CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 48 APRIL, 1962 NUMBER 2

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CALIFORNIA FISH AND GAME

VOLUME 48 APRIL, 1962 NUMBER 2

Published Quarterly by

THE RESOURCES AGENCY OF CALIFORNIA

CALIFORNIA DEPARTMENT OF FISH AND GAME

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FOOD HABITS OF THE MOURNING DOVE IN CALIFORNIA[1]

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INTRODUCTION

Hunters and nonhunters alike recognize the value of the attractive, popular mourning dove (*Zenaidura macroura*, Linn). To evaluate the population status of the mourning dove, to appraise the habitat it occupies in California, to properly assess bag and season limits, or in other words, to intelligently manage the mourning dove, it is necessary for the wildlife manager, researcher and protector to gather as much knowledge as possible about the life history of this important natural resource. Food habits are an integral part of the life history of the mourning dove.

Considering the cosmopolitan distribution of, and interest in the mourning dove, there have been surprisingly few major food habits studies of the dove published. Excluding McClure's work in Iowa (1943) and Korschgen's reports on the dove in Missouri (1955, 1958) most of the food habits studies have been carried out in the southeastern United States. A resume of these notable references may be found in Beckwith's recent report on the food habits of dove in Florida (1959). The results of many of these studies are based, necessarily, on the analyses of crops collected during the hunting season or during the spring through the fall months when dove are plentiful in the particular area.

Because of the range of latitude within the State's boundaries dove are present in California throughout the year; therefore, it is possible to collect a year-round sample of dove crops for analysis. This was done from 1956 through 1959 in five dove concentration areas which were under intense nesting and banding investigation. A total of 1,016 crops collected from these areas has been analyzed to determine some of the more important food items eaten by the mourning dove in California.

The results of the analyses of 275 of these crops are included in a previous report (Browning, 1959). This work was done at Mather Field in the lower Sacramento Valley.

THE STUDY AREAS

The sample study areas are representative of good dove habitat. Two of these sites, Butte and Mather Field, typify the Sacramento Valley. The Kern area is in the southern San Joaquin Valley. The

[1] Submitted for publication September, 1961. A contribution of Federal Aid in Wildlife Restoration Project California W-52-R, "Wildlife Investigations Laboratory."

San Luis Obispo area lies in the south coast foothill region and the Imperial area is in the heart of the Imperial Valley. Those areas notably absent from what would be a more adequate habitat representation are the southeastern desert region, the Great Basin area of northeastern California, and the North Coastal area. Future studies should fill in these gaps in the total food habits picture.

The following are brief descriptions of all of the sampling areas except Mather Field, which was described in detail previously (Browning, 1959).

Butte Area

For comparative purposes the Butte area may be considered representative of the Sacramento Valley proper, while the Mather Field area is characteristic of the range and pasture land lying between the floor and the foothills of the valley. Actually part of the Butte area lies in the flood plain of the Sacramento River and is characterized by relatively recent alluvial soils and a climate of dry, hot summers and mild winters with moderate rainfall. These characteristics favor a wide range of farm crops including fruit trees and such special crops as rice. The remainder of the Butte area consists of the foothill region of the Marysville Buttes which has more shallow, heavier soils supporting an interspersal of grain agriculture, pasturage and occasional orchards. The vegetative composition of this gentle, sloping foothill area closely resembles that of the Mather Field sampling area. The influence of the "California annual type" vegetation as described by Heady (1956) is evident throughout the foothill region.

Doves are scattered throughout the Butte area and most of the Sacramento Valley, nesting in any suitable location but tending to concentrate in isolated clumps of trees such as riparian willow growth, or occasional olive and almond orchards nestled in the foothills and surrounded by grain culture (Figure 1).

Kern Area

The Kern sampling site is located in the southern end of the San Joaquin Valley, which tends to have alkaline soils, and is delineated by the cities of Lost Hills, Terra Bella, Arvin and Taft. The terrain consists of old and new alluvial fans and basin areas—the largest of which is the Buena Vista Lake bottom and rolling hills. The alluvial areas and basin flats support interspersed agricultural crops, *i.e.* cotton, grain, safflower, alfalfa, potatoes and rice; pasture lands of red brome grass and red-stemmed filaree; and desert scrub, mostly of alkali tolerant plants such as salt grass (*Distichlis spicata*), iodine bush (*Allenrolfea occidentalis*), various species of saltbush (*Atriplex*), and in some areas, mesquite (*Prosopis juliflora*). There is some marsh vegetation; willows and cottonwoods are found along the sloughways; and the rolling hills are mostly in grassland with scattered brush patches.

Dove are present throughout the year in the Kern area and are found concentrated in those border areas between the pasture land and the crop land, or between the crops and the desert scrub, and from the desert scrub to the pasture land. They use the willows, mesquite, or tamarisk windrows for roosting and nesting cover and range in either direction to the crop land for food and water or to the desert scrub to find loafing shade (Figure 2).

FIGURE 1. The Butte area where mourning dove concentrate in the suitable nesting sites isolated by pasture and cultivated fields. *(Photo by Walt Stienecker.)*

FIGURE 2. A cultivated field in the Kern area immediately adjacent to mesquite-saltbush scrub creates edge habitat attractive to dove.

San Luis Obispo Area

This area is representative of much of the western side of the inner coastal mountains of south-central California. The terrain of rolling hills is interrupted by alluvial terraces and river washes. Wherever the slope and soil type permits, the hillsides are dry-farmed to cereals, notably wheat and barley. Along the intermittent water courses are scattered irrigated pastures, crop lands and orchards. The region is arid and the hillsides support either an annual grass, oak-grassland, or chaparral vegetative association (Figure 3). The chaparral is pres-

FIGURE 3. The San Luis Obispo area, characterized by rolling hills supporting either cultivated plants, oak-grassland, or chapparal. Many of the principal food plants may be found on the roadside.

ent mostly on the north-facing and steeper slopes and is interspersed with oak-grassland. Along the water courses are found willows, cottonwoods, and sycamores, which together with the scattered orchards and eucalyptus windrows furnish most of the nesting cover.

Dove are present throughout the year in this area and tend to concentrate during the winter about sheltered areas and disperse to nesting sites in the early spring, at which time the resident population is augmented by the influx of migratory birds.

Imperial Area

The Imperial Valley is situated in the region of the Colorado River flood plain most of which lies below sea level in what was once the Salton Sink. This uniform plain slopes gently to the north and is broken only by the channels of the New and Alamo rivers and occasional sand dunes. The sample sites included the lowland terraces adjacent to the Alamo River and the valley region lying adjacent to the southeastern tip of the Salton Sea.

Throughout the year these areas support the highest concentrations of doves in the State. They nest in the vicinity of Mullet Island in salt cedars (*Tamarix aphylla*), willows, arrow-weed (*Pluchea sericea*), and mesquite which crowd the river bottoms.

Imperial Valley because of its climate and soil supports a wide variety of crops. The more common field crops are alfalfa, barley, flax, sugar beets, wheat, cotton and grain sorghum.

The unimproved desert areas interspersed with the irrigated crop lands are vegetated with an association of saltbushes, mesquite, arrow-weed, and sea blite (*Suaeda* spp.). In many locations throughout the valley these unimproved areas are utilized for feed lots where cattle and sheep are winter fed on concentrates, silage and hay.

COLLECTION AND METHOD OF ANALYSIS

During the course of the study 1,016 dove crops were collected for analysis from the five sample areas. Approximately one-quarter of the crops was taken from hunter-killed birds; another quarter was obtained by flushing the crops of nestling birds with water as described by Macgregor (1958); and the remainder of the sample was from birds shot on the study areas.

Dove crops were collected every month of the year on the areas where there was a major concentration of wintering dove: the Kern, San Luis Obispo, and Imperial areas. In the Butte area a sampling was made each month from the time the birds arrived until they dispersed with hunting season or at the first cold, early fall weather. Whenever possible a sample of 10 per month was taken. However, study on the Mather Field area has shown that the most dramatic changes in the diet of the dove occurred during the spring and summer growing seasons. Therefore, the results of the food habits determinations are combined into two and three month "seasonal" groups, corresponding with the significant units of the growing season such as spring, early summer, summer, fall, and winter months.

The dove crop contents were analyzed by standard food habits determination procedures. The frequency of occurrence of each item was tallied, and the quantity measured by water displacement in a graduated cylinder. The volumes were converted to percentages which were summarized by the "aggregate percentage method" described by Martin, Gensch and Brown (1946).

DISCUSSION OF FOOD ITEMS

Table A-1 in the appendix is a check list of all food items identified. The seeds of 162 species of plants were 99.9 percent of the total volume of food. Seven items of animal food accounted for the remaining 0.1 percent. These data would substantiate the belief that the dove is virtually a 100 percent seed eating bird.

Species from 38 plant families contributed to the diet. The grass family is represented by 33 species, the largest representation of any family. The sunflower family is next with 15 identified species, followed by the pea family with 11 and the borage and mustard families with

10 each. The scientific names for individual species may be found in the appended check list.

To determine the more important foods eaten by the mourning dove, it was decided that any item which made up 10 percent or more of the total volume of food eaten in any one month on any one area should be considered a "principal food item." The seeds of just 22 plants species out of the total of 162 fall into this category and they comprised 93 percent of the food found in the 1,016 crops analyzed.

Figures 4-7 are graphic representations of the seasonal utilization of these principal food items on each of the study areas.

Butte Area

The seeds of 76 plant species were identified from the 152 crops collected from this area. Eight principal items comprised 83.8 percent of the total volume of food. The phenological succession of the annual plants affects the diet of the dove (Figure 4). In a small April sample, the seeds of chickweed and miner's lettuce were almost 80 percent of the food. Together, buckthorn weed, red maids, milk thistle and California poppy, all of which are "spring" and "early summer" annual weeds, contributed over 70 percent of the May and June diet and over half of that in July. By August safflower is being harvested and its large, nutritious seed was prominent in the diet. Turkey mullein, a "summer" annual, California's "dove weed," showed increased use into the hunting season. Seventy percent of the food eaten in September was mullein seeds.

This pattern of a seasonal shift in the diet compares very closely with the feeding habits of the dove in the Mather Field area. Five of the principal food items, turkey mullein, red maids, buckthorn weed, milk thistle and California poppy are the same on both areas. In fact, 54 items were identified in the dove crops collected from both areas, including all of the principal items except safflower. In all probability feeding habits of the dove throughout the Sacramento Valley are similar.

Other annual weeds, contributing more than 0.1 cc by volume to the food, were canary grass, prostrate pigweed, valley spurge, cursed crowsfoot, popcorn flower, windmill pink, scorpion weed, mustard, other pigweeds, wild radish, vetch, water grass, yellow star thistle, bull thistle and lambs quarters.

Cultivated plants made up 15.0 percent of the total volume of food, the most important being safflower at almost 30 percent of the August diet. Other agricultural plants were rice, with over 5 percent of May foods; wheat, over 5 percent of September, and barley and milo.

Kern Area

The seeds of 73 plant species were identified from 192 dove crops. Nine principal items comprised 83.4 percent of the total volume of food. Figure 5 shows the influence of the spring annual weeds on the dove's diet. Buckthorn and California poppy seeds together were from 45 to over 75 percent of the spring and early summer foods. Turkey mullein as well as the poppies and buckthorn weeds, mature as much as a month earlier in the southern San Joaquin Valley than they do in the Sacramento Valley; hence, their availability and utilization on the Kern area is earlier. Turkey mullein seeds constituted as much as one-third of the food eaten in the midsummer months and over half of the food found in the August sample. Cultivated plant seeds, mostly wheat and safflower, made up more than 30 percent of the summer diet. Sunflower is the only other summer annual contributing significantly, over 12 percent of the late summer foods. Other seeds found in appreciable volume were monolepis, hydra stick-leaf, horse purselane, filarees, chickweed, valley spurge, nettle, Napa thistle, penny cress, red maids, milk thistle, vinegar weed, popcorn flower, goosefoot,

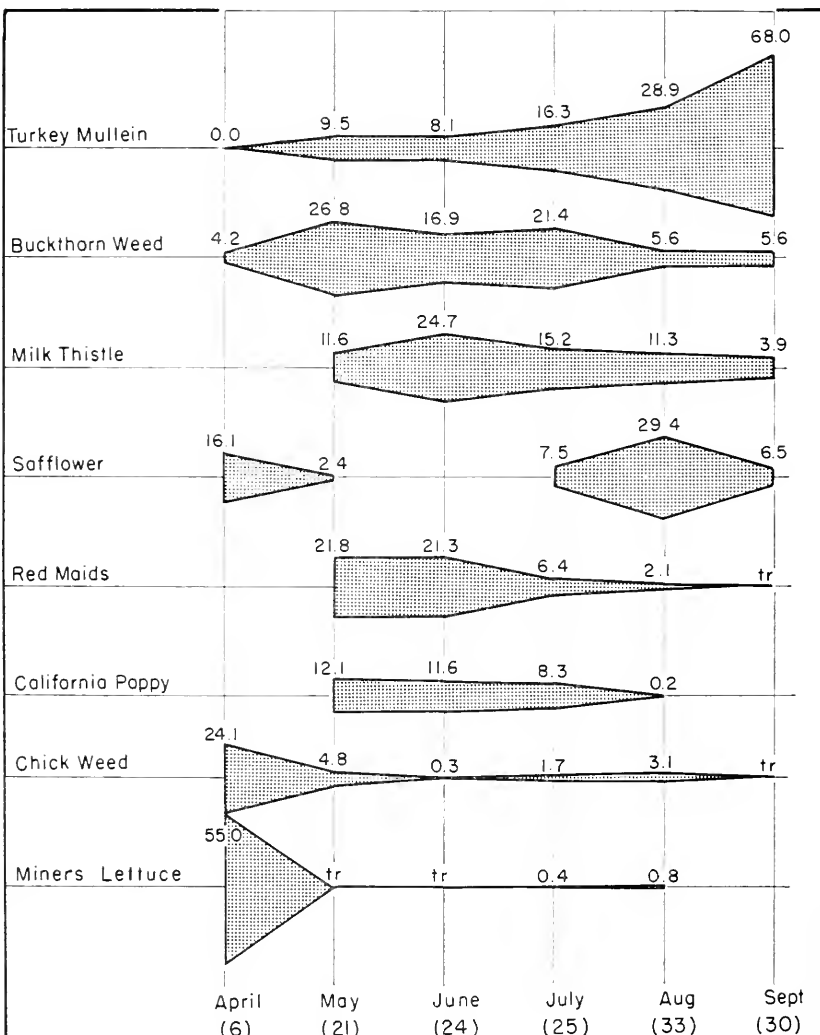

FIGURE 4. Seasonal utilization of important food items—Butte area.

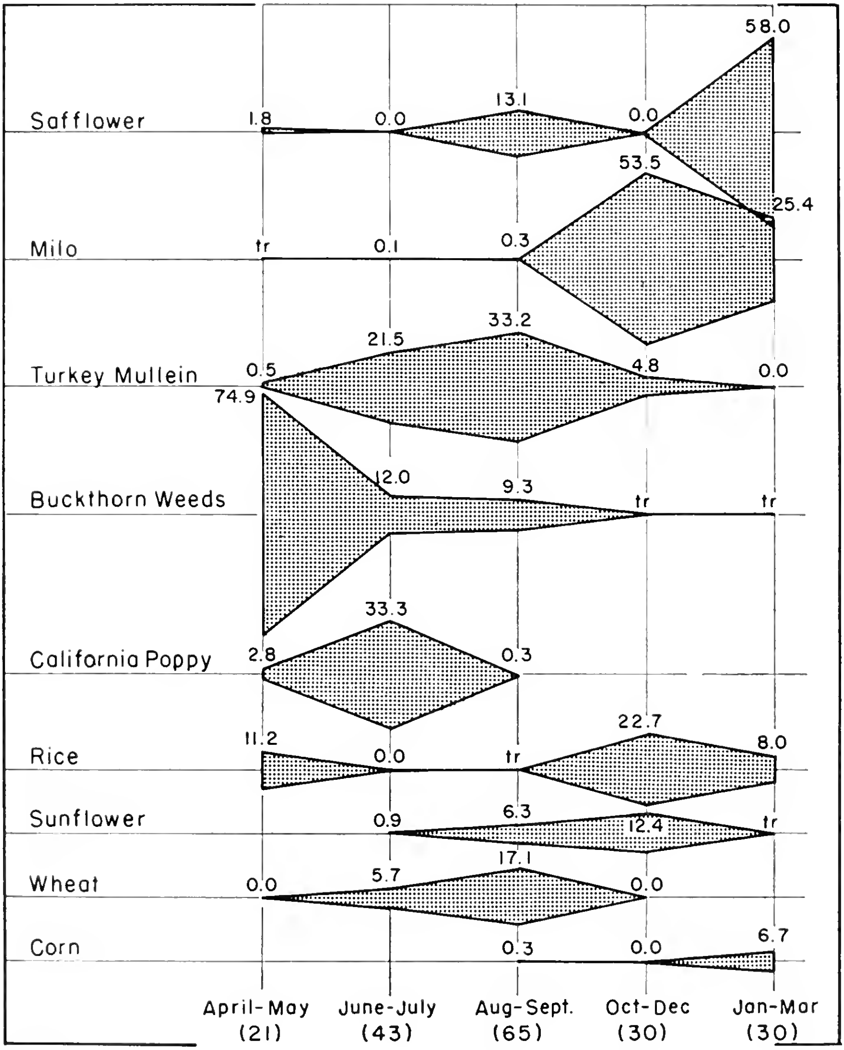

FIGURE 5. Seasonal utilization of important food items—Kern area.

water grass, alkali bulrush, prostrate pigweed, mustards, Johnson grass, and yellow nut grass.

A year-round feeding habits of the dove is presented for the first time with the data from the Kern area. At the autumn harvest it is the seeds of the cultivated plants that become the staple items of the fall and winter diet. Milo and rice contributed over three-quarters of the food eaten from October through December and together with safflower and corn made up virtually all of the winter foods in the Kern area. Other cultivated plants utilized were barley and melons.

San Luis Obispo Area

The seeds of 55 plants species were identified in 183 dove crops. Ten principal food items constituted 92.0 percent of the total volume eaten in this central intercoastal area. Figure 6 shows a very similar seasonal utilization pattern to that found on the Mather Field and Butte areas. Early annual weeds dominate the spring and early summer diets. Buckthorn weed, red maids, miner's lettuce, and California poppy contribute over 70 percent of the April and May foods and, together with Napa thistle and prostrate pigweed, their seeds were over 75 percent of the June and July diets. With the approach of summer, turkey mullein matured and its seeds constituted almost half of the food eaten by the dove during the summer months. Turkey mullein seeds also contributed almost one-third of the food consumed in the fall months and continued to be available over the winter and into the spring, comprising over 10 and 20 percent of the food during those periods. Other annuals showing up significantly in the dove crops examined from this area were sunflower, hydra stickleaf, popcorn

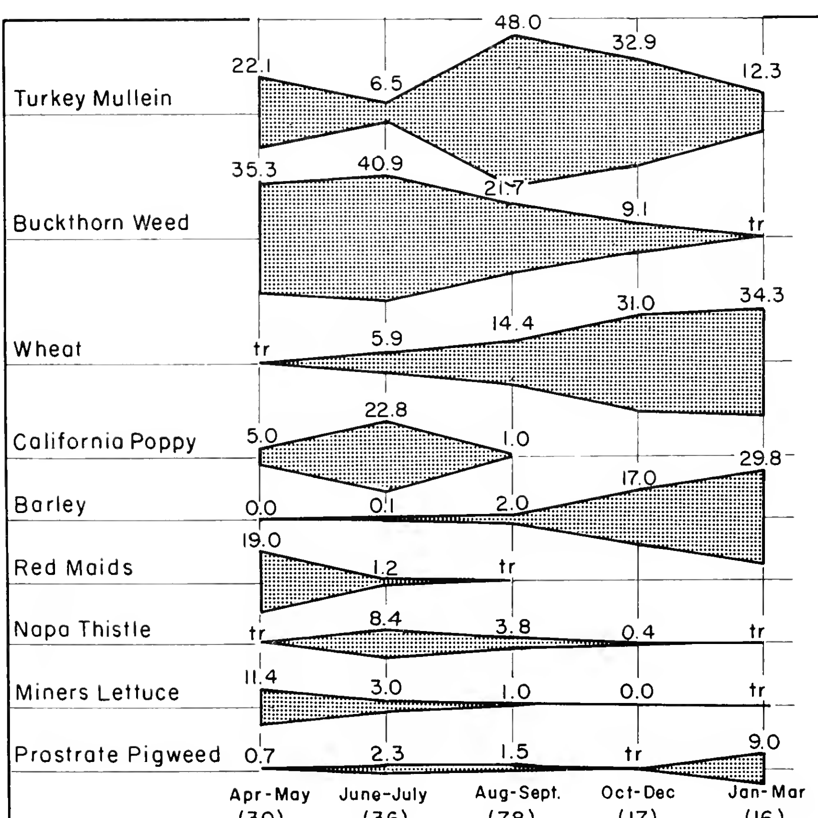

FIGURE 6. Seasonal utilization of important food items—San Luis Obispo area.

flowers, vinegar weed, vetch, filarees, sanicle, blue grass, phacelia, valley spurge, bur clover and lambs quarters.

A year-round analysis of the feeding habits of the dove in the San Luis Obispo area again shows the importance of the cultivated plants to the dove's winter diet. In this region, wheat and barley are the principal food items and constituted almost half of the fall foods and 65 percent of the winter diet. Milo is the only other cultivated plant that contributed significantly.

Imperial Area

The seeds of 66 plant species were identified from 214 dove crops collected. Ten principal food items were 94.0 percent of the total volume of food found in the crops. Figure 7 shows the influence of the agricultural environment on the diet of the Imperial dove. The seeds of cultivated plants formed 50 percent or more of the food during each of the "seasons" considered. The annual weeds were most prevalent during the spring and early summer months when lambs quarters—locally called "dove weed"—and Mediterranean canary grass, two of the most common agricultural weeds in the Valley, comprised 30-40 percent of the food eaten those months. These two annuals together with cup grass and common sunflower still were 40 percent of the dove's diet during the July-August period. During the hunting season 20 percent of the food consisted of the seeds of cup grass and water grass, another common weed in the cultivated fields. Other significant weedy annuals were knotweed, desert stillingia, lowland purselane, and ground cherry.

Cultivated flax, once harvested or made available by blackbird depredation, is a preferred food. Fifty percent of the contents of the July collection of crops consisted of flax seeds. Wheat contributed between 4 and 7 percent of the dove's diet throughout the year. Other cultivated crops used by the dove in Imperial are watermelon, oats, sesame, Sudan grass, and the grain sorghums. The most significant of the principal food items in the Imperial area, however, are cultivated barley and the grain sorghums. Together they contributed between 50 and 70 percent of all the food eaten during the fall and winter months and barley alone made up about one-third of the spring foods. Barley is the most important cereal crop grown in the desert area and sorghum silage is a very popular cattle feed. The feed lots play an important role in the ecology of the dove in Imperial Valley as evidenced by the appearance in the dove crops of broken and cracked barley and sorghum seeds, covered with greenish, ground feed material (Figure 8). When the dove disperse from the nesting areas, generally around hunting season, they tend to concentrate in these feed lot areas where they find shade, food and water.

NOXIOUS WEED UTILIZATION

The State Department of Agriculture has resolved that of the thousands of species of weed plants found in the State only 40 are to be classed as noxious weeds, 17 species as primary noxious weeds and 23 as secondary (Bellue, 1959). A noxious weed is defined as "any species of plant which is, or is liable to be, detrimental or destructive and difficult to control or eradicate."

It is interesting to note that of the 162 plant species found in the dove crops examined only seven are listed as noxious weeds. These are Bermuda grass, yellow star thistle, wild morning glory, dodder, yellow nut grass, alkali mallow and Johnson grass. All of these are classified as secondary noxious weeds. Of these seven weed species only three contributed a significant part of the volume of food eaten in any one area; namely yellow star thistle, 0.2 percent in the Butte area; yellow nut grass and Johnson grass 0.1 percent each in the Kern area. Only two yellow star thistle and Bermuda grass occurred in as many as 3 percent of the 1,016 crops collected.

FIGURE 7. Seasonal utilization of important food items—Imperial area.

FIGURE 8. Cereal grains are utilized extensively during the fall and winter months. Cattle feed lots and grain storage piles play an important part in the ecology of the dove in Imperial Valley. *(Photo by William Anderson.)*

From this evidence it doesn't seem likely that the mourning dove can be considered a significant factor in the control of noxious weed species in California.

ANIMAL FOOD ITEMS

With one exception the results of this study substantiate the opinion of most investigators that the dove utilizes animal foods only incidentally, if not accidentally. Insect fragments occurred in less than 5 percent of the crops. The exception is the tendency of the dove during the nesting season to pick up bits of shell and bone fragments if not in great volume, at least with a significant frequency of occurrence. Shell fragments, mostly gastropoda, occurred in 10 percent of the crops collected and principally from May through August on all of the areas studied. McClure (1943) has presented good evidence that this usage reflects the fulfillment of some physical mineral requirement, probably calcium.

DOVE MILK

The role of dove milk as a food for nestling dove and the treatment of nestling crop contents as being representative of the adult bird's diet have been discussed in the report on the dove's food habits on the Mather Field area (Browning, 1959).

Dove milk, the epithelial tissue sloughed off of the lining of the crop of the parent bird, made up approximately 13.6 percent by volume of all of the food examined in 307 nestling dove between ages of 5 and 12 days old. There is some loss of dove milk in the flushing technique and also in transferring the crop contents from the collection cloth or envelope. Therefore, the volume percentage obtained by crop examination is not absolute.

MISCELLANEOUS AREAS

Hunting seasons presented the opportunity to collect supplemental food habits data in places throughout the State other than the study areas. Such collections were made for several years in Modoc, Lassen, Shasta, Lake and Merced Counties. The results of these determinations are found in the appendix.

The seeds of 25 additional plant species were identified in the examination of 327 crops collected during the month of September from the above counties. None of the 25 were new principal food items and 18 of the 25 were from the Modoc-Lassen area. This makes a total of 187 food items identified in 1,333 dove crops.

This supplemental data shows a similarity of type of food plants utilized throughout California. There are enough differences, however, to indicate the need for further study in northeastern California (the Great Basin area), the southeastern desert region and the north coastal area.

CONCLUSIONS

Of all of the food eaten by the 1,016 mourning dove collected during this study, approximately two-thirds consisted of the seeds of a relatively few principal annual weed species. The other one-third was made up of the seeds of cultivated plants, the bulk of which were cereal grains of the grass family. Turkey mullein, red maids, and the buckthorn weeds contributed 44.3 percent of the total volume of food eaten and occurred in over 30 percent of the crops. These three weedy annuals, together with the cereal grains, wheat, milo, and barley seem to be important to the ecology of the dove throughout much of its range in California.

The significance of these food habits data obtained on a year around basis lies in the noticeable seasonal shift in diet from the early maturing annual weeds in the spring to the later maturing annuals in the summer and then to the cultivated grains in the fall and winter. This dramatic seasonal change in the feeding habits of the dove, seems to reflect a response to availability. The dove shift to those seeds that are available at the time, as red maids in the early spring on the Mather Field area, or those that are the easiest to obtain, as milk thistle seeds on a ditch bank and grain in a field recently harvested. On the other hand, only 22 plants species contributed almost 92 percent of all of the food eaten. This would seem to indicate some preference. Without further investigation, the question of whether availability or preference is most important in affecting the doves' feeding habits will remain unanswered.

It is the disturbed lands throughout the study areas, whether by cultivation, grazing or just roadside clearing and grading, that furnish the significant food items (Figure 9). The annual weed plants characteristically are those plants which, cannot stand much competition and have to cast their seeds upon the surface of the ground to reproduce. Hence, it may be the physical characteristics of the mourning dove that delineates its feeding habits. For, as Leopold (1943),

FIGURE 9. The roadside is important habitat for the dove, providing wires and fencing for loafing, road bed for dusting, grit and food plants. *(Photo by Walt Stienecker.)*

and Moore and Pearson (1941) have pointed out, dove do not seek their food by scratching or digging as do the gallinaceous birds, nor are they able to cling to upright stalks or stems; therefore, they rely on the surface of the ground for their food source.

Beckworth (1959) summarized succintly the important plant families that contribute significantly to the diet of the dove throughout the country as recorded by other investigators. The grass family generally is regarded as most important, comprising from 40 to 70 percent of food eaten by the dove, at least in the eastern half of the United States. The grass family, in terms of total volume of food consumed and number of species represented on the check list, may also be considered to be the most important family contributing to the dove's diet in California. However, it is noted that although the food items in the grass family made up over one-quarter of all of the food eaten most of it was in the form of cereal grains consumed in the fall and winter months.

Another family contributing another one-quarter of the dove's food in California is the spurge family. Turkey mullein is a spurge and, of course, bolsters the importance of this family to the California dove. The seeds of several species of the genus, *Euphorbia*, were also in dove crops collected during the summer.

Those interested in comparing further the important plant families in California with those recorded in other regions of the country will note that similarities generally end with the grass and spurge families. The sunflower family ranks next in California, including such food items as safflower, milk thistle, and common sunflower. Next follow the purselane and borage families. These latter three plant families contributed over 30 percent of the food found in the examined crops.

SUMMARY

A total of 1,016 mourning dove crops was collected over a four-year period, 1956-59, from five study areas in California. These areas are representative of much of the floor of the Sacramento Valley, the fringe of rangeland surrounding the valley, the southern San Joaquin Valley, the foothill area of the central section of the inner coastal mountains, and the Imperial Valley.

Food habits determinations show that the seeds of 162 plant species, from 38 plant families, made up 99.9 percent of the total volume of food eaten. Seven items of animal food accounted for the remaining 0.1 percent. However, the seeds of only 22 plant species contributed as much as 10 percent of the volume of food eaten in any one month on any one area. These important or principal food items are turkey mullein, red maids, buckthorn weeds, wheat, barley, sorghum, safflower, California poppy, milk thistle, Mediterranean canary grass, flax, lambs quarters, water grass, rice, common sunflower, miner's lettuce, Napa thistle, common chickweed, prostrate pigweed, cup grass, watermelon and corn.

Approximately two-thirds of the food is comprised of the seeds of annual weed species. Turkey mullein, red maids, and the buckthorn weeds are the most significant of the weed species; occurring in over 30 percent of the crops collected and contributing over 44 percent of the total volume of food. The other one-third is the cereal grains.

A study of the seasonal consumption of the preferred plants on the five areas reveals a shift from the seeds of early maturing weedy annuals in the spring to those maturing later in the summer, and then to cultivated plants in the fall and winter. Utilization correlates strongly with availability; however, the fact that 22 plant species contributed almost 92 percent of all of the food eaten and that the seeds of only 10 out of the 162 plant species identified occurred in as many as 10 percent of all of the crops collected, strongly suggests that the dove is a selective feeder. Nevertheless, the dove's physiological characteristics may dictate how and where it may feed, hence the answer to the question, "availability or preference," probably lies somewhere between.

The dove cannot be considered an important control of noxious weeds in California. Only two secondary noxious weeds, as classified by the State Department of Agriculture, appeared in as many as three percent of the 1,016 crops.

The use of animal food items was insignificant except for the small percentage of snail and bone fragments, which may provide a nutritional requirement, particularly during the nesting season.

Approximately 13.6 percent of the food eaten by 307 nestling birds sampled from the study areas was "dove milk".

Results of food habits determinations made of crops collected during hunting seasons from regions not included among the study areas brought the total to 187 food items identified in 1,333 dove crops. No new principal items were added.

The mourning dove in California obtains most of its food from lands disturbed by man, either by cultivation, grazing, ditch and road bed maintenance or similar practices which encourage weedy annuals and cultivated plants. Hence, as long as man continues these practices, food should not be a limiting factor for the mourning dove in California.

ACKNOWLEDGMENTS

Appreciation is due to Walton Smith, William Bailey, William Thomson, Russell Haynes, Robert Weld, Al Stumpf, and Wallace Macgregor, personnel or former personnel of the Pittman-Robertson Project, 47R, "Upland Game Investigations," for assistance in collecting dove crops and field data from the study areas. Walter Stienecker, Jack Spruill, Russell Murphey, and Peter Jackson each aided with the analysis work, and Cliffa Corson graciously donated her time and talent in preparing the accompanying graphs.

Thanks are due also to Department of Fish and Game unit managers Jack Spruill, Ed Schneegas, Bert Knowles, Gordon Ashcraft and to the hunters who co-operated to make the supplementary hunting season collections. The Merced County September data was supplied by Hugh Wooster, U.S. Fish and Wildlife Service through the courtesy of John Cowan, Department Game Manager. Finally, special acknowledgment is given to Howard Leach and Carol Ferrel for special direction and suggestions received as to the contents of this paper.

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APPENDIX

TABLE A-1

CHECK LIST OF FOOD ITEMS EATEN BY MOURNING DOVE IN CALIFORNIA

(Expressed in percentage of frequency of occurrence and based on examination of 1,016 crops)

Plant	Frequency of occurrence %	Butte	Sacramento	San Luis Obispo	Kern	Imperial
Marsilea Family—Marsileaceae						
Clover fern *Marsilea vestita*	0.1				x	
Pill-wort *Pilularia americana*	0.1		x			
Cypress Family—Cypressaceae						
Incense cedar *Libocedrus decurrens* (leaf)	0.2			x		
Pondweed—Naiadaceae						
Slender pondweed *Potamogeton pusillus*	0.1		x			
Grass Family—Gramineae						
Bentgrass *Agrostis arenacea*	0.2		x			
Silver-hairgrass *Aira caryophyllea*	0.1		x			
Cultivated oats *Avena sativa*	0.5		x			x
Quaking grass *Briza minor*	0.1		x			
Soft chess *Bromus mollis*	1.0	x	x	x		
Cheat grass *Bromus tectorum*	0.3			x	x	
Prickle grass *Crypsis aculeata*	0.1		x			
Bermuda grass *Cynodon dactylon*	1.3	x			x	x
Crab grass *Digitaria sanguinalis*	0.1					x
Salt grass *Distichlis spicata*	0.1	x				
Water grass *Echinochloa crusgalli*	12.3	x	x		x	x
Cupgrass *Eriochloa gracilis*	5.3					x
Fescue *Festuca* sp.	0.5	x	x	x	x	
Wild barley *Hordeum* sp.	0.3	x		x		
Cultivated barley *Hordeum vulgare*	12.1	x		x	x	x
Wild rye *Lolium* sp.	0.6			x	x	
Annual rye *Lolium multiflorum*	0.5	x				
Darnel *Lolium temulentum*	1.9		x			
Cultivated rice *Oryza sativa*	3.2	x			x	
Panic grass *Panicum* sp.	0.1		x			
Joint grass *Paspalum distichum*	0.3					x
Short-spiked canary grass *Phalaris brachystachys*	0.2					x
Med. canary grass *Phalaris minor*	12.5	x	x		x	x
Blue grass *Poa annua*	1.0	x	x	x		
Beard grass *Polypogon monspeliensis*	0.6	x	x		x	x
Cultivated rye *Secale cereale*	0.2			x		
Bristlegrass *Setaria* sp.	0.8	x	x		x	x
Johnson grass *Sorghum halepense*	0.5				x	
Milo *Sorghum vulgare*	10.5	x	x	x	x	x
Sudan grass *Sorghum vulgare* var. *sudanense*	0.2					x
Dropseed *Sporobolus* sp.	0.1	x				
Cultivated wheat *Triticum aestivum*	16.6	x	x	x	x	x
Corn *Zea mays*	0.6				x	x
Unidentified grass leafage	2.6	x	x	x	x	x
Sedge Family—Cyperaceae						
Yellow nutgrass *Cyperus esculentus* (tubers)	0.8		x		x	x
Spikerush *Heleocharis palustris*	0.9	x	x			
Tule *Scirpus acutus*	1.0	x			x	
Rough-seeded bulrush *Scirpus mucronatus*	0.2	x				
Alkali bulrush *Scirpus robustus*	0.3	x		x	x	
Sedge *Carex* sp.	0.1		x			

TABLE A-1—Continued

CHECK LIST OF FOOD ITEMS EATEN BY MOURNING DOVE IN CALIFORNIA
(Expressed in percentage of frequency of occurrence and based on examination of 1,016 craps)

Plant	Frequency of occurrence %	Butte	Sacramento	San Luis Obispo	Kern	Imperial
Rush Family—*Juncaceae*						
Toad rush *Juncus buffonis*	0.2		x			
Lily Family—Liliaceae						
Brodiaea *Brodiaea* sp. (tuber)	0.7		x			
Nettle Family—Urticaceae						
Dwarf nettle *Urtica urens*	0.8				x	
Buckwheat Family—Polygonaceae						
Persian wireweed *Polygonum argyrocoleon*	9.5					x
Wiregrass *Polygonum aviculare*	3.5	x	x	x	x	x
Knotweed *Polygonum lapathifolium*	0.4	x	x			
Lady's thumb *Polygonum persicaria*	0.4	x	x		x	
Sheep sorrel *Rumex acetosella*	0.3		x			
Curly dock *Rumex crispus*	1.1	x			x	x
Calif. buckwheat *Eriogonum fasciculatum*	0.2			x		
Goosefoot Family—Chenopodiaceae						
Saltbush *Atriplex* sp. (leafage)	1.3			x	x	x
Fat-hen *Atriplex patula*	0.1	x				
Five fingered hyssop *Bassia hyssopifolia*	0.1				x	
Lamb's quarter *Chenopodium album*	14.1	x	x	x	x	x
Mexican tea *Chenopodium ambrosioides*	0.4		x		x	x
Red sage *Kochia americana*	0.1					x
Monolepis *Monolepis nuttalliana*	4.0	x			x	x
Russian thistle *Salsola kali*	0.1			x		
Unid. Chenopodiaceae	0.2					x
Amaranth Family—Amaranthaceae						
Pigweed *Amaranthus* sp.	9.2	x	x	x	x	x
Prostrate pigweed *Amaranthus blitoides*	7.9	x		x	x	
Fringed pigweed *Amaranthus fimbriatus*	0.2					x
Carpet-weed Family—Aizoaceae						
Lowland purselane *Sesuvium sessile*	0.7					x
Horse purselane *Trianthema portulacastrum*	1.3				x	x
Purseland Family—Portulacaceae						
Red maids *Calandrinia caulescens*	32.7	x	x	x	x	x
Miner's lettuce *Montia perfoliata*	5.7	x	x	x	x	
Common purseland *Portulaca oleracea*	0.2	x				x
Pink Family—Caryophyllaceae						
Mouse ear chickweed *Cerastium viscosum*	0.3	x	x			x
Windmill pink *Silene gallica*	18.8	x	x	x		x
Corn spurrey *Spergula arvensis*	1.9	x	x	x		
Common chickweed *Stellaria media*	8.5	x	x		x	x
Buttercup Family—Ranunculaceae						
Carter's buttercup *Ranunculus alveolatus*	1.1		x			
Cursed crowfoot *Ranunculus scleratus*	2.4		x			
Poppy Family—Papaveraceae						
Calif. poppy *Eschscholtzia californica*	11.6	x	x	x	x	
Frying-pans *Eschscholtzia lobbii*	2.7	x	x			
Mustard Family—Cruciferae						
Mustard *Brassica* sp.	6.4	x	x	x	x	

TABLE A-1—Continued

CHECK LIST OF FOOD ITEMS EATEN BY MOURNING DOVE IN CALIFORNIA
(Expressed in percentage of frequency of occurrence and based on examination of 1,016 crops)

Plant	Frequency of occurrence %	Butte	Sacramento	San Luis Obispo	Kern	Imperial
Short-podded mustard *Brassica incana*	0.1					x
Indian mustard *Brassica juncea*	0.2	x				
Black mustard *Brassica nigra*	0.2					x
Toad-flax *Camelina microcarpa*	0.1			x		
Pepper grass *Lepidium* sp.	1.3	x	x	x	x	
Wild radish *Raphanus sativus*	0.6	x	x			
Tumbling mustard *Sisymbrium* sp.	0.7				x	x
Penny cress *Thlapsi arvense*	0.6				x	
Unidentified mustard	0.1				x	
Pea Family—Leguminosae						
Trefoil *Lotus* sp.	2.8	x	x		x	
Hill lotus *Lotus humistratus*	0.6			x		
Medick *Medicago* sp.	0.2		x			x
Bur clover *Medicago hispida*	0.2	x		x		
Lupine *Lupinus* sp.	1.0	x	x	x	x	x
Yellow sweet clover *Melilotus indica*	3.1	x	x	x	x	x
Mesquite *Prosopis juliflora* (leafage)	0.3					x
Colorado River hemp *Sesbania macrocarpa*	0.5					x
Clover *Trifolium* sp.	1.8	x	x	x	x	x
Tree clover *Trifolium ciliatum*	0.2			x		
Vetch *Vicia* sp.	1.3	x	x	x		
Unidentified legume	0.1					x
Flax Family—Linaceae						
Cultivated flax *Linum usitatissimum*	5.0					x
Geranium Family—Geraniaceae						
Filaree *Erodium* sp.	3.3	x			x	
Broad-leaf filaree *Erodium botrys*	2.0		x			
Red-stem filaree *Eriodim cicutarium*	18.6		x	x	x	x
White-stem filaree *Erodium moschatum*	0.3		x	x		x
Common geranium *Geranium dissectum*	3.4	x	x	x		
Spurge Family—Euphorbiaceae						
Turkey mullein *Eremocarpus setigerous*	13.0	x	x	x	x	x
Valley spurge *Euphorbia ocellata*	11.5	x	x	x	x	
Castor bean *Ricinus communis*	0.1					x
Desert stillingia *Stillingia linearifolia*	0.1					x
Mallow Family—Malvaceae						
Mallow *Malva* sp.	1.1		x	x		x
Alkali mallow *Sida hederacea*	3.2	x			x	x
Desert mallow *Sphaeralcea* sp.	0.1				x	
Unidentified mallow	1.5				x	
Tamarisk Family—Tamaricaceae						
Salt cedar *Tamarix aphylla* (leafage)	1.4	x			x	x
Loasa Family—Loasaceae						
Stick leaf *Mentzelia* sp.	0.1					x
Hydra stick leaf *Mentzelia affinis*	3.5			x	x	
Gourd Family—Cucurbitaceae						
Watermelon *Citrullus vulgaris*	0.9				x	x
Melon *Cucumis* sp.	0.3				x	x
Loose-strife Family—Lythraceae						
Red-stem *Ammania coccinea*	0.1	x				
Grass poly *Lythrum hyssopifolia*	0.1	x				
Evening primrose Family—Onagraceae						
Godetia *Godetia* sp.	0.1			x		
Parsley Family—Umbelliferae						
Coyote thistle *Eryngium vaseyi*	0.1		x			
Snake-root *Sanicula* sp.	0.1			x		
Primrose Family—Primulaceae						
Pimpernel *Anagallis arvensis*	1.9	x	x			

TABLE A-1—Continued

CHECK LIST OF FOOD ITEMS EATEN BY MOURNING DOVE IN CALIFORNIA
(Expressed in percentage of frequency of occurrence and based on examination of 1,016 crops)

Plant	Frequency of occurrence %	Butte	Sacramento	San Luis Obispo	Kern	Imperial
Morning-glory Family—Convolvulaceae						
Morning-glory *Convolvulus* sp.	0.2	x	x			
Dodder *Cuscuta* sp.	0.2			x	x	
Phacelia Family—Hydrophyllaceae						
Phacelia *Phacelia* sp.	0.7			x	x	
Borage Family—Boraginaceae						
Buckthorn weed *Amsinckia* sp.	31.2	x	x	x	x	x
Tesselate buckthorn weed *A. tessellata*	9.8			x	x	
Cryptantha *Cryptantha* sp.	0.2	x		x		
Greene's allocarya *Allocarya greenei*	0.1		x			
Scorpion weed *Allocarya stipitata*	6.7	x	x		x	
Pop-corn flower *Plagiobothrys* sp.	2.9	x			x	
Valley pop-corn flower *P. canescens*	1.1			x		
Fulvous popcorn flower *P. campestris*	0.4		x			
Rusty pop-corn flower *P. nothofulvous*	1.9			x		
Verbena Family—Verbenaceae						
Mat grass *Lippia* sp.	0.2	x				x
Verbena *Verbena* sp.	0.1				x	
Mint Family—Labiatae						
Douglas' pogogyne *Pogogyne douglasii*	0.1		x			
Vinegar weed *Trichostema lanceolatum*	4.3	x	x	x	x	
Nightshade Family—Solanaceae						
Ground cherry *Physalis* sp.	2.4	x			x	x
Figwort Family—Scrophulariaceae						
Owl's clover *Orthocarpus* sp.	0.1				x	
Pedalium Family—Pedaliaceae						
Sesame *Sesamum irdicum*	0.2					x
Sunflower Family—Compositae						
Mayweed *Anthemis cotula*	0.1	x				
Safflower *Carthamnus tinctorius*	5.3	x			x	
Napa thistle *Centaurea melitensis*	7.4	x	x	x	x	
Yellow star thistle *C. solstitialis*	3.4	x	x			
Spikeweed *Centromadia pungens*	0.9	x		x	x	
Bull thistle *Cirsium lanceolatum*	0.2	x				
Bur-weed *Franseria* sp.	0.1				x	
Common sunflower *Helianthus annuus*	7.7	x		x	x	x
Tarweed *Hemizonia* sp.	0.9	x	x	x	x	
Smooth cat's ear *Hypochoeris glabra*	1.1		x		x	
Prickly lettuce *Lactuca scariola*	0.7	x			x	x
Milk thistle *Silybum marianum*	7.7	x	x		x	
Soliva *Soliva sessilis*	0.1		x			
Sow thistle *Sonchus oleraceus*	0.6					x
Cockle bur *Xanthium canadense*	0.1	x				
Unidentified compositae	0.3		x			x
Unidentified seed fgmts	0.4					x
Forb leafage fragments	6.7	x	x	x	x	x
Vegetative stem fgmts	4.8	x	x	x	x	x
Rodent pellets (feces)	0.1				x	
Animal						
Snails Gastropoda (shell fgmts)	10.8	x	x	x	x	x
Seed shrimp Ostracoda (shell fgmts)	2.9	x	x		x	
Shell fish Mollusca (shell fgmts)	1.3				x	
Clam Pelecypoda (shell fgmts)	0.3				x	
Insect Insecta (fgmts)	4.5	x	x	x	x	x
Bone fgmts	3.0	x	x	x	x	
Fish scales	0.1		x			
Dove milk	28.3	x	x	x	x	x

Note: Sources for the scientific and common names on this list are: Jepson (1923), Abrahms (1940-1951), Abrahms and Ferris (1960), and Robbins, Bellue and Ball (1951).

TABLE A-2

FOOD ITEMS EATEN BY 100 MOURNING DOVES COLLECTED DURING THE 1957-58 HUNTING SEASONS IN MODOC AND LASSEN COUNTIES

Item	Volume percent	Frequency of occurrence %
No. of specimens	99	100
Plant Foods:		
Sunflower *Helianthus annuus*	29.0	57.5
Wheat *Triticum aestivum*	22.7	35.0
Turkey mullein *Eremocarpus setigerus*	15.2	31.2
Prostate pigweed *Amaranthus blitoides*	5.2	33.7
Thyme-leaved spurge *Euphorbia serpyllifolia*	5.1	10.0
Bull thistle *Cirsium lanceolatum*	3.3	6.2
Spurge *Euphorbia* sp.	3.2	13.7
Tarweed *Madia* sp. sativa	2.5	8.7
Willow herb *Epilobium paniculatum*	2.4	16.2
Mentzelia *Mentzelia* sp. *dispersa*	2.1	20.0
Trefoil *Lotus* sp.	1.7	26.2
Wire grass *Polygonum aviculare*	1.6	31.2
Barley *Hordeum vulgare*	1.4	2.5
Prickly poppy *Argemone* sp.	1.3	2.5
Buckthorn weed *Amsinckia* sp.	0.6	15.0
Allocarya *Allocarya* sp.	0.5	7.5
Douglas knotweed *Polygonum douglasii johnstonii*	0.5	5.0
Tessellate buckthorn *Amsinckia tessellata*	0.4	6.2
Caper family *Capparidaceae*	0.3	16.2
Goosefoot *Chenopodium* sp.	0.3	10.0
Pigweed *Amaranthus* sp.	0.2	25.0
Thistle *Cirsium* sp.	0.2	10.0
Cryptantha *Cryptantha* sp.	0.2	20.0
Saltbush *Atriplex* sp.	0.1	1.2
Gilia family *Polemoniaceae*	trace	2.5
Prickly lettuce *Lactuca scariola*		5.0
Juniper leafage *Juniperus* sp.		1.2
Panic grass *Panicum* sp.		1.2
Indian rice grass *Oryzopsis hymenoides*		1.2
Brome-grass *Bromus* sp.		1.2
Common spike-rush *Eleocharis palustris*		6.2
Spike-rush *Eleocharis* sp.		1.2
Buckwheat *Eriogonum* sp.		1.2
Knotweed *Polygonum* sp.		1.2
Mexican tea *Chenopodium ambrosioides*		2.4
Goosefoot *Chenopodium* sp. *gigantospermum*		2.4
Lambs quarters *Chenopodium album*		1.2
Goosefoot family *Chenopodiaceae*		1.2
Miner's lettuce *Montia perfoliata*		1.2
Mustard *Cruciferae*		2.4
Round-leaved pepper-grass *Lepidium perfoliatum*		2.4
Tumbling mustard *Sisymbrium* sp.		1.2
Flatpod *Idahoa scapigera*		1.2
Broad-podded cleome *Cleome platycarpa*		1.2
Clover *Trifolium* sp.		1.2
Filaree *Erodium* sp.		3.6
Red-stemmed filaree *Erodium cicutarium*		3.6
Mallow *Malva* sp.		1.2
St. Johns-wort *Hypericum* sp.		1.2
Mentzelia *Mentzelia* sp.		2.4
Evening-primrose family *Onagraceae*		1.2
Dense-flowered Boisduvalia *Boisduvalia densiflora*		1.2
Phlox *Phlox* sp.		4.8
Phacelia *Phacelia* sp.		2.4
Small-flowered dwarf flax *Hesperolinon micranthum*		1.2
Coyote tobacco *Nicotiana attenuata*		2.4
Figwort family *Scrophulariaceae*		1.2
Blue-eyed Mary *Collinsia* sp.		3.6
Annual burweed *Franseria acanthicarpa*		2.4
Blepharipappus *Blepharipappus scaber*		8.7
Common matchweed *Gutierrezia sarothrae*		2.4

TABLE A-2—Continued

FOOD ITEMS EATEN BY 100 MOURNING DOVES COLLECTED DURING THE 1957-58 HUNTING SEASONS IN MODOC AND LASSEN COUNTIES

Item	Volume percent	Frequency of occurrence %
Sunflower invol. fgmts. (Compositae invol. fgmts.)		1.2
Unidentified seed		13.0
Stem and vegetative fgmts.		18.7
Animal Foods:		
Snail shell fgmts. (Gastropoda)		7.5
Bone fgmts. (unidentified)		1.2
Insect larva fgmts. (Insecta)		1.2

TABLE A-3

FOOD ITEMS EATEN BY 44 MOURNING DOVES COLLECTED SEPTEMBER, 1958 IN SHASTA VALLEY, SISKIYOU COUNTY

Item	Volume percent	Frequency of occurrence
Turkey mullein *Eremocarpus setigerous*	77.5	42
Buckthorn weed *Amsinckia* spp.	7.1	18
Wheat *Triticum aestivum*	5.7	8
Cultivated rye *Secale cereale*	2.6	7
Trefoil *Lotus* spp.	1.7	7
Fitch's spikeweed *Centromadia fitchii*	1.5	9
Sunflower *Helianthus annuus*	1.5	6
Prostate pigweed *Amaranthus blitoides*	0.8	18
Red-stemmed filaree *Erodium cicutarium*	0.6	20
Cultivated oats *Avena sativa*	0.4	2
Mustard *Brassica* sp.	0.3	3
Tarweed *Madia elegans*	0.2	6
Cultivated barley *Hordeum vulgare*	0.1	1
Soft chess *Bromus mollis*	trace	1
Water grass *Echinochloa crusgalli*		1
Fescue *Festuca* sp.		6
Tule *Scirpus acutus*		1
California poppy *Eschscholtzia californica*		6
Pigweed *Amaranthus* sp.		2
White sweet clover *Melilotus indica*		1
Vetch *Vicia* sp.		2
Cursed crowsfoot *Geranium dissectum*		2
Spurge *Euphorbia* sp.		1
Scorpion weed *Allocarya stipitata*		1
Popcorn flower *Plagiobothrys* sp.		2
Vinegar weed *Trichostema lanceolatum*		1
Yellow star thistle *Centaurea solstitialis*		3
Thistle *Cirsium* sp.		2
Vegetate stem fgmts.		1
Insecta fgmts.		1
Gastropoda (shell fgmts.)		1
Epithelial tissue ("dove milk")		1

TABLE A-4

FOOD ITEMS EATEN BY 63 MOURNING DOVES COLLECTED SEPTEMBER, 1960 IN SCOTT VALLEY AND LAKEPORT AREAS, LAKE COUNTY

Item	Volume percent	Frequency of occurrence %
Plant Foods:		
Turkey mullein *Eremocarpus setigerous*	95.8	100.0
Fulvous popcorn flower *Plagiobothrys campestris*	2.3	33.3
Napa thistle *Centaurea melitensis*	0.4	6.3
Red maids *Calandrinia caulescens*	0.4	9.5
Miner's lettuce *Montia perfoliata*	0.3	4.7
Tessellate buckthorn *Amsinckia tessellata*	0.2	1.5
Common geranium *Geranium dissectum*	0.2	15.8
Mentzelia *Mentzelia* sp.	0.2	1.7
Safflower *Carthamnus tinctorius*	0.1	1.5
Vetch *Vicia* sp.	0.1	1.5
Bull thistle *Cirsium lanceolatum*	trace	1.5
Common chickweed *Stellaria media*		1.5
Canary grass *Phalaris minor*		1.5
Drop seed *Sporobolus* sp.		1.5
Bent-grass *Agrostis* sp.		1.5
Blue grass *Poa annua*		4.7
Wild rye grass *Lolium* sp.		3.1
Wild barley *Hordeum* sp.		1.5
Buckwheat *Eriogonum* sp.		1.5
Buckwheat flower fragment		1.5
Wire grass *Polygonum aviculare*		3.1
Curly dock *Rumex crispus*		1.5
Mexican tea *Chenopodium ambrosioides*		1.5
Pigweed *Amaranthus* sp.		11.1
Prostrate pigweed *Amaranthus blitoides*		1.5
Indian lettuce *Montia* sp.		3.1
Windmill pink *Silene gallica*		3.1
Poppy *Eschscholtzia* sp.		1.5
Pepper-grass *Lepedium* sp.		1.5
Lupine *Lupinus* sp.		7.9
Sweet clover *Melilotus* sp.		1.5
Clover *Trifolium* sp.		1.5
Trefoil *Lotus* sp.		7.9
Nemophila *Nemophilia* sp.		1.5
Filaree *Erodium* sp.		9.5
Broad-leaf filaree *Erodium botrys*		1.5
Red-stemmed filaree *Erodium cicutarium*		12.6
Spurge *Euphorbia* sp		3.1
Mallow *Malva* sp.		1.5
Allocarya *Allocarya* sp.		3.1
Buckthorn weed *Amsinckia* sp.		4.7
Pop-corn flower *Plagiobothrys* sp.		3.1
Rusty pop-corn flower *Plagiobothrys nothofulvous*		9.5
Blue-eyed Mary *Collinsia* sp		3.1
Napa thistle *Centaurea melitensis*		1.5
Sunflower *Helianthus annuus*		1.5
Tarweed *Madia* sp.		1.5
Unidentified seed fragments		12.6
Vegetative fragments		23.8
Rodent pellets		1.5
Animal Foods:		
Snail fragments		1.5
Bone fragments		1.5

TABLE A-5

FOOD ITEMS EATEN BY 120 MOURNING DOVES COLLECTED SEPTEMBER, 1946 IN LOS BANOS AREA, MERCED COUNTY

Item	Volume percent	Frequency of occurrence %
Plant Foods:		
Turkey mullein *Eremocarpus setigerous*	42.3	88.0
Wheat *Triticum aestivum*	11.2	28.0
Sunflower *Helianthus annuus*	10.0	27.5
Sorghum *Sorghum* sp.	9.3	40.0
Buckthorn weed *Amsinckia* sp.	6.0	38.0
Napa thistle *Centaurea melitensis*	4.0	16.0
Bristlegrass *Setaria* sp.	3.2	17.0
Alkali mallow *Sida hederacea*	3.0	28.0
Red maids *Calandrinia caulescens*	2.3	29.0
Red-stemmed filaree *Erodium cicutarium*	2.0	27.5
Pigweed *Amaranthus* sp.	1.2	19.0
Spikeweed *Centromadia pungens*	0.9	4.0
Milk thistle *Silybum marianum*	0.6	2.5
Water grass *Echinochloa crusgalli*	0.4	16.0
Spike rush *Eleocharis palustris*	0.4	7.5
Trefoil *Lotus* sp.	0.4	7.5
Cup grass *Eriochloa gracilis*	0.4	0.8
Phacelia *Phacelia* sp.	0.4	0.8
Clover fern sporocarps *Marsilea vestita*	0.3	4.0
Canary grass *Phalaris minor*	0.3	4.0
Common purselane *Portulaca oleracea*	0.2	26.0
Goosefoot *Chenopodium* sp.	0.2	10.0
Yellow nut grass tubers *Cyperus esculentus*	0.2	3.0
Saltbush *Atriplex* sp.	0.2	0.8
Chickweed *Stellaria media*	0.1	12.0
Knotweed *Polygonum* sp.	0.1	10.0
Mustard *Brassica* sp.	0.1	4.0
California poppy *Eschscholtzia* sp.	0.1	2.5
Wild rose *Rosa* sp.	0.1	0.8
Barley *Hordeum vulgare*	0.1	3.0
Crab grass *Digitaria sanguinalis*	trace	0.8
Panic grass *Panicum* sp.	----	2.0
Timothy *Phleum pratense*	----	0.8
Dock *Rumex* sp.	----	0.8
Pepper-grass *Lepedium* sp.	----	0.8
Sweet clover *Melilotus indica*	----	0.8
Vetch *Vicia* sp.	----	0.8
Spurge *Euphorbia* sp.	----	0.8
Mallow *Malva* sp.	----	0.8
Dodder *Cuscuta* sp.	----	0.8
Ground cherry *Physalis* sp.	----	0.8
Animal Foods:		
Insect fgmts. (Insecta)	----	0.8

A METHOD OF DISTINGUISHING MOUNTAIN AND VALLEY QUAIL BY SKELETAL ANALYSIS

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The geographic ranges of the mountain quail (*Oreortyx picta*) and the valley quail (*Lophortyx californica*) frequently overlap. For this reason, an ecologist working on a population study, a naturalist or a paleontologist might wish to distinguish these species on the basis of skeletal remains. This paper proposes a method of identifying a single specimen without the use of other known skeletons for comparison.

Skeletons of 45 quail were examined. A list of the skeletal material studied is as follows:

	Male	*Female*
Lophortyx californica californica	8	8
Lophortyx californica brunnescens	12	6
Oreortyx picta picta	5	5
Oreortyx picta confinis	0	1

All birds studied were believed to be five months of age or older. According to Hildebrand (1957) pheasants of four months cannot be distinguished from those of older birds by linear measurements. The same is probably true of quail.

A careful search was made for skeletal differences between mountain quail and valley quail. Gross skeletal differences were not found. Ten of 16 measurements, however, showed a significant size difference between the two species.

All dimensions of long bones are maximum overall lengths. The remaining measurements are illustrated in Figure 1. All measurements were taken to the nearest hundredth of a millimeter with a vernier caliper.

Graphs of the 10 most useful measurements are illustrated in Figures 2, 3, and 4. The open rectangle represents the calculated range, and is expressed as: $m \pm 3\sqrt{\frac{\Sigma(X-\overline{X})^2}{n-1}}$. This includes 99 percent of the population. A horizontal line is used to indicate the observed range of the samples studied. The mean is represented on the graphs by a vertical line which intersects the range at right angles. The darkened rectangle extends two standard errors beyond the mean in each direction, or within the limits of the expression: $m \pm \frac{2s}{\sqrt{n}}$. The difference between any two means may be considered significant if the darkened rectangles do not overlap. If, as in some instances, the calculated ranges do not overlap, the difference is significant on the 99 percent confidence level.

These data can be used to provide positive identification of a skeleton of unknown origin. For example, suppose that a quail humerus is 3.86 mm long. The graph (Figure 2) indicates that this measurement lies completely out of the calculated ranges given for valley quail of each sex and therefore the bone must be that of a mountain quail. We cannot, however, determine the sex from which the specimen was derived. If the range of a bone from the male valley quail overlaps the shaded rectangle of the same bone in the female mountain quail (as for the length of the tibiotarsus) (Figure 3), then there is a slight chance that an unknown bone falling in this position might be from an extremely large valley quail that deviates more than two standard errors from the mean for valley quail. In order to show how rare an event this would be, the reader is referred to the graph in Hildebrand's paper on pheasants (1957). If this particular bone were 2.4 standard deviations from the mean for male valley quail, then there is only one chance in 167 that the bone is from this species. If further evidence is needed, a different bone should be examined to provide a more positive identification.

I am indebted to the Curators of the Museum of Vertebrate Zoology, University of California, Berkeley, for the opportunity to study 32 quail skeletons; the other skeletons are my own. Also I would like to thank Dr. M. Hildebrand for his helpful suggestions. The figures were drawn by Stanley Bjorge.

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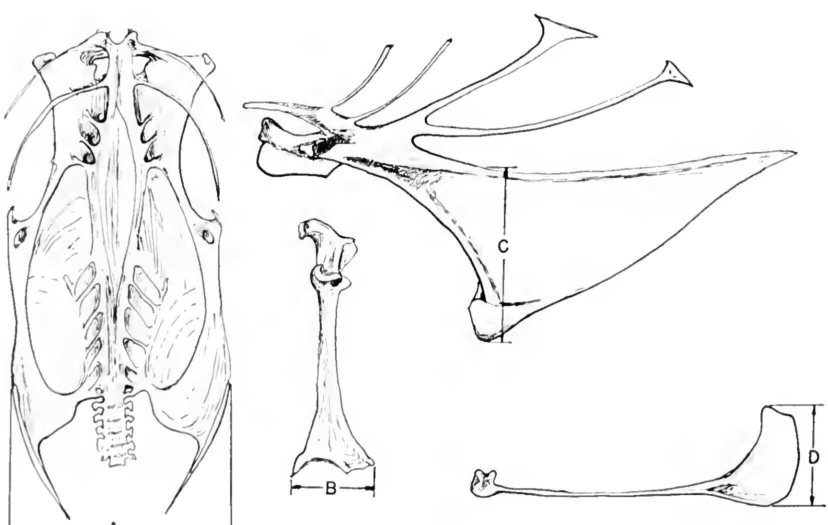

FIGURE 1. Some bone measurements used in comparing mountain and valley quail. $A =$ width of ischium, $B =$ width of clavicle, $C =$ depth of keel, $D =$ depth of clavicle keel.

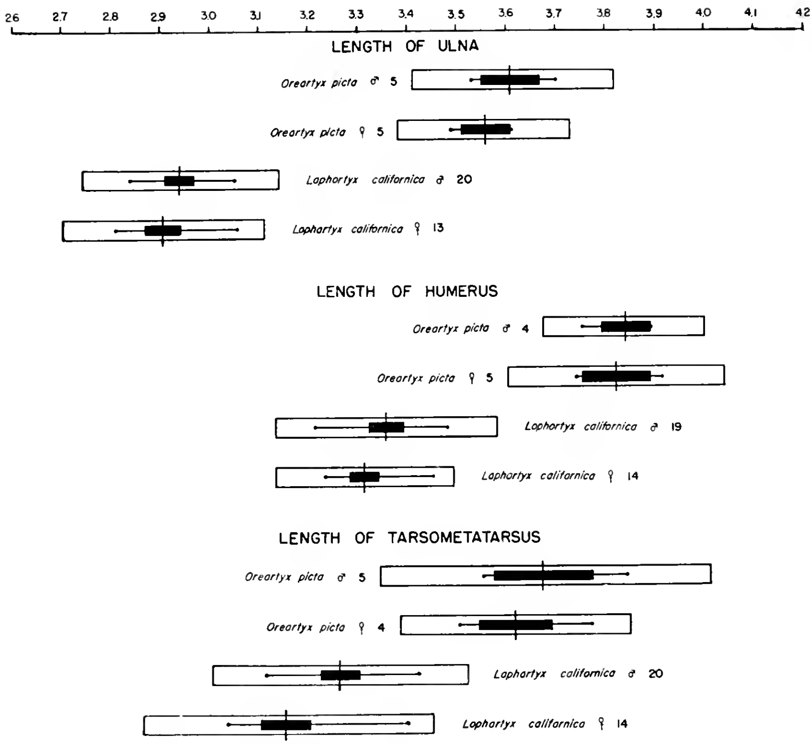

FIGURE 2. Bone measurements of mountain and valley quail compared.

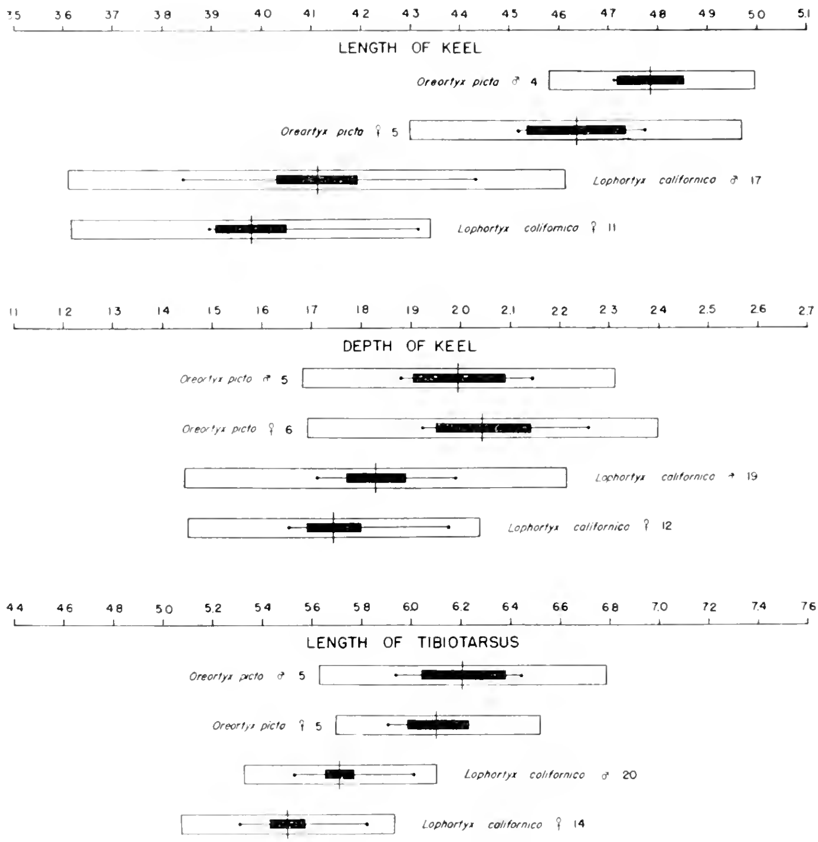

FIGURE 3. Bone measurements of mountain and valley quail compared.

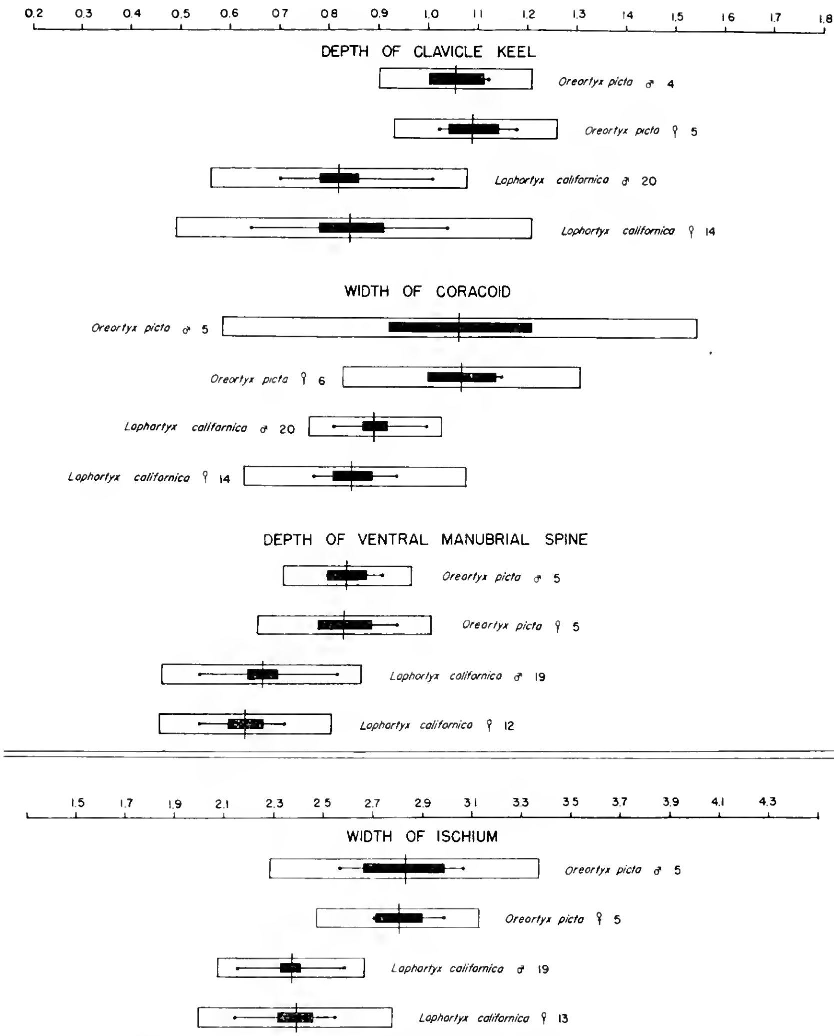

FIGURE 4. Bone measurements of mountain and valley quail compared.

EFFECTS OF SARDINE SPAWNING STOCK SIZE AND ENVIRONMENT ON YEAR-CLASS PRODUCTION[1]

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INTRODUCTION

For many years, the near catastrophic decline of the Pacific sardine (*Sardinops caerulea*) fishery has been a controversial subject among fishery biologists. Clark and Marr (1955) brought into sharp focus the debate over whether the collapse of the fishery was caused by man's over-exploitation or by an unfavorable environment. They did not agree on whether a relationship existed between the numbers of fish of a year-class and the spawning stock that produced it. Clark stated that large year-classes were produced from large spawning stocks and inferred that small year-classes might be produced from any size stock. Marr claimed no relationship was discernable over the observed stock sizes. They pointed out, however, that the answer to this question bore directly on the feasibility of managing the resource.

If no relationship exists between the size of a year-class and the spawning stock that produced it, the only effect of restricted fishing is to spread the catch over a period of years and allow greater natural mortality. A reduction in the adult population would not affect the annual young fish production. Regulation, in this case, would be primarily a matter of determining the most economical fish size to catch. On the other hand, if year-class size is a function of spawning stock size, it might be desirable to maintain the population at a level which would result in maximum reproduction.

The arguments presented by Clark and Marr (1955) center around their Figure 6 (Figure 1). Their differences manifest in the interpretation of this figure and its supporting data (their Table 3).

A casual look at Figure 1 reveals that Clark's observation holds; the largest year-classes were produced by middle-sized stocks. A large scatter also exists and, as Marr had indicated, variations are sufficiently extensive to mask any theoretical relationships.

If one assumes no relationship exists, the curve which best fits the data is a line, parallel to the abscissa, passing through the mean of year-class sizes. When Marr compared this line with a subjectively drawn curve, consisting of two lines forming an inverted-V (Figure 1) he found that the variance about the inverted-V line was 16 percent less than the variance about the horizontal line. He rejected the hypothesis suggesting a relationship existed and assumed no relationship existed despite the somewhat larger variance about the horizontal line.

[1] Submitted for publication December, 1961.

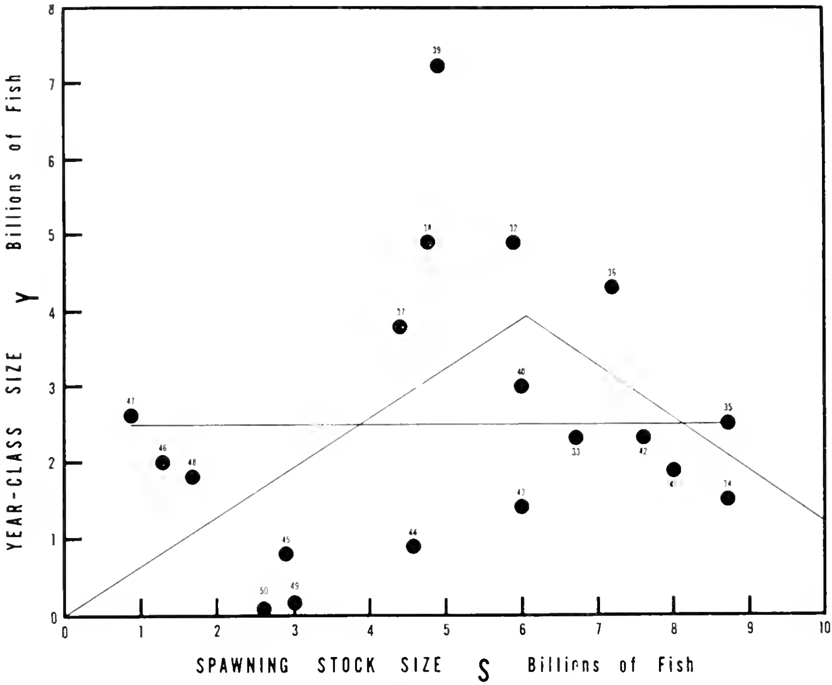

FIGURE 1. Pacific sardine year-class size related to spawning stock size. The horizontal line represents the mean year-class size. The inverted-V is subjectively drawn to represent a possible relationship (after Clark and Marr, 1955).

Obviously, with no parents no young can be produced, and any curve expressing the relationship between parents and young must pass through the origin.

On January 31, 1958, at the fifth annual meeting of the California section of the Wildlife Society at Davis, California, I orally presented a population model which took into consideration the effects of environment as well as stock size in the production of year-classes. I presented the same material at the 21st annual sardine conference at La Jolla, California on July 24, 1958.

Subsequently, the relative effects of environment and man on the sardine fishery were debated at some length at the World Scientific Meeting on the Biology of Sardines and Related Species, Rome, Italy, September 14 to 21, 1959. One conclusion reached at this meeting was that the effect of environment on year-class survival is very important. A number of the participants (including me) felt that despite environmental effects obscuring the issue, there is a relationship between spawning stock size and year-class size (FAO, 1959).

The main portion of this paper concerns the population model I proposed in 1958 at Davis and La Jolla. In addition, it discusses the possibility that a genetically distinct subpopulation of sardines, which may have existed during the height of the sardine fishery, collapsed. A glossary of terms appears at the end of this paper.

ESTIMATES OF YEAR-CLASS SIZE AND SPAWNING STOCK SIZE

Estimates of spawning stock size and year-class size are those of Clark and Marr (1955): year-class size is the total number of fish of that year-class that were caught following their second year of life (Table 1); spawning stock size, in a given year, is the total number of fish past their third year plus one-half the two-year-olds that were caught during that and subsequent years. Obviously, these estimates are minimal.

Radovich (1959) demonstrated that a year-class size estimate based on accumulated age, as well as one based on catch-per-effort, is markedly affected by availability when the year-class is two and three years old. Therefore, if availability to the fishermen is high during a particular two-year period, both methods overestimate the size of the year-class which was two and three years old during that period. Conversely, if availability was low for the same period, the strength of the year-class would be underestimated. It is also apparent that estimates of total population size are affected in the same manner.

TABLE 1

ESTIMATES OF YEAR-CLASS SIZE, SPAWNING STOCK SIZE,[1] AND SURVIVAL RATIO OF THE PACIFIC SARDINE IN BILLIONS OF FISH

Year-Class	Year-Class Size (Y)	Spawning Stock Size (S)	Survival Ratio (Y/S)
1932	4.9	5.9	0.8305
1933	2.3	6.7	0.3433
1934	1.5	8.7	0.1724
1935	2.5	8.7	0.2874
1936	4.3	7.2	0.5972
1937	3.8	4.4	0.8636
1938	4.9	4.8	1.0208
1939	7.2	4.9	1.4694
1940	3.0	6.0	0.5000
1941	1.9	8.0	0.2375
1942	2.3	7.6	0.3026
1943	1.4	6.0	0.2333
1944	0.9	4.6	0.1957
1945	0.8	2.9	0.2759
1946	2.0	1.3	1.5385
1947	2.6	0.9	2.8889
1948	1.8	1.7	1.0588
1949	0.05	3.0	0.0167
1950	0.01	2.6	0.0038

[1] Year-class size and spawning stock size estimates are after Clark and Marr (1955).

Despite the effects of availability on the estimates of spawning stock size and year-class size, the estimates based on accumulated age data may be reliable enough to show broad features. Better estimates of population size, year-class size and availability would allow a careful scrutiny of this whole problem.

If we can assume no young could be produced if there were no spawners, one end of the curve is fixed (Figure 1). To investigate what may happen as the stock size becomes extremely large, let us consider some natural examples.

NATURAL EXAMPLES

Deer Herds

Game managers are well-acquainted with the fact that the size of a deer herd is limited by the carrying capacity of its winter range. Overpopulation results in overgrazing, which may further lower food production by inhibiting growth of browse plants. Die-offs from malnutrition often result. Such losses are generally most severe among fawns which are not able to compete effectively with the adults. In addition to the density-dependent population limit, variations in environment also cause variations in the production of young. Very severe winters may result in virtually no fawns surviving as well as severe decimation of the adult population (Longhurst *et al.*, 1952).

Inland Waters

In inland waters, it has been demonstrated repeatedly that when a lake becomes saturated with fish, production of new year-classes, as well as growth of individuals, is retarded. There appears to be a theoretical limit to the population, which, if reached, would result in a failure of brood survival.

A dramatic example of this phenomenon was provided by the successful introduction of bairdiella *(Bairdiella icistius)* into the Salton Sea, California (Walker *et al.*, 1961). From a planting of only 67 fish (57 in 1950 and 10 in 1951), the population blossomed to millions in 1953.

With an abundance of polychaete worms, *Neanthes succinea*, as food and almost no competitors or predators, spawn survival was so excellent in 1952 that even the highly abnormal individuals survived. Many bairdiella were blind (some in both eyes), some had malformed maxillaries, some had abnormal lower jaws, some were snub-nosed, and some had twisted vertebrae. In 1953, approximately 20 percent of the population was abnormal in some way but still achieved good growth. Bairdiella born in 1952 grew rapidly in 1952 and 1953, and matured at the end of their first year of life.

Although the 1952 year-class apparently had a remarkable survival rate, the larger spawning stock of primarily 1952 year-class fish produced the outstandingly dominant 1953 year-class. The 1953 year-class did not grow as rapidly as did the 1952 year-class; its females did not mature until they were older than two, and the anomaly rate barely reached 1 percent (Whitney, 1961a).

Under the strain of greater competition and predation (cannibalism) created by the increasing population density, abnormal individuals could not compete successfully and biological selection became a factor that selectively reduced the survival rate. With increasing competition, even the anomaly rate for the 1952 year-class dropped to about 2.5 percent in 1954 (Whitney, 1961a).

With a large bairdiella population present, the 1954 year-class was very poor, and those for 1955 and 1956 were only slightly better. This is an excellent example in which the production of young is limited when a fish population becomes large. The first generation born in the sea had an extremely high survival rate, allowing it to become a substantial spawning stock for the second generation. The second generation was abundant enough to fill the Salton Sea sufficiently to cause a near failure of the third and subsequent generations. The population reached its ultimate size rapidly presumably because of a lack of interspecific competition.

Orangemouth corvina, *Cynoscion xanthulus*, large fish which prey on bairdiella, were also introduced into the Salton Sea in 1950 and 1951. They also spawned successfully in 1952 and in subsequent years. However, the enormous spawning success of the bairdiella provided strong competition and probably dampened a potential population explosion (Whitney, 1961b). The orangemouth corvina population has continued to expand more slowly than bairdiella and now supports a substantial sportfishery.

Another recent example of a density-dependent limit to population size and reproduction has been demonstrated under controlled laboratory conditions. Silliman and Gutsell (1958) found that reproduction in guppies, *Lebistes reticulatus*, dropped markedly for large population densities. In this experiment, the guppies were kept in 10-gallon aquaria. Food was controlled and no other predators or competitors were present. There was, of course, intraspecific competition and some cannibalism, particularly at high population densities.

The common element in these examples is direct competition between adults and young, with the adults being the stronger competitor. With the exception of deer, the adults also preyed on the young.

Pacific sardines seem to have similar habits. Radovich (1952) showed that food organisms ingested by adult sardines ranged at least from 0.02 to 13.7 mm; those eaten by sardine larvae were 0.025 to 0.25 mm (Calif. Mar. Res. Comm., 1953). Radovich also found fish larvae and eggs in adult sardine stomachs. Hand and Berner (1960) reported sardine eggs and fish larvae in sardine stomachs. They also found that large and small sardines of the lengths investigated (31 to 285 mm standard length), ate nearly the same size and species of food organisms. Davies (1957) reported that pilchard eggs were quite common in stomachs of the South African pilchard, *Sardinops ocellata*. It appears that sardines may behave similar to the examples described with respect to intraspecific competition and cannibalism.

A POPULATION MODEL

On the basis of evidence presented, we may infer that when the adults of a population are cannibalistic or have an advantage in competition with their young, the production of young will become zero when the spawning stock size either reaches the ultimate population size or becomes zero. If we construct a reproduction curve it will cross the abscissa at the origin and at some ultimate stock size. It may be skewed to the left or to the right depending on the fecundity of the species involved and the nature and degree of inter- and intraspecific competition (Figure 2). These factors also influence the height of the curve.

For convenience, let us assume that the curve is a parabola with its maximum midway between a spawning stock size of zero and the ultimate population size (Figure 2,A). We may hold environmental conditions constant for all stock sizes, and let these constant conditions be the average of environmental conditions that have existed. The curve (Figure 3,A) would then represent the relationship between

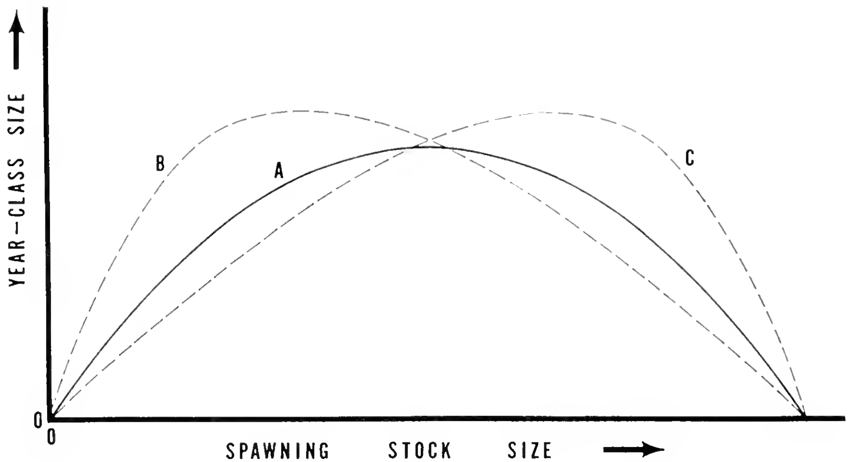

FIGURE 2. Three hypothetical reproductive curves: a parabola, A; a right-skewed curve, B; and a left-skewed curve, C.

year-class size and spawning stock size under these average (constant) environmental conditions.

If we take the best environmental conditions which could prevail and hold these conditions constant for all stock sizes, another parabola with a higher maximum and larger ultimate size would result (Figure 3,B). This latter parabola indicates that under the best environmental conditions, a larger population can be maintained than under just average conditions. It also indicates that at all stock sizes more young

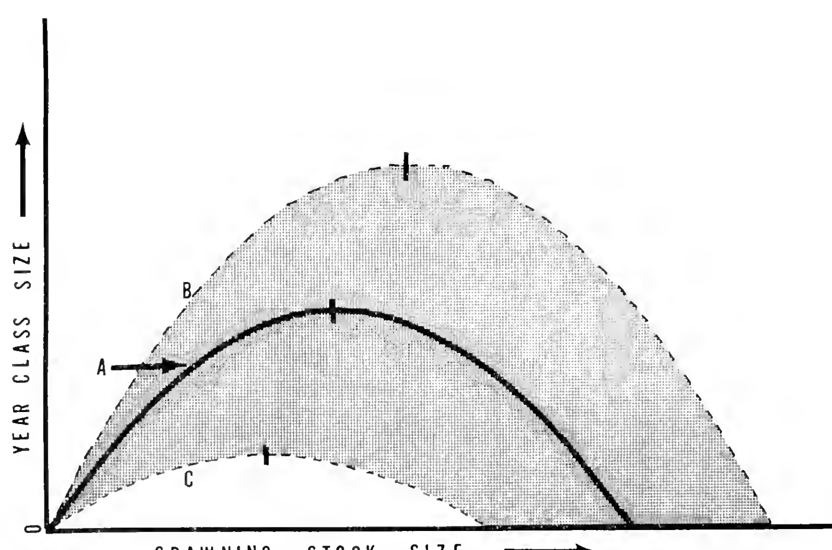

FIGURE 3. Effect of environment and spawning stock size on year-class production: curve A represents average environmental conditions; curve B, best conditions; and curve C, poorest conditions.

fish will be produced under better environmental conditions than under poorer conditions.

Another curve may be drawn depicting the worst conditions which have existed. Its maximum and its population limit are to the left of the others (Figure 3,C). Theoretically, environmental conditions could be so severe that a near year-class failure could result from any spawning stock size. In this case, the adult population would probably decline, also. The curve describing this situation would approach the abscissa. An example of this phenomenon is the failure of fawns to survive in some deer herds during a severe winter, accompanied by a substantial reduction in the number of adults (Longhurst *et al.*, 1952).

The relationship between year-class size and spawning stock size may be represented by the shaded area in Figure 3. At any stock size, the size of the resulting year-class would fall somewhere between the upper and lower curves depending on the environment. If very poor environmental conditions occurred when the population was near its ultimate size under good environmental conditions, then a reduction of adults would result as well as reproduction failure.

This relationship shows that the same increment removed from a small stock has a much greater effect on the production of young than if the stock were closer to the optimum. Theoretically, to achieve the highest production of young, it would be desirable to maintain the population at somewhere near optimal size. However, because a succession of year-class failures is possible at even the optimal stock size, it would be better to maintain the stock size to the right of the curve's maximum.

APPLICATION TO THE PACIFIC SARDINE

Now let us re-examine the data shown on Figure 1, where year-class size Y is plotted as a function of stock size S. If we divide the year-class size by the stock size, we can obtain a survival ratio Y/S for each year (Table 1). When these ratios are plotted against spawning stock size (Figure 4) it is obvious that lower survival ratios and small variations occur at higher stock sizes, while higher survival ratios and larger variations occur at lower stock sizes. This, in itself, is not significant since the straight line through means (describing a nonrelationship between spawning stock sizes and year-class sizes) transforms to a rectangular hyperbola, when plotting survival ratio against stock size. Thus, even with the hypothesis of nonrelationship the ratios become lower as the stock size becomes large.

The 1949 and 1950 year-classes were not included in Figure 4 for two reasons: data were incomplete at the time Clark and Marr (1955) estimated these year-classes; and the two year-classes were largely unavailable at ages when they should have been fully vulnerable to the fishery. Their inclusion would not alter the concepts which follow.

If the survival ratios are plotted against the year in which they occurred (Figure 5), it is apparent that survival rates have not declined over the years. Some uniformity seems to exist, however, between adjacent years and trends are strongly suggested.

To the scatter diagram shown on Figure 4, we may fit three lines (Figure 6): the least squares line of best fit (A); the maximum line (B) which includes all the points (drawn through the points represent-

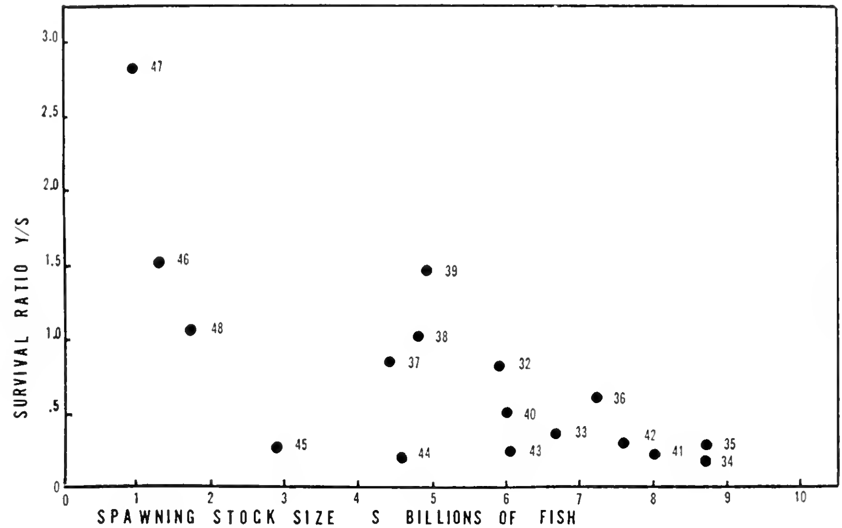

FIGURE 4. Pacific sardine survival ratios (year-class divided by spawning stock size) plotted as a function of spawning stock size.

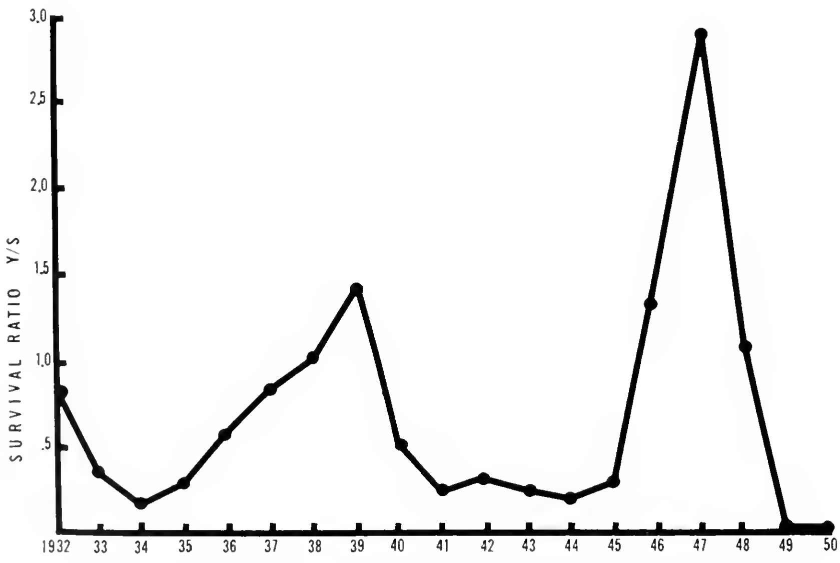

FIGURE 5. Pacific sardine survival rotios from 1932 through 1950.

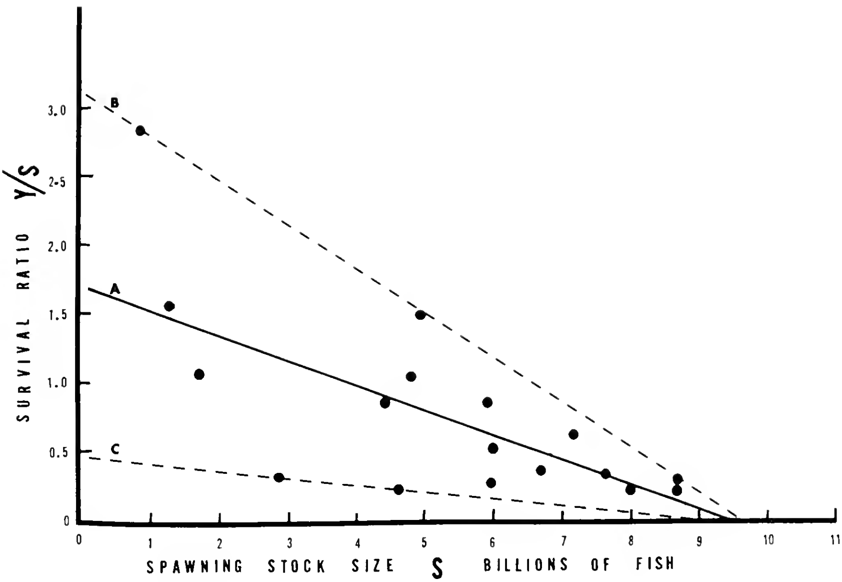

FIGURE 6. Maximum and minimum lines and line of best fit for relating Pacific sardine survival ratios to spawning stock size.

ing the years 1935 and 1947); and the minimum line (C) which excludes all the points (drawn through the points representing the years 1944 and 1945). All three lines are undefined at $S = 0$.

The equation for the three straight lines drawn on Figure 6 is

$$\frac{Y}{S} = a - bS.$$

They differ only in the Y/S intercept a, and in the slope b. If we multiply both sides of the of the equation by S we get

$$Y = aS - bS^2.$$

This, of course, is the equation of a parabola passing through the origin. This parabola in slightly different form is the Verhulst-Pearl logistic, which has been used to describe population growth for a number of organisms, including fish and humans. The logistic is discussed in some detail by Schaeffer (1954). We may now fit the transformed maximum and minimum parabolas to the scattered points of Figure 1 (Figure 7). The minimum parabola would have been lowered if data for 1949 and 1950 had been included. The parabola of best fit may be calculated directly by the least squares method or it may be approximated very closely by the transformation used to obtain the maximum and minimum parabolas.

The transformations of the maximum and minimum lines of Figure 6 to the corresponding parabolas in Figure 7 represent an envelope of the data resembling the theoretical relationship between stock size and year-class size and are the smallest maximum parabola and largest minimum parabola which can be drawn from the data. Although the parabola depicting the best conditions during this period would have

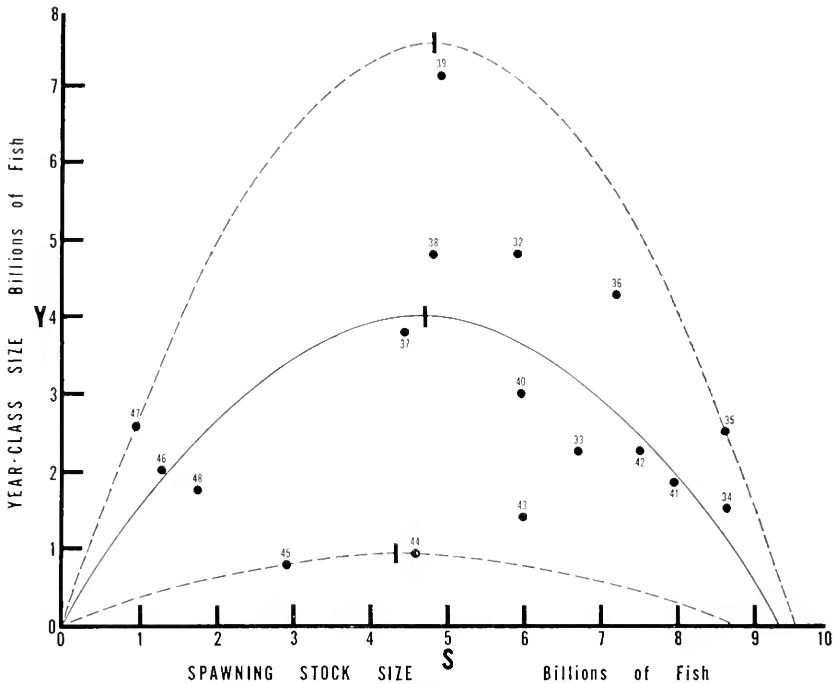

FIGURE 7. Pacific sardine year-class size related to spawning stock size, with the maximum and minimum parabolas and parabola of best fit.

passed through one of the points represented by the years 1935 and 1947, it is unlikely that it would have passed through both. Similarly, the parabola representing the poorest conditions probably would not pass through both the points represented by 1944 and 1945. In reality the ultimate size and maximum for the upper parabola (describing the best conditions) should fall farther to the right and for the lower parabola farther to the left (as in Figure 3).

It is noteworthy that during the 1930's and through 1942, the parabola of best fit describes the data quite well except for the 1939 year-class. The 1939 year-class, the largest recorded, was successful as far north as British Columbia but never was outstanding in the southern California catches. Thus, its availability may have been higher than for other year-classes.

Three successive poor year-classes (1943, 1944, and 1945) which resulted from near optimal stocks preceded the first collapse of the sardine fishery. With poor survival during these three years, continued high fishing effort (Clark and Daugherty, 1950) apparently helped reduce the population by 1946 to a level from which it has not yet recovered.

There is a possibility the fishery would have recovered if the spawning stock had been near the optimum size in 1946, 1947 and 1948, when environmental conditions may have been favorable.

Discussion of the Model

This model assumes that the fishery has been exploiting predominantly a single population, although at times a genetically distinct population off Baja California, Mexico, contributes to the southern California catch (Sprague and Vrooman, MS). If the assumption is true, the model is consistent with the data and takes into account the effects of the environment as well as spawning stock size in the production of young.

That there is a large scatter about the parabola of best fit does not negate this relationship, since this is just what would be expected if the environment varied considerably. With the scatter observed, no curve could be drawn having a low variance. The hypothesis of non-correlation (a straight line through the mean Y values, parallel to the S axis) has an even larger variance.

The model is consistent with many natural situations: a larger population can be maintained in a better environment than in a poor one; at any stock size good environmental conditions produce larger year-classes than do poor conditions; when the spawning stock is reduced to zero, reproduction is zero (an obvious, but sometimes overlooked fact); and environmental conditions may be so severe in a given year that a near year-class failure may result, regardless of spawning stock size.

CONSIDERATION OF A GENETICALLY DISTINCT NORTHERN SUB-POPULATION

It is believed on the basis of serological studies, that probably at least two genetically distinct stocks of Pacific sardines exist off the west coast of North America, excluding the Gulf of California (Sprague and Vrooman, MS). These stocks have the following ranges: one called the "southern stock," lives off the west coast of Baja California, and ranges from Magdalena Bay to central Baja California in some winters and to southern California (Los Angeles Harbor) in some summers; the second, referred to as the "northern stock," occupies the area just north of the "southern stock," and has been found as far north as Monterey Bay. Both the northern and southern stocks are distributed farther north during summer than during winter.

Since we now know that at least two stocks contribute to the California fishery from time to time, it is easy to speculate that another stock may have existed just north of the "northern stock." Let us refer to this theoretical stock as the "far northern stock."

Let us assume that the "far northern stock" ranged from as far south as southern California to off northern California during winter, and from central California to British Columbia during the summer. Let us also assume that it was distributed farther north during warm years and farther south during cold years. Under these conditions, decimation of the "far northern stock" could have been the primary cause of the decline observed in the sardine fishery.

Up to this point, I have used estimates which have been discussed and referred to considerably since their publication. I have demonstrated how a relationship between spawning stock size and year-class size can exist using data with which Marr concluded—"variations in survival rate are so large that they obscure any theoretical relationships which may exist between stock size and year-class size" (Clark and Marr, 1955).

To obtain better estimates of year-class size, Marr (1959) calculated accumulated age estimates from all ports for which he had data. He estimated contributions of some year-classes at ages for which there were no data. His estimates included data from British Columbia, but not from Oregon and Washington. Sufficient data were not available from San Francisco to arrive at total estimates for year-classes spawned prior to 1934. Table 2 contains the revised year-class estimates after Marr (1959) except that the 1932 and 1933 year-class estimates are after Clark and Marr (1955).

When these revised year-class size estimates are plotted against spawning stock size (Figure 8), the variance for the period 1932 through 1942 is reduced. This reduction in scatter may be due to having used more refined data, or it may be an artifact of plotting adjusted data against uncorrected data. The change to corrected data in the middle of this paper may seem unusual but, since the variance is reduced, its use facilitates presenting ideas expressed in this section. In any event, using unadjusted values of year-class strength would not alter the arguments advanced here.

When the points on the graph are connected in chronological order (Figure 8), distinct regimes are apparent. The years from 1932 through 1942 seem to constitute one, whereas the years following 1945 fall in another. Possibly, 1949 and the following years represent a

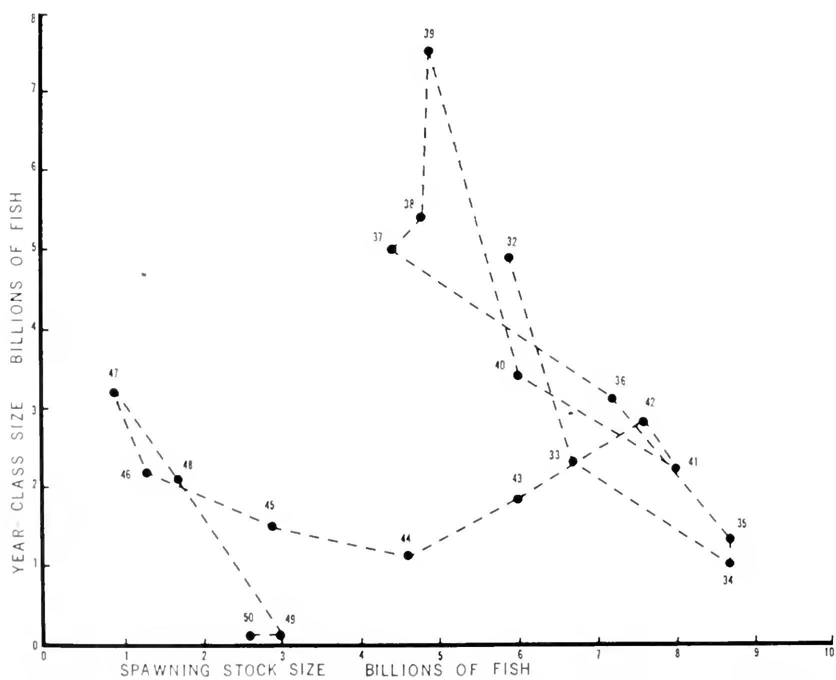

FIGURE 8. Pacific sardine year-class size related to spawning stock size and linked in chronological order.

TABLE 2

CORRECTED ESTIMATES OF YEAR-CLASS SIZE, IN BILLIONS OF SARDINES
(After Marr 1959)

Year-Class	Year-Class Size	Year-Class	Year-Class Size
1932[1]	4.9	1942	2.78
1933[1]	2.3	1943	1.85
1934	0.98	1944	1.10
1935	1.32	1945	1.50
1936	3.06	1946	2.17
1937	5.04	1947	3.18
1938	5.39	1948	2.08
1939	7.49	1949	0.10
1940	3.43	1950	0.10
1941	2.16	---	---

[1] Year-class estimates for 1932 and 1933 are after Clark and Marr (1955).

third. Further data refinement and the inclusion of recent years, should enable a more careful examination of this phenomenon.

We may now speculate that a genetically distinct population, the "far northern stock," existed north of the present population until about 1942. A relationship between year-class size and spawning stock size is clearly demonstrated from 1932 through 1942 (Figure 8). When the spawning stock was large, production of young was low. As spawning stock sizes approached a level approximately one-half the maximum stock size, year-class production was very high.

Following five successive poor survival years (the last three 1943, 1944 and 1945 at near optimum stock sizes), the relationship collapsed to another regime. This collapse could have been caused by an almost total decimation of the "far northern stock," resulting in a change in the total fishable population from three to two stocks. A similar relationship between stock size and year-class size would then prevail, but at a lower level. This is certainly suggested in Figure 8. The relationship may now be in a third regime, since the middle stock ("northern stock") is presently at a very low level. One would expect to find greater variance from the curve describing the third regime because accumulated age estimates would be more strongly affected by availability as the fishery became more dependent on the "southern stock."

A collapse of the "far northern stock" could account for the complete collapse of the sardine fishery in the Pacific Northwest. The British Columbia sardine catch dropped two orders of magnitude in three seasons: from 34,300 tons in the 1945-46 season; to 3,990 tons in the 1946-47 season; to 490 tons in the 1947-48 season (Clark, 1952). The 1947-48 season was the last to yield a sardine catch in British Columbia. The catches off Oregon and Washington ended just one season later. The lag in the collapse of the Pacific Northwest sardine fishery corresponds to the time it would have taken for the poor 1941 through 1945 year-classes to become fully vulnerable to the fishing gear; sardines do not become fully vulnerable until they are two or three years old (sometimes four or five years old in the Pacific Northwest).

Some ideas have been advanced indicating that a southward shift took place because the waters off the Pacific coast of North America cooled off at that time. However, the dramatic warming of the waters off the Pacific coast for the three-year period 1957-59 produced no catches north of California.

Although a relationship between ocean temperatures and the latitudinal distribution of sardines existed prior to 1945, their southerly distribution since 1944 cannot be attributed entirely to a southern movement caused by a drop in water temperatures (Radovich, 1961). A population decline in the northern portion of the sardine's former range, following the failure of the 1943, 1944 and 1945 year-classes, could have caused the fish to be distributed farther south than one would have expected from the water temperatures.

Thus far, I have used a parabola ($Y = aS - bS^2$) to develop a hypothesis regarding the relationship of stock size and environment to year-class size. The parabola was used for simplicity and because it has certain properties: it passes through the origin, it has a maximum, and it returns to cross the abscissa at some higher value. However there is no compelling reason why the reproductive curve should be a parabola. Under controlled experimentation, Silliman and Gutsell (1958) found the reproductive curve for guppies was skewed to the right.

A right-skewed curve was fitted by eye to the data from 1932 through 1942 (Figure 9). Two other hypothetical curves were also drawn, representing the other theoretical regimes which have been discussed. No mathematical significance is implied in the skewed curves shown in Figure 9; they merely fit the data empirically and follow the parameters of passing through the origin, crossing the abscissa at an ultimate size, and possessing a maximum. Theoretically, each regime should have a maximum and minimum curve forming an envelope for a family of curves depicting the range of environmental conditions.

DISCUSSION

Although it is obvious that a decline in the northern portion of the sardine population did occur, it is not certain that this northern portion was a genetically separate group.

Radovich (1959) showed that year-classes originating farther north tend to be more available to the fishery throughout their lives. This may reflect the varying spawning success of genetically different stocks, wherein the "far northern stock" is more available than the "northern stock" which is more available than the "southern stock"; or it may reflect a tendency of sardines to remain in the area in which they grew up.

A homing tendency could keep sardines within a certain geographical range, related to the area in which they were spawned and subject to shifts because of extreme environmental conditions. Successful spawning farther north could give rise to nongenetic groups which would tend to remain farther north.

Either situation (genetic separation or homing tendency) is consistent with the model (Figure 9). The answer to the question of whether or not a genetically distinct "far northern stock" existed has significance in intepreting the potential recovery of the sardine fishery, since recovery to its former abundance necessitates re-establishing a population in the Pacific Northwest. If the "far northern stock" existed and is not extinct, or if a genetically distinct "far northern stock" did not exist, it is probably necessary to curtail the fishery drastically to build the population to an optimal size for producing large year-classes. A rate of exploitation sufficient to maintain a southern stock within a certain population size range may also be sufficient to keep an adjacent, and more available, northerly stock at a very low level.

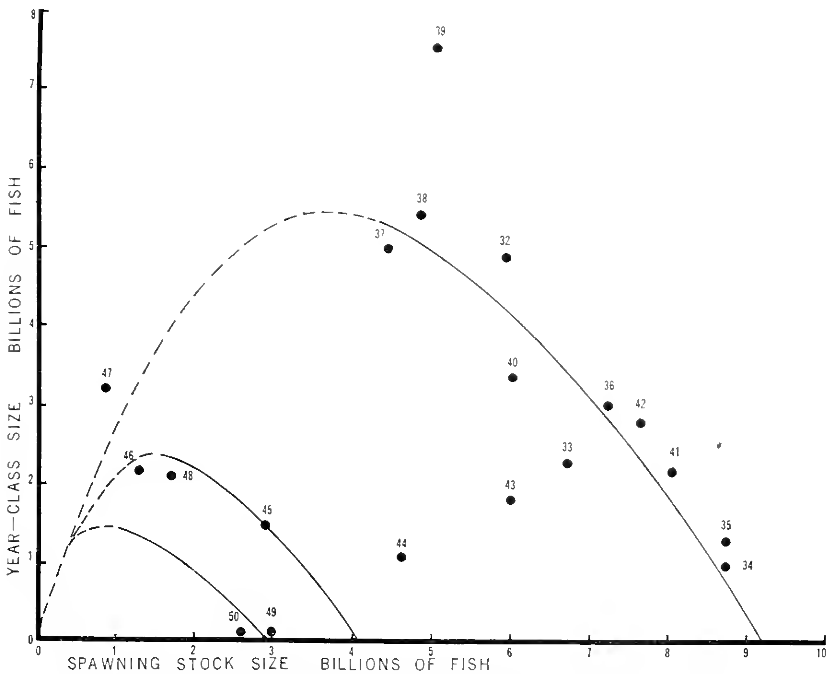

FIGURE 9. Hypothetical curves representing three regimes relating Pacific sardine spawning stock size to year-class production.

It has been suggested that the effect of environment is so large that the effect of the spawning stock size is insignificant, since year-classes varied from a ratio of 1 to 75 (Table 2), while spawning stock sizes varied from about 1 to 10 (Table 1).

Actually, a range of nearly two orders of magnitude in year-class sizes is not significant because a year-class failure can occur at any stock size, and an infinite number of orders of magnitude will be traversed as a complete failure is approached. On the other hand, a maximum observed survival ratio of 3.53 in 1947 (Tables 1 and 2) indicates the best environmental conditions resulted in a year-class only 3.5 times the size of the spawning stock producing it. Since this is the largest observed ratio, the effect of the spawning stock clearly limits year-class production.

SUMMARY

In this paper, I have developed a model describing the relationship of spawning stock size and environment to production of young. Natural examples, including deer herds in California, bairdiella in the Salton Sea and guppies under controlled experiments fit the model. I have generalized that other species, whose adults competed directly with their young or preyed on them (cannibalism), also fit the general model. Sardines have these habits. When estimates of spawning stock size and year-class size of sardines were compared, they were consistent with the model.

A genetically distinct stock of sardines may have existed prior to the mid-1940's north of their present range. The sardine fishery declined at the time and in a manner consistent with the hypothesis that a "far northern stock" was decimated when very poor environmental conditions produced poor year-classes from what should have been optimal stock sizes.

GLOSSARY OF TERMS USED

Accumulated age estimates: all the fish of a year-class, population, or spawning stock caught during a given year and subsequently. These are minimal estimates.

Availability: the ratio of the number of fish within range of the fishery to the total number in the population or stock. This involves their horizontal distribution.

Genetically distinct group: a group (stock or subpopulation) which does not interbreed with the rest of the population, thus preserving its identity in some measurable way.

Maximum parabola: a parabola describing the relationship between year-class size and spawning stock size under the best observed environmental conditions.

Minimum parabola: a parabola describing the relationship between year-class size and spawning stock size under the poorest observed environmental conditions.

Optimal spawning stock size: the quantity of fish in the spawning stock that produces the greatest number of young.

Population size: the total number of fish in all the stocks contributing to a fishery.

Spawning stock: the mature fish in a population or genetically distinct group. For sardines this is approximately half the two-year-olds and all the older fish.

Stock: a genetically distinct, or geographically separated, group of fish contributing to a fishery. In proper context it is sometimes used to designate spawning stock.

Survival ratio: the ratio of the number of fish in a year-class to the number in the spawning stock producing it.

Ultimate size: the population or stock size limit attainable under a given set of environmental conditions. Theoretically, the point where the environmental niche is filled and no young are produced.

Vulnerability: within the range of a fishery, the proportion of fish accessible to the fishing gear. This involves fish behavior and their vertical distribution, and may be related to their age or size. Note the distinction from availability.

Year-class: all the fish surviving a given year's spawn, *i.e.* fish resulting from spawning in 1939 represent the 1939 year-class.

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NOTE

INTRODUCTION OF POND SMELT FROM JAPAN INTO CALIFORNIA

It is well known that in most outstanding trout lakes throughout the world both basic productivity and food chains are unusually good. At present, it is difficult or impossible to increase basic productivity at reasonable costs, but improvement of food chains is sometimes a simple procedure. In waters with an abundance of plankton, a forage fish serving as a link between plankton and trout should be present. In many California lakes and reservoirs, plankton consumers are absent or inadequate. A search for a good forage fish for these waters was made and, after consideration of a number of possibilities, it was decided that the pond smelt (also known as freshwater smelt), *Hypomesus olidus*, should be tried.

The pond smelt is distributed as far south as San Francisco Bay on the North American continent and as far south as Japan on the Asiatic side of the Pacific. It is primarily a freshwater fish, although it does enter brackish water. The possibility of obtaining smelt in the freshwater portions of the Sacramento-San Joaquin Delta above San Francisco Bay was investigated but found to be unsatisfactory. The Department of Fish and Game then began correspondence with Japan, where the species is well established in many lakes, with the hope that smelt eggs could be purchased. Biologists of the Research Institute for Natural Resources in Tokyo furnished a great deal of information on the ecology of the fish and put the Department in contact with a Tokyo firm from whom eggs could be purchased.

The requirements of this smelt in Japan are similar to those of the rainbow trout (*Salmo gairdnerii*) there. The preferred temperatures seem to be essentially the same. Both spawn in the spring in tributaries of lakes and reservoirs. The smelt eggs are small and adhesive, becoming attached to the rocks and gravel of the streams. The hatching time at 58 degrees F. is about 12 days. The fry begin to feed when about 7 mm. long. Their food is primarily zooplankton. Although the smelt can attain a length of five inches under optimum conditions, they usually do not become this large. Sexual maturity is reached at the end of the first year, and they usually do not live to spawn a second time. In Japan the smelt has been introduced successfully into reservoirs as trout forage.

The plan called for the experimental introduction of pond smelt into a few lakes or reservoirs in different parts of California. Then, if they became established in any of these waters, they could be transferred elsewhere. Six lakes and reservoirs, which appeared to meet the ecological requirements of smelt and could be chemically treated if it were found that the smelt were undesirable, were selected. The six waters were: Dodge Reservoir, Lassen County; Dwinnell Reservoir, Siskiyou County; Freshwater Lagoon, Humboldt County; Spaulding Reservoir, Nevada County; Jenkinson Lake (Sly Park Reservoir), El Dorado County; and Big Bear Lake, San Bernardino County.

Air shipments of eggs were received in San Francisco from Tokyo on March 18 and 31, 1959. The eggs had been taken at Suwa Reservoir, about 70 miles east of Tokyo. They had been spawned artificially onto palm fiber mats, and after eyeing had been packed into fiberboard boxes lined with plastic sheeting. The eggs and mats were wet, but no ice or other refrigeration was used. Upon arrival, many of the eggs were dead from drying, premature hatching, and bacterial decomposition; however, enough were alive to furnish sizable plants. Approximately 3,600,000 eggs had been shipped, but the numbers going into each of the six test waters are not known.

The trays of eggs adhering to the fiber mats were arranged in stacks and anchored in the flowing water of tributaries. Observations on the plants in Dwinnell Reservoir tributaries showed that the fry began to hatch and drift away within a few days. It is presumed that in some of the plants the number of viable fry was small.

By August 1961, only one of the test waters was known to contain a good self-propagating population of smelt. This was Freshwater Lagoon, where seine hauls made by Professor John DeWitt and students of Humboldt State College indicated that enough fish could be obtained for introduction elsewhere. These fish were presumably of the first and second generations of the plant made in the spring of 1959. The extent to which these fish are being eaten by trout in Freshwater Lagoon is not known.

Chemical treatment of Big Bear Lake during the fall of 1960, to eradicate stunted crappie *(Pomoxis nigromaculatus)* and goldfish *(Carassius auratus)*, resulted in the killing of some smelt. Judging by the dead specimens observed by fisheries personnel, the smelt population numbered in at least the hundreds.

In April 1961, a smelt measuring 4.3 inches was recovered from Dwinnell Reservoir. No other smelt have been seen in this reservoir.—*Joseph H. Wales, Department of Fish and Game Management, Oregon State University, Corvallis, Oregon, September 1961.*

BOOK REVIEW

Deep Sea Trawling and Wing Trawling

Published by The Gourock Ropework Company, Ltd., Port Glawgow, Scotland, 1961; 106 pp., 21 s.

This is a reprint of the book *Deep Sea Trawling*, originally published in 1956, with a section on wing trawling added; it is a book of techniques of trawl fishing.

Section I contains a detailed description of the Granton trawl net, materials needed for construction, and construction method. There is included an excellent chapter on net braiding and mending. One chapter is devoted to shooting and hauling the otter trawl net complete with diagrams of the deck layout and working gear as used on a side-set Atlantic trawler; however, most of the photographs showing the gear being worked were made aboard the stern trawler "Fairtry."

Section II is a general description of the wing trawl but lacks the construction details provided in Section I. Descriptions are given of the wing trawl used as either an otter trawl net or as a seine net.

The section on net braiding and mending will make this book useful to anyone working with nets.—*E. A. Best, California Department of Fish and Game.*

The Salmon

By J. W. Jones; Harper & Bros., New York, 1959; xvi + 192 pp., 24 figs., 12 black and white photos, 2 table., $4.50.

Dr. Jones is a senior lecturer in Zoology at the University of Liverpool. Here are the results of his extensive research on the Atlantic salmon, along with material from other English as well as American and Canadian workers. For comparative purposes, pertinent studies on the Pacific salmonids are also included.

Especially outstanding is the description of the spawning behaviour of the Atlantic salmon. The author constructed an experimental tank directly in a river bed so that fish could be observed at an underwater level as they went about their spawning activities. This is somewhat similar to facilities utilized by Dr. Paul R. Needham at the University of California's Sagehen Creek Wildlife and Fisheries Station. It is these observations that are the source of an excellent series of frames from a movie film showing a female salmon digging her redd

The book covers many other interesting points about salmon and salmon management. The homing instinct and the parent stream theory are explored in considerable detail. The ability of salmon to move between fresh and salt water is discussed. In talking about fishways, there is mention of locks built in a 60-foot dam solely for use by fish. Fish rescue is proposed for spent adults to safeguard their return to the ocean. Also of interest is the explanation of terms commonly used in Britain: alevin, baggot, branlin, bull-trout, kelt, kype, laspring, locksper, parados, parr, peal, rawner, samlet, samson, sil, skegger, skirling, smolt, spate and many others. Wardens, burdened by a multitude of responsibilities, are called "water bailiffs" and further charged with being "the eyes, ears and noses of . . . scientific officers" on the salmon rivers. Water diversions are known as "water abstractions," and the King salmon is indexed under "Sacramento salmon" rather than King or Chinook.

Canadian and U. S. West Coast readers may not take kindly to the fact that Dr. Jones spells salmon with a capital "S" when referring to the Atlantic salmon and a lower case "s" for all other salmon.

The "bibliography" contains over 140 titles, but unfortunately does not include the classic paper by Taft and Shapovalov on steelhead and silver salmon. There is an index to authors cited and a very good general index. Four appendices give further details on taxonomy, hybridization, parasites, disease and techniques in estimating lengths from scale measurements.—*H. E. Pintler, California Department of Fish and Game.*

Porpoises and Sonar

By Winthrop N. Kellogg; University of Chicago Press, Chicago, 1961; xlv + 177 pp., 8 plates, 24 figs., $4.50.

The great improvement in electronic gear of many kinds, plus military demands for still greater improvement, have triggered this interesting new field of research. Underwater listening devices set up in World War II revealed that the ocean was a very noisy place and that among the animals contributing to this noise were the whales and dolphins. Further examination of the noises made by whales and dolphins (or porpoises) resulted in the conviction that these animals possessed sonar sending and receiving systems which might surpass any devices made by man for this purpose. For the past ten years a number of researchers have been studying dolphins to test this conviction and to learn more details about how efficient this sonar was. The present book describes the experiments made by the author, plus the findings of a number of other workers.

The book opens with a more or less popular account of porpoise behavior, and other general facts about porpoises and whales. There follows a chapter on undersea noises in general, and a chapter on those made by Cetaceans in particular. The listening and recording instruments used were described (this part may be beyond the easy comprehension of many readers). Then follow descriptions of the experiments that were performed by the author using captive bottlenose dolphins.

The author set out to find the answers to three questions: (1) Do the noises made by porpoises fall within the temporal and frequency patterns suitable for echo-ranging in water? (2) Can the senders of the noises hear sufficiently well and do they possess sufficiently fine acoustic receptors to react to any echoes that are present? (3) Do they actually use these signals as a means of navigating? He came up with a yes answer to all three questions.

Facts brought out in this book that were of particular interest to the reviewer included the following: Intelligence in porpoises is believed by many to rank above that of the apes, and one test that has been made supports this belief. The porpoise has highly developed organs of hearing and a great enlargement of that part of the brain connected with hearing. It has a sense of taste but no sense of smell, and its eyesight is probably not very good. A porpoise cannot be given a general anesthetic because it stops breathing; the author speculates that, because of its being an aquatic mammal, it would not be desirable to have breathing be an involuntary act as it is in terrestrial animals (how, then, does it sleep?). The upper threshold of hearing in the porpoise extends to a frequency of at least 80 kilocycles per second, as compared with 20-23 in the human; it is exceeded only by the mouse and the bat.—*Anita E. Daugherty, California Department of Fish and Game.*

The Natural History of North American Amphibians and Reptiles

By James A. Oliver; D. Van Nostrand; Princeton, New Jersey; 1955, reprinted 1960; xi + 359 pp., with 12 plates, 71 figures, and 15 tables, $6.95.

As the author points out in his preface, there is an increasing interest in herpetology—the study of amphibians and reptiles. Many colleges offer courses in this field, and recent years have seen the publication of a number of fine identification handbooks for North America plus several beautifully illustrated and expensive general books covering species of the world. The author felt that there was need for a book covering the general ways and habits of amphibians and reptiles, and therefore produced the present volume. This he is well qualified to do. He is a well-known herpetologist, with a university and museum background, and is at present in charge of the Reptile House at the Bronx Zoo (run by the New York Zoological Society).

The author says that "This book is intended for the naturalist and the beginning student of amphibians and reptiles. No knowledge of biology is necessary to understand its contents." It is based largely on an extensive compilation of the work of others. Workers' names are frequently mentioned, but there are no lists of references. In the interests of keeping the book to a printable size and of simplification, many things have of course had to be omitted, and some readers may complain about some of these omissions. The geographical limits of the book are Alaska, Canada, and the United States.

The thirteen chapters cover such subjects as Folklore; Economic Values; Locomotion and Movements; Food and Feeding; Growth, Size, and Longevity; etc. The reviewer was particularly interested in the chapter on amphibians and reptiles as pets; she learned a few useful things from this, but there were a number of other points which she would have liked to see included. Perhaps the remark made above on the necessary limitations on size would apply here too, and there may be room in the publishing field for expansion of this subject into a separate volume.

The fifteen tables consist of very interesting photographs illustrating the natural history or behavior of various species. There is a four-page glossary; a one-and-one-half page list of recommended references, a rather small list but perhaps containing the best of the more recent comprehensive manuals on North American amphibians and reptiles; and a twenty-four and one-half page index.

Altogether, this is a book which will probably be of value to the student of high school or college level, as well as being of value at times to the more advanced student.—*Anita E. Daugherty, California Department of Fish and Game.*

Dolphins, the Myth and the Mammal

By Antony Alpers; Houghton Mifflin Company, Boston, Mass., 1961; 268 pp., with 20 black and white photographs, $5.

The domesticated antics of a dolphin, or more correctly a porpoise, on a northern New Zealand beach during 1955 inspired the writing of this book. Instead of recounting this one event, Mr. Alpers, a New Zealand journalist, made a thorough literature search resulting in the production ot an extensive treatise designed to increase mankind's understanding of this fascinating group of marine mammals. Much of the material in this volume was taken from a shorter English edition published a year previously.

As the title implies the story is a pleasant combination of fact and legend. In the first of three sections, the reader is introduced to the earliest references to dolphins the Greek and Roman mythology. This is followed by a review of observations made by such students of "delphinology" as Aristotle, Pliny and Plutarch. Many of these early accounts seem unbelievable, but their credulity is firmed in the light of biological facts discovered in the last 400 years. The final section follows the pattern of the first, but this time recounts the more recent fables of the Polynesians. The final two chapters are devoted to verbose accounts of dolphins befriending the human race.

Most everyone who takes an extensive boat trip encounters and marvels at a school of porpoise. For these casual observers this book offers an interesting opportunity to learn something of their life history and habits. The text forms a pleasant introduction to an excellent list of references for the serious student of "delphinology" and the professional biologist.—*William L. Craig, California Department of Fish and Game.*

Animal Ecology

By S. Charles Kendeigh, Prentice-Hall, Inc., Engelwood Cliffs, N.J., 1961; 468 pp., illus. with black and white photographs, maps, graphs, drawings. Bibliography, Subject index, Species index, $11.

This is a very fine book giving broad coverage to the already broad subject of animal ecology. It will serve well as perhaps one of the best textbooks ever written on this subject, as well as providing a broad informative reference. This publication shows the reader the various kinds of animals living in their different habitats and geographic areas. It presents how they cope with the problems of existence, how they interrelate within the biotic communities to obtain food and shelter, how their numbers are controlled, how they evolve, and how they pose problems of wildlife management and conservation.

For the reader to establish a background in this subject, chapters are presented on Scope and History of Ecology, General Nature of Environmental Responses, The Biotic Community and Measurement of Populations.

Chapter data on local habitats, communities and succession are presented as they relate to streams, lakes, ponds, marshes, swamps and bogs, etc. The ecological processes and community dynamics are presented as they affect such matters as dispersal migration, food, reproductivity, population size, niche segregation and cycles of animal behavior. The subject of animal geographic distribution as it relates primarily to species of this country and to the North American continent is given considerable coverage.

Mr. Kendeigh has introduced many new and stimulating ideas apparently for the purpose of prompting individual research in this broad subject. Animal ecology stresses the importance of fieldwork and helps give the reader the background to set about intelligently to investigate local faunas, habitats, successions and problems of animal existence.

One of the outstanding features of this book is its many photographs, drawings and maps which help explain the often complicated subject of animal ecology.—*John B. Cowan, California Department of Fish and Game.*

Birds of the World

By Oliver L. Austin, Jr., Golden Press Inc., New York, 1961; illustrated by Arthur Singer, edited by Herbert S. Zim, 316 pp. $17.50.

Spectacular is the word for this book. Some 700 birds are shown; at least one species of each bird family in the world. All illustrations are color reproductions of paintings. The birds are presented in lifelike poses and the quality of the illustrations is excellent.

This reviewer found this book to be thoroughly entertaining. For the reader who has a general interest in birds and for the individual who appreciates a beautiful book, this volume is heartily recommended.—*C. M. Ferrel, California Department of Fish and Game.*

The Living Land

By Roderick Haig-Brown: William Morrow and Co., New York, 1961, 269 pp., $12.50

The British Columbia Natural Resources Conference has completed its 14th year as an independent, nonprofit organization devoted to the objective study of natural resources of British Columbia. Membership in the conference is drawn from the universities, government at all levels, and industry, both labor and management. Transactions of the conference are published each year, the 11th one of which was published in 1958. The transactions are comprehensive and authoritative. Inventories, research, and management of natural resources are covered with varied emphasis each year.

Roderick Haig-Brown has presented in his book "The Living Land" a readable condensation of the conferences over the first twelve years. It is surprising that the philosophy of Roderick Haig-Brown and his feeling for the land, shine through in spite of the mass of condensed technical material on forestry, agriculture, water power, mining, recreation, transportation, pollution and people.

His description of what conservation should be exceeds the trite. The impact of Haig-Brown's definition is similar to that of Aldo Leopold, as presented in a chapter entitled The Conservation Ethic, in his book, Sand County Almanac. Conservation as defined by Haig-Brown is "It means having enough faith in the future to respect the future and the needs of future people; it means accepting moral and practical restraints that limit immediate self-interest; it means finding a measure of wisdom and understanding of natural things that few peoples have attained; ultimately, though we no longer see it in this way, it is a religious concept—the most universal and fundamental of all such concepts, the worship of fertility to which man has dedicated himself in every civilization since his race began. We may well believe now that an intellectual and scientific approach is more likely to succeed than a mystical one. But without moral concepts and without a sense of responsibility for the future of the human race, the idea of conservation could have little meaning. Since it deals for the future as well as for the present, it must always be as much an act of faith as an intellectual exercise."

The book has an implied value to the people of British Columbia and to others who have little or no knowledge or appreciation of the involved balance of man and nature. The importance of soil to the general welfare of British Columbia and concern for "city spread" on agricultural lands is well expressed. The history of the destruction of the natural resources in British Columbia and the subquent development of a conservation philosophy in the Province is well described and amply illustrated throughout the book. It provides a dynamic view of the basic substance of conservation; soil, its formation, destruction, and repair.

It is appropriate that a man was chosen to write this book who has feeling for the land and a remarkable ability to communicate such feeling. It is quite evident that he recognizes the importance of utilizing the natural resources but not to the point of destroying the people who are to be served by the resources.

For those who want to know the natural resource wealth of British Columbia, the book is highly recommended, and for those desiring a perspective in conservation, it is a fine text book. Each state in the United States and each province of Canada should have a comparable publication for the enlightenment of its people.

Those familiar with the other writings of Roderick Haig-Brown may find in this book a background for understanding him better. They will find more of what is only hinted at or lightly touched upon in his books on fishing. *R. L. Butler, California Department of Fish and Game.*

Parasitology of Fishes

Editors: V. A. Dogiel, G. K. Petrushevski, Yu. I. Polyanski; Oliver and Boyd, Edinburgh and London; Translated by Z. Kabata, 1961, x + 384 pp., 57 figs., 84s.

This volume, comprising 13 chapters by 8 Russian parasitologists, was first published in Russia in 1958. The English translation is now available to workers in English-speaking countries who can neither read Russian nor who would have the original book at their disposal.

The 13 chapters are entitled: Ecology of the parasites of freshwater fishes; Ecology of parasites of marine fishes; Relationships between host fishes and their parasites; Specificity of fish parasites; Physiology of fish parasites; The life cycles of fish helminths and the biology of their larval stages; zoogeography of parasites of USSR freshwater fishes; Zoogeography of the parasites of USSR marine fishes; Formation of the parasite fauna and parasitic diseases of fishes in hydro-electric reservoirs; Changes in the parasite fauna of acclimatised fishes; Parasitic disesases of cultured fishes and methods of their prevention and treatment; The parasitic diseases of fishes in the natural waters of the USSR; and, Fishes as carriers of human helminthoses.

A few lines from the translator's foreword seem pertinent at this point: "This book represents the first attempt at a comprehensive summing up of the problems of fish parasitology, both marine and freshwater. It is based on a prodigious effort of scientists of a county which offers within its frontiers an almost full range of the habitats existing on the earth. — — — This book is intended to mark trails, perhaps not always the best or most convenient, through an unexplored area. Its value lies more in stimulating discussion and offering food for thought, than in presenting the reader with cut-and-dried, facile explanations."

Therein lies must of the book's worth; however, of even greater importance is the vast insight it affords into the Russian knowledge of this science and the literature they have published on the subject. Nineteen of the 29 pages of references pertain exclusively to Russian works. While most of the rest of the world has been short on information regarding their knowledge and publications in this (and other) fields, it is equally apparent that the Russians have not had access to many of our important works on parasitology.

Regardless, this volume is an extremely valuable contribution to our knowledge and can offer a great deal to any serious student who opens its covers. The index of latin names in the back of the book will ease the task of seeking out specific information.—*John E. Fitch, California Department of Fish and Game.*

Mollusks of the Tropical Eastern Pacific, Panamic-Pacific Pelecypoda

By Axel A. Olsson; Paleontological Research Institution, Ithaca, N.Y., 1961; 574 pp., 86 b + w plates, $15. (paperbound.)

To review a work such as this in other than general terms would require weeks or even months of critical analysis and comparison—a project I was unable to undertake. In view of this, I felt it would be desirable to outline briefly the format of the book and then to present the impressions of others regarding its merit.

Mr. Olsson has dealt primarily with the pelecypods known from the southern half of the Panamic-Pacific zoogeographic province, roughly Costa Rica to northern Peru. Within this area, he has concerned himself mostly with those forms which live from the shore to depths of 300 feet.

He gives a brief historical account of exploration, voyages, and shell collecting within this region, beginning with the French Mission sent out by the *Academie des Sciences* in 1735-44. This is followed by a discussion of the major coastal features that lie between Panama and the northern part of Peru which might influence molluscan distribution. The introductory section is completed with résumés of what comprise the Panamic-Pacific faunal province, the Peruvian province, and what the author terms the "Paita buffer zone."

Part II is comprised of a general statement regarding pelecypods, an artificial key to the principal bivalve families covered in this volume, a glossary of technical terms, the systematic account, illustrations, and an index. The systematic treatment (420 pages) and the plates (86 pages) make up the bulk of the volume.

A request for opinions, among numerous practicing malacologists and conchologists, elicited as many variations as there were individuals polled. The replies ranged from unadulterated praise to reserved approval. Most felt they would have liked more coverage of the items in the northern Panamic province and most agreed that some groups "made sense" for the first time. Numerous typographical errors were bothersome, several groups showed the ravages of "splitting", and three or four "omissions" were sorely missed; however, a couple of illustrated types have clarified perplexing, long-standing problems and the overall quality of the illustrations eases the task of comparing material.

The author is to be commended for this very helpful volume, which, within a month or two of publication, already was proving indispensable to the serious student of Panamic-Pacific mollusca.—*John E. Fitch, California Department of Fish and Game.*

130 Feet Down; Handbook for Hydronauts

By Hank and Shaney Frey; Harcourt, Brace, World, Inc., New York, 1961; 274 pp., illus. black and white photographs, $6.50.

This book is a welcome addition to the literature dealing with skin and SCUBA diving. It is divided into 11 sections, as follows: skin diving, spear fishing, SCUBA diving, mechanics of SCUBA equipment, physics and physiology of SCUBA diving, a discussion of other forms of diving and diving equipment, underwater photography and underwater oil painting, a discussion of dangerous marine life, underwater search and recovery, and a final chapter on professional opportunities available to the SCUBA diver. The book is remarkably free of technical and typographical errors, although the divers' flag is incorrectly described, with the staff on the wrong side. In the chapter on dangerous marine animals, the authors put greater emphasis on East Coast animals than on those found on the West Coast. Except for the rather mediocre drawings of the marine animals, most of the drawings and all of the photographs are quite good. The chapters on spear fishing and underwater photography are well done. Some of the other chapters are not as detailed as one would expect in a book of this type. I would recommend this book to anyone who is beginning to engage in diving, and believe that it would be of value to most advanced divers.—*Michael L. Johnson, California Department of Fish and Game.*

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printed in CALIFORNIA STATE PRINTING OFFICE

56731 1-62 5,300

FISH AND GAME COMMISSION
STATE OF CALIFORNIA

Notice is hereby given that the Fish and Game Commission shall meet on April 2, 1962, at 9.30 a.m., in the State Employment Building, 722 Capitol Avenue, Sacramento, California, to receive recommendations from its own officers and employees, from the department and other public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to birds or mammals, or any species or variety thereof, in accordance with Section 206 of the Fish and Game Code.

FISH AND GAME COMMISSION

LESLIE EDGERTON
Assistant to the Commission

FISH AND GAME COMMISSION
STATE OF CALIFORNIA

Notice is hereby given that the Fish and Game Commission shall meet on May 25, 1962, at 9.30 a.m., in Room 1138, New State Building auditorium, First and Broadway, Los Angeles, California, to hear and consider any objections to its determinations or proposed orders in relation to birds and mammals for the 1962 hunting season, such determinations resulting from hearing held on April 2, 1962, commencing at 9.30 a.m. in the State Employment Building, Sacramento. This notice is published in accordance with the provisions of Section 206 of the Fish and Game Code.

FISH AND GAME COMMISSION

LESLIE EDGERTON
Assistant to the Commission