonable to accept the interpretation presented on page 391 relative to the constancy of the fall and winter percentages given in Table II.

Table III, column v8/V7 or v9/V8, further corroborates Table II and shows that marginal growth is resumed in April. All the fish killed after April, 1921, completed the new annulus and showed various amounts of new marginal growth on their scales.

The percentages of Table II show, then, (1) that there was no marginal growth present in November and December of 1920, and in January, February and March (?) of 1921, and, (2) that a new annulus was recognizable in April, 1921, and was correlated with a resumption in scale growth. The percentages of Table III corroborate the conclusions based on Table II, and in addition show in conjunction with Table II that marginal growth was presumably arrested by August in 1920 and 1921, and certainly by September. The data of both tables (II and III) therefore prove that the annulus is a winter-mark due to a retardation or cessation of scale growth and is completed upon the resumption of rapid scale growth in the spring of the year.

Table IV—Showing for 76 Alpena whitefishes collected September, 1917, the relation of the average length of the diameter (v), anterior (ac) and posterior (pc) radius of the scale to the average body length (K), all lengths expressed in mm., for fish in years III to VII inclusive.*

In Year	III	IV	V	VII
K	269 (47)	315 (14)	352 (9)	456 (6)
v	5.75 (47)	6.75 (14)	7.49 (9)	9.58 (6)
ac	3.19 (47)	3.86 (14)	4.34 (9)	5.80 (6)
pc	2.56 (47)	2.89 (14)	3.15 (9)	3.78 (6)
K/v	46.78	46.67	46.99	47.60
K/ac	84.33	81.61	81.11	78.62
K/pc	105.08	108.99	111.75	120.63

*Numbers in parentheses following averages indicate the number of specimens employed; the sixth age-group contains only one specimen, therefore, omitted.

Correlation Between Annual Growth in Length of Body and Scales

It now remains to examine for the whitefish the correlation between the annual increment in length (or other dimension) of scales and length of body. Had it been possible to measure the body lengths of the living aquarium whitefish accurately at the time of the removal of their scales, this correlation could have been established by direct observation. Obviously, Table I does not afford material for this purpose as the number of specimens received each month is too small to warrant valid averages of monthly growth increments in body and scales. The available aquarium whitefish therefore cannot show the proportionate growth of body and scale.

Wild whitefishes may be used to show this correlation. In this case it is necessary that a large amount of strictly homogeneous material be used, *i. e.*, the fish of the several age-groups must all belong to the same race and have similar rates of annual growth increments, and only scales from corresponding body areas must be employed. These requisites necessitate the acquisition of a large collection of fish taken at the same time and at the same locality. At present no such whitefish material is available. There are, however, at hand, series of body and scale length measurements of a small collection (76 fish) of Lake Huron whitefishes taken September, 1917, at Alpena, Mich. A summary of their data is given in Table IV.

In row K, Table IV, is shown the average length in mm. of the fish of each age-group, the age-group referring to the year of life in which the fish were captured. The number of specimens in each age-group is shown in parenthesis. In row (v) is given the average length in mm. of the scale diameters of the fish of each age-group. In rows (ac) and (pc) the same averages are

Table V—Showing for each year for Alpena whitefish (Table IV) in the seventh year the average length in mm. calculated from the diameter (v), anterior (ac) and posterior (pc) radius of scales (Table IV), and the difference between the calculated averages and those of the age-groups obtained from actual measurements (K).

	III	IV	V	VII
K	269	315	352	456
Calculated (K) from (v)	274	321	357	
Calculated (K) from (ac)	251	303	341	
Calculated (K) from (pc)	309	349	380	
Difference (K) & (K from v)	+5	+6	+5	
Difference (K) & (K from ac)	—18	—12	—11	
Difference (K) & (K from pc)	+40	+34	+28	

given for the anterior and posterior radius of the scale respectively. In the last three rows are shown the body-scale ratios for each age-group based on the diameter (v), anterior (ac) and posterior (pc) radius respectively.

The number of fish in each age-group is not as large as one could wish, but may be sufficiently large to show roughly the relation of the length of the various scale dimensions to body length. It may then be seen that the K/v ratio is about the same for the third and fourth age-group and rises slightly in the fifth and again in the seventh. This means that the diameter increases in length in a simple proportion to the increase in the length of the body during the fourth year and increases at a slightly slower rate relative to the body in the fifth and seventh years and presumably also in the sixth for which no values can be given. The K/ac ratio is found to decrease with age, while the K/pc ratio increases with age. This means that the anterior radius of the scale grows faster relatively than the body with age, whereas the posterior radius grows more slowly with age. None of the measured scale dimensions therefore grow strictly proportionate to the body.

In order to show roughly in a practical way which dimension most nearly acquires this proportionate growth and furnishes the most accurate estimated length values, I calculated the average length for each year of the fish in the seventh year, using the average scale dimensions of Table IV. The estimated lengths are shown in Table V. From this table it may be seen that there is a high degree of correspondence between the lengths calculated from the diameter and the actual lengths, and that the former are somewhat higher than the latter. The lengths calculated from the anterior radius are lower, while those calculated from the posterior radius are much higher than the actual lengths. It is, however, realized that these calculated and actual values may not be strictly comparable as the two series of values represent different year-classes which may have varied considerably in their rate of growth. Strictly, series of fish of the same year-class collected in the same season of different years and at the same locality are required for an absolutely valid check on calculated values.

Table V also shows that the calculated values from diameters are consistently found between those based on the radii. This was also found to be true for the individual fish. Experience has shown that in practically every species of fish whose scales were studied the calculated values based on radii (no other dimension is ever used) and checked with the actual values were always found to be too low for the early years of life. The Coregonines prove to be no exception. In the light of past experience therefore, and in view of the fact that diameter measurements of whitefish scales raise the calculated values, especially those for the earlier years, above those based on the anterior radius, it may be deemed advisable to test the various dimensions of the scales, where possible, before undertaking any extensive scale work for a species.

Tables IV and V show for the whitefish (1) that the diameter, anterior and posterior radius of scales increase in length at very different rates with respect to the rate of increase in the length of the body and that consequently the calculated length values based on the different scale dimensions vary significantly, (2) that none of the three scale dimensions considered increase in length at a rate strictly proportionate to the rate of increase in length of the fish, (3) that, presumably, the diameter of the scale increases in length at a rate more nearly proportionate to the rate of increase in body length than either the anterior or posterior radius and therefore should be used for the calculations of length values, and (4) that the calculated values based on the diameter always lie between those based on the anterior and posterior radii.

Life History of the Aquarium Whitefish and the Factors of Annuli Formation

In view of the great diversity of opinion among investigators, and in view of the disagreement and contradiction of the conclusions reached by various authors from laboratory experiments and field observations relative to the factors responsible for the formation of annuli, it was deemed advisable to obtain as complete a life history as possible of the New York Aquarium whitefishes and thus, perhaps, determine to a certain degree the relative significance of each environmental factor in the formation of annuli. It is realized that these life history data are not equivalent to those of carefully planned and executed series of experiments in which only one factor of the environment is altered at one time and the results checked with those of a control. Yet, it will be seen that experimental requirements are partly fulfilled for the fish were regularly supplied with food in amounts controlled by their appetites, while the temperatures varied from those of summer to those of winter and vice versa. And as the period of rapid scale growth and the time of the formation of an annulus are known the effect upon the scales of a change in a factor may be approximately ascertained. I am indebted to Miss Mellen and to Mr. Robert J. Lanier, who reared the whitefishes, for most of the life history data. I alone am responsible for the conclusions derived from them.

It has now been proved (p. 394) that the formation and completion of an annulus is dependent upon the retardation or cessation and resumption of scale growth, and that scale and body growth are closely correlated; therefore, any factor that can affect the growth rate of the body may have primary significance in the formation of an annulus. But to hold such a factor responsible it must be established that a change in this factor occurred previous to or synchronously with the change in the rate of growth and that no resumption of rapid scale or body growth can occur until the change in the factor is reversed or its effectiveness lost. The primary factors may be different from year to year or even from season to season in the same year.

(a) Food

The Aquarium whitefish were fed in about the same way throughout the year. Miss Mellen writes: "I have consulted our superintendent (Mr. Robert J. Lanier), who reared the whitefishes born in 1913, as to their food since hatching, and find that in early infancy they had the advantage of some live food, receiving first herring roe, next a few mosquito larvae, third, the fry of pike perch, which happened to be hatching at just the right time, although all would not take this food, as, unlike most fishes, they do not normally eat their own kind, and lastly, minced beef-heart. Feedings were very frequent during the first couple of years, after which they were fed daily on beef-heart. From 1915 to 1918 inclusive they were fed exclusively on beef-heart three times a week; and it is only since 1919 that they have been fed with beef-heart exclusively three times a week in summer and beef-heart once, clam twice a week in winter."

The amount of food, however, actually consumed by the fish varied somewhat with the seasons. In the earlier years when the fish were fed daily, Mr. Lanier gave them less food during January, February and March in spite of the fact that they were always ready to eat. During their third year an apparent change in their appetites occurred, so that thereafter they were fed only three times a week. Since this year (1915) it was also noticed that the fish "did not eat quite as much during January, February and March," though the number of feedings remained constant throughout the year.

It is obvious that since the character of the food and the number of feedings remained constant summer and winter for several consecutive years these factors could not have altered the rate of scale or body growth. The amount of food, however, offered or taken by the fish, did vary with the season. How much the amounts varied is not known. In the fall of 1920 this change in the amount of food could not have had any significance inasmuch as scale growth was arrested before January, 1921, when this factor was first altered. In April, 1921, the rations were increased for the same reasons that they were decreased in January, viz.—a change in the appetites of the fish. It was previously shown that scale growth was resumed in March (?) or April (p. 393). It thus appears that food and growth are correlated in April, 1921, but in this case the former is presumably only of secondary importance. As nothing definite is known about the distribution of growth in the other years of life of these fish, the relative significance of food as a factor in these years can only be conjectured and therefore requires no discussion here.

(b) Temperature

Table VI shows the monthly and yearly mean temperatures in degrees, Fahrenheit, of the fresh water entering the New York Aquarium, from 1913 to 1920, inclusive. As soon as the water reached a temperature of about 60°F (15.6°C) in the summer, it was refrigerated and maintained at a temperature which varied from 54° to 57°F and averaged about 55°F (12.8°C), except during the summer of 1921, when the range was changed to 50° and 54°F, and the average reduced to about 52°F (11.1°C). The months in which the refrigerating plant was started and stopped are indicated by the letters r and s respectively in Table VI. In Fig. 143 are plotted a curve (T) based on the average monthly temperatures of Table VI and growth curves of the scales of Double-crook (D) and Open-gill (O)

Table VI—Record in degrees, Fahrenheit, of Monthly and Yearly Mean Temperatures of Fresh Water Entering the New York Aquarium, from 1913 to 1920, inclusive.[a]

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Averages
1913	43	41	42	50	....	....r	67	71	70	65	56s	48	55
1914	41	38	40	45	53r	60	67	71	70	65s	54	43	54
1915	39	38	40	47	53r	59	65	69	70	63	54s	42	53
1916	38	37	36	43	52r	56	64	69	69	63	55s	45	52
1917	37	36	39	44	50	57r	62	65	64	58s	49	39	50
1918	35	37	39	44	55	56	58r	64	66	59s	52	42	51
1919	39	38	40	45	54r	60	64	67	66	63	54s	43	53
1920	37	37	39	43	51	61r	66	68	67	63	54s	45	53
Monthly Averages	39	38	39	45	53	58	64	68	68	62	54	43	53

a—From daily observations made by Mr. W. J. DeNyse.

r—Refrigerating plant started.

s—Plant stopped; the temperatures do not represent those of the refrigerated water. The temperatures of the refrigerated water averaged about 55° F. every summer, except that of 1921 when it averaged 52° F.

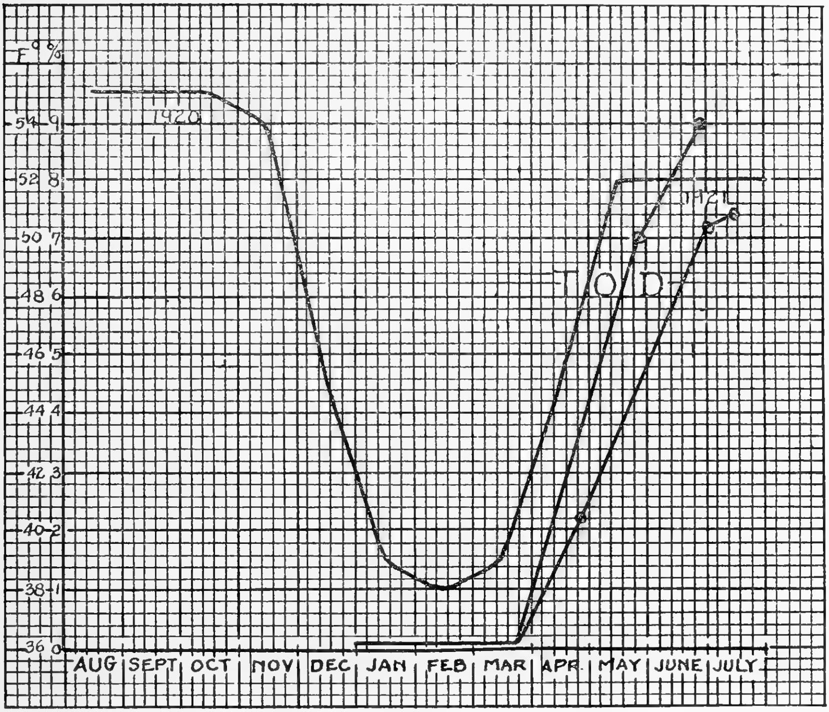

FIG. 143. Showing the relation between the rate of growth of the scales of Open-gill (O) and Double-crook (D) and the temperature (T) of the aquarium water. T-curve based on the average monthly temperatures of the refrigerated and non-refrigerated water shown in Table VI. O-curve based on the percentages of Table II, which represent the total scale growth of Open-gill from March, 1921, to June, 1921. D-curve based on the percentages of Table II, which represent the total scale growth of Double-crook from March, 1921, to July, 1921.

based on the percentages of Table II, which represent the renewed growth of the scale after March, 1921. The growth curves are only approximately correct as the scales of each fish were taken in alternate months.

Fig. 143 shows that the curves of scale growth adhere very closely to the curve of temperature. No growth occurred during the period of low temperatures in January, February and March, and the greatest increase in growth took place at the time of the greatest rise in temperature in April and May. The maximum temperatures were reached in May when the water was refrigerated and maintained throughout the summer at an average constant temperature of about 52°F. Scale growth, however, continued, at least in Open-gill, throughout June. Scale growth therefore was not arrested by the temperatures of the refrigerated water. As these temperatures do not represent those of the water in the whitefish tanks, they may be a little too low, especially those of the non-refrigerated water. This, however, would not alter the general appearance of the temperature curve nor the conclusions based on it.

It is thus seen that scale growth and the temperature of the water are correlated in the spring of 1921, the latter presumably having primary significance. That a low temperature is here a primary factor in growth seems corroborated by the fact that a decrease in the amount of food consumed occurred synchronously with a decrease in temperature and an increase in food consumption with an increase in temperature. The effect of low temperatures upon the metabolism of the body is well stated by Dr. Fulton (1904), who writes (p. 170): "Temperature is active in modifying the rate of growth by acting directly upon the metabolism of the fish and also by affecting the rapidity of digestion. In very cold water the fishes give up feeding altogether, because the ferments upon which digestion depends do not act, or act very slowly, at low temperatures, and in fishes, as in other animals, appetite waits on digestion, and this is, on the other hand, correlated with the metabolism in the tissues. It has been shown by Krukenberg that the pepsine or analogous body in the stomach of fish acts as well at 20°C as at 40°C, at which, among mammals, digestion is most active, and that the rapidity of its action is closely related to temperature; and Knauthe and Zuntz have shown that the same thing applies to the metabolism in fish, the vital activities being more active in the higher temperature, as shown by the excretion of carbonic-acid gas and other products of metabolism."

But, as both food and temperature remained practically constant during the summer until November, what factor must then be held responsible for the arrest in scale growth in August or September? As the aquarium water is well aerated its gaseous content cannot be held responsible; nor could any probable changes in its mineral or salt content account for the decrease in growth. The only remaining variable is sexual maturity.

(c) Sexual Maturity and Spawning

Before attempting to describe the conditions of the ovaries and testes of the various New York Aquarium whitefishes at the time of death, it seems advisable to describe first the normal natural conditions of the sex organs as found in wild whitefishes of various ages. The following description is based on many specimens of Lake Huron whitefishes.

In order to determine the sex of immature wild whitefishes the sex organs must be closely scrutinized often with the aid of a magnifying lens or microscope. This difficulty of determination is due to the fact that the ovaries and testes are quite similar in appearance in the very young whitefishes. Both consist of narrow, thin, flat strands of soft, whitish material and extend from the anterior to the posterior end of the body cavity along its dorsal wall. In the larger immature fish the two kinds of sex organs can be distinguished by their structure. When an ovary is picked up and stretched transverse folds or layers become evident, while the testis under like treatment appears to be a compact homogeneous structure. In still older fish color may also be critical; the ovary becomes yellowish, while the testis retains its whitish color.

In a maturing female the ovary gradually increases in size, the enlargement beginning at the anterior end of the body cavity. Minute round yellowish eggs appear in the ovary folds. At the time of spawning the ovaries have usually enlarged to such extent as to distend and fill the entire body cavity. The condition of the ovary and the size of the eggs thus indicate the stage of sexual maturity in the female. A ripe egg is about 3 mm. in diameter. The maturing testis also increases in size, the enlargement commencing at the anterior end of the body cavity. As the testes grow they extend further into the abdominal cavity and increase in width and thickness. At the time of spawning they nearly fill the body cavity, but usually do not distend it, as do the ovaries. The size of the testes is then a rough index to sexual maturity in the male. When the eggs and sperm are ripe they are easily pressed out of the body. The sex organs of a spent fish are soft and flaccid. This condition is more easily determined for females than for males, and even among the former doubtful cases arise, the magnitude of the doubt depending partly, I presume, upon the length of the interim between the spawning and the date of the capture of the fish.

In describing the various conditions of the sex organs of the New York Aquarium whitefishes I devised a number of phases, each phase indicating rather definite conditions. As the individuals represent nearly every month of the year the conditions of their sex organs intergrade more or less imperceptibly, and it is therefore impossible always to refer a specimen to one phase; parts of different phases may be found in one individual. The ovaries alone permit of a rather definite classification and they only must be considered reliable in a discussion.

The various stages of development[3] are considered under five principal phases designated by the letters A, B, C, D and E as follows:

[3]These descriptions are based on the sex organs of the Aquarium fish preserved in 5% formalin and later transferred to 70% ethyl alcohol.

E: ♀—anterior 1/4 of ovary enlarged; eggs microscopic or very small in size.
♂—anterior 1/4 of testis enlarged into a flat, white gland; remainder transparent.

D: ♀—anterior 1/2 of ovary enlarged; ovary flat, rigid, 3/4 in. at its widest; eggs of year are round, whitish, easily visible to naked eye, 1 mm. or less in diameter.
♂—anterior 1/2 of testis enlarged; compact gland thicker and wider than in (E), about 1/4 in. at its widest.

C: ♀—entire ovary enlarged; eggs 1-2 mm. in diameter.
♂—anterior 3/4 and posterior end of testis enlarged, 1/2 in. at its widest.

B: ♀—compact ovaries fill body cavity; yellowish eggs nearly ripe, 2-3 mm. in diameter; fish about ready to spawn; body may be pearled.
♂—hard testes fill body cavity; fish about ready to spawn; body may be pearled.

A: ♀—matured eggs retained and in process of absorption. Coincident with this condition is that of (E) or (D), *i. e.*, eggs of the year are evident. Ovaries may be soft, flaccid; retained eggs found either in ovary, in body cavity or in both; eggs average 3 mm. in diameter when round and smooth; eggs are found in various conditions, several of which may be found in one individual; these conditions are designated by number under (A):

1. Eggs hard, round, smooth; each egg partly turned a brownish yellow.
2. Eggs wrinkled, indented, of brownish yellow color; float in water.
3. Eggs wrinkled, indented, peripheral portion of each egg of a dull or dirty transparency; float in water.
4. Eggs flattened, crushed, sometimes a little brown color left; contents absorbed.
5. Eggs with dark reddish color, and a solid, glassy appearance; filled with minute oil globules; eggs about 1 mm. in diameter and scattered among the eggs of the year in a soft ovary; glassy eggs show no evidence of absorption.
6. Ovary soft, flaccid with many eggs of the year, but no retained eggs evident.

♂—testes smaller than in (B); flabby, *i. e.*, fish spent, or testes compact, of reddish color with sex products seemingly retained and undergoing absorption; body may be pearled.

Table VII—Showing distribution in time of the phases of sexual development in the Aquarium whitefish. For explanation of letters and numbers see page 403. Also see Table I.

Month	Females	Males
November	None	None
December	B(20), peduncle pearled; A1-2-4E(30) numerous retained eggs in ovary and body cavity	D(1); A(20) body heavily pearled, testes reddish
January	B(3), abdomen distended; A1-2-3D-(28) retained eggs numerous, mostly in body cavity	C or A(3)
February	None	None
March	A3D-(4) retained eggs numerous, in body cavity; A4D-(28) ½ doz. flattened eggs in body cavity	None
April	None	E(28)
May	A2D-(28) retained eggs numerous, in body cavity	None
June	A2-4D-(25) few wrinkled eggs in ovaries and few partly absorbed ones among pyloric coeca	None
July	D(28); A5D(13) ovary soft, no wrinkled eggs	E(27, 28); C(27, 28)
August	D(25); A3-4-5D + (3) retained eggs numerous, in ovaries and body cavity	D(3, 13)
September	A6D-(18) ovaries flaccid, no retained eggs	C(11)
October	None	D(26); C(25)

The distribution of these phases in time among the aquarium whitefishes is indicated in Table VII. The number in parenthesis following each phase refers to the day of the month on which the specimen died. Each such number represents one individual. The minus or plus sign following a letter indicates an early or a late phase respectively. Two or more phases in one individual are designated by a combination of the proper letters. The phase of each specimen is also shown in Table I.

Table VII shows (1) that no immature female whitefish were received, (2) that two females were ready to spawn in December and January, (3) that retained eggs were present from December to August (no females were received in February, April, October and November), but that after January all the retained eggs, the glassy ones excepted, were undergoing absorption or disintegration, (4) that the eggs of the year, whether found with the retained eggs or not, were in the same phase of development from January to September, those of fish received July and later being a little more advanced than those of females received before July, and (5) that the ovaries of the specimens that died July 13 and September 18 were soft, but did not contain wrinkled eggs.

From these facts we conclude, (1) that the Aquarium whitefish were sexually mature in both their eighth and ninth years, (2) that in most fish spawning conditions were present in December and January and thus that the sex products of the Aquarium whitefish ripen later in the season than those of the wild whitefishes which usually spawn sometime in November and (or) early December, and (3) that the majority of the Aquarium whitefish do not spawn, but retain their eggs in the ovaries or in the body cavity where they undergo a process of absorption or disintegration. From the condition of the eggs of the year and of those undergoing disintegration in different months, it appears highly probable that the phase of rapid growth is initiated in the eggs sometime after September and completed sometime before March or February (?). The conclusion that the aquarium whitefish do not spawn agrees with the statements of Mr. Lanier to the effect that no spawning was ever observed among these fish. It may also be observed here that sexual maturity is not correlated with the size of the whitefish, but rather with its age. Thus, for instance, in Table I the eight and nine-year-old females of January 28 and May 28, which measure 219 mm. and 210 mm. respectively, are no larger than a two-year-old whitefish from Lake Huron; yet, no two-year-old whitefish has ever been known to spawn.

That sexual maturity can be a factor in the formation of annuli becomes evident when it is recalled that many species of fish, especially the salmon to which the whitefish are related, practically cease growing when developing a spawning condition, even though the amount of food ingested remains practically constant. It is also a fairly well established fact for many species that the annual increments in body growth of the young fishes are very noticeably reduced in that year when sexual maturity first occurs. Since it was found that the sex products of the Aquarium whitefish began their development after June, entered the phase of rapid growth sometime after September and completed this phase sometime before March or February(?) sexual maturity could account for the cessation in body and scale growth in August or September. Sexual maturity would then be a primary factor in the formation of annuli in the adults.

It has thus far been shown that the scales of the Aquarium whitefish ceased growing sometime in August or September and resumed growth in April or March(?), that sexual maturity was reached sometime between September and March or February(?), that the lowest temperatures of the aquarium water occurred in January to March inclusive, and that the amount of food required by the fish was less for the months of January to March inclusive than for the other months of the year. It was suggested that food could only have had secondary significance in the formation of annuli since the reduction of food was caused by some other factor which affected the appetite of the fish. It was further suggested that since reduction and increase in food consumption occurred synchronously with the decrease and increase in temperature respectively, and since the scales resumed their growth at the time of a rise in temperature in April, when sexual maturity could have had no influence on growth, temperature must be considered a primary factor in the formation of annuli. Lastly, since the sex products began their development at approximately the same time when a retardation or cessation of scale growth occurred in late summer, when the environmental factors of food and temperature were known to have been constant, it appears reasonable to assert that sexual maturity is also a primary factor in the formation of annuli in scales. If sexual maturity is not such a factor, then it must be conceded that the retardation or cessation of scale or body growth, and consequently the formation of annuli, is caused by some unknown physiological factor or factors of annual recurrence.

The year of life in which sexual maturity first occurred can only be conjectured. The break in the growth curve (a) of Fig. 144, which represents the average annual increments of the Aquarium whitefish, suggests that most of these fish attained sexual maturity in the third year of life. This suggestion agrees with the statements of Evermann and Smith (1896, p. 300) and the U. S. Fish Manual (1903, p. 110) to the effect that the whitefish reach sexual maturity in the third or fourth year; and with the statement on p. 120 of the Fish Manual where it is asserted that three-year-old whitefish artificially reared in the hatchery at Northville, Mich., yielded a large number of eggs, a fair percentage of which were fertilized. My data on the wild whitefishes indicate that sexual maturity may be attained in the fifth and sixth years by whitefishes from Lake Huron proper and in the fourth year by those of the North Channel and Georgian Bay; but, an overwhelming majority of the available individuals of these years and localities appear to be immature. The wild whitefishes perhaps attain sexual maturity for the first time at an older age than has previously been assumed, or the first year of spawning may vary with the locality.

The attainment of sexual maturity in the third year by the Aquarium fish would also account for the apparent change in their appetite in the third winter of life. With sexual maturity eliminated, food and temperature must have been the only environmental factors of growth in the first two years of life. Temperature did not seem to impede the metabolism of the body very seriously as the young fish were always ready to eat. Restriction in food must then have been the principal factor in the formation of annuli in the first two years of life.

(d) Annual Rate of Growth

The lengths in millimeters attained by each Aquarium fish at the end of each winter of life (K_1, K_2, etc.), and the annual growth increments in mm. of each year (k_2, k_3, etc.) are shown in Table I. These values were obtained by the method described on pp. 385 and 386 and the formula given on p. 383 from the diameter of scales. The average length and increment for each year is given at the bottom of the respective column. Below the calculated averages are shown corresponding averages of actual measurements of 238 Lake Huron whitefish taken at different localities in the fall of 1917 and 1919. In Fig. 144 are shown four growth curves based on the averages of Table I. Curve (a) represents the annual growth increments of the New York Aquarium whitefish, while curve (b) represents those of the Lake Huron whitefish. Curve (c) shows the total length reached by the aquarium fish at the end of each winter of life, while curve (d) shows the same thing for the Lake Huron fish.

From curves (c) and (d) it is at once evident that the Aquarium whitefish have been greatly retarded in growth. Knowing the limitations of their food and swimming space retarded growth is to be expected. Curves (a) and (b) show that in no year did the Aquarium fish attain the rate of growth of

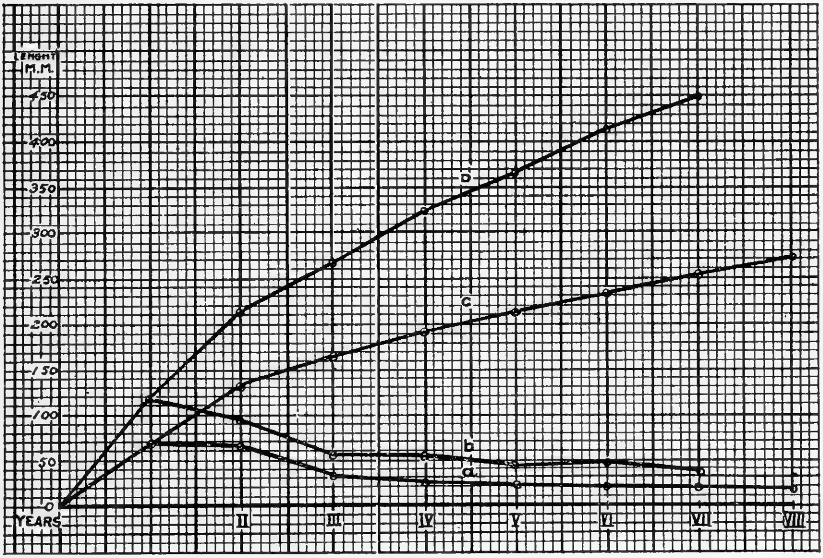

FIG. 144. Showing growth curves which represent the average total length in mm. attained at the end of each winter of life by the Lake Huron Whitefish (d) and the New York Aquarium Whitefish (c), and the average annual growth increments in mm. of each year of life of the Lake Huron Whitefish (b) and the New York Aquarium Whitefish (a). All curves are based on the averages of Table I.

the wild fish and that the greatest retardation in the growth of the Aquarium fish occurred in the first year of life. After the second year the annual growth increments were much reduced, but remained nearly constant to the eighth year in both series of fish.

The validity of the scale method is sometimes questioned because of the great range in the extreme lengths of the specimens placed by it in the same age group. This criticism is wholly refuted in column K, Table I. Specimens 54509 and 54510 of the same age and with the year's growth completed measure 219 and 334 mm. respectively, showing a difference in length of 115 mm., while specimen 54514, several months older than the two just mentioned, measures 9 mm. less than the first.

SUMMARY.

1. Scales were examined from whitefish hatched January, 1913, from eggs from the Put-in-Bay hatchery and reared in the New York Aquarium. The scales studied were removed from fish that were in their eighth and ninth year of life.

2. The annuli in the scales of the Aquarium whitefish are of the same number as that of the winters of the fish's life, the first one in which the fish were hatched excluded. The age of whitefish may therefore be determined from their scales.
3. The annuli in the scales of the Aquarium whitefish are winter-marks formed by the retardation or cessation of scale growth in late summer and winter and completed by the resumption of scale growth in the spring of the year.
4. The different dimensions (diameter, anterior and posterior radius) of whitefish scales grow at very different rates with respect to the rate of growth of the body and consequently the lengths and growth increments calculated from these dimensions vary significantly.
5. The anterior radius of the whitefish scale grows relatively faster than the body and consequently the lengths calculated from it are too low.
6. The posterior radius of the whitefish scale grows relatively much more slowly than the body and consequently the lengths calculated from it are much too high.
7. The diameter of the whitefish scale, on the whole, grows relatively only a little more slowly than the body and consequently the lengths calculated from it are only a little too high.
8. The lengths calculated from diameters are always higher than those calculated from anterior radii and lower than those calculated from posterior radii.
9. The diameter of scales seems to be a better basis for the length calculations of whitefish than the anterior radius which has nearly always been used in the past for many species of fish.
10. A rather complete life history of the New York Aquarium whitefish is given, which includes a statement as to the character of the food consumed, the number of feedings, the changes in the amount of food consumed, the temperature of the water in different months of different years, sexual maturity, spawning and the rate of body growth. The rate of body growth of the Aquarium fish is compared with that of Lake Huron whitefish. The significance of each of the above life history facts, rate of growth excepted, as a factor in the formation of annuli, is discussed.
11. Food is only a secondary factor in the formation of annuli in the adults studied, but may have been a primary factor in the immature fish.
12. Temperature appears to be a primary factor in the formation of annuli in the adults, but only a secondary one in the immature fish.

13. Sexual maturity appears to be a primary factor in the formation of annuli in the adults.
14. The method employed in the study of the scales of the Aquarium whitefish differs somewhat from those described and used by other investigators. The method and the apparatus used are therefore briefly described.

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OBSERVATIONS ON ITS HABITS AND LIFE HISTORY

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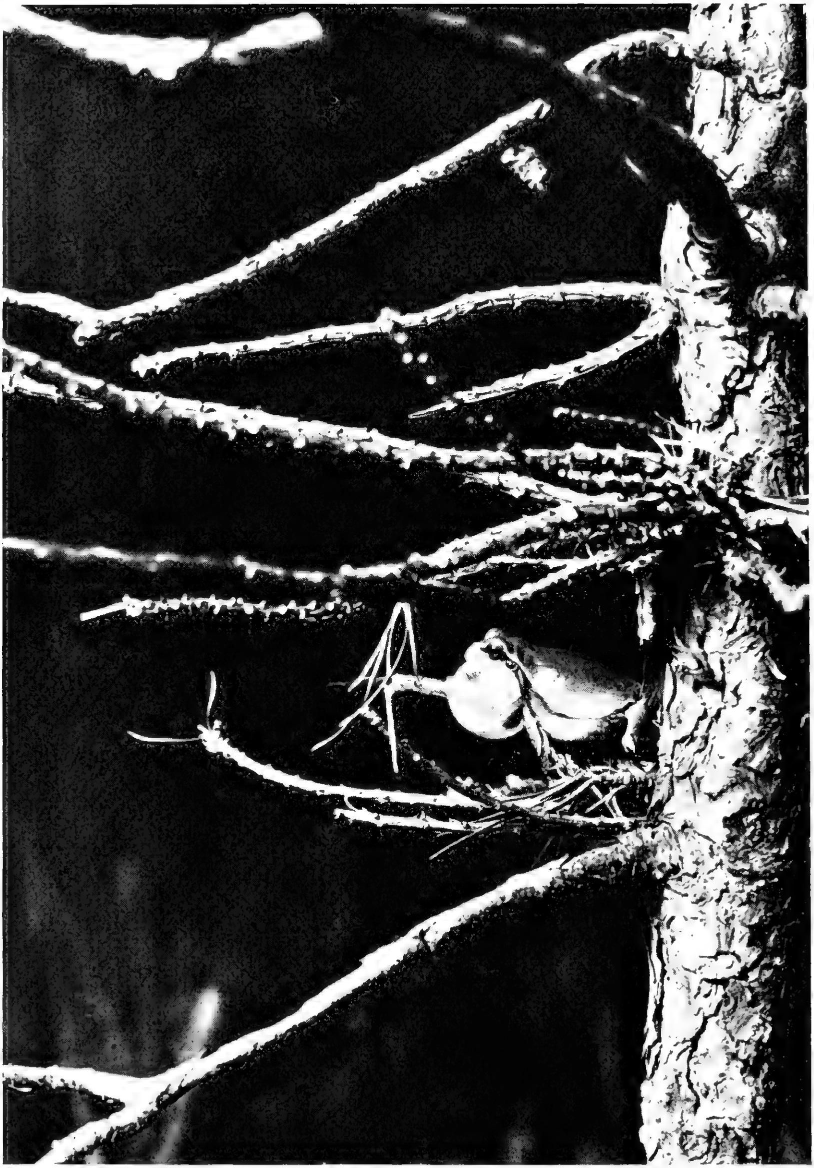

FIG. 145. THE CALL

Male *H. andersonii* calling from a pitch pine on the edge of a pine-barren bog, Lakehurst, New Jersey. *Flashlight Photograph.*

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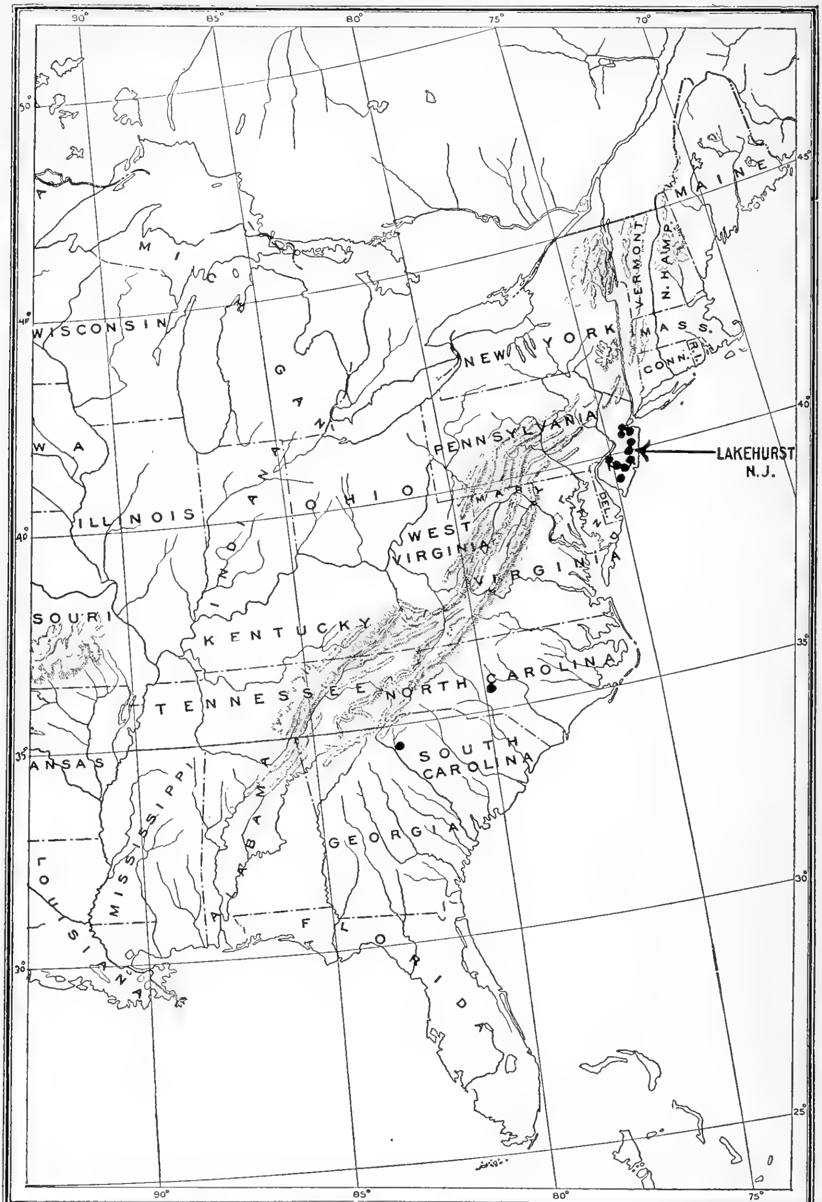

FIG. 146. DISTRIBUTION OF *HYLA ANDERSONII*
Spots indicate locality records.

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(*Hyla andersonii* Baird)

OBSERVATIONS ON ITS HABITS AND LIFE HISTORY

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Introduction.

The Anderson Tree Frog has often been considered the most attractive of North American hylas, and yet no attempt has hitherto been made to study its life history in detail. Former observations were made as opportunity permitted and none were continued at frequent intervals throughout a season.

The following observations represent only a single season's work, but they were made with a definite plan in view. The question which we have had before us throughout the work was: what are the relationships of *H. andersonii* so far as these may be deduced from its habits and life history? Wright (1914), by comparing the life histories of certain American batrachians with those of European species, has brought forth some clear-cut evidence as to the relationships of the species he considered. In the present paper we have made no attempt to discuss morphological or embryological data which do not have a direct bearing on our main problem.

The following observations were made by the writers at intervals during May, June and July, 1922. To these observations there have been added others made by one of us on various occasions during the three preceding years. Field observations have been supplemented by studies in the laboratory. Our knowledge of the life history of the Anderson Tree Frog is still far from complete. In the hope that someone more favorably situated than ourselves will continue this work, we have made some attempt to give a complete picture of what is known concerning the life history of this delightful tree frog. Not only have most of the published accounts been available to us, but we have been fortunate in having near at hand Messrs. W. T. Davis, J. P. Chapin, W. De W. Miller, G. S. Myers, K. P. Schmidt, C. L. Camp and others who are very familiar with the Anderson Tree Frog in the field. Many of the problems which arose we have discussed with these gentlemen. Wherever their observations have supplemented our own we have included them below with full acknowledgment. It was obvious from the first that no complete study of the life history of *H. andersonii* could be made in a few months time. Emphasis was therefore laid upon those features which might be expected to shed light upon the relationships of the species. These features we have discussed under separate headings.

Historical.

Hyla andersonii has until comparatively recent years been considered one of the rarest of American batrachians. When Cope wrote his standard work on "The Batrachia of North America," only two specimens had ever been taken: the type specimen, described by Baird (1854) captured at Anderson, South Carolina, and a second specimen collected by Professor J. Leidy "in a cedar swamp near the town of Jackson in New Jersey, sixteen miles east of Philadelphia." Cope (1862) gave a description of this second specimen from life. This description, with a few emendations, was later repeated by him (Cope 1889) and again by Fowler (1907). A third specimen of *Hyla andersonii* was recorded the year Cope's general work appeared (Peters 1889). It was captured the previous year "on the border of a pine barren at May's Landing, N. J." Abbott (1890) who had this specimen in captivity, criticises Peters for his description of the call. A few years later Moore (1894) published a short but informing account of observations he made at Pleasant Mills, N. J. This was followed by the capture of an additional specimen at Clementon, N. J., and Stone (1901), in a note concerning the specimen, states that "the species would no doubt prove more abundant if specially sought for, the comparative remoteness of the New Jersey barrens, where most of the specimens were found, and the retiring habits of the animal both tending to make its detection difficult."

This prophecy was soon substantiated. Davis (1904, 1905 and 1907) made a series of observations at Lakehurst and Farmingdale, N. J., tending to show that the species was not rare in the New Jersey pine-barrens. We owe to Davis our first account of the tadpole, and its metamorphosis. Fowler (1909) has given an excellent color description based on additional specimens. Of equal value is the splendid color plate given by Miss Dickerson (1906). She kept under observation one of the specimens secured by Mr. Davis and has given a good account of the species in captivity. Recently Barbour (1916) captured (July 8 at Lakehurst) "well up in a pine tree" two pairs while in embrace. These laid the same evening under abnormal conditions and no record was made of the egg-masses or eggs. More recently Miller (1916) has extended the known range of the species by finding it in several localities, "all in the sandy pine-barren 'island' north of the Pine-Barrens proper." Since 1916 the species has been studied at Lakehurst on one or more occasions by Messrs. C. L. Camp, K. P. Schmidt, R. Deckert, G. S. Myers, the writers and perhaps others. Lastly it may be pointed out that mention has been made of *H. andersonii* by various authors not listed above. Among these are Boulenger (1882), Sherwood (1898), Ditmars (1905), Stone (1906) and Deckert (1918). Further, Davis (1922) has very recently reported the occurrence of the species in North Carolina.

Distribution.

Hyla andersonii is a tree frog of the pine-barrens. The type specimen is credited with coming from Anderson, South Carolina and the species was named by Baird after that town. But as Anderson lies neither in the pine-barrens (Livingston & Shreve 1921) nor even in the coastal plain, we suspect that the type specimen actually came from some other locality. As shown in the accompanying map, all the other locality records for *H. andersonii* lie within the pine-barrens or their outlying "islands." Although *H. andersonii* is abundant throughout most of its range, this range does not extend the entire length of the pine-barrens. The species has not been recorded south of South Carolina nor in the pine-barrens of Long Island. It is, however, widely spread throughout the New Jersey pine barrens occuring even in the pine-barren "island" just south of the Raritan River.

It should be noted, however, that the pine-barrens of New Jersey have a flora somewhat distinct from those of North Carolina. Mr. W. T. Davis who has studied both regions assures us that the facies of the country about Southern Pines, N. C., where he and

FIG. 147. THE PINE-BARRENS AT LAKEHURST, NEW JERSEY

A. Portion of the square mile of bog that was intensively studied. Four pairs of *H. andersonii* were taken while in embrace in a small pool on the left side of the road, directly behind the figure. Not one was found to breed in the deep water to the right. B. Cedar swamps bounded our area on two sides. It is from these cedars that most males call.

Dr. Chapin collected *H. andersonii* is very different from that of the New Jersey pine-barrens. The soil of both regions, however, is sandy, and much of the vegetation is the same. Until more extensive investigations can be made in the Carolinas, it is perhaps most conservative to say that *H. andersonii* is confined to the "pine-barrens."

It will be noticed that the distribution of *H. andersonii* cannot be expressed by a single term such as "Carolinian Life Zone" or "Coastal Plain." To be sure, it is to be found in these regions, but its range does not agree at all closely with either area. Many have attempted to reduce the distribution of life in North America to a few terms,—to a few zones—or to a few physiographic areas. But always objections have been brought forth in opposition to these attempts.

Confronted by such conflicting views, one is at first inclined to deny that the distribution of any one form can be explained in terms of another. The physiology of no two related animals is the same, —why should we expect that related animals would react the same to temperature? If we should pick two animals at random that have the same reaction to temperature, we might find that they reacted differently to ten additional stimuli. Further, the distribution of one species might be due to one factor, and of another species to another. There is no reason why one should expect to discuss the distribution of frogs in terms of the distribution of birds. But one may, I believe, make a distinct advance by speaking of the distribution of one frog in terms of another's range. During the breeding season batrachians congregate in distinct habitats. At other times of the year they do not wander far from these habitats. There is some reason to suppose that closely related species will have somewhat similar breeding habits. It was on the basis of this that Wright made comparisons between the affinities of certain European and American batrachians.

Hyla andersonii is a "coastal plain form." Many other species seem to be typically coastal plain forms in our area. These may be listed with their breeding habitats:

(1) *Scaphiopus holbrookii*—Temporary pools in sandy regions.
(2) *Acris gryllus*—Weedy, especially water-lily, ponds.
(3) *Hyla andersonii*—Small pools in sphagnaceous bogs of pine-barrens.
(4) *Rana virgatipes*—Larger pools of pine-barrens.

(5) *Rana pipiens*—Shallow ponds.
(6) *Bufo fowleri*—Shallow ponds.

Whether or not it is because the last two species are not particular as to the exact nature of their breeding cite, the fact remains that they have a much greater distribution in our local region than the other four species. Further, these two species often extend their range beyond the coastal plain, and probably because of this tolerance. *Scaphiopus holbrookii* has been taken in various parts of New England where the soil was sandy. *H. andersonii* and *R. virgatipes* are confined to the pine-barrens. Why *R. virgatipes* has a more extensive range to the south than *H. andersonii* it is impossible to say at this time. *Acris gryllus* is not found in the pine-barren bogs, and probably because of its preference for less acid water. When the life histories of all our American Amphibia are known, the species arranged according to their breeding cite preferences, many of the present anomalies of distribution among our Batrachia will be explained.

Habitat.

The pine-barrens of New Jersey have been well described by various botanists (Stone 1911, Harshberger 1916, etc.). *H. andersonii* is not limited to any association within the pine-barrens. Specimens have been captured in many different kinds of bushes and trees. When pursued, *H. andersonii* invariably leaps to the ground and, with a series of short jumps, disappears among the grass and sphagnum of the bog. Specimens captured by us on the ground have been taken only in sphagnaceous areas.

Specimens of *H. andersonii* are taken most easily by running down the calling males at night, with an electric hand lamp. Such specimens have been captured on the ground, on low bushes, on the top of bushes six to eight feet in height and rarely in trees or tall bushes more than eight feet from the ground. We have captured only two specimens in the latter position, but Mr. Myers has observed a third.

Breeding Season.

Previous to our work during the spring of 1922, the eggs of *H. andersonii* had only been observed twice and both under abnormal conditions. Barbour (1916) reports the capture of pairs in embrace at Lakehurst, New Jersey, on July 8. Eggs were laid in a crowded vessel during the night. Messrs. Davis and Chapin captured a pair at Southern Pines, North Carolina, which later embraced and laid eggs the night of June 13, 1922, and also on the following night under abnormal conditions. No detailed observations were made on the egg laying process and no record made of the egg form. Previous to this, Davis had found tadpoles of *H. andersonii* in "all stages of development" at Lakehurst on July 21, 1907. From these observations it seemed probable that the breeding season of the Anderson Tree Frog at Lakehurst extended through June and part of July and may have begun earlier.

At Lakehurst, New Jersey, during 1922, the breeding season had apparently not begun by May 14. A few males were calling, but these from concealment on the ground (with a single exception, Camp), and mostly from among the sphagnum. On May 20 and 21 at exactly the same place in the bog, the breeding season was well under way. Two females were observed before embrace and taken during oviposition; a third female was taken just before oviposition. The chorus of the males was loud, approximately twenty-five to fifty calling within an area of one square mile. On June 4 and 5, approximately one hundred males were calling in this same area. One female was captured just before the embrace, and four pairs were taken in embrace. Although eggs had been found on May 20 and 21, no tadpoles could be found June 4 and 5. On June 18–19, the chorus of *H. andersonii* within the square mile of territory we were studying reached its maximum. At least two hundred and fifty males were calling within this area. Although no mated pairs were found, tadpoles of a wide range of sizes (up to appearance of hind limbs) were captured. On July 22–23, the chorus had diminished. Only about forty males were calling. Tadpoles of all sizes from shortly after the formation of the operculum up to metamorphosis were captured in this same region.

These observations make it clear that the breeding season of *H. andersonii* is not an explosive one, but is more or less protracted. Rains occurred at Lakehurst on the days preceding our observations of May 20–21, June 4–5 and June 17–18. The days, therefore, were comparable so far as humidity was concerned. (Unfortunately, no thermometers were used to determine this exactly.) Comparing this data with random observations made on previous years at Lakehurst, the breeding season of *H. andersonii* seems to be more or less dependent on the rains and may extend from the middle of May to the middle of July.

It was perhaps not surprising to find that in correlation with this protracted breeding season, the species breeds in more or less isolated pairs. As this method is not the general rule among our local Salientia, it may be of interest to make some comparisons between the breeding season of *H. andersonii* and that of other local forms. So little is known concerning the factors controlling these differences that only the most obvious will be mentioned.

I. Internal factors
  1. Maturing of gonads, may be either
    a. Uniform for all individuals of a species within an area, or
    b. Irregular, small colonies breeding at different times.
  2. Physiological cycle (correlated with the development of gonads) may be
    2. Genetic (closely related species living under similar conditions may have different breeding season), or
    b. Acquired. It is well known that Amphibia in captivity gradually modify their breeding season, and may eventually lay at very irregular times. The life cycle characteristic of the species may have been induced by the environment, just as it has been modified by the new environment of captivity.

II. External factors
  1. Temperature
    a. Air temperature,—affects those batrachians hibernating on land. These are, for the most part, early breeders (Wright, 1914).
    b. Water temperature,—affects the species hibernating in the bottoms of ponds. These are chiefly late breeders.
  2. Rains (often correlated with a change in temperature)—are the chief controlling factors in the breeding of Batrachia within the tropics. This has been shown experimentally by Bles (1906) but field observation has further demonstrated the fact. In temperate regions, the rains play a vital part in the life cycle of some forms (as *Scaphiopus*), but much less in the case of others.

As a result of the interaction of these external and internal factors, the various species of Batrachia within our local area are found to breed at different times. We may group them according to the time and period of their breeding season into several categories with the understanding that these categories are subject to fluctuations according to variability of both external and internal factors:

I. Explosive Breeders
   1. Temperature controlled; mostly early breeders which have hibernated on land. *Bufo americanus, Rana pipiens* and *Rana sylvatica.*
   2. Rain controlled; *Scaphiopus holbrookii,* often selecting a poor breeding cite.

II. Protracted Breeders
   1. Temperature controlled; including a few early but mostly late breeders, forms which have either hibernated in the water, *Rana palustris, Rana clamitans, Rana catesbeiana* and *Rana virgatipes,* or others on land,—*Pseudacris triseriata* (?), *Hyla crucifer, Hyla versicolor,* and *Acris gryllus.*
   2. Rain controlled; *Bufo fowleri, Hyla andersonii* may choose a poor breeding cite but more often one favorable to the welfare of the tadpoles.

The distributions made above are only approximate, and, moreover, apply chiefly to our local area. At Ithaca, New York, Wright (1914) found that temperature was the chief factor controlling the breeding season of the Salientia. Wright was able to arrange the species he considered in a series according to their first appearance and time of breeding. South of Wright's locality, even in the New York region, the rains begin to play an important part in the breeding of the Salientia. In the tropics, as we have recently seen in Santo Domingo, it is the rains—and apparently only the rains (correlated of course, with slight changes of temperature)–which initiate the breeding season.

In the case of *H. andersonii* our observations have not been of sufficient frequency to determine exactly the part played by the rains and the part by temperature in determining the breeding season. By comparing several seasons' observations, it would seem that both rain and temperature are effective, but as the season is a long one—possibly due to an irregular maturing of the gonads in the colony—it would seem that the rains may be the more important factor, although, of course, not as effective as in the case of explosive breeders such as the Spadefoot toad (*Scaphiopus*).

We may add, in passing, that not sufficient consideration has been given to the rains in initiating the laying process of Amphibia in general. The breeding season of not only some northern Salientia, as *Scaphiopus,* but even of some northern Caudata, may be controlled primarily by the rains. This has been very thoroughly demonstrated in the case of *Hynobius nebulosus* by Kunitomo (1910). It is to be hoped that more exact data of this sort will be forthcoming for other northern species. It would be interesting to know whether the breeding season of a single species may be primarily rain or temperature controlled, according to the northernness of its breeding site.

VOICE.

One of the most characteristic features of *H. andersonii* is its distinctive voice. As in the case of all known hylids, only the male is thus provided. The call has been variously described as a "keck-keck" (Abbott), a "peep-peep" (Peters), a "quack-ack" (Moore), a "whang" (Deckert) or a "aquack-aquack-aquack" (Davis). One would gather from the literature that the Anderson Tree Frog had a variety of calls. Our common tree toad (*Hyla versicolor*) has two distinctive calls. Although Wright (1914, p. 46) states that "an individual tree-toad may give one or two voice-forms totally unlike the normal and better-known call," undoubtedly these "abnormal calls" will be found referable to what Overton (1914, p. 33) has called the "turkey root." Since Overton's paper appeared, we have watched on several occasions *Hyla versicolor* give its "turkey root." On none of these occasions was there any bobbing of the head such as Overton describes. The call, variable as to number of syllables, is given with a half inflated pouch. When *H. versicolor* calls with fully inflated pouch it gives its characteristic trill; when it calls with only half inflated pouch, a series of mournful notes arise.

H. andersonii has only one call and that is given with fully inflated pouch (Fig. 148). It is a series of ten to twenty, or even more, resonant nasal notes, usually increasing in volume. Each note is a sonorous, high nasal quănk. If one tries to shout the word quank while holding the nostrils closed, a sound is produced not unlike the note made by this frog. The call sounds somewhat different from a distance, especially when several frogs are calling at once. Then the notes tend to run together, each note having two syllables, a-quănk, a-quănk.

SEX RECOGNITION.

Although the call of *H. andersonii* is loud, often carrying nearly a mile on quiet evenings, nevertheless, little or no significance has been attributed to it, or to the voices of any frogs and toads, in the breeding season. Voice is stated not to control the direction of migration towards the breeding grounds, or the movements of individuals on the grounds (Boulenger, 1912, p. 22, Cummins, 1920, p. 325). It is generally believed that "courtship does not take place in any of the tailless batrachians. The female is seized by the first comer, ———" (Boulenger, 1898, p. 68). Some years ago it was pointed out by Courtis (1907, p. 678) and later by Miller (1909, p. 650) and by Wellman (1917, p. 107) that the breeding female toad (*Bufo*) may respond positively to the trill of the male. But Cummins (1920, p. 243, italics his) has recently shown that in the case of frog material the "*voice does not direct* the movement of the frogs into the pond" and "that 'sex recognition' . . . results from the differential behavior of the two sexes when clasped, . . ."

The following observations made during 1922, on *Hyla andersonii* would tend to show that in that species, and by inference in tree frogs in general, the voice plays a considerable rôle in bringing the two sexes *in contact.*

At Lakehurst on May 13–14, *H. andersonii* was calling only from concealment (with one exception) on the ground, chiefly among the sphagnum of the bog. On May 20–21 some were calling from the ground, but mostly from trees and bushes a few feet from the ground. On all other occasions during June and July, *H. andersonii* called chiefly from some point of vantage above the ground; only very few were seen calling from the ground.

As pointed out above, the breeding does not occur simultaneously throughout the limited region under observation. By means of the flashlamp, individual frogs were studied for several consecutive hours on the days indicated above. The following observations were made the night of May 20–21.

Case I. 11:30 P.M. A male was observed calling from edge of small and weed-grown ditch, about one and one-half to two and one-half feet across, one to ten inches deep; bottom covered with sphagnum and water weed.

Female was first observed three feet away from male, hopping in his direction. Without hesitation the female leaped on back of the male; but the latter gave a slight wriggle, which threw her off his back and he continued calling.

Female turned and leaped again on the back of the calling male. Again he threw her off with a wriggle, but this time, as she moved again toward him, he caught sight of her and quickly turned about and embraced her with the normal supra-axillary amplexus. The pair maintained their position about eight inches from the water

(Fig. 149*c*) until 12:30 A.M., when the female leaped with her mate into the stream, and a moment later ovulation began.

Case II. A male was observed calling at 3:00 A.M. (May 21) from the edge of the same stream about one hundred yards away from place where the above observations were made. The character of the stream was identical to that of Case I. The male was sitting on a soaking mass of sphagnum close to the water's edge. The female was first observed two feet away, making short leaps toward the male. The female approached to within six inches of the male and while he continued calling, she hopped rapidly about him twice. In making these two circuits she had to splash through about one-half inch of water. In completing the last circuit, the female approached so close to the male that the side of her body touched his side and she nudged him with her limbs as if to draw as close to him as possible. On completing his call, he turned and embraced her.

The pair in embrace hopped for about six yards along the edge of the stream and began to ovulate in the water. They were finally placed in a vessel where ovulation was completed.

The following observations were made during the night of June 4–5:

Case III. A male that was calling from a bush, and photographed twice, (Fig. 149*a*) seemed particularly nervous because he frequently changed his position a few inches. Suddenly, at 12:30 A. M., he left the bush without warning. He was followed with the flash-light to which he paid no attention, and although we changed the position of the light frequently, the frog hopped straight across the bog over ruts and small depressions to a small stream flowing in a sphagnum-grown ditch. There he took up a position (Fig. 149*b*), three inches from the water and approximately thirty feet from his first calling station, and began to call.

Half an hour later a female came hopping across the bog. She was first observed about fifteen feet from the male. She came straight toward the male which continued calling. When about four inches from him she turned slightly and hopped past him but he paid no attention to her. She then continued her journey toward a thicket where over thirty males were calling. The female began to cross through a weed-grown bog, and as it was apparent that we could not follow her, she was collected. Later we found only a few yards ahead a flooded but very shallow bog in which there were four mated pairs. It was over one hundred and fifty yards from the point where the female was first observed to the place where she was taken. In making the journey, the female had passed no less than four calling males, but she came close only to the first.

From these data the following tentative conclusions may be reached:

1. *H. andersonii* begins calling in early May from concealment on the ground.
2. In the middle of May and throughout June and July the males call chiefly from bushes or from trees.
3. At various intervals throughout May and June (and some years, in July) when the rains have flooded the bogs and changed the ditches into small sphagnum-choked streams, the males leave their calling stations and make their way to the nearest of these small streams. This migration occurs about midnight. The males begin calling again from their new positions near the sphagnaceous streams.
4. The females are *attracted toward the male by his call.* This attraction is so great that it causes the female to leap upon the calling male.
5. After a more or less persistent courtship on the part of the female, during which she strikes the male one or more times, the male recognizes the female and embraces her.
6. It is possible that the female may, under certain circumstances, climb a tree after the calling male. At least, this seems to be the most feasible explanation for the observation made by Barbour (1916) of a pair in embrace while high in a tree.
7. The female may exercise some choice in the selecting of a mate. The call is not the only factor involved in bringing the sexes together.

Although no one has observed this method of female courtship in any species of *Rana* and only part of the phenomenon has been witnessed in *Bufo* material, we believe it will be shown to be the rule in the case of *Hyla*. On June 7 at 11:00 P.M. near Patchogue, Long Island, we observed a female *H. versicolor* swiftly approach a calling male from behind and leap directly on his back. The male broke off his call at once, turned, and embraced the female.

When the movements of individuals of other species of frogs have been followed throughout the night, we believe it will be clearly

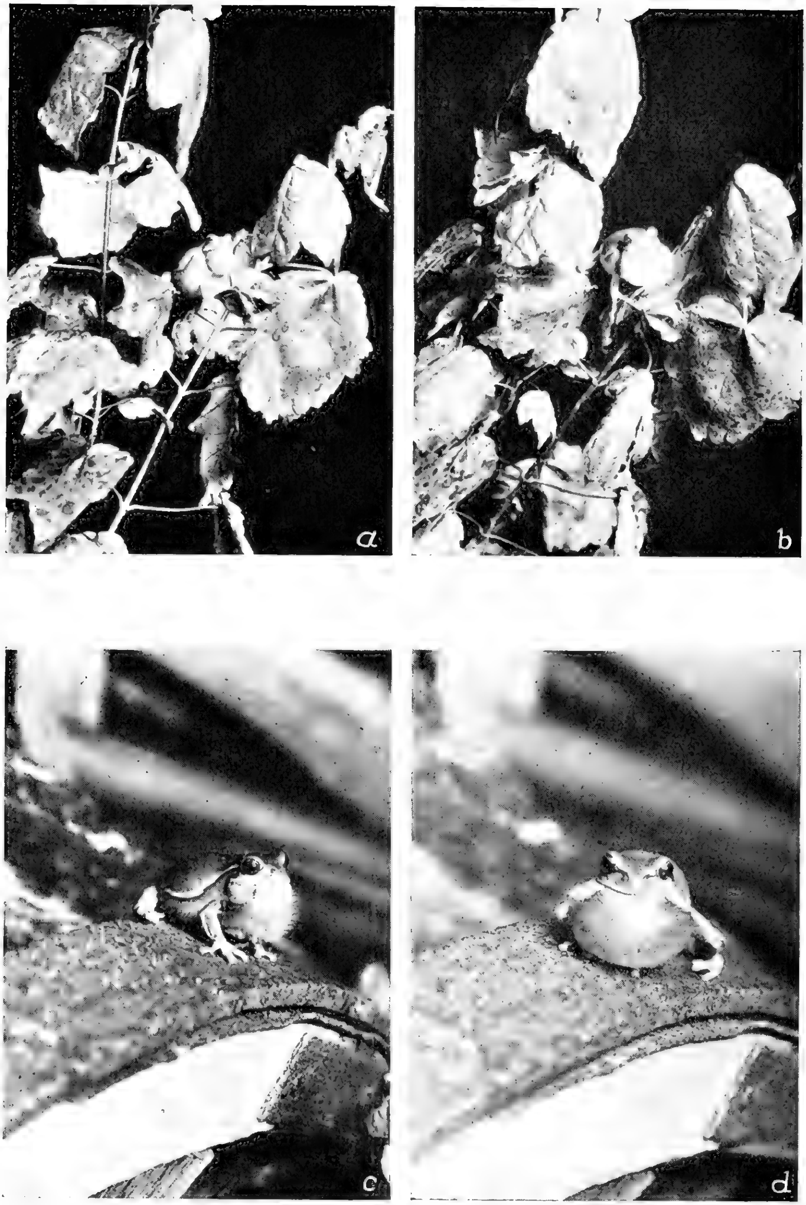

FIG. 148. FLASHLIGHT PHOTOGRAPHS ILLUSTRATING THE DIVERSITY OF THE CALLING STATIONS.

a. Beginning the call from top of a pine-barren maple; note the inflation of the body, and the rain drops on the leaves. *b.* The height of the call. *c.* Calling from the wheel of an old abandoned cart on the edge of the pine-barrens. *d.* The height of the call.

FIG. 148. FLASHLIGHT PHOTOGRAPHS ILLUSTRATING THE DIVERSITY OF THE CALLING STATIONS.

e. Beginning the call from the top of a bush about three feet high. *f*. The height of the call. *g*. The rest between calls from a blue-berry-bush. *h*. The call; note the position of the hands and feet.

demonstrated that voice plays a considerable rôle in bringing the two sexes together. The problem of sex retention is a more difficult one, and can be determined only by careful experimental work.

It will very probably be shown that voice plays a considerable rôle, not only in bringing the two sexes in contact, but also in attracting individuals together to form breeding colonies. We have found that males of *Scaphiopus holbrookii*, *Bufo americanus* and *H. andersonii* often came toward us when we imitated their call. In the case of one male *H. andersonii*, the hand-light was directed from a variety of angles and yet when we called, the frog always came toward us. We have never noticed a male *H. andersonii* jump on a calling male of the same species. It therefore seems likely that the attraction of the call is not as great in the case of the male as in that of the female. It, nevertheless, may play a considerable rôle in the ecology of a species, and to our tentative conclusions above we may now add two others.

1. The gregariousness of a species during the breeding season is a function of the attracting power of the call upon males of the same species. For example, *Scaphiopus holbrookii* is more gregarious than *Rana palustris* because it is readily attracted by the calling of the colony.

2. When several species are breeding in one marsh, the species are usually separated into colonies because of the *specific* attraction of the different calls.

Sexual Dimorphism.

With the several excellent descriptions of coloration of *H. andersonii* available, especially the color plate of Miss Dickerson (1906, color plate VII), it would be superfluous to give a new description of this form. Nevertheless, it has not hitherto been pointed out, although recognized by some (Davis, Myers), that there is a distinct sexual dimorphism in this hylid. I find the following constant differences between the two sexes. These differences are sufficiently marked to permit one to distinguish between the two sexes in the field.

1. Throat of breeding male, purplish gray; throat of breeding female pale gray or white, rarely as dark as the throat of palest male.

2. Green patch below angle of jaw broadly edged with

white in all females, without a white border in the breeding male, or with a very narrow and indistinct one.

3. Breeding females distinctly larger than males. Average head and body length (snout to vent) in the ten females taken in embrace is 40.9 mm. (extremes 44 and 38 mm.). Average head and body length of fifteen breeding males is 36.7 mm. (extremes 35 and 38 mm.).

In addition to these three characters of which the best field mark is the second, there are the two sexual differences to be expected. First, the vocal pouch of the breeding male is always more or less indicated even in quiet individuals. Secondly, the male bears on the inner and upper side of the thumb (prepollex region) a patch of minute pigmentless asperities hardly recognizable without a lens. The female bears in this same position glandular skin as smooth as the adjoining regions.

As pointed out by Dickerson (1906), the color pattern of *H. andersonii* is very constant, the change of coloration being limited to a darkening or lightening up of the tones. These changes of color are correlated with at least three factors,—(1) excitement, (2) light, and (3) humidity.

A pair in embrace are usually of a different color. If the female is ovulating and moving only short distances about the pool, the male is much the darker probably because of the sexual excitement accompanying fertilization; but if the female is moving rapidly along the edges of a bog, the male merely retaining his position on her back, the female is the darker. These facts were clearly shown in the three cases discussed above.

The effect of light and moisture on the color of these hylids may be readily demonstrated by keeping them in terraria of various degrees of humidity. Individuals in cold, wet terraria are very dark.

Method of Oviposition.

Amplexus in *H. andersonii* is supra-axillary. No other type or no abnormal amplexus was observed. The partly closed hand of the male is dug into the sides of the female just behind the head of the scapula, and just below the diapophyses of the anterior vertebrae. These diapophyses prevent the hand of the male from slipping dorsally, the scapula prevents it from slipping anteriorly, while the viscera of the female prevents it from sliding posteriorly.

FIG. 149. FLASHLIGHT PHOTOGRAPHS OF *H. ANDERSONII* ILLUSTRATING STAGES IN THE BREEDING PROCESS.

a. Beginning the call from ferns and bushes on a bank about two and one-half feet above the level of the bog (see text, Case III). *b*. The new calling station, about 30 feet from the first, close to a small sphagnaceous stream. *a*. and *b*. same individual.

FIG. 149. FLASHLIGHT PHOTOGRAPHS OF *H. ANDERSONII* ILLUSTRATING STAGES IN THE BREEDING PROCESS.

c. The embrace. After the female had flung herself twice upon the calling male, he finally turned and embraced her (see text, Case 1). A male *Bufo fowleri* is calling close at hand (left of picture). Oviposition did not take place until an hour later. *d.* The beginning of oviposition; note the position of the male and the sphagnum projecting above the water.

Oviposition takes place always in the water and only in small basins, or slow-moving streams on the pine-barrens, never, however, in stagnant water. All eggs, tadpoles and pairs in embrace were found in puddles and streams lined with sphagnum. The water of the pine-barrens is always more or less coppery, even after hard rains. The color is due to tannin derived from the roots of the bog plants. This tannin makes the water slightly aseptic. Eggs will develop in other kinds of water. We have found that several lots developed normally in tap water. We were not, however, successful in raising the tadpoles in tap water. Dilutions of bog and tap water proved more satisfactory. From our observations it would seem that the bog water is essential to the normal development of the tadpole.

The details of oviposition were studied in four pairs, two in the field and two in the laboratory. Mirrors were used to determine the exact course of the egg. The process of egg-laying was found to be the same in both captive and wild specimens.

In Cases I and II, discussed above, oviposition began almost immediately after the female leaped from land into the deeper water of the streamlet. The characteristic attitude in the water is shown in the photograph of another pair (Fig. 149*d*).

The egg-laying process seems to be initiated by the female. She bows her back suddenly, at the same time protruding the cloaca. A bunch of eggs appears in the orifice of the cloaca and as the female bows her back, either these eggs or the cloaca of the female touches the male between the legs. Immediately the male wriggles. It is assumed that the male emits the spermatozoa at this moment, but these are invisible. In the fully bent position (Fig. 150) the cloaca of the female is anterior to that of the male. As soon as this position is reached, the female straightens her body, suddenly ejecting the eggs. The eggs may have received a wash of sperm as they were protruding from the cloaca. It is more likely, however, that they strike the spermatozoa as they are shot from the cloaca. It will be observed that this method of fertilization is unlike that of the spring peeper, *H. crucifer*. Here the egg (rarely 2 eggs) is held in the orifice of the cloaca not only during the upturning of the cloaca, which, as in *H. andersonii*, seems to function in stimulating the male, but also during the return movement and subsequent forward movement of the whole posterior region of the female. Hence, the egg of *H. crucifer* is apparently fertilized while held in the cloacal orifice of the female, while it may or may not be fertilized at this time in the case of *H. andersonii*. The ovipositions of *H. andersonii* and *H. crucifer* may be compared as follows:

H. crucifer	*H. andersonii*
(1) Cloaca upturned, and egg or its capsule (rarely two eggs) appears in orifice of cloaca.	(1) Back bowed greatly, and cloaca upturned; part of a bunch of eggs (7 to 14) appear in orifice of cloaca.
(2) Cloaca of female usually touches posterior ventral surface of male's body in upward movement.	(2) Same.
(3) Emission of spermatozoa apparently takes place as cloaca touches or passes near ventral surface of male.	(3) Same.
(4) Back straightened and cloaca of female brought forward beneath body where the egg (or eggs) is shot out against some object to which it adheres.	(4) Back straightened and eggs are shot out against body of male to which they do not adhere, but glance off to the bottom of the pond.

The remainder of the egg-laying process of *H. andersonii* cannot be compared in detail with that of *H. crucifer*. At the moment the eggs are extruded, the hind limbs of the female are convulsively straightened, forcing the pair forward in the water. The female makes one or two nervous half strokes which continue the headway of the first stroke. In one to three seconds they have again come to rest, the female again bows her back and the process is repeated. After two to ten (possibly more) layings, the pair come to rest and oviposition may not continue until half an hour later. The exact length of these "rests" between sexual periods were not determined in the field. In the laboratory this "rest" was extremely variable.

The most remarkable feature of this egg-laying is the course taken by the eggs (Fig. 150). The female bows her back very much as in the case of the ovipositing *H. versicolor*, and even makes

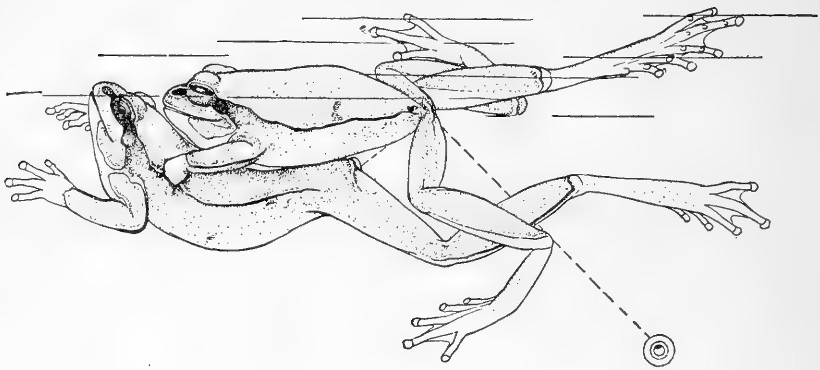

FIG. 150. THE OVIPOSITION OF *HYLA ANDERSONII*

This bombardment of the male with eggs seems to be a specialization derived from the method of oviposition found in *H. versicolor*, where the female lifts her cloaca above the water. In this diagram, only one egg has been represented (instead of nine), and the legs of the male have been abnormally extended in order to show better the course of the eggs.

some attempt to raise the cloaca above the water, as in that species, but the eggs never (or very rarely) reach the surface of the water. On being shot from the cloaca they strike the male on his ventral surface immediately below his cloaca and are carromed off to the bottom of the pool. Of the many times we watched this bombardment of eggs both in the two pairs studied in the field, and the laboratory specimens, only twice—and then in laboratory specimens—did we see the eggs miss the posterior part of the male's ventral surface. In these cases the eggs missed the male entirely and fell considerably to the rear of the pair.

This phenomenon of egg bombardment is of special interest from a phylogenetic point of view. The eggs of most species of *Hyla* float. In the case of *H. versicolor*, it would seem that the air bubbles entangled in the jelly when the female raised her cloaca above water, caused the eggs to float. In other forms it would seem more likely that it was some phenomenon of surface tension (Harrison 1922) holding the eggs near the surface where they were laid. Now in *H. andersonii*, the eggs cannot reach the surface for a very definite mechanical reason,—namely, the male is in the way. Nevertheless, the female goes through all the movements as if intending to lay the eggs on the surface of the water. It would thus seem that in *H. andersonii*, its habit cf laying bottom eggs has been derived from the more characteristic surface egg habit.

The eggs of *H. andersonii*, although shot from the cloaca in bunches of from seven to fourteen (average, nine), do not adhere to one another. They fall to the bottom of the pool where they usually adhere to sphagnum or debris. Here they swell rapidly and frequently lose their attachment to the sphagnum. At Lakehurst, many eggs (in late cleavages) were found lying free on the bottom of the sphagnaceous streams.

In nature, *H. andersonii* was estimated to lay eight hundred to one thousand eggs. None of our laboratory animals laid more than eight hundred eggs.

The Egg and Its Capsules.

The eggs of *H. andersonii* may be readily distinguished from all other eggs found in the pine-barrens by the following characters: The eggs are—

1. Single, not adhering to one another, usually scattered among the water weed.
2. Attached to sphagnum (rarely debris), or free and rest on bottom.
3. Found on bottom of small, non-stagnant pools, or in slow-moving streams of the pine-barrens.
4. With dark cap of the animal pole extending only over one-third of the surface of the egg. (Early cleavage stage.)

Before cleavage the cap on the animal pole is usually dark brown, the other two-thirds of the egg, creamy-white. As the cleavage continues, new pigment is formed. At the end of cleavage, before any gastrulation has begun, about two-thirds the surface of the egg is pigmented (Fig. 151). Harrison (1922) has noticed a similar phenomenon of pigment increase during segmentation in some of the Australian hylas he studied. In making a comparison of the eggs of *H. andersonii* with the eggs of other frogs, care should be taken to use only eggs very recently laid, not those which have gone beyond the 32 cell stage.

As gastrulation continues, the egg becomes much lighter in color. The late gastrula is pale brown, often with streaks of a darker tone.

The egg is surrounded by the vitelline membrane and by the

FIG. 151. PIGMENTATION OF THE EGG OF *H ANDERSONII*

a. Eight cell stage viewed from side of the gray crescent. *b*. Late cleavage stage, to show the increase of pigmentation.

two gelatinous membranes of the usual type. The gelatinous capsules vary enormously according to their age, and treatment. The following measurements are taken from a series preserved in formalin. They agree well in size with some living specimens.

Diameter of Ovum—1.2–1.4 mm.
" " Inner Capsule—1.9–2.0 mm.
" " Outer Capsule—3.5–4.0 mm.

The vitelline membrane may be best demonstrated just after maturation when the animal pole is slightly flattened leaving a space between membrane and ovum.

In passing, a word may be said in regard to egg membranes in general. The eggs of most batrachians possess two gelatinous capsules in addition to the vitelline membrane. European pelobatids are stated by Boulenger (1898) to possess only the inner capsule, while Wright (1914, p. 16) allows us to infer that some American Salientia may lack the same. We should like to emphasize that the outer egg capsule of all batrachians is subject to great modification, even within a species. Thus, our pelobatid *Scaphiopus holbrookii* has two layers of "jelly" about the eggs. At oviposition, the outer layer is extremely adhesive. As development continues, this outer capsule swells rapidly, losing its adhesive quality, and changing its appearance.[1] We do not believe that the presence or

[1] The eggs of *S. holbrookii* are not twisted around the grasses in the spiral manner indicated by Deckert (in Overton 1914); on the contrary, they are laid on the upper side of grass stems which have been flattened down by the female. As the outer gelatinous membrane swells, the egg-masses take on the appearance of being arranged in a spiral, having much the same form as the egg-masses of European pelobatids.

absence of the outer capsule in all batrachian eggs can be determined without investigating the structure of these membranes at the moment of oviposition.

We have had no difficulty in distinguishing two gelatinous capsules in the living eggs of *H. crucifer*, although Wright (1914) figures only one capsule.

Development of the Egg.

The egg of *H. andersonii*, in spite of its reduced pigmentation, shows some indication of a "gray crescent." At least one side of the fertilized egg is paler than the other. The pale region is in no sense a crescent, but is an area probably homologous to the gray crescent of *Rana*. The first cleavage plane tends to cut the mid-point of this "crescent" at right angles. However, some irregularities occur. The second cleavage plane is as usual meridional, but in most eggs it cuts the first cleavage plane not at its mid-point, but nearer the "crescent" side. As a result, the two cells containing the crescent material are usually smaller than the opposite pair. The third cleavage is latitudinal. It cuts the egg at right angles to its axis and at such a point that on the "crescent" side the third cleavage furrow sharply demarcates the pigmented from unpigmented region. Later cleavages are usually irregular. This is probably due to the fact that the second cleavage plane does not cut the egg systematically, but leaves less material on the "crescent" side than on the other. It would be interesting to know the conditions in other species of *Hyla*.

With the little comparative material available to us it does not seem advisable to discuss the later stages in any detail. The changes of pigmentation which accompany the development within the egg have been mentioned above. The late gastrula shows some dorsal flexure as in *Bufo* and *Rana*. No marked differences between the gastrulation in these groups were noted.

Eggs laid in the laboratory hatched in four days. This is probably a much shorter period than would occur in nature. Although the period of development within the egg may be greatly modified by temperature, not all eggs placed under identical conditions develop in the same time. Wright (1914, p. 19) found that the eggs of the species he considered all developed in about the same time under laboratory conditions,—namely, in four or five days. But Boulenger (1898) has found a marked difference in the developmental period of two such allied genera as *Alytes* and *Discoglossus*. We have found that the eggs of *Scaphiopus* hatched within thirty-six hours, while the eggs of most species of *Rana* require five days under the same conditions.

Lastly, a word may be said in regard to laboratory conditions. If a breeding pair is placed in a very small container, the chances that all the eggs will be fertilized and develop are very much better than if they are in a large jar. We experienced none of the difficulties with our material that Wright (1914) mentions.

The Adhesive Organs and Their Development.

Very few have studied the adhesive organs of batrachian larvae. Although the form of these organs differs in the various species and may be utilized as a character diagnostic of the species, these organs have been described in only a few hylids. It is, therefore, perhaps not surprising that we should find that the adhesive organs of *H. andersonii* bridge, during their ontogeny, the gap supposed to exist between the bufonid and hylid types.

Thiele (1888, pl. 10) found that the adhesive organs of *H. arborea* arose as two swellings, one on either side of the midline in a way very similar to the ontogeny of these organs in *Rana agilis*. Thiele pointed out that the more primitive method of development was that of *Pelobates* and *Bufo*, where the organs arise by modification from a crescentic furrow. It is, therefore, of considerable interest that we should find some indication of this crescentic type of development in *H. andersonii*.

In the early embryo of *H. andersonii* there appears a crescentic swelling on the ventral surface of the head (Fig. 152). This becomes slightly more pigmented than the surrounding region, but never invaginates to form a furrow as in European species of *Bufo*. As development continues, the two horns of the crescent increase in size and gradually differentiate into the definitive adhesive organs, while the posterior part of the crescent (Fig. 152) becomes less and less distinct.

By the time the tadpole is ready to hatch, the adhesive organs have assumed a position lateral to the mouth. It will be noticed from fig. 152 that these organs, when fully formed, are not as far anterior as the adhesive organs of *H. arborea*. In *H. crucifer* we find that the adhesive organs have a similar position lateral and posterior to the mouth.

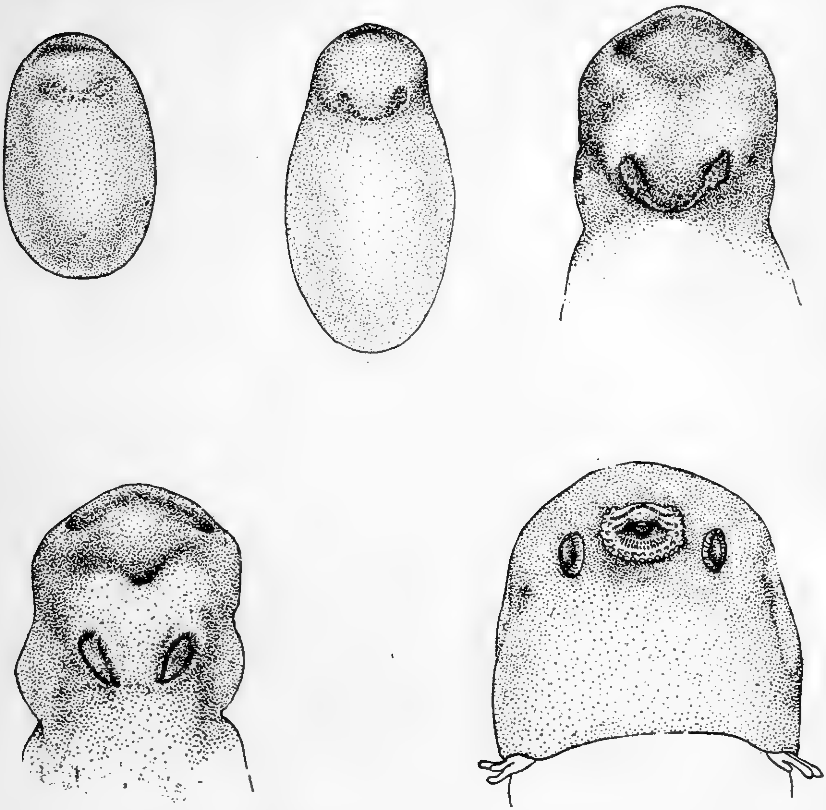

FIG. 152. DEVELOPMENT OF THE ADHESIVE ORGANS.
All but the last stage occur within the egg capsules. The frontal organ (extreme anterior end) is conspicuous in all but the last stage.

It will be noticed from fig. 152. that the frontal organ in *H. andersonii* is very distinct. This would indicate that it must have considerable functional significance.

Development of the Tadpole.

Eggs raised in the laboratory in shallow watch glasses hatched four days after oviposition. The recently hatched tadpoles varied somewhat in size, an average specimen measuring 4.5 mm. in total length. The color of these tadpoles was pale yellow finely stippled or suffused with brown. As the tadpoles grew older the pigment became darker. Approximately five days after hatching some indication of the distinctive pattern of the mature tadpole appeared. The pigment of the head first increased on the inner wall of the lymph space just anterior to the eye. This gave the tadpole a "pathological appearance" as though it carried two blisters, one on either side of the snout (Fig. 153*b*). Pigment developed slowly in the outer wall of this lymph space. It was not until just before the appearance of the posterior limb buds that the tadpole lost these "blisters."

The color pattern became well established in tadpoles of 11 mm. in length. Living specimens were uniform dull, chocolate brown above, golden or bronzy below. A dark stripe early made its appearance on the upper half of the fleshy part of the tail (Fig. 153c). An irregular series of blotches of the same dark brown developed above the stripe on the upper tail fin and a few smaller ones on the lower fin. (Fig. 153*c*.)

Only two external gills ever develop in the tadpole of *H. andersonii*. These are pigmented like the body. Each gill consists of a single stalk with four branches. Three of the branches of each of the anterior gills become well developed while the fourth remains a mere bud. Only two of the branches of the posterior pair of gills elongate, the other two branches of each gill remaining as short stumps. The longest gill measures only .7 mm. (three days after hatching). It is about as long as the diameter of the eye (which, although hidden beneath the skin, is visible in both living and preserved specimens).

In laboratory specimens the operculum grew over the external gills six days after hatching. The tadpoles at this age averaged 8 mm. in total length. The pale coloration of the early tadpole had darkened, and some indication of the dark tail streak had appeared. Although the mandibles were well formed and pigmented, no horny teeth had yet developed. The vent at this stage had just begun its asymmetrical growth which soon resulted in its characteristic dextral twist.

The horny teeth began to develop immediately. As the tadpole matured, the teeth increased in number. This may be seen in our series of preserved specimens. In a tadpole of 11.5 mm. total length, the number of teeth in each row, reading the rows from above down, is as follows: 38/10 + 10//31/24/5. In one of 17 mm., the formula is: 52/21 + 21//47/45/21. In a mature tadpole of 32.5 mm. total length and having the limb buds well developed, the formula is as follows: 96/36 + 35//67/82/40. The number of teeth in each row is closely correlated with the relative extent of the row. Hence, little may be said about the diagnostic value of the teeth rows of *H. andersonii* unless they be compared with those of a tadpole of the same age. The mouth parts figured above (Fig. 153*a*) are those of the tadpole figured (Fig. 153*c*).

Perhaps the most distinctive feature of the tadpole of *H. andersonii* is its short and narrow tail fin (Fig. 153*c*). This gives the tadpole a Rana-like appearance, or at least permits one to readily distinguish it from the tadpole of *H. versicolor*, or that of *H. arborea*. The question may be raised: is this reduced fin an adaptive feature? It may possibly be such, but the evidence at this time is by no means clear. The tadpoles of *H. versicolor* live for the most part in quiet, weedy ponds and these broad fins aid them to make quick turns very much in the same way that flattened or deep-finned fishes are able to dodge suddenly when avoiding an enemy. But let us look further. Most of the vertebrate inhabitants of the pond are deep-bodied or deep-finned. The ambystomid larvae have a back fin which undoubtedly serves them in their jerky dashes. A glance at a neighboring brook and we have a different picture. Here most of the forms have reduced the fin and have adopted better "stream lines." This is especially noticeable in the larvae of *Desmognathus* and *Eurycea*. The rule holds true for practically all mountain brook salamanders as *Rhyacotriton* in this country and many exotic genera. In the puddles of the slower streams we sometimes find the narrow-finned tadpoles of *Rana pipiens* or *Rana clamitans*. The comparison, however, between brook salamanders and brook tadpoles may not be drawn too closely. Frequently narrow-finned tadpoles occur in the ponds. It is interesting, however, that the tadpole of *H. andersonii* dwells primarily in the slow streams of the pine-barrens, and as if in adaptation to the current, it has given up its broad "pond life fin" for the sake of a more efficient one. We say "given up," for it seems probable from what has appeared above, that the species was evolved from a type having much the habits of *H. versicolor*. Whether or not we have pushed too far this comparison of brook salamanders and brook tadpoles, the fact remains that *H. andersonii* with its short fin has much more the habits of a *Rana* or a *Bufo* tadpole than it has the characteristic *Hyla* mannerisms (*see below*).

Metamorphosis first occurred at Lakehurst in the area under

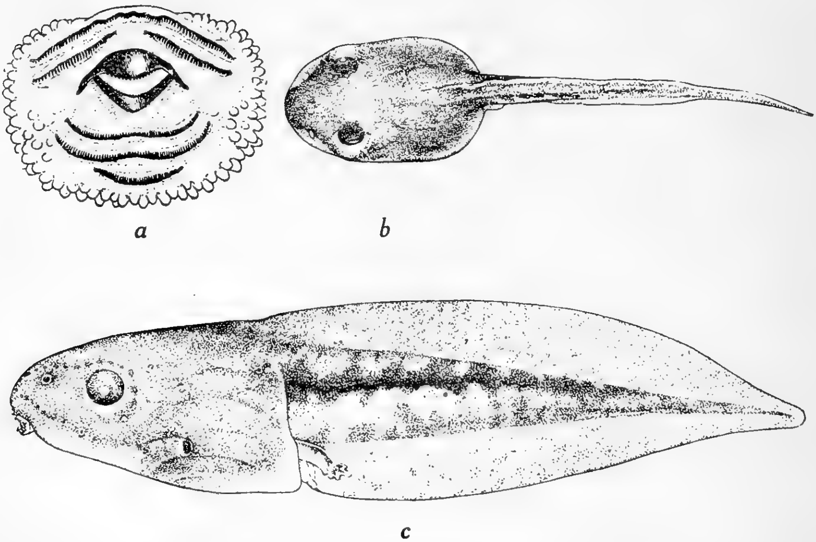

FIG. 153. TADPOLES OF *HYLA ANDERSONII.*

a. The mouth parts of mature tadpole. *b*. Early tadpole, showing the conspicuous lymph sacs on either side of the snout. *c*. Mature tadpole, showing the characteristic pattern.

observation on July 23. None of the laboratory animals reached metamorphosis, probably because of our limited supply of bog water. Metamorphosis usually followed the day after the right fore-limb appeared. The left fore-limb appeared usually a day before the right limb. The spiracle became greatly widened to permit the passage of the left limb through it. The usual phenomena of metamorphosis occurred. The head widened, the mouth changed its shape and the body decreased in size. The head and body length (excluding the tail) of five tadpoles, having only the posterior limbs present, averages 13.1 mm., the head and body length of five others, having all four limbs present and the head already changed in form, averages 12.1 mm. Metamorphosing tadpoles became slightly greener in coloration but did not assume the full color of the adult while in the water.

Description of a Mature Tadpole.

A tadpole is said to be mature at the time of the appearance of the hind limbs. In some forms this does not correspond to the full development of larval characteristics. In *H. andersonii* the larval color pattern may or may not be complete at this stage. For this reason, we have utilized slightly older specimens in drawing up the following description. As is customary in the describing of adult batrachians, the detailed description is based upon a single typical specimen, the diagnosis upon several specimens.

Diagnostic Characters Spiracle sinistral, anus dextral, eyes visible from the vental surface, upper fin crest not extending beyond the vertical of the spiracle, distance from spiracle to base of hind limb contained about 1.3 times in its distance from the snout; labial teeth 2/3. Uniform brown above, yellowish on the tail, a conspicuous irregular stripe of dark brown extending the length of the tail. Greatest length of tadpole, 35 mm.

Detailed Description Length of body contained 2.6 times in the tail length; width of body 1.7 times in its own length; nostril nearer the eye than the tip (midpoint) of snout; eye dorso-lateral, visible in part from the ventral surface, nearer the snout than the spiracle; distance between nostrils contained 1.66 times in the interorbital width, exactly equal to the width of the mouth; spiracle sinistral, its distance from the base of the hind legs 1.29 times in its distance from the snout; anus dextral; depth of the muscular portion of the tail at its base contained 2.5 times in the greatest depth of the tail.

Upper labium with two series of teeth, a boundary row of teeth and an inner or lateral row on each side (Fig. 153*a*); the median space between these two lateral rows only a third the length of one of the lateral rows; three continuous rows of teeth on the lower labium, the second or median longest, the outer or boundary row slightly more than half as long as the median one; a complete circlet of papillae around the mouth, broken only for a short space along the upper median margin; a clump of papillae at either corner of the mouth, medial to the boundary papillae.

General color (formalin preservation) of the body, chocolate brown above, translucent below; tail yellowish; an irregular streak of dark brown running the length of the fleshy part of the tail just dorsal to the median line; lower border of the fleshy part of the tail irregularly spotted with a slightly paler brown; tail fin both above and below streaked or finely spotted with brown; the streaks sometimes forming irregular stellate figures but never a network.

In life the color pattern was the same, the brown and yellow tones of about the same intensity. The belly was very different.

It was golden, irridescent or whitish, according to the direction of the light. The throat was yellowish. The iris was golden, vermiculated with black; the black pupil was large and round. Some indication of internal structure visible, especially the nasal passage and two of the posterior cranial nerves. Lateral line system feebly indicated.

Measurements

Total Length	31.0 mm.
Greatest length of head and body	12.5 "
Greatest length of tail	18.5 "
Greatest depth of tail	7.5 "

Habits of the Tadpole.

Larvae raised in the aquarium and those studied in the field had similar habits. The larvae of *H. andersonii* are not active swimmers. At Lakehurst, these tadpoles seek out the shallows whether or not these be weed-grown. In such favored places, great numbers of tadpoles were found resting motionless just below the surface with dorsal crest touching the surface film. When approached they dived quickly into the nearest masses of sphagnum. Tadpoles of *H. andersonii* exhibited similar resting and diving behavior in the laboratory. No other tadpoles with which we are familiar make such erratic plunges into concealment.

Laboratory specimens ate some fish food (dried shrimp) and some of the water weed in their aquaria. They invariably skeletonized within a day any of their companions that died.

Food Habits.

The food habits of *H. andersonii* are in no way specialized. This is to be expected since it has been shown elsewhere (Noble, in press) that the food habits of most tree frogs do not radically differ from those of frogs living near the water's edge. Frogs and toads seize anything of small size moving in their vicinity.

The stomachs of ten males which were captured during June while calling from bushes or low trees contained the following food: 5 grasshoppers (two species); 2 beetles, 3 ants (2 species), 1 dipterous insect, 2 dipterous pupae (tabaniid?), and some unidentifiable insect remains. None of the specimens taken in embrace contained food in their stomachs, but only a few pairs were killed immediately after oviposition.

Relationships.

H. andersonii has been generally considered a close relative of the European Tree Frog. Long ago Cope (1889) said of *H. andersonii*, "in proportions and general appearance similar to *Hyla arborea* of Europe." Since then everyone who has had the occasion to consider the relationships of *H. andersonii* has agreed that the resemblance was very close. More recently, Barbour (1914, p. 239) has expressed the opinion that *Hyla pulchrilineata* of Santo Domingo was allied to *Hyla arborea*. We have recently had the occasion to study *H. pulchrilineata* in the field, and could find very little resemblance between these two species in either color, structural characters, voice, vocal-pouch, breeding habits, or in any other than generic characters. In a paper now in preparation, we have concluded that the two species are only distantly related.

As pointed out above, the object of the present paper is to describe those features of the habits and life history of *H. andersonii* which might shed light on its relationships. As no one has previously attempted to ally *H. andersonii* to any other species than *H. arborea*, it is important that we should first consider the resemblances and then the differences between the two species. Our information in regard to *H. arborea* is taken chiefly from Boulenger (1898).

Resemblances between *H. andersonii* and *H. arborea*.

1. General color and proportions.
2. Small size.
3. Many structural features,—as smooth skin, position of vomerine teeth, form of nuptial asperities, form of vocal pouch, etc.

Differences between *H. andersonii* and *H. arborea*.

1. Color pattern differs in many details of which the most noteworthy are as follows: the lumbar and the dorsal spots frequently found in *H. arborea* are never present in *H. andersonii*; the ground tone of *H. arborea* is subject to variation of color, of *H. andersonii*, to only a change of intensity; the details of coloration of thighs, throat and often the appendages differ remarkably in the two species.

2. Contracted pupil of *H. arborea* diamond-shaped; not so in *H. andersonii.*

3. Fingers slightly webbed in *H. arborea*; free in *H. andersonii.*

4. A strong odor of "raw peas" from *H. andersonii* after handling; no such odor from *H. arborea.*

5. A marked sexual dimorphism in *H. andersonii*; not so in the other species. In *H. andersonii*, as pointed out above, there is a difference between the sexes in the size, in the color on the sides of the throat, and in the ground tone of the throat. These differences do not appear in the several specimens of *H. arborea* before us. A breeding pair taken at Blois, France, measures 42 mm., total length in both sexes. A female of *H. arborea* from Germany measures 41 mm., while four non-breeding males from Germany measure 40.5, 40.5, 36.5 and 35 mm. respectively. Thus, there might be a slight difference in size between the sexes of *H. arborea,* but this difference is not constant. There seems to be no sexual dimorphism in *H. arborea* other than some indication of breeding asperities in the male, and sometimes a difference in size between the sexes.

6. The call of the two species is radically different. The following notes have been kindly given us by Dr. J. P. Chapin.

> "In company with Dr. R. E. B. McKenny, at Blois, on the River Loire, France, during April, 1918, I found eight or ten individuals of *Hyla arborea* assembled just after dusk in a temporary pond in an open grassy field. Their notes, by which we were attracted, bore no resemblance to the voice of *Hyla andersonii,* with which I was very familiar; on the contrary, they produced a confused, hoarse, croaking chorus, which reminded me far more of the voices of common European toads. There was nothing of the curious nasal resonance of the "quank" of *andersonii.* The behavior of the individual frogs, too, was very different. They were all in the water while calling, not perched in bushes, as is usual with *andersonii;* and from the number of them in one or two small pools, I might describe them as far more sociable. In view of the striking external resemblance between *andersonii* and *arborea,* I was greatly impressed by the dissimilarity of their voices and actions."

7. The habitat of the two species differs greatly,—*H. andersonii* being confined to the pine-barrens, while *H. arborea* has a wide distribution in many types of country throughout Europe.

8. The breeding cites of *H. andersonii* are always shallow sphagnaceous streams or puddles on the pine-barrens, while

H. arborea selects "deep pools or ponds of clear water, more or less richly endowed with vegetation," (Boulenger, 1898, p. 258). Thus, *H. arborea* agrees with *H. versicolor* in the selecting of a breeding cite and differs remarkably from *H. andersonii*. Deep ponds are available to *H. andersonii* but it selects only the small pools.

9. Eggs of *H. arborea* are deposited "in several lumps, . . . attached to weeds below the surface of the water" (Boulenger, 1898, p. 259) Many more eggs are laid at one time by *H. arborea* than by *H. andersonii*, and these are adherent in the former species, not in the latter. From the form of the egg-masses, their attachment to weeds, and the number of eggs, it is apparent that the method of oviposition in *H. arborea* must be very unlike that of *H. andersonii*.

10. The external gills of *H. arborea* are "unbranched or bifid"; in *H. andersonii* there are only two pairs of gills, the posterior pair having two well developed branches, the anterior pair, three such branches.

11. The adhesive organs arise separately in *H. arborea*; in *H. andersonii* they develop from a crescent somewhat as in *Bufo*. The final position of the adhesive organs is more anterior in the former than in the latter species.

12. The mature tadpole of *H. andersonii* differs radically from that of *H. arborea* in the extent of its fin crest, and in its coloration both above and below. It also differs in having its eyes more dorsal and in having somewhat different proportions.

13. The mature tadpole of *H. andersonii* differs from that of *H. arborea* in its habits. It is a slow-moving form, accustomed to bask in the sun with dorsal fin in contact with the surface film. The description of the tadpoles of *H. arborea* given by Boulenger reminds us very much of *Scaphiopus* tadpoles for they are found "swimming about like fish in every direction."

14. Activity of the adults of the two species differ. *H. andersonii* does not stick well to smooth surfaces; when it climbs it frequently grips the branch with opposed fingers (Fig. 148*h*) and the feet wrap around the support. The movements of *H. arborea* agree well with the majority of hylas.

The above differences are far too numerous to be disregarded, for some of these differences are of considerable consequence. The resemblances between *H. arborea* and *H. andersonii* do not outweigh the differences. We have examined specimens of *H. regilla* which seem as nearly like *H. andersonii* as do some specimens of *H. arborea.* The resemblance in color pattern may be due to convergence, for Boulenger looks upon the spotted pattern as the more primitive and ancestral to the unspotted type, at least in the *H. arborea* group of forms. Further, Boulenger (1898, p. 252) considers that *Hyla immaculata,* described by Boettger, from China as a race of *arborea* "cannot be united with *H. arborea* . . . as it lacks the web between the fingers." *H. andersonii,* too, lacks the web between the fingers, and the question is immediately raised whether it might not be closely allied to *H. immaculata.*

It may be further pointed out that both botanically and herpetologically there are as good *a priori* grounds for seeking the ancestral stock of a form, at present restricted to eastern United States, not in western Europe, but in eastern Asia. *Cryptobranchus* and *Leiolopisma* are two striking examples of American forms having close allies in China. To this list we may now add *H. andersonii.*

Conclusions.

1. *H. andersonii* is not closely related to *H. arborea* nor to *H. pulchrilineata.*
2. *H. andersonii* has been derived from a group of hylas which laid surface eggs, its method of oviposition being a modification of their method.
3. *H. andersonii* exhibits a primitive method of adhesive organ formation.
4. Voice plays an important rôle in the mating of *H. andersonii* and probably in other American tree frogs.
5. *H. andersonii,* by its coloration (including sexual dimorphism), method of oviposition, distinctive tadpole, and restricted habitat, occupies an isolated position among American species of *Hyla.*
6. The relationships of *Hyla andersonii* are to be sought in Chinese forms and probably in *H. immaculata* (Boettger).

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