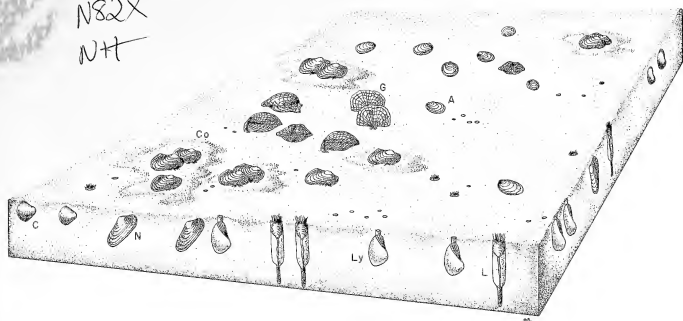




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NUCULITES-COLPOMYA COMMUNITY

Late Ordovician Benthic Marine Communities in North-Central New York

by Peter Bretsky

BULLETIN 414

NEW YORK STATE MUSEUM AND SCIENCE SERVICE



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Late Ordovician Benthic Marine Communities in North-Central New York¹

by Peter Bretsky²

ABSTRACT

Invertebrate faunas in the shales and sandstones of the Lorraine Group (Upper Ordovician) in north-central New York provide an excellent example of well-defined onshore-to-offshore benthic marine communities. The distributional trends of the New York faunal associations and their environmental setting can, furthermore, be traced into the central Appalachians.

About 35 species dominate the Lorraine fauna, mainly trepostomatous bryozoans, brachiopods, gastropods, bivalve molluscs, crinoids, and trilobites. Three benthic marine communities are recognized on the basis of species which consistently occur together. These communities are:

(1) *Dalmanella-Sowerbyella* Community: widespread, lived on muddy silts of the outer infralittoral zone; abundant dalmanellid (*Dalmanella*), strophomenid (*Sowerbyella*, *Rafinesquina*), and atrypid (*Catazyga*) brachiopods, crinoids, trepostomatous bryozoans (*Hallopora*), and trilobites (*Flexicalymene*, *Cryptolithus*) with locally abundant pleurotomariid (*Lophospira* and *Ruedemannia*) gastropods.

(2) *Nuculites-Colpomya* Community: widespread, lived on or buried in silts and fine sands of the outer and inner infralittoral zone protected environments; abundant nuculoid (*Nuculites*, *Ctenodonta?*), modiomorphid (*Colpomya*) and actinodontoid (*Lyrodesma*) bivalve molluscs, crinoids, and orthid brachiopods (*Glyptorthis*).

(3) *Ambonychia-Modiolopsis* Community: patchy distribution, lived on or partially buried in medium to coarse sands of the shallow infralittoral and intertidal exposed environments; abundant ambonychiid (*Ambonychia*), modiomorphid (*Modiolopsis*), and cyrtodontid (*Cyrtodonta*, *Ischyrodonta*) bivalve molluscs, and monoplacophorans (*Cyrtolites*) with locally abundant pleurotomariid (*Clathrospira*) and bellerophonitid (*Sinuities*) gastropods, crinoids, trepostomatous bryozoans (*De-kayia*), and orthoconic cephalopods.

The pattern of offshore brachiopod-dominated communities transitional shoreward into molluscan-dominated communities shown by these benthic marine faunas from New York also is characteristic of Late Ordovician deposits in the central Appalachians. The zoogeographic distribution of major community types is correlated with the position of a major deltaic complex in central Pennsylvania.

¹Manuscript submitted for publication January 29, 1970.

²Department of Geological Sciences, Northwestern University, Evanston, Illinois.

Introduction

Fossiliferous shales, siltstones and sandstones of the Lorraine Group (Upper Ordovician) crop out along the fringes of the Tug Hill Plateau (=Uplift) in north-central New York (fig. 1, insert). Located between the Black River Valley on the east and Lake Ontario on the west, the Tug Hill Plateau has been an area of classic paleontological investigations dating from the reports of Conrad (1839) and Hall (1847). These studies provided the basis for the more expanded investigations of Foerste (1914, 1916) and Ruedemann (1925a, b; 1926a, b). Since the 1920's, however, little work has been done on the Upper Ordovician rocks of north-central New York except for some regional reconnaissance prior to publication of the 1961 New York State geological map (Fisher and others, 1961).

The present investigation concentrates on the zoogeographic distribution and ecology of the Late Ordovician benthic marine invertebrates in north-central New York. In addition ecological comparisons are made with Late Ordovician invertebrate communities in the central Appalachians (Bretsky, 1969). The first and second generation studies in New York were concerned, of course, mainly with the description and subsequent identification of Late Ordovician species and the main stress was placed on using these newly compiled species lists for the interpretation of biostratigraphic relationships between north-central New York and the Cincinnati type area. This is not to say that other aspects of the fauna were totally neglected; in fact, Foerste (1924) and Ruedemann (1925a, 1926a) briefly outlined New York Ordovician paleogeography and paleoecology. Furthermore, Foerste (see especially 1924, p. 32) discussed possible environmental controls on the distribution of Late Ordovician New York species.

The fossiliferous units studied in this report are referred to the Lorraine Group of Emmons (1842; emended by Ruedemann, 1925a), which is composed of two main intergrading lithologic units; an upper medium-bedded fine-grained sandstone, siltstone, and shale—the Pulaski Shale (Vanuxem, 1840) and an underlying thin-bedded shaly siltstone and shale—the Whetstone Gulf Formation (Ruedemann, 1925a). No major break in bedding or lithology is evident throughout the Lorraine Group, though there is a noticeable increase upward in the amount of arenaceous

material, as well as in the thickness and irregularity of bedding. In fact the overlying Oswego Sandstone can be distinguished from the upper Lorraine strata only because the progressive increase in arenaceous content is at the expense of shale and siltstone intercalations. The Oswego has been characterized as being unfossiliferous, and unfossiliferous Oswego-like sandstones also are common in the upper parts of the Pulaski Shale. These lithologic gradations, as well as the lack of continuous exposures, have caused the definition of these lithologic units to lack precision. The reader is referred to Ruedemann (1925a) and Foerste (1916) for reviews of the earlier stratigraphic nomenclatorial difficulties.

The present study of the distribution and ecology of benthic marine invertebrates is restricted stratigraphically to the Pulaski Shale and some portions of the upper Whetstone Gulf Formation. The total thickness of the fossiliferous Upper Ordovician strata investigated amounts to about 400 feet (122 meters), whereas the overall thickness of the Lorraine may be as much as 2000 feet (609 meters). The most complete Tug Hill exposures are normally less than 20 to 30 feet (6 to 9 meters) thick and not closely spaced; because of this and the monotonous and gradational lithologic sequence, precise tracing of individual beds is unlikely. Thus the estimate of 400 feet was pieced together from about 50 localities (fig. 1). Study of the Lorraine fauna was begun along the southwestern fringe of Tug Hill (near Pulaski and Bennett Bridge, localities 4, 5, 6, 6A, and 7) where the fossiliferous strata crop out beneath the massively bedded, unfossiliferous, orthoquartzitic Oswego Sandstone. The faunal assemblage was traced northward and eastward around the plateau, terminating at exposures along the southeastern fringe of Tug Hill near Taberg, Lee Center, and Starr Hill (localities 33, 36, and 37).

About 35 abundant species dominate the Pulaski and upper Whetstone Gulf faunas, which are composed mainly of trepostomatous bryozoans, crinoids, brachiopods, and bivalve molluscs, associated with lesser numbers of monoplacophorans, gastropods, and trilobites. The dalmanellid and strophomenid brachiopods, modiomorphid bivalve molluscs, and trilobites of the Lorraine Group have been correlated by Ruedemann (1925a), Foerste (1914), and Ulrich (1911,

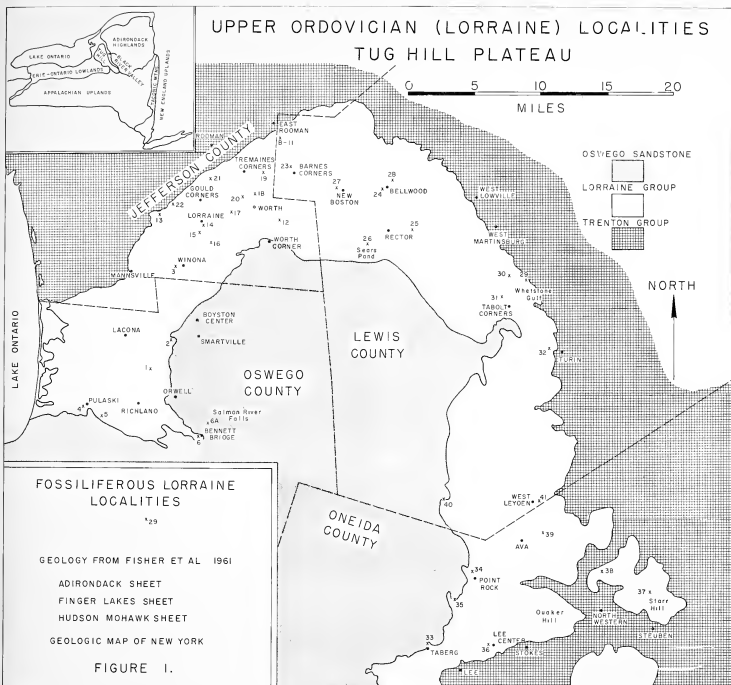


FIGURE 1. Locality map. Numerals represent localities where Lorraine Group strata are exposed and in place (see locality register, p. 33). Exposures of glacial drift containing Lorraine Group fossiliferous boulders are not indicated on this figure.

1913) with strata of Eden and lower Maysville age in the Cincinnati region. Furthermore, Ruedemann (1925a, p. 122-138) has divided the Lorraine Group fauna into six assemblage [?] zones, some of which are found only at the classic Lorraine Gulf sections (my localities 12 to 18, 20; fig. 1); other zones apparently are correlative with Eden and Maysville beds

near Cincinnati. I have interpreted the Pulaski and upper Whetstone Gulf fauna as comprising three benthic marine invertebrate communities which can be traced south of central New York and are ecologically compatible with other Late Ordovician faunas from central Pennsylvania and northern Virginia (Bretsky, 1969). The three New York communities are defined

on the basis of the recurrence of abundant species throughout the Tug Hill region, and are interpreted as having occupied relative onshore to offshore positions; the bathymetric analysis is based primarily on stratigraphic position, zoogeographic distribution and autecology of the fauna as well as primary sedimentary and biogenic structures.

It is likely that the age of the Pulaski Shale is not everywhere the same and, in fact, the entire Lorraine Group may become progressively younger to the west (Fisher, 1962). Although I believe that unequivocal paleontological evidence for this age differentiation is lacking, the hypothesis seems probable in view of the Late Ordovician stratigraphic-sedimentological setting which emphasizes a westward progradation of the Queenston deltaic complex. The Pulaski and upper Whetstone Gulf thus are interpreted as westwardly time-transgressive, nearshore marine phases within this deltaic setting.

ACKNOWLEDGMENTS

I am indebted to my colleague Laurence L. Sloss at Northwestern University and Donald W. Fisher, New York State Museum for reading the manuscript and offering helpful suggestions. I also appreciate the care spent in drafting the text figures by Miss Pauline Mohr and the typing of numerous drafts of this manuscript by Miss Linnea Danchi. Special thanks are due Mr. Richard L. Snyder, Adams, New York, whose knowledge of local geography helped the author in locating several rock exposures, and Mr. Robert Iredale of the Niagara-Mohawk Power Company, Pulaski, for permission to examine an exposure in the channel at the Red Brick Power Station, Bennett Bridge. The project was supported in part by research grant No. 443-07 from Northwestern University.

Stratigraphic Setting and Environmental Framework

Lorraine Group rocks studied in this report crop out around the western, northern, and eastern fringes of the Tug Hill Plateau, which is capped by the Oswego Sandstone and presumably some isolated outliers of the Queenston Formation (fig. 1). A thick sequence of Trenton Group limestones and shales underlie the Lorraine (Fisher, 1962 for stratigraphic details). Fossils were collected from only the upper part of the Lorraine Group, specifically the Pulaski Shale and the uppermost portions of the Whetstone Gulf Formation. The total thickness of the Upper Ordovician section examined is estimated to be about 400 feet (122 meters). The exact position of the Pulaski-Whetstone Gulf boundary is difficult to place because of a gradual lithologic transition from the dominantly thin-bedded siltstones and shales of the Whetstone Gulf into the overlying medium-bedded sandstones, siltstones, and shales of the Pulaski. This lithologic gradation is accompanied by a gradual change in the faunal content of these rocks; the fossils closely resemble Eden and lower Maysville species in the Cincinnati region.

The strata of the Lorraine Group constitute part of the major Late Ordovician Queenston deltaic complex which had its origin in a progressive uplift that took place along the present eastern seaboard of the United States from New Hampshire to Virginia (Kay and Colbert, 1964, figs. 9 and 21). The Late Ordovician regression is well documented from sedimentological studies in the central Appalachians (McBride, 1962; Yeakel, 1962) and eastern Canada (Mason, 1967). These Late Ordovician sediments, in all cases, were transported in a generally westward direction, giving rise in central New York to the Queenston clastic wedge (King, 1959, p. 61, fig. 34; for an informative and concise review of the Queenston clastic wedge see Clark and Stearn, 1968, p. 286). The Late Ordovician regression in New York is documented by an upward coarsening of sediments and progressive increase in bedding thickness; primary sedimentary

structures emphasize a progressive shallowing trend that culminated in the deposition of the red shales and sandstones of the Queenston Formation. These red beds represent migrating deltaic deposits laid down on a broad alluvial plain. This apron of predominantly terrestrial red shales and sandstones graded westward into the terrestrial and shallow marine (supratidal?) virtually abiotic Oswego sandstones which, in turn, passed into the shallow marine faunally-rich Pulaski sandstones, siltstones, and shales. The shales and siltstones of the underlying Whetstone Gulf Formation represent progressively deeper marine deposits. Thus the Late Ordovician environments in central New York represent a series of transitional marine-terrestrial depositional regimes that exhibit an overall east-to-west regressive pattern (see Fisher, 1962, five left-hand columns, Niagara Falls through Rome Quadrangles for east-west interpretation cross-section); during any given instant of time the eastern subaerial and western subaqueous environments would have existed simultaneously (fig. 2; see Grabau, 1913; Broughton and others, 1962, p. 20). Mason (1967) reached similar conclusions from a sedimentological study of Upper Ordovician rocks along the Chambly-Fortierville Syncline in Quebec.

The sediments of the Pulaski Shale were deposited in nearshore marine regimes, most likely inner infralittoral, perhaps in part intertidal, whereas the sediments of the Whetstone Gulf Formation were laid down in deeper water, outer infralittoral regions (fig. 3). Changes in the faunal content of these sediments take place very gradually and are accompanied by numerous repetitions of faunal associations, thereby emphasizing the periodic cycling of benthic marine conditions that favored one faunal assemblage then another on a gently sloping submarine shelf. Bayer (1967) has documented somewhat similar Late Ordovician bottom conditions in southeastern Minnesota, where repetitious changes in sediment influx and bottom chemistry led to periodic changes in the benthic fauna.

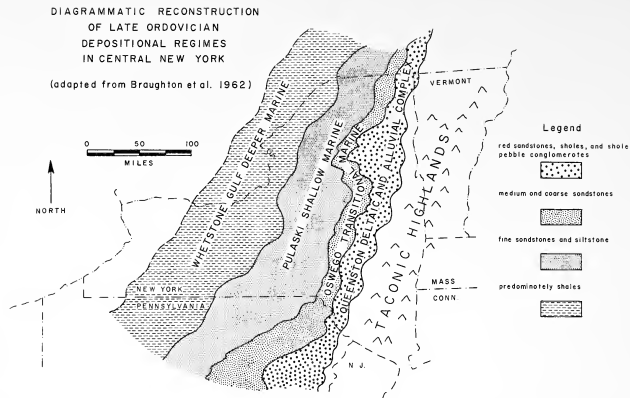


FIGURE 2. Diagrammatic reconstruction of Late Ordovician depositional regimes in north-central New York; interpretation adapted from Braughton *et al.* 1962.

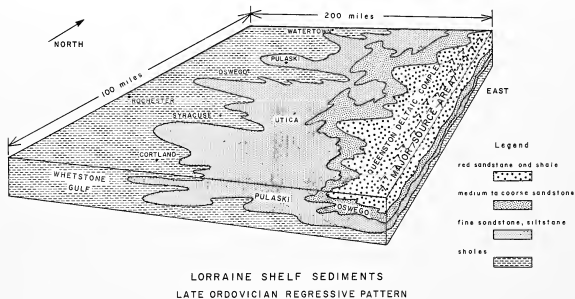


FIGURE 3. Inferred distribution of Lorraine shelf sediments from stratigraphic and sedimentological evidence. The sinuosity of the Oswego-Pulaski and Pulaski-Whetstone Gulf boundaries is a diagrammatic representation of the very gradational and recurrent nature of these lithologies. It is important to note that the diagram portrays lithologic distributions at any one time during the Late Ordovician in north-central New York. Present-day reference points are included specifically for scale and do not imply present geographic relationships to the distribution of Ordovician rocks.

Faunas

Numerically dominant taxonomic groups in the central New York Upper Ordovician fauna are trepostomatous bryozoans, brachiopods, bivalve molluscs, and crinoids, with lesser numbers of trilobites, gastropods, and monoplacophorans; the latter three taxa are normally more restricted geographically, and presumably ecologically, than the dominant taxa. The fossils are distributed throughout the Lorraine Group, but are most often concentrated in lenses and layers. In fact, crossbedded crinoid-bryozoan coquinities are present in the upper parts of the Pulaski Shale. Table 1 is a list of the abundant genera and / or species in the Pulaski and upper parts of the Whetstone Gulf Formation. Although only about 35 taxa are listed, it is probable that there are more than 100 species of macrofauna preserved in these Late Ordovician sediments. I would expect that a percentage of abundant to total macrofaunal species, if precisely documented, would fall between 10 and 25 percent. A scale of

relative taxonomic diversity was employed, however, in this introductory study and applied at each locality where areal exposure and preservation deemed it applicable. Taxa were thus identified in the field, relative abundances being recorded at the locality along with stratigraphic relationships and associated lithology. These preliminary results were refined in the laboratory and then again re-examined in the field. Although vertical and horizontal trends in species composition were evident, the observed density of some species commonly varied from one to another of closely spaced localities. I suspect that this variation not only reflects actual differences in species diversity, but also is, to some extent, an artifact of areal extent of the exposures. What is important, however, is the consistent stratigraphic and zoogeographic occurrence of the same species. Utilizing this systematic occurrence these Late Ordovician faunal communities can be outlined.

Table 1. Abundant genera and/or species from Late Ordovician rocks, north-central New York

BRYOZOA:

Dekayia
Hallopora
 ?*Heterotrypa*

BRACHIOPODA:

Lingulapholis?
Dalmanella multisepta
Sowerbyella (Sowerbyella) sericea
Rafinesquina "alternata"
Rafinesquina mucronota?
Glyptorthis crispata
Catazyga erratica
Zygospira modesta

GASTROPODA:

Sinuities?
Clathrospira subconica
Eotomaria?
Ruedemannia? lirata
Loxoplocus (Lophospira) abbreviata
Loxoplocus (Lophospira) ventricosta
Loxoplocus (Lophospira) bowdeni
Hormotoma gracilis

BIVALVIA:

Nuculites "scitulus"
Lyrodesma poststriatum
Ctenodonta? cf. pulchella
Colpomya faba
Ambonychia radiata
Ambonychia praecursa
Modiolopsis modiolaris
Ischyrodonta unionoides
Cyrtodonta
Cyrtodontula

MONOPLACOPHORA:

Archinacella
Cyrtolites ornatus

CRINOIDEA:

columnals

TRILOBITA:

Flexicalymene
Cryptolithus
Isotelus

CEPHALOPODA:

orthocones

CONICAL SHELLS OF UNKNOWN AFFINITY:

Cornulites

Benthic Invertebrate Communities

The consistent and recurrent associations of the abundant invertebrate species (i.e. bryozoans, brachiopods, bivalve molluscs, gastropods, monoplacophorans, crinoids, and trilobites) has led to the recognition of three faunal associations, termed communities. These are outlined in table 2. Each of these Late Ordovician communities is named for its most conspicuous and co-dominant species. The communities are as follows:

1. *Ambonychia-Modiolopsis* Community
2. *Nuculites-Colpomya* Community
3. *Dalmanella-Sowerbyella* Community

These three communities are composed of groups of species all of which show a high degree of affinity and pronounced tendency to occur together throughout the Pulaski Shale and upper Whetstone Gulf Formation. Some species are completely restricted to one community, but normally those species listed as members of a particular community (table 2) are numerically significant in that community alone. Furthermore, this designation of communities does not imply that community boundaries, either faunally or geographically portrayed, are rigid, and that no mixing of species among communities takes place.

TABLE 2.

AMBONYCHIA-MODIOLOPSIS COMMUNITY	DALMANELLA-SOWERBYELLA COMMUNITY	NUCULITES-COLPOMYA COMMUNITY
DEKAYIA?	HALLOPORA DEKAYIA	
	DALMANELLA MULTISECTA SOWERBYELLA (SOWERBYELLA) SERICEA RAFINESQUINA "ALTERNATA" R. MUCRONOTA? CATAZYGA ERRATICA ZYGOSPIRA MODESTA	GLYPTORTHIS CRISPATA LINGULAPHOLIS?
GLATHROSPIRA SUBCONICA HORMOTOMA GRACILIS	SINUITES? LOXOPLOCUS (LOPHOSPIRA) ABBREVIATA LOXOPLOCUS (LOPHOSPIRA) BOWDENI LOXOPLOCUS (LOPHOSPIRA) VENTRICOSTA RUEDEMANNIA? LIRATA	
AMBONYCHIA PRAECURSA MODIOLOPSIS MODIOLARIS CYRTODONTA ISCHYRODONTA UNIONOIDES	AMBONYCHIA RADIATA	NUCULITES "SCITULUS" LYRODESMA POSTSTRIATUM CTENODONTA? cf. PULCHELLA COLPOMYA FABAE
	FLEXICALYMENE CRYPTOLITHUS ISOTELUS	
CYRTOLITES ORNATUS		ARCHINACELLA
ORTHOCONIC CEPHALOPODS	CORNULITES	
	CRINOID COLUMNALS	

TABLE 2. North-central New York Late Ordovician communities

The genus *Ambonychia* Hall and the crinoids are excellent examples of significant ubiquity among communities.

The stratigraphic distribution of the faunas comprising these three communities shows considerable overlap but a definite gradational trend from one into another (fig. 4). The obvious effects of post-mortem transport accounts for some of this overlap, especially in the upper parts of the Pulaski, where comminuted fragments of crinoids, bryozoans, and some brachiopods were reworked into crossbedded coquinas. Aside from the obvious instances of post-mortem transport, evidence of abrasion is not significant and measurements of disarticulated valve ratios and of shell sizes of abundant species on bedding planes shows little evidence of significant winnowing and highly sorted shell concentrations. I think it is reasonable to state that most of the benthic fauna was preserved in the area in which it was living. Because the communities are defined on the replication of numbers of abundant species, the chance accumulation of fossil assemblages as mere artifacts of physical energy and mixing is minimized. This consistent association of certain species was the basis for Petersen's (1914) concept of a marine bottom community. A more rigorous statistical delineation of these communities has been carried out at a few of the sample localities (Bretsky, unpub. data). At the present time, it adds little background to this preliminary study, but this work is continuing on larger numbers of samples from the more continuously exposed Upper Ordovician Nicolet River section in the St. Lawrence Lowlands of Quebec.

Each of the three benthic communities extends across the 2000 square mile Tug Hill region. Some zoogeographic differences, however, exist, but at present can be incorporated within the community structures as defined. Thus a local abundance of *Rafinesquina mucronota*? Foerste along the northern fringes, or of *Loxoplocus* (*Lophospira*) Whitfield and *Ruedemannia* Foerste in the southeast, are more simply incorporated into the *Dalmanella-Sowerbyella* Community and do not merit a separate designation. These and other examples are discussed in the following sections.

Ambonychia-Modiolopsis Community (fig. 6)

The fauna of the *Ambonychia-Modiolopsis* Community (table 2) is exposed only along the southeastern (fig. 1, localities 33, 34, and 35) and southwestern (localities 5, 6-A, and 7) portions of Tug Hill Plateau, but the *Ambonychia-Modiolopsis* faunas are found in numerous glacial erratics to the north

of the present exposures. Thus I suspect that this community was more widespread than would be inferred from present exposures. The community is dominated by large epifaunal suspension-feeding bivalve molluscs, associated with somewhat lesser numbers of detritus-feeding gastropods and monoplacophorans, (fig. 7, no. 1-4). Suspension feeders consist of the mussel-like species *Modiolopsis modiolaris* (Conrad), *Ambonychia praecursa* (Ulrich), *Cyrtodonta* Billings, and *Ischyrodonta unionoides* (Meek), whereas the most abundant detritus feeders are the coiled monoplacophoran *Cyrtolites ornatus* Conrad and pleurotomariid gastropod *Clathrospira subconica* (Hall). Orthoconic cephalopods are found in large numbers only at locality 33 (East Branch of Fish Creek) where several bedding planes of south-eastward oriented orthocones are exposed immediately above the stream bed. While specimens of *Ambonychia*, *Modiolopsis*, *Ischyrodonta*, and *Cyrtolites* are most abundant in the west, *Modiolopsis* and *Clathrospira* are more common in the south-eastern exposures. *Cyrtolites* appears much more common in weathered glacial erratics, and thus may have been dominant to the north.

Most of the previously described and photographed species that are now included in the *Ambonychia-Modiolopsis* Community came from weathered glacial erratics uncovered in the vicinity of Trenton Falls, where bedrock are limestones of the Middle Ordovician Black River or Trenton Groups. Actually, these species were found to be much more abundant in glacial boulders from the vicinity of Pulaski and, in general, from the more southwestern portions of Tug Hill. Furthermore, fine specimens can be obtained from partially weathered exposures of Lorraine bedrock.

The fossils of the *Ambonychia-Modiolopsis* Community are common in thin- to medium-bedded, fine- to medium-grained sandstones, which are interbedded with irregularly crossbedded coarse orthoquartzites and dark grey-black silty shales. The coarse tabular and planar crossbedded sandstone lenses commonly thicken from 5 inches to 3 feet over a lateral distance of less than 6 feet (fig. 5). Thinner, but similarly crossbedded or laminated, crinoid-bryozoan, sand-pebble conglomerates are generally enclosed within or occur at the base of orthoquartzites. The orthoquartzites alternate and intertongue with dark grey-black silty shales that are commonly mottled, less commonly fissile and contain a patchy fauna composed of small-sized taxodont, modiomorphid, and desmodont bivalve molluscs, graptolite fragments and more rarely long, oriented crinoid stems. This fauna is not considered part of the *Ambonychia-Modiolopsis* Community.

DIAGRAMMATIC COMPOSITE COLUMNAR SECTION UPPER LORRAINE GROUP

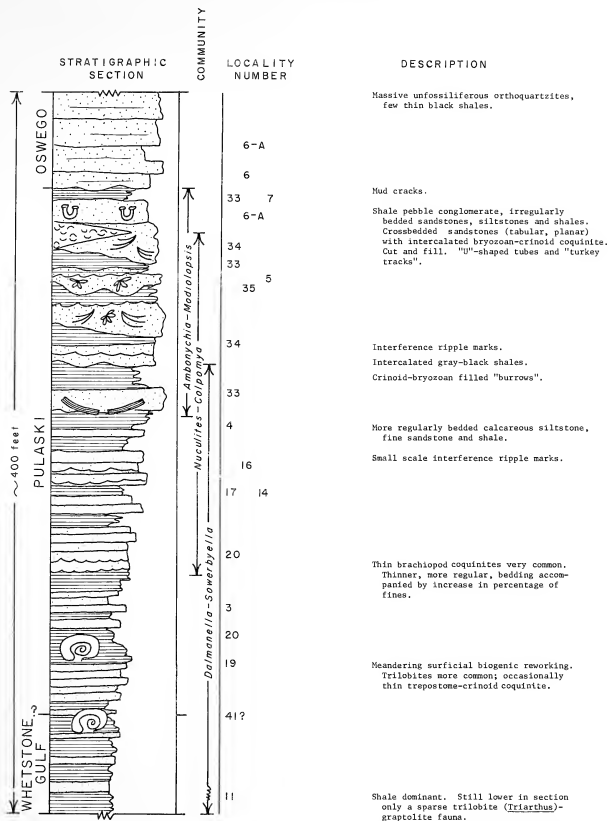


FIGURE 4. Diagrammatic composite columnar section Upper Lorraine Group in central New York showing the vertical distribution of the three benthic marine communities and a short description of the associated lithologies, primary sedimentary structures and biogenic structures.

DETAILED SECTION (LOCALITY 33) OF UPPER PULASKI AT TABERG, N.Y.

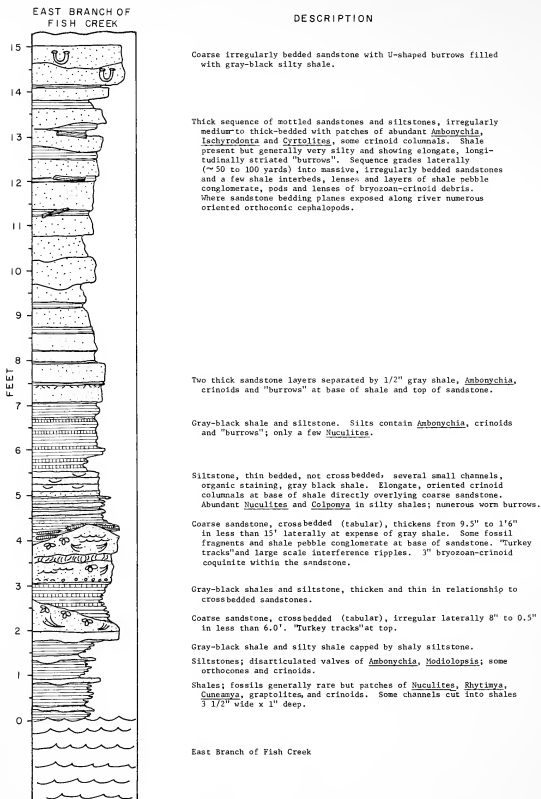
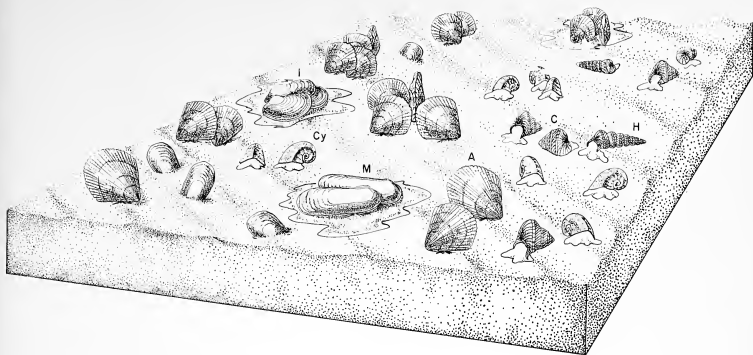


FIGURE 5. Detailed section of Upper Pulaski at Taberg, New York (locality 33). Of particular interest are not only the faunal associations but also the extreme irregularity in bedding and lithology. Coarse crossbedded sandstones thicken and thin by several orders of magnitude over very short distances.



AMBONYCHIA-MODIOLOPSIS COMMUNITY

FIGURE 6. A reconstruction of the *Ambonychia-Modiolopsis* Community. The community is dominated by large epifaunal suspension-feeding bivalve molluscs, *Ambonychia praecursa* (A), *Modiolopsis modiolaris* (M) and *Ischyrodonta unionoides* (I) which are associated with detritus-feeding gastropods, *Clathrospira subconica* (C) and *Hormotoma gracilis* (H), and the coiled monoplacophoran *Cyrtolites ornatus* (Cy). Excluded from this reconstruction are the common burrows, grazing and/or resting tracks (see fig. 5 and 10).

bonychia-Modiolopsis Community, but actually constitutes the partial remains of another faunally distinct community. The oriented crinoid stems are especially common at the base of the silty shales overlying the massive crossbedded orthoquartzites. Figure 5 diagrams in partial detail a stream section from Taberg (locality 33) that shows the stratigraphic relationships of these various lithologies. In the midst of the grey-black silty shales occur fine- to medium-grained sandstones that contain elements of the *Ambonychia-Modiolopsis* Community. These fossiliferous sandstones and silty shales are cut by shallow channels 2 to 3 inches wide and normally less than 1 inch deep, that are filled with crinoid-bryozoan debris. Additional current reworking of the bottom sediments is evident in the large-scale flattened interference ripples (fig. 8)

and the disarticulated crinoid stems and worn fragments of trepostomatous bryozoans in the sand-pebble coquinites. Thus the overall stratigraphic sequence is characterized by extreme lithologic irregularities and little gradation of one rock unit into another (fig. 9). Lithologic variation is rather abrupt and includes lens-like crossbedded orthoquartzites and numerous shallow cut-and-fill structures. The entire sequence grades upward into the unfossiliferous orthoquartzites and shale pebble conglomerates of the Oswego Sandstone.

The extreme irregularity in bedding is accompanied by numerous burrows, grazing and/or resting tracks (also fig. 5). Evidences of biogenic reworking in the upper part of the Pulaski can be grouped into three main morphological types that occur in a particular stratigraphic order and normally within specific litho-

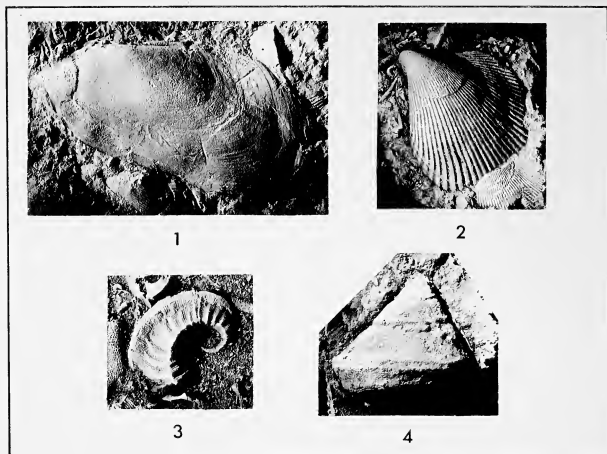


FIGURE 7. Faunas of the *Ambonychia-Modiolopsis* Community.

- 1.— *Modiolopsis modiolaris*, composite mold natural X1 (locality 33).
- 2.— *Ambonychia praecursa*, latex impression of left valve X1 (locality 41).
- 3.— *Cyrtolites ornatus*, latex impression X2 (locality 29).
- 4.— *Clathrospira subconica*, latex impression X2 (glacial drift).

ologies. The most numerous and widespread biogenic structures are burrows or grazing tracks which form a pattern of 3 or 4 broad, blunt, shallow finger-like projections on bedding planes (fig. 10); I have seen this type of biogenic structure, called "turkey tracks" by workers in the Cincinnati region, in the Corryville Member of the McMillan Formation at the Stone-lick Creek section about 20 miles east of Cincinnati (also see Hofmann, 1964 for locality data). "Turkey tracks" are most common in New York on the bedding planes of coarse sandstones that alternate with flattened interference-rippled sandstones. Shinn (1968, pl. 110, fig. 2) and Schäfer (1962, fig. 52) photographed present-day crustacean burrows and bivalve mollusc grazing patterns that appear somewhat analogous morphologically to these Ordovician "turkey tracks."

A second, less common biogenic structure consists of longitudinally striated surface burrows that intersect bedding planes at low angles and which are 4 to 5 inches long and about ½ inch wide; considerably deeper than the "turkey tracks" and in some places filled with crinoid-bryozoan debris (fig. 12, no. 12). These striated burrows are very similar to some of the *Cruziana* facies burrows of Seilacher (1964 see esp. fig. 8, showing basal parts of *Diplocraterion*), and occur in mottled shaly sandstones with patches of abundant *Ambonychia* and *Cyrtolites*; therefore, they may represent a soft-bodied member of the *Ambonychia-Modiolopsis* Community.

The third type of biogenic structure is least common and consists of "U"-shaped tubes that are found only in the massive-bedded orthoquartzites. The tubes, which are filled with the dark grey silty shales,



FIGURE 8. Interference ripple marks



FIGURE 10. Biogenic reworking "turkey tracks"

outline a dumbbell shape on the bedding plane (the dumbbells are normally $2\frac{1}{2}$ to 4 inches apart; see Ruedemann, 1926b, p. 81 and Foerste, 1924, p. 78); they were called *Artharia* Billings by these early investigators. The tubes have been found only in the coarse unfossiliferous Oswego-like sandstones that are interbedded with the fossiliferous shaly sandstones, siltstones, and shales of the Pulaski. *Corophioides* in

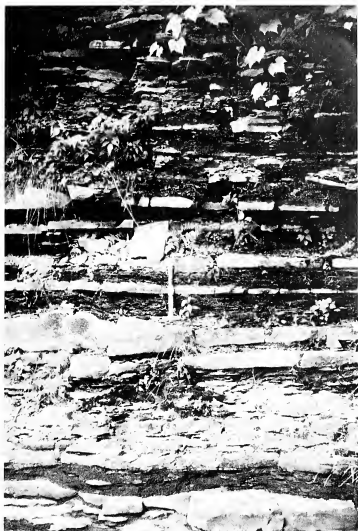


FIGURE 9. Rock exposure at locality 5, southeast of Pulaski

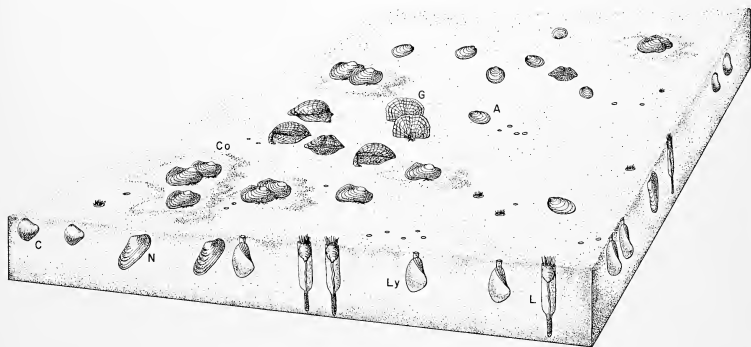
Seilacher's *Cruziana* facies (1964, p. 309-310) and Schäfer's *U-Bau von Arenicola* (1962, Abh. 174, 175) are morphologically very similar. Stratigraphically the "U"-shaped tubes are the highest of all three biogenic structures and presumably may cross the transitional Pulaski-Oswego boundary.

As outlined in figures 4 and 5, the faunas of the *Ambonychia-Modiolopsis* Community are interbedded and in some places mixed with other species believed to be more diagnostic of other communities. The other species are small taxodont, modimorphid, and desodont bivalve molluscs which are of patchy abundance throughout the grey black silty shales. These small bivalve mollusc species constitute a major part of another faunal assemblage, the *Nuculites-Colpomya* Community, which appears to have occupied part of the same geographic area as the fauna of the *Ambonychia-Modiolopsis* Community. A third faunal assemblage is composed of fragmented remains of the

brachiopods *Dalmanella* and *Sowerbyella*, crinoids, and bryozoans, and forms the thin coquinites. Some of these species, especially the crinoids and bryozoans, are occasionally observed mixed with the faunas of the *Ambonychia-Modiolopsis* Community but normally form distinct layers and lenses of shell debris. The local abundance, however, is evidence of the reasonable proximity of a third distinct faunal assemblage—the *Dalmanella-Sowerbyella* Community; but because the species occur abundantly only in the coquinite and show signs of abrasion and size sorting, it is probable that no significant portions of the *Dalmanella-Sowerbyella* Community lived in this particular area in which they are now preserved.

Bretsky (1969) outlined a similar Late Ordovician faunal association in the central Appalachians termed the *Orthorhynchula-Ambonychia* Community, which is common at the top of the Reedsville Formation from south-central Pennsylvania into central Virginia. The similarities that exist between the New York

and central Appalachian communities are evident not only in the number of dominant taxa common to both (table 3), but also in quite analogous stratigraphic-sedimentologic situations. The faunas of both communities are abundantly represented in fine- to medium-grained sandstones interbedded with crossbedded orthoquartzites and grey-black laminated shales, a succession which represents a shallow marine depositional regime within the Late Ordovician eastern North America regressional sequence; differences are evident in that the shales are less abundant and unfossiliferous in the central Appalachians and the crinoid-bryozoan coquinite is common only in New York. Species of the large epifaunal suspension-feeding bivalves *Ambonychia*, *Modiolopsis*, and *Ischyrodonta* are abundant in both communities but faunal differences are evident beyond this comparison. The most apparent difference is that the *Ambonychia-Modiolopsis* Community of New York contains no extensive brachiopod fauna such as the extremely abundant *Lingula*?



NUCULITES—COLPOMYA COMMUNITY

FIGURE 11. A reconstruction of the *Nuculites-Colpomya* Community. The community is composed of predominantly small infaunal detritus feeding bivalve molluscs, *Nuculites* "scitulus" (N) and *Ctenodonta*? cf. *pulchella* (C), and an infaunal suspension (?) feeding bivalve, *Lyrodessa poststriatum* (Ly). There are two numerically important epifaunal suspension feeders, the small modiolomorphid bivalve mollusc, *Colpomya faba* (Co) and the orthid brachiopod, *Glyptorthis crispata* (G). The detritus feeding, epifaunal cap-shell monoplacophoran, *Archinacella* (A), is common at some locales.

CENTRAL
APPALACHIAN COMMUNITIES

ABUNDANT SPECIES

NEW YORK COMMUNITIES

ORTHORHYNCHULA-
AMBONYCHIA

Lingula?
Orthorhynchula linneyi
Plectonatus?

Ambonychia praecursa
Medialopsis medialaris
Ischyradonta? truncata

Tancrediopsis cuneata

AMBONYCHIA-
MODIOLOPSIS

Clothraspira subconica
Cyrtolites anatus
Ambonychia praecursa
Medialopsis medialaris
Ischyradonta unionoides
Cyrodonta

Glyptarthris crispata
Nuculites "scitulus"
Lyradesma poststriatum
Ctenodonta? et pulchella
Colpomya faba
Archinacella

SOWERBYELLA-
ONNIELLA

Hallopora
Sowerbyella (Sowerbyella) sericea
Rafinesquina "alternata"
Onniella multisepta
Zygospira modesta

Loxaplocus (Lophospira) abbreviata
L (L.) ventricosta
L (L.) perangulata

Sinuapea?
Ruedemannia? lirata
Ambonychia radiata
Flexicalymene
Cryptolithus
Isotelus
Crinoid columnals

Ctenodonta? pulchella
Proenacula levata
Lyradesma poststriatum

DALMANELLA-
SOWERBYELLA

Hallopora
Dekayia
Sowerbyella (Sowerbyella) sericea
Rafinesquina "alternata"
Dalmanella multisepta
Zygospira modesta
Cataozya erratica
Loxaplocus (Lophospira) abbreviata
L (L.) ventricosta?

L (L.) bawdeni

Ruedemannia? lirata
Ambonychia radiata
Flexicalymene
Cryptolithus
Isotelus
Crinoid columnals
Cornulites

ZYGOSPIRA-
HEBERTELLA

Batostomella
Heterotrypa
Peranopora?
Monticulipora
Hallopora
Amplexopora
Dekayia
Zygospira recurvirostra
Hebertella sinuata
Murchisonia?
Pterinea (Coritodens) demissa
Ambonychia cultrata
Medialopsis medialaris?

TABLE 3. Comparison of Late Ordovician faunal communities

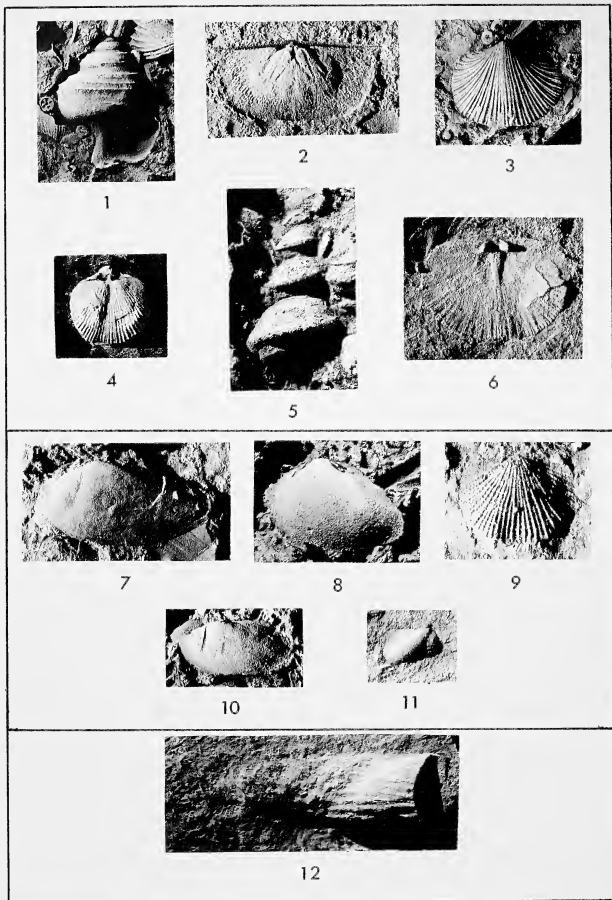


FIGURE 12

Brugiere and *Orthorhynchula linneyi* (James) in the central Appalachians. Bellerophonitid gastropods (*Plectonotus*? Clarke and some *Bucania* Hall) common in the central Appalachians appear to be absent in New York and perhaps were replaced in part by the large coiled monoplacophoran *Cyrtolites* and the pleurotomariid gastropod *Clathrospira*. The protobranch bivalve mollusc *Tancrediopsis cuneata* (Hall) is also entirely missing from the New York community but is ubiquitous throughout the central Appalachians. Thus, the most significant differences are the absence of the *Tancrediopsis-Lingula*?-*Plectonotus* and *Orthorhynchula linneyi* fauna in New York (Bretsky, 1969, figs. 5 and 6), and conversely the abundance of *Cyrtolites* only in New York. Despite these faunal differences, however, the two communities are comparable in their overall dominance by large epifaunal, suspension feeding bivalve molluscs, and, of course, their environmental setting.

Nuculites-Colpomya Community (fig. 11)

The fauna of the *Nuculites-Colpomya* Community (table 2) is exposed around the western, northern, and eastern fringes of the Tug Hill Plateau (localities 7, 14, 17, 20, 33, and 41). The community is composed of predominantly small infaunal detritus and suspension(?) feeding bivalve molluscs (fig. 12, no. 7-11). The detritus feeders consist of the nuculoid bivalves *Nuculites* "*scitulus*" Emmons and *Ctenodonta*? cf. *pulchella* (Hall) with lesser numbers of *Praenucula* Pfab and *Palaeoconcha* Miller. Infaunal suspension (?) feeders are less numerous and include the actinodontid bivalve *Lyrodesma poststriatum* (Emmons) and assorted desmodonts-*Rhytimya* Ulrich, *Cuneamya* Hall and Whitfield, *Cymatnota* Ulrich, and *Psiloconcha* Ulrich. In addition, there are two numerically important epifaunal suspension feeders, the small modiomorphid bivalve *Colpomya faba* (Emmons) and the orthid brachiopod *Glyptorthis crispata* (Emmons). Some of these species are not widely distributed; *Lyrodesma poststriatum* is abundant only in the west, *Glyptorthis crispata* is common only in the north, whereas the desmodont bivalve molluscs are more commonly found in the southeast.

The fossils of the *Nuculites-Colpomya* Community are common in silty shales and siltstones, which are high in the Pulaski Shale section and are sporadically interbedded with irregularly, crossbedded orthoquartzites (see especially localities 7 and 33). Other siltstones and shales, however, contain the *Nuculites-Colpomya* fauna and are found lower in the stratigraphic section, where the bedding is thinner and more

FIGURE 12.—Faunas of the *Dalmanella-Sowerbyella* and *Nuculites-Colpomya* Communities.

- 1.—*Ruedemannia*? *lirata*, latex impression X2 (locality 37).
- 2.—*Sowerbyella* (*Sowerbyella*) *sericea*, pedicle valve internal mold natural X2 (glacial drift).
- 3.—*Dalmanella multisepta*, latex impression of pedicle valve external X2 (locality 16).
- 4.—*Catazyga erratica*, brachial valve external X2 (glacial drift).
- 5.—*Loxoplocus* (*Lophospira*) *bowdeni*, latex impression X2 (glacial drift).
- 6.—*Dalmanella multisepta*, latex impression brachial valve internal X2 (locality 39).
- 7.—*Nuculites* "*scitulus*," composite mold natural X2 (locality 33).
- 8.—*Lyrodesma poststriatum*, internal mold natural X2 (glacial drift).
- 9.—*Glyptorthis crispata*, latex impression pedicle valve external X2 (locality 3).
- 10.—*Nuculites* "*scitulus*," internal mold natural X2 (locality 41).
- 11.—*Colpomya faba*, latex impression X2 (locality 14).
- 12.—Longitudinally striated "worm" burrow X1 (locality 7).

regular, the shales are fissile, and the fine sandstones sporadically exhibit only small symmetrical ripple marks (see especially localities 14, 17, 20, and 41). The faunas of the *Nuculites-Colpomya* Community thus extend over a broader stratigraphic range within the Pulaski Shale than do the faunas of the *Ambonychia-Modiolopsis* Community (fig. 4). Differences in the faunal composition of the *Nuculites-Colpomya* Community do exist stratigraphically, as well as zoogeographically, although an overall consistency is maintained; *Nuculites* and *Colpomya* are abundant throughout, but there is a trend toward increased numbers of smaller-sized (3 to 10 mm) *Nuculites* lower in the section whereas larger (1.5 to 2.0 cm) ones exist higher up (fig. 12, no. 7, 10). *Lyrodesma poststriatum* and the desmodont bivalve molluscs are more abundant in the upper Pulaski, whereas *Glyptorthis crispata* is more abundant lower in the section.

The fossils of the *Nuculites-Colpomya* Community are, of course, associated with other species more representative of the other two communities. High in the Pulaski section, remnants of the *Ambonychia-Modiolopsis* Community, especially *Ischyrodonta*, *Ambonychia*, and a few *Modiolopsis* are mixed with the dominant *Nuculites-Colpomya* fauna, but the faunas of the two communities are normally interbedded and mixing would be expected since the two communities presumably occupied part of the same geographic area. Occasionally, long-stemmed crinoids without calyces and graptolite fragments are found with the abundant species of the *Nuculites-Colpomya* Community, but crinoid columns and graptolites (unidentified) are few in number and are believed to be derived from outside the immediate area. Lower in the Pulaski section the *Nuculites-Colpomya* fauna is interbedded with the *Dalmanella-Sowerbyella* fauna, and as might be expected, some mixing of these faunas is common. Crinoids become more commonly mixed with the *Nuculites-Colpomya* fauna as well as scarce trilobites, dalmanellid brachiopods, and a few trepostomatous bryozoans.

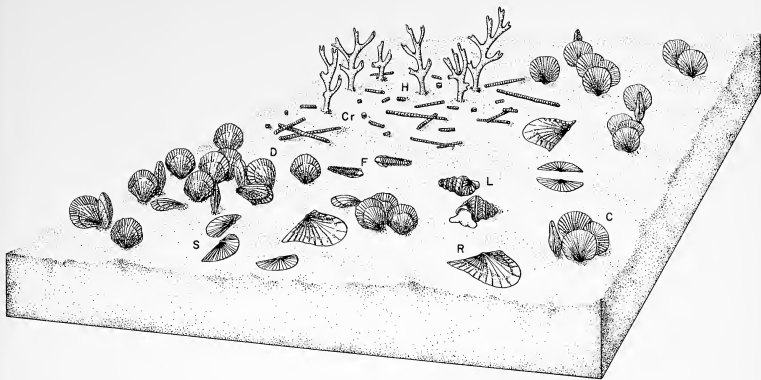
Species which are numerically significant in the *Nuculites-Colpomya* Community are either not present or occur in much lesser numbers in the central Appalachian. Small patches of nuculoid bivalves and *Lyrodesma poststriatum*, however, occur in north-central Pennsylvania. These forms were, because of their scarcity, incorporated into the central Appalachian *Sowerbyella-Onniella* Community (Bretsky, 1969). Specimens of *Nuculites* are insignificant, and *Colpomya* was not found, in the north-central Appalachians, but the nuculoids *Ctenodonta?* and *Prae-*

nucula, as well as *Lyrodesma poststriatum*, are common in some places in a regularly bedded siltstone associated primarily with the dominant dalmanellid-strophomenid-crinoid and trilobite fauna of the central Appalachian *Sowerbyella-Onniella* Community. Because of the increased development of the protobranch fauna to the north, the protobranch-rich assemblage is no longer considered part of the strophomenid brachiopod community as in the north-central Appalachians but now stands as a separate major faunal assemblage in north-central New York. At the present time there is no evidence for the development of such a community south of north-central Pennsylvania. The protobranch bivalve and *Lyrodesma* fauna is strictly a north-central Appalachian and New York Late Ordovician development.

Dalmanella-Sowerbyella Community (fig. 13)

The fauna of the *Dalmanella-Sowerbyella* Community (table 2) encircles the Tug Hill Plateau and is very common in weathered glacial boulders. Excellent exposures yielding the faunas of the *Dalmanella-Sowerbyella* Community are seen at localities 3, 4, 11, 14, 16, 17, 19, 20, and 41. The approximate stratigraphic position of these exposures is indicated on figure 4. The community is dominated by large numbers of epifaunal suspension feeding brachiopods and bryozoans (fig. 12, nos. 1-6). Orthid [*Dalmanella multisecta* (Meek)], and strophomenid [*Sowerbyella* (*Sowerbyella*) *sericea* (Sowerby)] brachiopods are most abundant, in addition to trepostomatous bryozoans *Hallopora* Bassler and *Dekayia* Milne-Edwards and Haime, and crinoids. Less common overall, but locally highly concentrated in patches, are strophomenid, [*Rafinesquina* "alternata" (Hall) and *R. mucronota?* Foerste] and atrypid [*Catazyga erratica* (Hall) and *Zygospira modesta* (Hall)] brachiopods, and species of *Loxoplocus* (*Lophospira*) Whitfield and *Ruedemannia* Foerste. Specimens of *Catazyga* and *Rafinesquina* are found in layers and lenses along the northern portions of Tug Hill, especially in the Lorraine Gulf section, and also appear much more frequently in drift blocks than would be expected from their present limited areal exposure (also see Ruedemann, 1925a, p. 122 and 134). *Ambonychia radiata?* Hall and the trilobites *Flexicalymene* Shirley and *Cryptolithus* Green are ubiquitous but less numerous than the brachiopods and crinoids.

The fossils of the *Dalmanella-Sowerbyella* Community are common in thin-bedded calcareous siltstones and shales. Bedding is regular throughout, but there is a definite tendency for thicker and more



DALMANELLA - SOWERBYELLA COMMUNITY

FIGURE 13.—A reconstruction of the *Dalmanella-Sowerbyella* Community. The community is dominated by large numbers of epifaunal suspension feeding brachiopods, *Dalmanella multisecta* (D), *Sowerbyella (Sowerbyella) sericea* (S), *Rafinesquina "alternata"* (R), *Catazyga erratica* (C), and trepostomatous bryozoans, *Hallopora* (H). In addition there are less common crinoids (Cr), three species of *Loxoplocus (Lophospira)* (L) and trilobites, *Flexicalymene* (F).

numerous calcareous beds to occur higher in the section. Fragmented specimens, especially crinoids and bryozoans, are common high in the Pulaski section, interbedded with the massive Oswego-like orthoquartzites and the siltstones and shales bearing faunas of the *Ambonychia-Modiolopsis* and *Nuculites-Colpomya* Communities. These reworked crinoid-bryozoan lenses continue downward in the Pulaski section for a short distance, but rapidly give way to fossiliferous siltstones that show little evidence of the higher physical energy present in the overlying beds. The regularly thin-bedded siltstones are interbedded with gray-green silty and non-silty shales; within this regular alteration there is a gradient toward increased shale in the middle and lower portions of the Pulaski Shale as well as the upper parts of the Whetstone Gulf Formation. The fossiliferous silts finally grade

downward into fissile gray-black organically rich shales and a few thin-bedded silty shales that are dominated by a sparse trilobite (*Triarthrus* Green)-graptolite fauna.

The extremely regular, thin-bedded siltstones are marked in places by small symmetrical interference ripples (localities 14, 16). The wave length and height of these ripples are about 1/10 the size of those found in the coarser sandstones of the upper parts of the Pulaski Shale. Biogenic reworking also varies significantly. Instead of the large burrowing and grazing patterns associated with the faunas of the *Ambonychia-Modiolopsis* Community, fine meandering patterns cover the bedding plane (see Seilacher, 1964, p. 308, for fine meandering grazing patterns in the *Nereites* facies); very rarely do these burrows penetrate from one bed into another.

The faunas of the *Dalmanella-Sowerbyella* Community are closely associated with those of the other two communities. Crinoids and bryozoans in the upper Pulaski Shale are interbedded and in places mixed with the faunas of the *Ambonychia-Modiolopsis* Community apparently constituting a part of an adventitious fossiliferous sandstone or coquinite. This brachiopod- and crinoid-dominated community is also interbedded and mixed with the bivalve fauna of the *Nuculites-Colpomya* Community, again especially throughout the upper and middle parts of the Pulaski Shale.

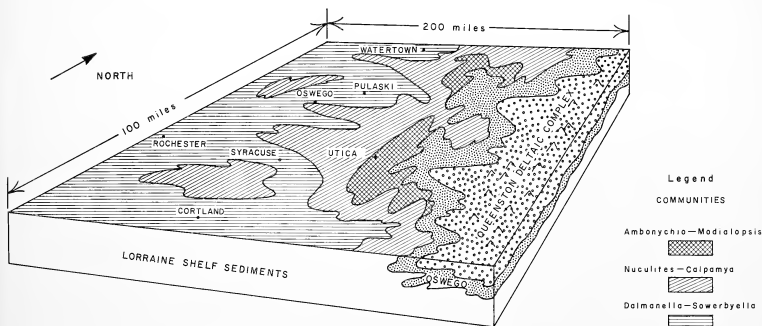
The north-central New York *Dalmanella-Sowerbyella* Community is very similar to the *Sowerbyella-Onniella* (= *Dalmanella*) Community of the central Appalachians and Shochary Ridge in eastern Pennsylvania (Bretsky, 1969; Bretsky and others, 1969), and the Late Ordovician *Thaerodonta-Onniella* Community in southeastern Minnesota (Bayer, 1967).

Differences that exist among the faunal components in these three communities are much less significant than their similarities, especially in the domination of the dalmanellid and strophomenid brachiopods, trilobites, and numerous crinoids (table 3). A very close relationship exists between the New York and central Appalachian communities, although dalmanellids are more abundant and strophomenids less common in New York. The pleurotomariid genera *Loxoplocus* (*Lophospira*) and *Ruedemannia* are common in the north-central Appalachians (Pennsylvania and north-central Virginia) and New York and, in both cases, they occur along the eastern edges of the Upper Ordovician outcrop belt. As indicated above, the *Sowerbyella-Onniella* Community in the central Appalachians included some species that belong to the New York *Nuculites-Colpomya* Community.

Environmental Interpretations

The definition and recognition of these three New York Late Ordovician communities permits a reconstruction of the inferred onshore to offshore community distribution (fig. 14), based on the stratigraphic relationships (fig. 4), present geographic distribution of the faunas and autecological interpretations of the

species. The reconstruction is drawn on the Late Ordovician sedimentological framework of a prograding depositional regime (fig. 3). Figure 15 is a profile taken across this reconstructed Late Ordovician shelf showing the inferred distribution of the abundant faunal elements from their present vertical distribu-



LATE ORDOVICIAN COMMUNITIES
CENTRAL NEW YORK

FIGURE 14.—Environmental reconstruction Late Ordovician communities north-central New York based on stratigraphic, sedimentologic and faunal evidence. The zoogeographic pattern of the communities is portrayed as they may have been distributed at any given instant in time during the deposition of the Late Ordovician Lorraine sediments. As in figure 3 the present day reference points are for scale and do not imply present geographic distribution of the Late Ordovician communities.

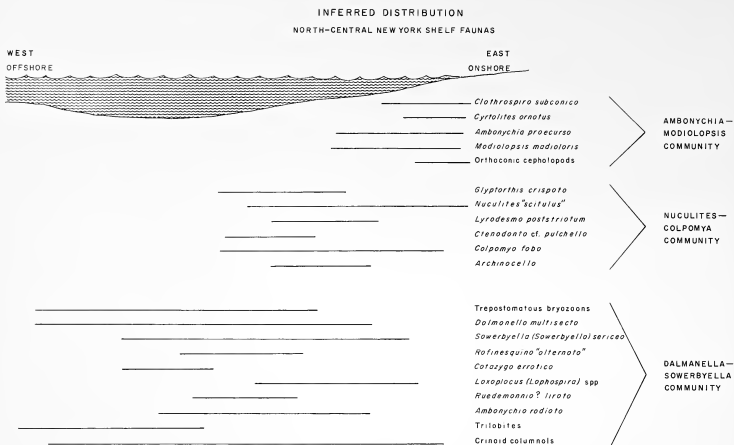


FIGURE 15.—Inferred distribution north-central New York shelf faunas. Refer to figure 14 for areal view of the environmental setting. Species ranges are drawn from their present vertical distribution in the Pulaski Shale and upper parts of the Whetstone Gulf. No estimate of water depth are inferred although the deepest portions of these Late Ordovician shelf environments was probably not greater than 50 to 75 meters.

tion in the Pulaski Shale and upper parts of the Whetstone Gulf Formation. This figure emphasizes the pronounced nearshore-to-offshore change in the abundant faunas, although there is considerable mixing and overlap of the individual species.

The fauna of the *Dalmanella-Sowerbyella* Community was probably outer infralittoral and was abundant away from nearshore turbid environments and regions of relatively high sediment influx. The numerous crinoids and dalmanellid, atrypid, and strophomenid brachiopods are most likely indicative of waters of normal marine salinity. The most favorable substratum was a calcareous silt or muddy silt, although

some individuals lived in coarser sands; the community as a whole is more common in silts. Local patches of slightly mobile, calcareous silt and sand may have given rise to locally higher concentrations of trepostomatous bryozoans, some branches of which show growth around crinoid columnals. The *Dalmanella-Sowerbyella* Community intergrades at some localities with the *Nuculites-Colpomya* Community which was composed primarily of infaunal detritus feeders living in silty muds. Conversely, the *Dalmanella-Sowerbyella* Community was dominated by epifaunal suspension feeders presumably on a firmer silt or fine sand. The *Dalmanella-Sowerbyella* Community graded

shoreward (east) into sands and silts containing a fauna dominated by large epifaunal suspension feeding bivalves comprising the *Ambonychia-Modiolopsis* Community, and graded seaward (west) into fissile gray-black muds and silts, containing only a sparse trilobite-graptolite fauna. The silty bottom was occasionally marked by low, closely spaced interference ripples, and trails and tracks exhibit a fine meandering pattern that is correlated with the deeper or at least offshore *Nereites* facies of Seilacher (1964).

The *Nuculites-Colpomya* Community occupied both outer and inner infralittoral environments and was characterized by the major expansion of infaunal detritus feeding bivalves that were only sparsely distributed in the offshore waters of the brachiopod-dominated *Sowerbyella-Onniella* Community in north-central Pennsylvania. The fauna appears to have been normal marine, although some individuals in nearer shore environments may have experienced periods of variable salinity. The substratum presumably was a silty mud, but the community shows some noticeable onshore to offshore changes in faunal composition. Intergrading with both offshore *Dalmanella-Sowerbyella* and nearshore *Ambonychia-Modiolopsis* Communities, the deeper-water faunas of the *Nuculites-Colpomya* Community contained greater numbers of the orthid brachiopod *Glyptorthis crispata*, the modiomorphid bivalve *Colpomya faba*, and the monoplacophoran *Archinacella*. In contrast, the nearer shore faunas, those interbedded with the *Ambonychia-Modiolopsis* Community, exhibit a greater diversity of burrowing, infaunal desmodont bivalves *Rhytmya*, *Cymatonota*, *Cuneomya*, and *Psilocoencha?* Lesser numbers of *Colpomya faba* are found in the nearshore regions but do occur with some patches of graptolites; it is suspected that these small mussels may have been attached to other planktonic forms and floated in like the graptolites. *Nuculites* also undergoes considerable size changes from offshore deposits where it is only 4 mm in length, to nearshore deposits, where it mea-

sures 1.7 cm (measurements medians of slightly less than 100 specimens). The size differential, if significant, may be the result of this protobranch having to maintain a certain distance beneath the sediment water interface; therefore, small size would compensate for decreased firmness of the substratum with increased water content of the muds.

The dominant nearshore assemblage was the *Ambonychia-Modiolopsis* Community, composed primarily of an epifaunal, suspension-feeding, bysally-attached bivalve fauna. This fauna was seemingly well adapted to regions of irregular sedimentation and in areas of mobile bars and barriers; thus most of the species presumably existed on a firm, but slightly mobile sandy substratum. In some areas cut-and-fill channels, bars, crossbedded coquinites, large scale interference ripples and oriented orthoconic cephalopods testify to a reasonably high energy nearshore environment. These fossiliferous marine environments graded landward (east) into transitional nearshore marine and alluvial Oswego orthoquartzites and seaward (west) into the finer silts and shales dominated by the extensive epifaunal brachiopods of the *Dalmanella-Sowerbyella* Community. The lower Oswego sandstones enclose only a very few disarticulated valves of *Modiolopsis modiolaris* and it is thought that much of the Oswego may have been supratidal or alluvial in origin. Biogenic reworking also emphasizes, by analogy with Recent and ancient deposits (cf. *Cruziana* facies of Seilacher, 1964), the intertidal and shallow sublittoral pattern of the upper Pulaski deposits. U-shaped tubes and lobate grazing patterns ("turkey tracks") appear to represent possible parts of intertidal and shallow sublittoral tunnels, burrows or grazing patterns (cf. Shinn, 1968 and Schäfer, 1962). The total *Ambonychia-Modiolopsis* fauna was presumably broadly tolerant and able to withstand the rigors of salinity fluctuations, occasional harsh physical regimes and possibly desiccation, having been attached and partially buried in a slightly mobile substratum.

Summary and Conclusions

The major objectives of this paleoecological study were to outline the benthic marine invertebrate communities that were present in north-central New York during the Late Ordovician, and to compare these community structures with those to the south in the central Appalachians (see Bretsky, 1969). Precise tracing of the faunas between the two areas is not possible because of the Late Paleozoic overlap in south-central New York and northern Pennsylvania, but it appears that a reasonably integrated Late Ordovician benthic community pattern can be constructed for eastern North America despite this gap in the record.

The Late Ordovician benthic communities occupied a westward sloping shelf that was receiving sediment from uplifts to the east, prograding the shoreline westward throughout the Late Ordovician. This shoreline and associated shelf environments have now been traced from north-central Tennessee into central New York; and it has been shown that the area of central Pennsylvania was the region of greatest sediment influx (see especially Yeakel, 1962; Horowitz, 1966). A clastic wedge is readily apparent on isopach and sediment distribution maps of the Late Ordovician (Sloss *et al.*, 1960, p. 8; Kay and Colbert, 1965, p. 170). Previous workers have interpreted this region as representing the development of a major deltaic complex. Although subsidiary clastic wedges developed immediately to the north (Queenston) and south, the same intensity in the amount of sediment contributed to the basin is not exhibited. Thus the development of this major deltaic complex in central Pennsylvania gave rise to a well-delineated onshore-to-offshore sediment gradient, and it is thought that longshore currents reworked some of this deltaic material and transported it southward along the shoreline where it was deposited in the form of bars and barriers (Bretsky, 1969). Thus to the south of central Pennsylvania and extending into central Virginia are developed a number of Late Ordovician nearshore barrier-bar-lagoonal environments that are quite distinct from those delta-front environments in central Pennsylvania (also Horowitz, 1966 and Thompson, 1967). Somewhat similar nearshore environments are found in north-central New York, but they are not as ex-

tensively developed, and are physically cut off from those to the south of the deltaic complex. In south-western Virginia and northern Tennessee, the rate of sediment influx and deltaic progradation is markedly lower so that much more significant amounts of carbonate mud and shells were deposited. In the south the accumulation of substratum depended more on shell debris and less on sediment influx into the area. Thus the onshore-to-offshore sediment gradient becomes very slight in the south-central Appalachians when compared to those in the north-central Appalachians and central New York.

Into this general sedimentological scheme are placed four major benthic community types, each one closely associated with the progradation of the main deltaic complex in central Pennsylvania. The four community types are arranged on p. 28 on a very general bathymetric scale (also see table 3 and fig. 16).

As depicted in figure 16 the distribution of these community types is correlated with the position of the major deltaic complex. Environmental implications may be determined from the amount and type of sediment being delivered to a particular region of the shelf, which in turn would have a direct bearing on the attachment sites or burrowing and feeding habits. Details of the distribution patterns within this overall structure emphasize further environmental controls, such as the selection for broadly tolerant species in some nearer shore environments where the effects of variable salinity and desiccation are added to the sedimentological effect on feeding habits and substratum type.

The degree to which the distribution of the Late Ordovician communities is affected by the location of source areas is observed in the abrupt change that takes place in the nearshore environments on either side of, and immediately off of, the deltaic complex; whereas offshore communities (*Dalmanella-Sowerbyella* and *Sowerbyella-Onniella*) on the apron or fringes of the delta front show little change in faunal composition. (table 3).

Although both *Orthorhynchula-Ambonychia* and *Ambonychia-Modiolopsis* Communities are dominated by

Offshore:

- I { *Sowerbyella-Onniella* Community (north-central Appalachians)
Dalmanella-Sowerbyella Community (New York)
dominant fauna: strophomenid and dalmanellid brachiopods
crinoids
trilobites

Offshore and Onshore:

- II { *Zygospira-Hebertella* Community (south-central Appalachians)
dominant fauna: trepostomatous bryozoans
atrypid and orthid brachiopods

- III { *Nuculites-Colpomya* Community (New York)
dominant fauna: nuculoid, actinodontoid, and
desmodont bivalves

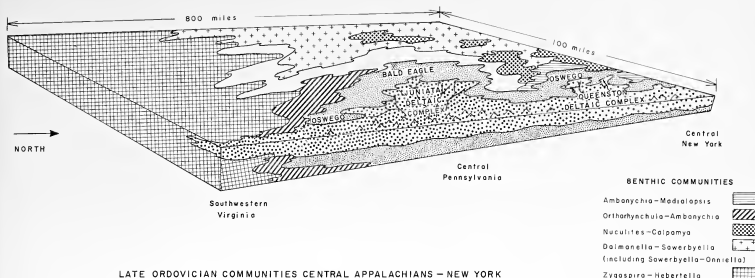
Onshore:

- IV { *Orthorhynchula-Ambonychia* Community (north-central Appalachians)
dominant fauna: rhynchonellid and linguloid brachiopods
ambonychiid and modiomorphid bivalves
bellerophontid gastropods
Ambonychia-Modiolopsis Community (New York)
dominant fauna: ambonychiid and modiomorphid bivalves
monoplacophorans

large, byssate, epifaunal suspension-feeding bivalves, there are significant differences in faunal composition from the community in south-central Pennsylvania and the one in north-central New York, and, in fact, neither community occurs off of the delta front in central Pennsylvania. The most significant faunal differences are seen in the abundance of the rhynchonellid brachiopod (*Orthorhynchula linneyi*), the linguloid brachiopod (*Lingula?*), the bellerophontid gastropod (*Plectonotus?*) and the nuculoid bivalve mollusc (*Tancrediopsis*) in the north-central Appalachians. Seemingly related to this barrier-bar-lagoonal faunal suite (i.e. the bellerophontid, linguloid, and nuculoid) in New York is a much more widespread community, the *Nuculites-Colpomya* Community, that shows neither the bellerophontid or lingulid, but rather an abundance of nuculoid (*Nuculites*, *Ctenodonta?*, *Palaeoconcha*, *Praenucula*) and desmodont bivalve molluscs that were common in some offshore delta-front environments in central Pennsylvania, but have expanded in numbers, diversity, and areal extent in New York. It appears that the offshore nuculoids and desmodonts of central Pennsylvania came to dominate the infaunal nearshore niche in New York, where the detritus feed-

ing nuculoid *Tancrediopsis* is completely absent. This much broader development of the more southerly offshore nuculoid fauna into the nearshore regimes may be a result of larval dispersal problems, *Tancrediopsis*, simply being unable to migrate around the environmental-sedimentological barrier. Possibly current or temperature controls were operative so that the more southerly deeper-water nuculoid came to occupy a nearshore environment in central New York. The acceptance of a possible north-south bathymetric temperature control of the distribution of the nuculoid bivalve molluscs appears to be in conflict with previous paleomagnetic and faunal interpretations of Ordovician paleogeography. Allowing for individual interpretational differences, Irving (1964), Opdyke (1962), Spjeldnaes (1960), Whittington (1966) and most recently Fell (1968) have emphasized that eastern North America during Ordovician time would have been a tropical or sub-tropical environment. In fact, in one instance (Fell, 1968, fig. 2), the latitudes parallel the reconstructed central Appalachian and New York Late Ordovician shoreline.

The large epifaunal, suspension-feeding bivalve molluscs continued to dominate the nearshore regime



LATE ORDOVICIAN COMMUNITIES CENTRAL APPALACHIANS—NEW YORK

FIGURE 16.—Late Ordovician communities central Appalachians—New York. Note that the *Dalmanella-Sowerbyella* (New York) and *Sowerbyella-Onniella* (central Appalachian) Communities have been combined into a single pattern (community type I), whereas for clarity in graphical presentation the *Ambonychia-Modiolopsis* (New York) and *Orthorhynchula-Ambonychia* (central Appalachian) Communities have remained as separate patterns although forming a distinct onshore community type (IV). (See text).

with, however, the addition of the large coiled monoplacophoran *Cyrtolites*, which was not present in the central Appalachians. This represents a possible niche replacement for the browsing detrital-feeding bellerophonid gastropod that was so abundant to the south.

Only a few of the nearshore species occur in numbers in offshore environments; these are the large modiomorphid and ambonychiid bivalve molluscs, both of which are found in small numbers in the *Dalmanella-Sowerbyella* and *Sowerbyella-Onniella* Communities and, incidentally, immediately off the delta front in central Pennsylvania. These are the only species that are common in the nearshore environments both to the north and to the south of the deltaic complex

and it is possible that they are the only broadly tolerant forms able to exist, albeit in small populations, around the perimeter of the delta. Here they could take advantage of the organically rich nearshore regimes in both north and south. Single specimens of *Orthorhynchula*, *Lingula?*, *Plectonotus?*, and *Tancrediopsis* are rarely if ever found in the off-delta front environments in central Pennsylvania. Detailed explanations of the probable migration patterns must remain until further studies are completed in the Mid-Continent and Canada, but it is evident that this major deltaic complex in central Pennsylvania was a major environmental factor in the distribution of Late Ordovician benthic marine invertebrate communities.

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Locality Register

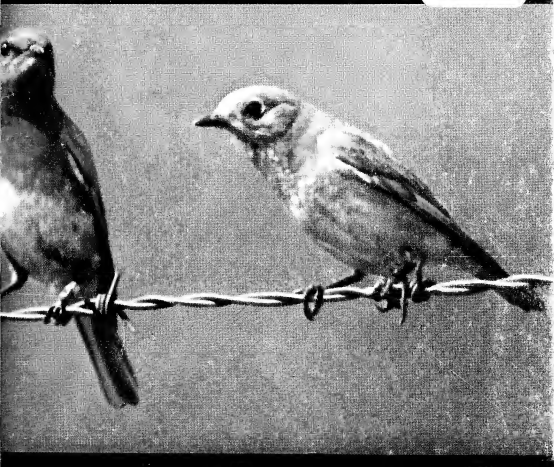
(not including exposures of glacial drift containing Lorraine Group fossils; all quadrangles 1:24,000 unless otherwise noted)

Locality	Description
1	Richland Quadrangle—Road cut at intersection of Oswego County Route 22 (Lacona-Orwell Road) and Lester-Jerry Look Road.
2	Sandy Creek Quadrangle—Road cut 2.3 miles east of Lacona on Oswego County Route 15 (Lacona-Smartville Road); exposure immediately west of cutoff to Boylston Center.
3	Boylston Center Quadrangle—Stream cut 0.3 mile southwest of Winona where stream crosses the Mannsville-Winona Road.
4	Pulaski Quadrangle—Stream cut (Salmon River) in Pulaski Village; exposure along river bank below River Street.
5	Richland Quadrangle—Stream cut (Salmon River) beneath overpass of Rome, Watertown, and Oswego Railroad bridge; 1.3 miles southeast of Pulaski Village where tracks cross Pulaski-Centerville Road.
6-A	Orwell Quadrangle—Stream cut, Salmon River Falls, 1.1 miles east on dirt cutoff from Orwell-Bennett Bridge Road.
6	Orwell Quadrangle—Stream channel cut in front of Red Brick Power Station (Niagara-Mohawk Power Company) Bennett Bridge; 0.1 mile north of Bennett Bridge along Orwell-Bennett Bridge Road.
7	Richland Quadrangle—Road cut along U.S. Interstate 81 immediately north of intersection with New York Route 13.
8	Barnes Corners Quadrangle—Road cut 0.2 mile south of East Rodman along Whitesville Road.
9	Barnes Corners Quadrangle—Road cut 0.1 mile east of Jefferson-Lewis County line along Whitesville Road.
10	Barnes Corners Quadrangle—Road cut 0.2 mile east of locality 9 along Whitesville Road.
11	Barnes Corners Quadrangle—Stream cut (Shingle Gulf) at a point 0.5 mile south of junction of Whitesville and Cronk Corners Roads.
12	Barnes Corners Quadrangle—Stream cut (South Sandy Creek) immediately south of Seven-by-Nine Corners and extending west downstream for 1.1 miles.
13	Adams Quadrangle—Stream cut (South Sandy Creek) 0.2 mile south of Allendale where New York Route 178 crosses South Sandy Creek.
14	Rodman Quadrangle—Stream cuts (Fox Creek? and Big Brook) southeastern part of Lorraine Village.
15	Rodman Quadrangle—Stream cut (Fox Creek south branch) 1.2 miles south of Lorraine along Lorraine-Pierrepoint Manor Road.
16	Boylston Center Quadrangle—Stream cut (Fox Creek) 1.1 miles south of Lorraine along Lorraine-East Boylston Road; 0.4 mile north of Watertown Road cutoff.
17	Rodman Quadrangle—Stream cut (Abijah Creek) at intersection of creek and New York Route 178; 1.0 mile west of Bullock Corners.
18	Rodman Quadrangle—Stream cut (South Sandy Creek) 0.1 mile north of Worth on New York Route 178.
19	Barnes Corners Quadrangle—Road cut immediately east of Babbits Corners (junction of New York Routes 177 and 178) on New York Route 177.
20	Rodman Quadrangle—Stream cut (South Sandy Creek; Lorraine Gulf) 0.3 mile north of Bullock Corners along Bullocks Corners-Tremaines Corners Road.

- 21 Rodman Quadrangle—Stream cut (Fish Creek) 1.0 mile south of Rodman on Rodman-Ross Corners Road.
- 22 Adams Quadrangle—Stream cut (Towle Gulf) 0.9 mile east of Allendale in Washington County Park off of Washington Park Road.
- 23 Barnes Corners Quadrangle—Stream cut (Gulf Stream; Inman Gulf) 0.1 mile north of intersection of New York Route 177 and Whitesville Road at Barnes Corners.
- 24 New Boston Quadrangle—Stream cut 0.1 mile east of Bellwood immediately off of New York Route 177.
- 25 West Lowville Quadrangle—Road cut 0.6 to 0.9 mile west of West Martinsburg along West Martinsburg-Rector Road.
- 26 Sears Pond Quadrangle—Road cut and stream cut 0.2 to 0.4 mile northeast of Sears Pond along Sears Pond-Rector Road.
- 27 New Boston Quadrangle—Stream cut (Deer River) immediately west of New Boston along New York Route 177.
- 28 New Boston Quadrangle—Stream cut near secondary road 0.5 mile north of junction with New York Route 177; junction 0.4 mile west of Bellwood.
- 29 Port Leyden Quadrangle (1:62,500)—Stream cut (Whetstone Gulf) exposures extending 1.8 miles upstream from park entrance.
- 30 Port Leyden Quadrangle (1:62,500)—Road cuts 1.0 to 1.5 miles southwest of Martinsburg along Corrigan Hill Road to Tabolt Corners.
- 31 Page Quadrangle—Stream cut (Whetstone Creek) where Corrigan Hill Road crosses Whetstone Gulf.
- 32 Port Leyden Quadrangle (1:62,500)—Stream cut (Mill Creek) 1.5 to 1.7 miles west of Turin along Turin-Welch Hill Road.
- 33 Lee Center Quadrangle—Stream cut (East Branch Fish Creek) immediately west of intersection of stream and old New York Route 69 at village of Taberg.
- 34 Point Rock Quadrangle—Stream cut (East Branch Fish Creek) 0.8 mile northwest of Point Rock along Yorkland Road.
- 35 Lee Center Quadrangle—Stream cut (Florence Creek) 3.1 miles north of Taberg along Coal Hill Road.
- 36 Lee Center Quadrangle—Stream cut (?Wood Creek or Canada Creek) in Lee Center where stream crossed by Center Road.
- 37 North Western Quadrangle—Quarry at Fink Hollow immediately north of the intersection of the Steuben-Boonville Road and Big Brook.
- 38 Boonville Quadrangle—Road cut 0.9 mile west of North Steuben Church along Buck Hill Road.
- 39 West Leyden Quadrangle—Stream cut 0.7 mile east of Ava along East Ava Road and in Mohawk River.
- 40 Point Rock Quadrangle—Stream cut (East Branch Fish Creek) 0.3 mile east of Swancott Mill along Swancott Mill Road.
- 41 West Leyden Quadrangle—Road cut 0.3 mile east of West Leyden along New York Route 294.

The Behavioral Patterns of the
Eastern Bluebird (*Sialia sialis*)

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New York State Museum and Science Service

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Dedicated to the Memory of
ELON HOWARD EATON
author of
The Birds of New York 1910 and 1914

NEW YORK STATE BIRD

On May 18, 1970, Governor Nelson A. Rockefeller signed chapter 824, section 78 of the State Laws of 1970 and made the Eastern Bluebird the State Bird of New York.

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The Behavioral Patterns of the Eastern Bluebird (*Sialia sialis*)¹

By David C. Krieg²

INTRODUCTION

This study describes the species-typical behavioral patterns of the eastern bluebird (*Sialia sialis*) and interprets this behavior from an ethological standpoint. The author intends to make a comparative ethological study of the genus *Sialia*, but prior to any such study, an attempt must be made to study intensively one species to obtain a comparative standard for the group.

The available literature on bluebird behavior is scattered and concerned primarily with breeding biology (Butler, 1907; Harper, 1926; Low, 1933, 1934; Musselman, 1935, 1939; Pettingill, 1936; Smith, 1937; Brodrick, 1938; Hamilton, 1943; Bent, 1949) with major work being done by Laskey (1939, 1940, 1943) Thomas (1946) and Hartshorne (1962). Reported information on agonistic and courtship behavior is cursory because no bluebird has yet been studied ethologically. Therefore, the conclusions presented here are to be considered first approximations.

Bluebird refers to *Sialia sialis* in this publication.

Sialia sialis was studied in the field through five breeding seasons, 1963 to 1967. Most observations on behavior of the bluebird were made within a 15 mile radius of St. Bonaventure University, the same

¹ Manuscript submitted for publication May 21, 1970.

² Holder of Student Honorarium, New York State Museum and Science Service, 1966. Present address: Department of Biology, State University of New York, New Paltz.

area covered by the annual Christmas Bird Census (*Audubon Field Notes*, April, 1951, pg. 67). Approximately 75 percent of this area is wooded, with the broad Allegheny River valley and tributary valleys open and used to some extent for agricultural purposes (Eaton, 1953), although few farmers gain a livelihood from the soil. The river valley has an elevation of 1400–1500 feet and the tributary valleys extend to 2000 feet. These open tributary valleys provide ideal nesting habitats, at this time, for bluebirds.

Although field studies were made in all the tributary valleys within this area, Wing Hollow, in the township of Allegany, Cattaraugus County, New York, was selected for intensive behavior work. A sheep farm is located in the middle of the hollow and a larger dairy farm is at its mouth. These two operations provide approximately 300 acres of permanent pasture and many rows of fence lines. In addition to these, abandoned orchards, a centrally located brook with a few tributary streams, and electric utility lines, provide good habitat for bluebirds.

Wintering behavior of *S. sialis* was studied from January 10 to January 24 and February 21 to February 28, 1967, in the Apalachicola National Forest, 15 miles south of Tallahassee, Leon and Wakulla Counties, Florida. Observations were also made at Tall Timbers Research Station, 20 miles north of Tallahassee and near the city of Vero Beach, Indian River County, Florida.

Population Buildup

The lack of a sizable breeding population of bluebirds to facilitate an ethological study was overcome by placing nest boxes in the study area. The nest box used was basically the one described by Pettingill and Hoyt (1963) and measured 7 inches deep with a floor space of 5 x 5 inches, a 1½-inch opening, and a hinged top.

More than 100 such boxes were placed in the study area and table 1 shows the number of bluebird pairs using these boxes during the 5 years of this study.

Trapping, Banding, and Marking

Birds were banded and marked for individual recognition. Males, due to their strong territorial attachment and Nest Demonstration Display, could be caught almost anytime during the breeding cycle without abandonment of territory. The most effective trap was a nest box with a manually operated shutter similar to that described by Fischer (1944). A rectangular piece of cardboard (2" x 5"), with

TABLE 1

Number of Bluebird Pairs Using Nest Boxes Over a 5-year Period

AREA	YEAR	NUMBER OF BOXES	NUMBER OF NESTING PAIRS
Wing Hollow	1963	3	1
	1964	3	2
	1965	10	7
	1966	40	11
	1967	43	10
Morgan Hollow	1963	4	3
	1964	3	1
	1965	10	2
	1966	9	1
McClure Hollow	1963	3	2
	1964	3	3
	1965	12	3
	1966	9	2
Smith Hollow	1963	3	2
	1964	4	2
	1965	6	3
	1966	11	3
Five Mile Valley	1963	8	1
	1964	6	2
	1965	13	5
	1966	8	1
Four Mile Road	1963	4	1
	1964	2	2
	1965	6	4
	1966	6	2
Lippert Hollow	1963	4	2
	1964	3	2
	1965	5	2
	1966	5	2
West Branch	1963	4	0
Four Mile	1964	4	2
	1965	9	5
	1966	12	7

a long string attached, was nailed to one side of the entrance. After the bird entered the box, the string was pulled from a distance of about 100 feet and the cardboard moved up to cover the entrance. In the later stages of the nesting period, however, this method was not effective because the males, feeding the young at the entrance, seldom enter the box.

Females are more sensitive and often will abandon the territory after being handled, and therefore, were usually not trapped until the later stages of incubation. The shutter trap was used in some instances but the female was more effectively captured at night as she roosted with her eggs or young. After banding and returned to the nest, she seldom abandoned the territory.

Sometimes a stretch of cold weather early in the breeding season offered an unusual opportunity to capture and band most of the population in the study area. The birds would roost inside the nest boxes and (see roosting, pg. 21) were easily captured and banded at night.

Early in the study, mist nets, and a modified bow trap (that released a net over the box top and entrance when sprung) were used but proved too time-consuming and less effective than the shutter trap and nightly checking of nest boxes.

To facilitate behavior observation, both adults and young were banded. An aluminum U.S. government band, plus one to three colored aluminum bands were placed on the birds' legs. Different color combinations of aluminum bands identified each individual in the area. The most successful colors were white, yellow, red, and green.

To make instant recognition from a distance possible and to gain valuable information on the timing of the molt, the remiges or rectrices were painted with white, red, or yellow airplane dope (see Lanyon, 1957).

TABLE 2

Number of Adult and Young Bluebirds Banded During Each Year

YEAR	ADULTS	YOUNG
1963	—	90
1964	10	180
1965	47	81
1966	28	66
1967	7	13
Total	92	430

Collection of Data

Field observations were made almost daily from the arrival of the males in mid-March until the young had fledged. The visits varied from 1 to 7 hours, depending upon the weather, time of the breeding cycle, and activity of the birds. Occasional shorter visits were made in late summer when the birds were molting, and again in the fall when they were flocking.

Observations were facilitated by 7 x 35 binoculars and a 20X spotting scope. Notes in the field were tape recorded for later transcription. Outline maps, taken from aerial photographs, were used to record the location of activities and to chart the location, size, and shape of territories. The portable blind used initially proved unnecessary, for observations could be made in the open from 20 to 30 yards without disturbing the birds.

To obtain data on pair formation, agonistic behavior, and maintenance of territory, both stuffed (with and without recorded vocalizations), and live decoys were placed in the territory and the pairs' reactions recorded. These experiments were highly successful and similar to those used by Lack (1953) and Dilger (1956a). Power (1966) using this type of investigation on *Sialia currucoides* had little success, because the birds ignored the decoy.

The decoy and tape recorder (if vocalizations were used) were placed on a fence post by the nest box or elsewhere in the territory. A 50-foot wire extended from the tape recorder to the observer and by closing the switch the vocalizations could be played. Live decoys were kept in ordinary bird cages (12" x 7" x 12") tied to fence posts inside the territory. No tape recorded vocalizations were used. The live decoys elicited much stronger responses from the territorial pairs. The results of some experiments were recorded on 16 mm color film for later analysis. Over 100 experiments were conducted.

Vocalizations were tape recorded at 7½ IPS (inches per second). Sometimes in the field the birds were so close that vocalizations were recorded on the portable tape recorder with the microphone mounted on a 24-inch parabolic reflector.

In July 1966, eight young were taken from three nests at the age of 8 days. They were kept in a 10' x 10' x 10' (length x width x height) indoor flight cage connected (by a window that opened) to a smaller outdoor cage, 8' x 6' x 8'. In March 1967, three pairs were removed and placed in separate indoor cages approximately 8' x 6' x 8'; the fourth pair remained in the indoor-outdoor cage. Three of the four pairs mated and laid eggs, but no young were successfully raised. In the fall of 1967, the flock was reduced to two pairs and kept

in an indoor cage (8' x 6' x 8') until March 1968, when they were separated for breeding.

The first cages, constructed of $\frac{1}{2}$ -inch mesh hardware cloth, proved unsatisfactory as rectrices and feathers at the base of the bill were lost when caught in the small mesh. Welded wire of 1 inch by 2 inch rectangular mesh was then used satisfactorily to cover the front and top. Each side consisted of two 4' x 8' sheets of $\frac{1}{2}$ -inch plywood nailed together. The wooden sides with the wire front and top rested against the back wall of the room. Each cage contained perches, nest box, infrared light, and a continual supply of food and water. In one cage, the birds were observed through a "one-way glass" window on the side of the cage.

Data on the ontogeny of maintenance activities came from three young, hand-reared from 5 days of age. The birds were released when 30 days old.

Some observations were also made on two pairs of hybrid bluebirds (*Sialia sialis* x *Sialia currocooides*) obtained from Dr. Robert Nero, Manitoba Museum of Man and Nature, Winnipeg, Canada (see Lane, 1968). The birds were housed in a 7' x 5' x 8' cage from September 1967 to March 1968 and then placed in separate 7' x 5' x 8' cages for breeding.

Behavior of the captive birds was recorded in notebooks and on color film, using a Bell and Howell Model 432-A Super 8 camera with a 5 to 1 zoom lens. These movies were later analyzed; 35 mm photographs were made in the field and laboratory with 125 mm and 300 mm lenses.

The laboratory diet of captive birds consisted mainly of Ken-L-Ration Burger for dogs, dried currants, and sumac (*Rhus typhina*), mealworm (*Tenebrio* sp.) larvae, insects, and various fresh fruits were given as supplements. Commercial vitamins (e.g. Vi-Sol) were added to the drinking water or mixed in the food.

ACKNOWLEDGEMENTS

I am especially indebted to Stephen W. Eaton, Professor of Biology at St. Bonaventure University, St. Bonaventure, for his advice and guidance during this study. He was very helpful in obtaining nest boxes, tape recorders, photographic supplies, aviaries, and other equipment needed during field and indoor work and generous in allowing unlimited use of his personal library.

Thanks are due to Wilson Baker for his hospitality at Tall Timbers Research Station, Tallahassee, Fla.; Anthony Moriello for preparing the drawings of the bluebird postures and displays; Jerry Noles for assistance in photographing wild bluebirds; Vernon Rounds for technical advice; and Marvin Wing for permission to use his land as a study area.

Field work was supported by a Student Honorarium grant from the New York State Museum and Science Service and one from the Chapman Fund of the American Museum of Natural History.

The cover photograph was taken by Ralph S. Palmer, State Zoologist, who has also helped in many other ways.

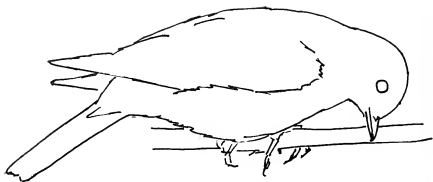


Fig. 1 Eastern Bluebird Bill Wiping

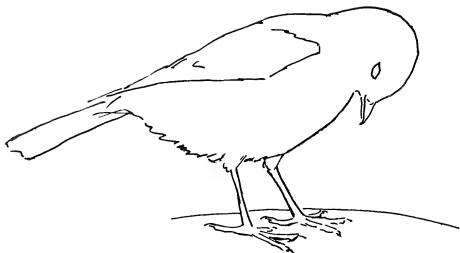


Fig. 2 Eastern Bluebird Nodding

MAINTENANCE ACTIVITIES

Marler (1956) defines maintenance activities as "those activities which are concerned with locomotion and the general health and efficiency of the body, mostly occurring throughout the year."

As Ficken and Ficken (1966) point out, maintenance activities are not only important in the animal's survival but also in understanding the evolution of bird displays. They may even be useful as taxonomic characters.

Because maintenance activities often provide the raw material from which agonistic and sexual displays have evolved, understanding these activities is essential to understanding the specialized displays derived from them.

CARE OF THE BODY SURFACE

Bill-wiping

The body is lowered and directed along the perch. The bill is wiped from base to tip, on alternate sides of the perch several times in succession, often with short pauses between. Incomplete bill-wiping movements were first seen in young 12 days old.

Wing-flapping

Young in the nest rise up on their legs, stretch out both wings and flap them vigorously. The bird then settles back in the nest and may preen the wings. Wing-flapping was first seen in young 11 days old and either disappears or is rare in adult birds (some flapping may be used in drying movements). Wing-flapping helps arrange the flight feathers and with preening may aid in breaking the sheaths enclosing the feathers.

Head-shaking

Head-shaking is uncommon in nestling bluebirds although Dilger (1956b) commonly found it in fledgling and young thrushes (*Catharus* sp. and *Hylocichla* sp.), but not in adult birds.

I observed it only once in nestling bluebirds. A 5-day old stretched its neck in the air then shook the head and neck laterally. This is quite common in adults, but the neck is not extended. Head-shaking can occur with bill-wiping, bathing, drying, and often is associated with feather settling movements, especially ruffling and shaking the plumage.

Head-shaking is also associated with food rejection. Both young and adult birds will open the mouth wide then shake the head violently until the unacceptable object is removed. Pellets (compacted indigestible food remains) can be cast without violently shaking the head. As the bill is opened there are throat movements, and the pellet is voided.

Nodding

Nodding is a deliberate downward head movement with the bill pointing directly at the perch. The nod, held momentarily as the bird

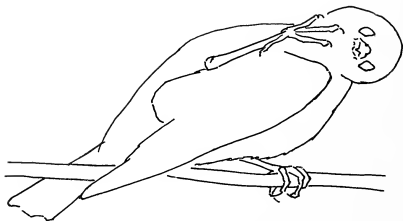


Fig. 3 Eastern Bluebird scratching the throat indirectly

"inspects" the feet or surrounding area, may be successively repeated, then completed by pecking the tarsometatarsus, leg band, or toes, as the bird cleans its feet. After inspecting the feet, the bird frequently preens the belly. If on a flat surface (top of a nesting box), the bird may hop backwards between nods.

Nodding frequently precedes bill-wiping, head-rubbing, and cleaning the feet, and probably is an intention movement to do so.

Yawning

Yawning was first seen in young 9 days old. The bill is opened widely then closed in a deliberate manner, often while the bird is resting. Hartshorne (1962) reports that incubating female bluebirds preen, scratch, and yawn.

Head-scratching

Bluebirds scratch the head indirectly, with the foot moving up and over the dropped wing (Ficken and Ficken, 1958; pers. obs.). The bill and eyes may be open. The crown, sides of the head, and throat are scratched.

Extended-scratching (Simmons, 1961) is used to oil the head feathers. After bathing, the bird obtains oil from the uropygial gland with its bill, scratches first the bill, then the head, moving the head in an irregular fashion underneath the foot.

Head-scratching was first seen in young 12 days old. The first movements appear awkward with many incomplete attempts as the bird loses its balance. One young scratched under the wing (direct) with the foot, scratching the breast instead of the head.

Stretching

The bluebird uses the same three main types of stretching as the other North American thrushes (*Hylocichla* sp. and *Catharus* sp.) studied by Dilger (1956b).

1. One wing and leg stretch. The tail is spread, then the wing is lowered and extended as the leg, on the same side, is lifted from the perch and stretched down and outward with the wing. The tail is spread toward the side of the wing and leg stretch.
2. Both wings up stretch. Both wings are stretched up over the back, partly unfolded, then returned to the side.
3. Both legs stretch. Both legs are stretched together lifting the bird from the perch with a corresponding lowering of the head, lifting of the rump, and depression of the tail, giving the bird an arched appearance. This is the rarer type of stretching. An

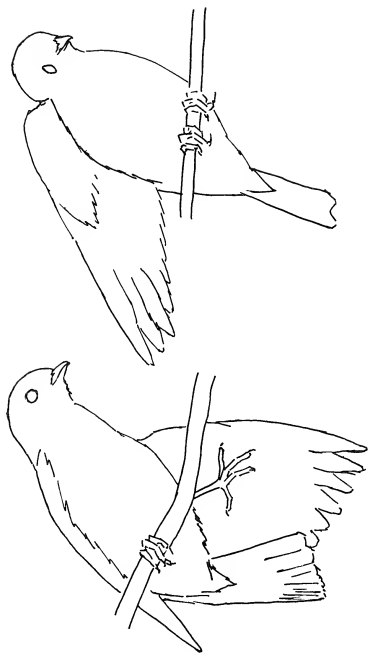


Fig. 4 Eastern Bluebird stretching. Left — one wing and one leg stretch; right — both wings upstretched

adult female in captivity gave both wings up stretch and both legs stretch simultaneously.

Any of these types may occur alone or in a sequence with the others. The most common sequence is: one wing and leg stretch, both wings up stretch. This can be continued to include the other wing and leg or both legs stretch. A typical full stretching sequence in the thrushes studied by Dilger (op. cit.) is to first stretch both wings over the back, then stretch a wing and leg on one side, stretch the wing and leg on the other side, then stretch both legs. This kind of sequence, one type (wing and leg) followed by the same type (wing and leg), did not exist in the bluebirds I studied in the field and aviary.

Stretching was first seen at the age of 9 days. In addition to the three types described above, young bluebirds employ the both wings down stretch. This movement has been reported for other species (Andrew, 1956; Dunham, 1964; Ficken, 1962b; Nice, 1943) and becomes rare or nonexistent in adults.

The both wings down stretch is usually given with the both legs up stretch in young bluebirds. The bird pushes up on the legs lifting the rear end and at the same time stretches both wings out and down. The head is tilted down and the back arched up. The wings down stretch can be given without the both legs stretch but they usually occur together.

Both wings down never was observed in adult birds and Ficken (op. cit.) considered it a transitional movement in the redstart (*Setophaga ruticilla*) giving rise to the wing and leg sideways stretch. This is not a transitional movement in the bluebird. Both types (both wings down; one wing and leg) are well developed by the 10th day and both are used until the young bird leaves the nest (17th day, Hartshorne, 1962; pers. obs.). Possibly, the disappearance of the both wings down stretch in adults is due to body mechanics preventing the fledged bird from performing this stretch without losing balance. (A captive 16-day-old bird spent most of the day out of the nest and performed the both wings down only once, but performed it frequently in the nest at night.)

Preening

Preening was not studied in detail. The bird can reach all areas of the body with the bill except the head and neck. Remiges and rectrices are cleaned by being drawn through the bill. The eyes are usually closed.

Young will preen the remiges and rectrices before the feathers have broken through the sheaths and by the age of 9 days all major feather

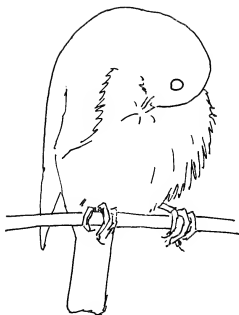


Fig. 5 Eastern Bluebird preening the breast

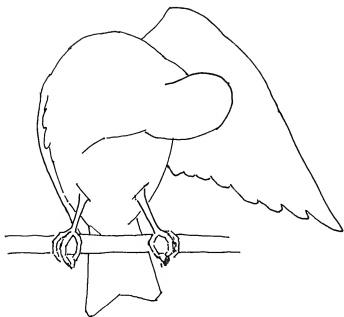


Fig. 6 Eastern Bluebird preening under the wing after bathing

tracts are worked by the bill. Nibbling on a feather or sheath is interspersed with preening.

Bluebirds were not seen to eat dislodged feathers but Dilger (A. Weisbrod, 1965, Unpublished Masters Thesis; Cornell University) has observed juvenal and adult thrushes (*Catharus* sp. and *Hylocichla* sp.) eating feathers and feather sheaths.

The tarsus and toes are pecked (sometimes scales are nibbled) to clean them. Both wild and captive birds show considerable irritation after being marked with aluminum bands. They peck at and even grasp the band with the bill, pulling at it, causing a loss of balance and sometimes toppling from the perch. Aluminum bands were never removed from the legs by the birds themselves as Dunham (1964) reported for the rose-breasted grosbeak (*Pheucticus ludovicianus*).

The feathers near the base of the bill are cleaned by rubbing this area on the side of the perch. The bill is generally open and the rubbing is a slow and deliberate movement progressing from either the front of the head toward the back or from the back toward the front. Bill-wiping is often combined with head-rubbing.

Preening, like many other maintenance activities, acts as a social stimulus with both members of a pair preening together unless one is engaged in another activity. Members of a flock frequently preen in concert. A winter flock (wild) of 18 birds landed in the top a leafless oak tree (*Quercus* sp.) and all preened for 5 minutes before leaving.

Feather-ruffling

This is a feather-settling movement where the body feathers are ruffled simultaneously, in various intensities, then lowered. Ruffling can occur by itself or in association with other feather-settling movements. A typical full sequence would be: the feathers are ruffled momentarily, the bird leans forward, the body is shaken from side to side with a corresponding shuffling of the wings and tail (the tail may also be fanned), the feathers are then lowered as the head is shaken and the bill wiped.

Bluebirds ruffle the body feathers during preening, sunning, drying, and bathing. It is a common displacement activity in many conflict situations and resembles (except the plumage of the head is not laterally compressed nor is the tail spread) the spread display of the wood thrush (*Hylocichla mustelina*) (Dilger, 1956a), but in the bluebird feather-ruffling has not yet become ritualized to serve as a display.

Bathing

Bluebirds have two methods of bathing, dipping and complete-bathing. Either can be preceded by drinking or dipping the bill in the water with a sideways flick of the head, splashing water upon the bird. Both methods consist of two alternating phases :

1. The head and breast are lowered into the water, the bill is shaken from side to side, and both wings are beaten. Sometimes the wing movement may be omitted.
2. The head and breast are raised, the rump is lowered into the water, the tail is spread, and the wings are fluttered.

In dipping, the bird is in the water briefly and may only perform phase (1) before leaving. If both phases are performed they are done quickly and without ruffling the feathers. Bluebirds rarely take one dip but usually return two to three times in succession without thoroughly wetting the plumage.

In complete-bathing (almost always preceded by dipping) the bird remains in the water and alternates between both phases, while ruffling the feathers until the plumage is thoroughly wet. Sometimes the bird will rest between the two phases with the body partly immersed, feathers ruffled, and tail spread on the water, giving the bird a floating appearance. When leaving the water, flight is labored. A bird taking a complete bath is reluctant to leave the water when challenged by a conspecific, whereas a dipping bird will leave immediately.

In captivity bluebirds bathe daily. It is generally a social affair, for when one bathes, the others usually follow. Low ranking birds in the social hierarchy, when thoroughly wet from complete-bathing, were often attacked by dominant birds.

Wintering bluebirds bathed in ditches along highways, swampy areas, and puddles in fields. As many as seven were seen bathing at once. (Also see Thomas 1946, pg. 171.)

The alternate wing movements reported by Nice (1943), Coutlee (1963), and Andrew (1956) were not observed in the bluebird.

Drying

Upon reaching a perch after bathing, bill-wiping, head-scratching, head-rubbing, and preening are common. The body is ruffled and shaken repeatedly and excess water is removed from the plumage by a variety of wing and tail movements.

The wing is extended sideways and forwards, carpometacarpus and carpals raised. The head is bent beneath the exposed wing and the ventral surface of the remiges are preened from base to tip, the bird

giving a slight flick of the wing as the tip of the feather is pulled through the bill. The bird preens the opposite wing, then rapidly alternates between both wings. Interspersed with underwing preening is a rapid opening and closing of the wings and tail as the wings are repeatedly flicked outward and the tail is fanned. In synchrony with underwing preening and lateral flicking of the wings and tail, is an intense whirling of wings that almost lifts the bird from the perch.

The bird may interrupt drying movements and fly rapidly around the cage. As the plumage dries, the bird perches in a fluffed position and continually shuffles the wings and performs other cleaning movements such as preening, head-scratching, rubbing, and bill-wiping.

Sunning

Bluebirds show two responses to the sun (infrared lamp in captivity). In the first the crest is raised, the plumage is ruffled, and the body is directed at right angles to and tilted away from the light source. The bill and eyes may be open. This is essentially the level III of Hauser (1957) except that the wings are not drooped, the tail is not spread, and the feathers are ruffled.

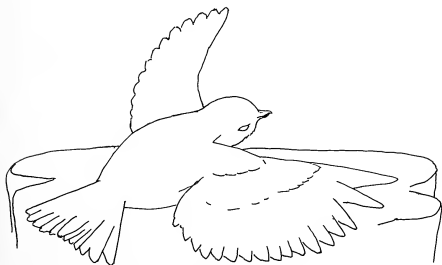


Fig. 7 Eastern Bluebird Sunbathing (Level IV)

In the more exaggerated (level IV of Hauser, op. cit.) form, both wings are completely spread (with each primary being exposed) and somewhat drooped, the tail is spread, crest raised, and body plumage ruffled. The bird lies in a horizontal position on the perch with the head cocked to one side. The bill and eyes may be open. Any part of the body can be directed toward the light source. There is some variation in the degree of spreading the wings. If only one is spread it is the one toward the light source and may be spread in a series of hitches as it moves toward the light until fully spread. Spreading of both wings is more common.

Hauser (op. cit.) mentions the social quality in sunbathing. In captivity as many as four bluebirds would sun together. In the wild, a pair on territory would often be observed sunning together.

While sunning, the bird may perform other maintenance activities without leaving the original perch. A 14-minute recorded sequence for a captive female is: bird lands 15 inches from infrared lamp — scratches side of head — rubs head across perch — sunbathes (level III) — nods, scratches bill — sunbathes (level III) — pivots — sunbathes (level IV) — preens — scratches crown — scratches side of head — preens breast — sunbathes (level III) — scratches side of head — sunbathes (level IV) — scratches chin — nibbles wrist — sunbathes (level IV) — scratches crown — sunbathes (level III) — preens primaries — scratches chin — nibbles wrist — stretches both legs — ruffles feathers and shakes — stretches wing and leg — bird leaves.

Anting

Although captive birds were fed ants (*Camponotus* sp.), they were never observed to ant, i.e. place ants among their feathers. Whitaker (1957), in her resume of anting, listed all the other North American thrushes, except the bluebird, as anting.

FEEDING AND FORAGING

Drinking

Bluebirds normally do not enter the water to drink. They remain at the edge, the bill is dipped into the water and opened, there are throat movements. The head is tilted back and with the bill slightly open there are swallowing movements. Usually three to seven sips are taken at each visit. Head flicks can be given between sips to remove water from the bill.

As many as six wintering bluebirds have been seen drinking at once from ditches and swampy areas along the highways. Caged birds prefer to drink from running, rather than, standing water. Power (1966) when studying *S. currucoides* never observed the birds drinking and felt this need was satisfied by animal juices and green plant food, but Criddle (1927) reported that to induce *S. currucoides* to nest one must provide a nesting box and a watering place for the birds to drink and wash.

Feeding

The bluebird feeds on both animal and vegetable matter; Beal (1915), Bent (1949), Forbes (1880), Forbush (1929), Hamilton (1943), and Hartshorne (1962) list the foods consumed.

The bluebird takes its food mostly from the ground but captures are also made in the air and from the outside foliage of trees and shrubs. Exposed lookout posts afford a clear view of the surrounding terrain (see Preston and McCormick's (1948) report on the eyesight of the bluebird). Once prey is detected there are a few wing beats, the bird glides to the ground, landing with wings raised, seizes the prey, and flies back to the same or adjacent perch. Sometimes they hover just above or skim the top of the ground to make captures. Bent (1949), Power (1966), and Criddle (1927) report that the mountain bluebird (*S. currucoides*) hovers in the air like a sparrow hawk (*Falco sparverius*) before descending to make a capture. I have never seen this type of hovering in *S. sialis*.

The prey is eaten immediately on the ground or carried in the bill to a perch where it is either "scissored" (a rapid sideways movement of the prey back and forth between maxilla and mandible) or "hammered" (beating the prey over and over against the perch). Sometimes the bird will combine both methods. In hammering a large insect (e.g. June Bug) the appendages are often broken off, the elytra removed, and the body swallowed whole. A controlled fall occurs when the bird is "working" the prey on a high perch (telephone pole) and it is dropped or escapes. The bird falls vertically with fluttering wings, sometimes recapturing the prey before it reaches the ground. Power (op. cit.) reported that *S. currucoides* always eats the prey on the spot of capture unless feeding young.

Perches are usually utility lines, fence posts, bare tree branches, small bushes, and even "weed" stalks. When feeding in pine forests, (Sprunt, 1954; pers. obs.) bluebirds will use the lower branches for perches but seem to prefer the bare trunks of the trees as they perch with the body parallel to the ground. When using a utility

line the bird either perches in the typical round-shouldered position (Peterson, 1961), pivoting frequently, or directs the body along the wire in a semicrouch as it peers down. The head may be cocked to one side in either position.

Two methods of flycatching are used in foraging. One is to snap at an insect passing a fixed position; the other is flying from the perch to make the capture in midair. I have never seen *S. sialis* make more than one capture in the air and Marshall (1957), observing both *sialis* and *mexicana*, reported only *mexicana* making several captures in one flight.

Bluebirds sometimes feed on the ground in a manner similar to the robin (*Turdus migratorius*), (Bent, 1949; pers. obs.). When thus engaged I have never seen them use their bill or feet to turn over foliage in search of food as reported by Baird et al. (1905).

When feeding in winter flocks along the highway berm the birds are spread out, mainly along utility lines. There is a constant drifting movement of subgroups and individual birds within the flock as they move back into cutover pine forests to feed on sumac (*Rhus* sp.) and mistletoe (*Pharadendron flavescens*), before returning to the utility lines. Drifting continues throughout the day as the birds alternate between feeding, digesting, and maintenance activities.

Stoddard (1963) lists the bluebird as being especially attracted to recently burned-over ground.

While feeding on sumac, the bird usually perches on top of the spike and bends the head down, pecking the fruit around the feet. The bird may, however, perch on the stem and peck forward or upward at the fruit. Sumac and adult stoneflies such as *Taeniopteryx nivalis*, are an important food source during spring snow storms (Krieg, 1962; Eaton, pers. comm.).

Defecation

For the first few days of nestling life the parents will eat the fecal sacs (Hartshorne, 1962; pers. obs.). A fecal sac is not presented at each feeding. At 5 days the young back to the nest rim, lift the rear, and spread both wings as the sac is voided. This is similar to behavior described by Dilger (1956b) for a young olive-backed thrush (*Catharus ustulatus*) except *ustulatus* does not spread the wings.

Adult birds spread the belly feathers, lower the rear, and lift the tail slightly when defecating. Defecation in fear-producing situations (e.g. holding the bird in the hand while banding) rarely occurred.

LOCOMOTION

Nestlings crawl using their wings as legs. At 14 days the bird can right itself and make short shuffling movements forward and backward. Hopping is well developed by the 16th day. Movement is straight ahead and there are no conspicuous corresponding head and tail movements. Hopping can be rapid or slow.

Bluebirds move along a perch by hopping sideways, sidling (a lateral movement with short alternate steps), and pivot-hopping. In pivot-hopping the bird hops and simultaneously turns its body through a 90 to 180° arc, repeating this, as it moves first one way then the other along the perch. This is similar to "pirouetting" (Ficken, 1962b) in the American redstart except the bluebird does not use it for foraging.

When fully drenched from bathing, bluebirds will climb (with corresponding wing beats) up the cage wire. During molting they will run along a semivertical branch to reach a higher perch.

Pivoting, without lateral movement, is common while perching.

The young leave the nest at approximately 18 days (Hartshorne, 1962; pers. obs.) and can fly short distances (sometimes up to 100 yards). Thomas (1946) reported nestlings, out only a day or two before they can fly, are able to get into a tree by climbing the trunk.

ROOSTING

Resting

In captivity bluebirds spend long periods of time resting in concert. The highest perch is used and an individual distance of 2 feet is normal. The body feathers are fluffed, the head is drawn in and may be turned toward another bird, the bill may be a slight degree upward. Sometimes the legs are fully flexed so the bird rests with the abdomen on the perch. Either foot may be tucked up into the ventral feathers. The eyes may be closed for short periods of time and yawning occasionally occurs.

Rehearsed song (Lanyon, 1960) is given repeatedly.

Sleeping

Young nestlings sleep with the head drooped down over the abdomen. At 5 days the head is held limply in front or curled to the side.

Soon they begin to sleep with the head and neck either retracted or extended, and the head held a little above the horizontal. These two positions persist until the 12th day. Laying the head on the scapulars was first seen at the age of 9 days and by the 13th day the young all slept in the typical adult manner described by Dilger (1956b) and Nice (1943).

Roosting

During the breeding season pairs do not normally roost inside the nest box. The female will, however, spend the night inside the box, throughout the incubation and fledging periods, but rarely will be joined by the male (Hartshorne, 1962; pers. obs.). In cold weather the pair sometimes roost inside the box or even join other bluebirds and roost in one box. As Thomas (1946) and my observations show, pairs that fight over a territorial boundary may roost together at night during cold weather.

Wintering bluebirds, however, will roost communally and a few observations on roosting behavior were made in the Apalachicola National Forest, 15 miles south of Tallahassee, Florida.

Two roosting sites were used. One was the top branches of pine trees (*Pinus* sp.) located in a cutover area 100 yards from the highway. The flock fed in this area during the day and went to roost at sundown in a drifting manner with small groups of two to three or single birds leaving the utility lines and flying to the pines. More than one bird would try to roost in the same branch causing considerable unrest, squealing, aggressive calling, and pushing as birds moved from one tree to another. Sometimes two birds would topple off a branch, grasping one another, and fighting part way to the ground. By darkness the birds were settled and the whole flock ($25 \pm$) roosted in six or seven medium-sized pine trees growing close together. By shaking the trees at dark, an estimate could be made of the number of birds roosting on one branch. Seven birds came out of one treetop but the usual number was one to three.

The other roosting site was an electric power substation located next to the highway approximately 2 miles from the one previously described. When first discovered the weather had turned cold (Feb. 23, 36° ; Feb. 24, 33° ; Feb. 25, 26° ; Feb. 26, 21° (low for month and winter); Feb. 27, 26°) and it is not known if the birds roosted at this site during warm weather. At sundown small flocks (four to 10 birds) gathered on utility lines along the highway and silently, or with occasional location notes, flew into the power station area to roost. Some roosted on the labyrinth of wires, condensers, and beams

inside the station fence but the majority preferred roosting on the top of a steel I-beam that held three large transformers. As many as seven at once flew silently up under the same transformer. Due to the difficulty of observation, the number, posture, and arrangement of the birds could not be determined. The transformers gave off a continual "hum" and probably some heat suggesting that birds roosting under them in cold weather would benefit from this heat and shelter.

Frazier and Nolan (1959) reviewed and described communal roosting in the bluebird. Their report was based on observing five to 14 bluebirds roosting together in a nest box during cold weather. I observed this same behavior (five birds involved) at Wing Hollow, Allegany, New York on March 27, 1966. The temperature was 22° F. and there was 3 inches of snow. On checking the nest boxes at night, box 11S contained five bluebirds, two pairs that had adjoining territories and a migrating male. All five were on the floor of the box with heads facing the south-east corner, bills straight ahead and somewhat raised; the birds were crowded together with those in back snuggled in between with their bills on the side of the heads of those in front. This arrangement is different from that reported by Frazier and Nolan (*op. cit.*) where their birds slept with heads together and bodies pointed downward, forming an inverted cone.

In captivity, preferred roosting spots were unpredictable. Birds would seldom roost side by side but at times as many as four roosted together. As the birds began to roost much unrest and fighting took place. The fighting seemed due more to violation of individual distance than over a "select" roost. Two birds would fight violently on a particular perch with the winner (after some settling movements) leaving, only to try to supplant another bird on a different perch. Movement, therefore, was aggressively from perch to perch. A bird appeared to have no preferred roost or partner.

However, in the winter of the second year in captivity, the flock was reduced from eight to four birds and these four (two pair that had bred in captivity) did show a preference for a particular roost. The one female roosted inside a nest box (the only time in 2 years of observation that a bird roosted inside a nest box) with the male on a perch next to the box. The other male and female roosted on the other side of the cage, each with its preferred perch (not side by side).

AGONISTIC BEHAVIOR

The word "agonistic" comes from the Greek root *agōn* which means "to struggle" and refers to behavior concerned with attack and escape. The term agonistic behavior, as used in this study, has been described by Scott and Fredericson (1951) and includes the general group of behavioral patterns that involve aggressive and defensive fighting, escape behavior, and passivity.

Such behavior results from variations in the actual and relative strengths of the attack and escape tendencies. It is assumed that these tendencies are usually, if not always, simultaneously present (Moynihan, 1955b) but either may be so predominant that the animal simply flees or attacks the opponent. However, as these two tendencies are incompatible (Tinbergen, 1940) the animal is usually in some state of conflict resulting in various displays depending upon the actual and relative strengths of the two conflicting tendencies.

The agonistic displays of the bluebird will be described and their context given. Where possible, the cause and function of the display will be postulated according to the methods described by Tinbergen (1959). Daanje's work (1951) forms the foundation for describing the derivation of display components.

The following definitions of ethological terms are essential to this investigation:

* Display — Those peculiarly standardized and often exaggerated performances, including all vocalizations and many movements and postures, which have become specialized and modified as social signals or releasers. (Moynihan, 1955a)

Ritualization — The evolutionary process responsible for the existence of inter- and intra-specific signaling movements. (Blest, 1961)

* The names of stereotyped display-activities are ordinary words used hereinafter in a special sense, hence are capitalized.

Intention movement — Applies to various incomplete and low intensity movements, so called by Heinroth because they reveal what the animal is "intending to do" to the observer. (Marler, 1956)

Tendency — Is used in the sense of Hinde (1955-56) as given by Marler (1956): "...the readiness to show a particular type of behavior as observed under natural conditions."

Feather postures — (Morris, 1956a):

Sleeked — The feathers are fully depressed against the body, giving it a slim appearance.

Fluffed — The feathers are erected, but only partially, giving the body a very rounded appearance, with a smooth, unbroken outline.

Ruffled — The feathers are fully erected and the body, although rounded, has a ragged appearance, with a broken outline.

ATTACK RESPONSES

Supplanting Attack

The Supplanting Attack of bluebirds is similar to that of most passerine species. The aggressive bird flies toward the perch occupied by another bird, which vacates its perch. Supplanting Attacks, often accompanied by Bill Snaps, may occur in rapid succession resulting in a prolonged Chase.

Supplanting Attack reflects a strong tendency to attack, and as Hinde (1955-56) and Marler (1956) suggest, a more confident expression of hostility than any other form of agonistic behavior.

This "confidence" is shown by both captive and wild bluebirds. In captivity Supplanting Attacks were the commonest expression of aggressiveness as shown by female DG who made 41 Supplanting Attacks upon female W within a 1-hour period. Subordinate birds often left their perch just as the aggressor started to fly. Sometimes this resulted in aggressive Chases with the submissive bird being Supplanted as soon as it alighted on perch after perch. These aggressive Chases were terminated either by the aggressor "losing" interest or by the subordinate refusing to fly and showing defensive threat or some other willingness to Fight. Some Chased individuals landed close to a bird dominate to the chaser thereby ending the Chase with the aggressor perching quietly nearby.

In the wild, a territorial male will Supplant any bluebird it finds in its territory; females often do the same. The Supplanting Attack

is extremely important during pair formation because the pair bond is not formed until, leaving the nest box, the female Supplants the male. As the courtship period progresses this act of dominance by the female becomes more intense. Collisions occur when the bird being Supplanted is highly motivated to stay, i.e. between members of a pair during early pair formation, e.g., females will fly at and knock males off the top of the nest box.

Both sexes make Supplanting Attacks on other species that loiter near the nest box.

Chases

Chases occur during skirmishes between males within and at the boundary of the territory. These appear to be lowly motivated if the birds know one another (i.e. hold adjacent territories). In such cases there may be a series of Supplanting Attacks each followed by a silent, slow, short Chase as the birds move along a fence line or hedge row.

If an unknown male (or pair) moves into the area the Chase is more violent and sometimes prolonged over 300 yards. The pursuer may fly at top speed, dive, and catch the pursued in midair, then topple to the ground, Fighting.

Most Chases occur between males but females have Chased other females out of their territory. After a Chase the male may return and land by his female or nest box and start to sing.

Chases appear to be nonritualized for the pursuer flies at top speed and tries to catch the pursued, often succeeding, resulting in a violent Fight.

Low motivated Chases were rarely seen in captivity; rapid aggressive Chases were the rule, as a dominant bird Chased a subordinate around and around the cage.

Fighting

The average Fight took place between males or between females, as stated by Thomas (1946), but when I placed a live or mounted decoy in the territory of an established pair, both members of the pair attacked whether the decoy was male or female. In the aviary both members of the pair attacked intruding birds of either sex. In the wild, Fights between male and female were occasionally observed. The situation here resembled that described by Lack (1953, pg. 57) with the English robin (*Erithacus rubecula*).

During contact, both combatants may strike with their wings, grapple at one another with their feet, and peck viciously at each

other's head. On April 14, 1966, one combat lasted for 15 minutes; the two males, feet locked together, wings outstretched, and bills open were Pecking at one another as they tumbled about in a ditch.

Experiments with decoys and mirrors showed bluebirds strike one another with both the beak and feet, as do the English blackbird, *Turdus merula* (Brown, 1937) and the American robin (Young, 1951).

In this study Fights never resulted in real injury but Pettingill (1936) reported a female with the crown featherless and bleeding as a result of a Fight with another female and Blake (1954) reported a Fight between two females in which one died. In captivity where escape was sometimes impossible, wounds were inflicted. On one occasion male DY had invaded pair GY and DR's cage through a hole in the wire. When the cage was examined, male DY was wedged in the corner, his head protected by an overlapping 2 x 4, with both male GY and female DR Pecking him viciously in the shoulder region that was completely featherless with a raw wound.

Fights between members of a pair are frequent. The male lands on the female's back, violently Pecking her head several times in succession. Some females will Fight back but the normal response is passive; the female crouches with closed eyes as the male Pecks. These attacks are not strictly agonistic but have a sexual tendency in conflict with the attack and escape tendencies and are discussed under courtship.

If perches are lacking during a boundary dispute, birds may Fight on the ground like robins. They face one another with sleeked plumage, one bird flies up about 3 feet with wings and tail spread and lands, then the other flies up and lands. This is repeated several times and ends either in combat as both fly up and meet in midair, or by one or both returning to guard the nest box or female. Sometimes Fighting is interrupted by a series of zigzag hops by both birds that resembles "pushing" in the American robin (Young, 1951). Thomas (1946) also mentioned this type of Fighting " . . . the males were on the ground within a few feet of each other, teasing at grass. They came face to face, and there was a brief encounter, the two jumping like little cocks; then they hopped in opposite directions and pecked at the ground; . . .".

Pecking

When individual distance is violated, one bird may turn and Peck the other. These Pecks seem weak but usually cause the recipient to flee.

During courtship when the males attack tendency is highly motivated, he lands on the female's back and delivers a series of Pecks to the top of her head. These are impetuous but apparently never harm the recipient. Repeated Pecking is also seen when two bluebirds are fighting.

Both captive and wild bluebirds bite when held in the hand.

THREAT POSTURES AND DISPLAYS

Facing

This is the simplest act of threat in the bluebird and involves turning the head to face the opponent. Facing is usually seen when individual distance (Conder, 1949) is violated among birds in a flock or between members of a pair.

In its lowest intensity the bird merely looks at the opponent with no noticeable feather adjustments. However, if the opponent approaches, the aggressor will sleek the head and neck feathers and lean somewhat toward the approaching bird. In its highest intensity the threat valence of Facing is reinforced by Gaping, Bill Snap, or Rasp and may even develop into a lunge at the opponent.

Gape

In this display the bird turns the head toward the opponent and holds the bill open for several seconds. The closer the opponent advances the wider the bill is opened. In its highest intensity the head is sleeked and the bird leans toward the opponent with the bill held open and finally, may move toward or lunge at the other bird.

Gape reflects a stronger tendency to attack than to flee and is often reinforced with Bill Snap and Rasp giving the display a strong threat valence.

In captive birds this is a common display when individual distance is violated and during such social activities as feeding, bathing, and sunning. In wild birds it is most often seen during encounters between members of a pair, especially during pair formation. For example, when courtship feeding commences the female will often Gape as the male approaches with food or when the male advances to copulate.

Gape is probably derived from an intention movement to bite.

Wings-flicked

In Wing-flicking the bird perches in an oblique position and rapidly flicks both wings out from, and back to the body. The wings are com-

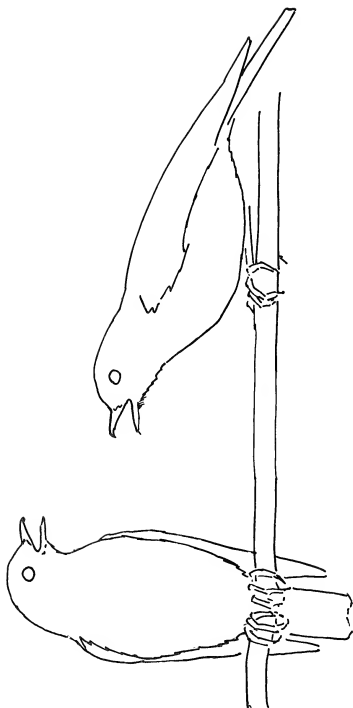


Fig. 8 Two Bluebirds involved in an agonistic encounter. The bird on the left Facing while the one on the right shows Head Forward (stronger attack tendency). Both displays are reinforced with Gape.

pletely unfolded and are flicked simultaneously to a plane level with the body. Tail-fanning and Chatter usually accompany this display.

In the wild, Wing-flicking was employed by both sexes, usually when a live decoy was introduced into a pair's territory. The pair became greatly disturbed and one will start Wing-flicking (usually accompanied by Tail-fanning and Chatter) as it perched within 5 feet of the decoy, usually not facing it. Wing-flicking may then give way to attack. It is also employed in interspecific encounters as when trying to dislodge a starling (*Sturnus vulgaris*) from a nest box.

Dilger (1956a), describing a similar display in *Hylocichla mustelina* and *Catharus* sp., stated that Wing-flicking was indicative of low intensity attack and escape drives and was employed in a vertical plane. The bluebird differs in that Wing-flicking appears to reflect a high attack tendency, and Tail-fanning accompanying the Wing-flicking is given in a horizontal plane.

In captivity when a bird became extremely aggressive and started to harass a subordinate, Wings-flicked was the predominate display. The aggressor would continually give Chatter, Wing-flicking, Tail-fanning and then Supplant and Chase the subordinate.

Wings-flicked is probably derived from a flight-intention movement.

Tail-fanning

The tail is rapidly fanned in and out in a horizontal plane. Tail-fanning never occurred alone, but was always employed with Wings-flicked.

Tail-fanning occurs in the same contexts as does Wings-flicked and is probably a flight-intention movement.

Wings Out

The bird faces its opponent, with legs fully flexed, body horizontal, plumage sleeked, and the wings held out horizontally to the side. The degree that the wings are lifted horizontally from the supporting feathers varies with the attack motivation of the bird.

In bluebirds this display was performed by both sexes (wild and captive) in response to Scream given by a bird held in the hand. The display reflects a strong attack tendency and after adoption a strong aerial attack is given as the bird, uttering Chatter and/or Bill Snaps, dives at the adversary.

Wings Out was only observed in response to Scream and was never seen to be directed toward a conspecific. To typify this:

July 11, 1967; St. Bonaventure Aviary. Six bluebirds are in an outdoor flight cage; all show different stages of postnuptial molt.

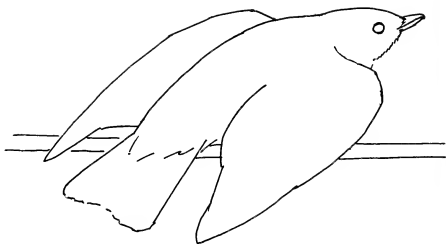


Fig. 9 Wings Out threat display of Eastern Bluebird

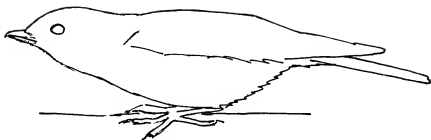


Fig. 10 Eastern Bluebird in Head Forward display

Male Y is captured (to examine the progress of the molt) and while being handled, he Screamed. The other five birds immediately line up on a wire perch in varying degrees of the Wings Out display. Uttering Chatter, they now start to mob me. As they return to the perch Wings Out is again adopted.

This display is similar to the Wings Out Display described by Ficken (1962a) for the redstart (*Setophaga ruticilla*) except in that species it is directed at conspecifics.

The flexed horizontal body with sleeked plumage and extended wings are all flight-intention movements and express a strong attack tendency.

Head Forward

The bird faces the opponent, body horizontal with head somewhat retracted, legs flexed, and tail slightly lowered. The body feathers usually are sleeked and rarely are fluffed. Gaping usually accompanies this display and Bill Snap and Rasp are common. Head Forward often precedes the Supplanting Attack.

In captivity Head Forward often was unsuccessful in causing an opponent to flee and even in its most intense form (orient toward, plumage sleeked, Gape, Bill Snap) the displayer often was Supplanted; thus suggesting a weak threat valence.

Head Forward is a common threat posture in the passerines (Andrew, 1961) and is similar to the Horizontal Stretch of *Catharus* (Dilger, 1956a) and possibly the Attack Run of *Turdus migratorius* (Young, 1951).

Bill-raising

Bluebirds have two postures that involve raising the bill above the horizontal.

- a. Oblique Bill-up — In this display the body is oblique with the head, bill, and tail in line with the rest of the body. The tail may be slightly lifted.
- b. Horizontal Bill-up — The body is horizontal, legs extended, neck somewhat stretched, the head and bill are pointed upward.

In both displays the tail is not spread and Gaping may occur. Normally the plumage is compressed but this varies with the strength of motivation. When the bird is highly motivated (a strong attack tendency in conflict with a tendency to flee or to feed young) the neck and head are extremely sleeked with the belly and breast feathers remaining fluffed. In this conflict state the bird may alternate between the Oblique and Horizontal Bill-up showing ambivalent movements

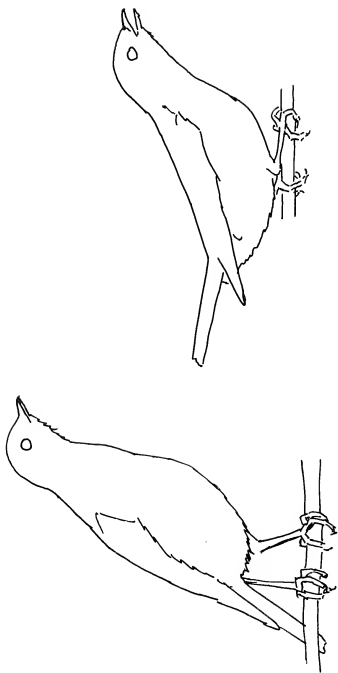


Fig. 11 Eastern Bluebird Bill-raising display. On left—the Oblique Bill-up; on right—the more aggressive Horizontal Bill-up.

toward and away from the opponent. The sleeking of the head and neck reflect a stronger tendency to attack than to flee.

When the bill is raised the two black chin stripes (occurring in both sexes) are exposed to the opponents' view. However, the Bill-up Display has a weak threat valence for the opponent rarely flees.

The Horizontal Bill-up is not as common a display as the Oblique Bill-up and was seldom seen. When observed it seemed to reflect a shift in the strengths of the attack and escape tendencies, with attack seeming more dominant.

Bill-raising is not always directed toward the opponent for when in this posture, a bird can face the opponent, stand parallel to it, or even face away. The displaying bird can incorporate movement into the Bill-raised Display by sidling, pivoting, or pivot-hopping toward the opponent; or when in conflict show intention movements to both approach and flee by hopping in a circle.

In the wild, Wings-flicked and Tail-fanning were never employed with the Bill-raised Display. In captivity, however, both were sometimes used with the Oblique Bill-up. This indicates a stronger attack tendency as the bird adopts the Oblique Bill-up followed by Wing-flicking, Tail-fanning, and Chatter. The bird then flies at and Supplants the opponent.

The following extracts from my notes provide typical observations involving Bill-raising.

June 30, 1967; Wing Hollow; Pair 3S. A live decoy is placed on a fence post approximately 40 yards from the nest box. A predator had just destroyed the nest. Male 3S flies and lands in front of the cage. He assumes an Oblique Bill-up and keeping this posture moves in a circle on the fence post then pivots and starts to move away; assumes another Oblique Bill-up, nods, and touches the tarsus; assumes a Head Forward and flies closer to the cage. Assumes an Oblique Bill-up with breast fluffed then turns away, down into a horizontal position, back to Oblique Bill-up, nods, Oblique Bill-up, flies over cage, assumes Oblique Bill-up with head and neck sleeked, now assumes a Horizontal Bill-up and flies closer to the cage.

February 4, 1966; Indoor aviary; St. Bonaventure University. Female DG assumes Oblique Bill-up then rapidly gives Wings-flicked, Tail-fanning, and Chatter. Now DG Supplants female W. After Supplanting W, DG assumes Oblique Bill-up, Wings-flicked, Tail-fanning then repeats the Supplanting Attack.

January 16, 1967; Indian Springs Camp; Leon County, Florida. 3:20 p.m. Bluebirds are spread out on utility lines along Rt. 369. Suddenly a male flies in and Supplants another male who then moves a short distance. The aggressor now assumes a Horizontal

Bill-up, gives a Location Call then flies at and Supplants the same male again.

3:25 p.m. Two females are close together on the utility line and one assumes an Oblique Bill-up and Gapes. The other female leaves.

4:10 p.m. A female on a utility line assumes an Oblique Bill-up and sidles laterally toward another female who then leaves.

May 18, 1967; Wing Hollow; Pair 10N. 5:15 p.m. Boundary dispute with pair 1N. Two males are on utility line and male 1N adopts an Oblique Bill-up as he faces male 10N. Male 1N assumes another Oblique Bill-up then a Head Forward as he goes and Supplants 10N. After attack 1N assumes Oblique Bill-up but is now lateral to 10N; 1N pivots while still in the Bill-up. Female 1N comes to utility line and male 1N moves back and guards female. Female 10N comes and two pair move closer together and male 1N adopts Oblique Bill-up then three more in succession (now head and neck are sleeked with body fluffed). Male 10N sits Fluffed by his female. Now both pairs leave.

The Oblique Bill-up is similar to the Upward of *Catharus* studied by Dilger (1956a) except that *Catharus* do not sleek the head and fluff the body feathers nor do they incorporate movement into the display. Hartley (1949), however, describes a similar posture in the mourning chat (*Oenanthe lugens*) where the belly and lower breast feathers are fluffed. *Turdus merula* and *T. migratorius* (Andrew, 1961) spread the tail in the Bill-up Display while *Erithacus rubecula* (Lack, 1953) in a similar display raises the tail.

Bill-raising is probably derived from an upward flight-intention movement.

VOCALIZATIONS

Bill Snap

Bill Snap is given (by both sexes) in interspecific and intraspecific encounters. It usually accompanies the Supplanting Attack but can be given with stationary displays such as Facing, Gaping, or Head Forward.

Bill Snapping reflects a strong attack tendency and is presumably, a ritualized intention movement to bite. It occurs in the thrushes of the genera *Catharus* and *Hylocichla* (Dilger, 1956a) and in the American robin (pers. obs.).

Screech

Screech, a single harsh sound given by captive birds, was rarely heard. It is usually uttered when individual distance is violated and may accompany Facing or Gaping.

Rasp

Rasp is a loud nasal sound which can be repeated. It is given in the same situations as Screech and is often uttered by birds engaged in combat. Rasp can accompany a Supplanting Attack but this is rare.

Rasp indicates an attack tendency and seems to function as a threat since it often stops the advance of the other bird when individual distance is violated.

Squawk

In captivity, Squawk is given by a bird being Chased. It is a single vocalization which may be repeated as the Chase continues. Birds caught by the pursuer and sometimes bitten, would utter Squawks.

Similar vocalizations are given in much the same context in such diverse species as Stellers jay (*Cyanocitta stelleri*) (Brown, 1964) and rose-breasted grosbeak (Dunham, 1964).

Chip

Chip, a low pitched soft sound, may be given by females when the male approaches during early courtship. Normally the female is in a Fluffed posture and Faces the male as Chips are uttered. At times Chips plus Facing quell the approach of the male thus indicating a weak threat valence.

"Turring"

This is a single high pitched "turr" which can be repeated to make a series of two to four such notes. Long pauses can occur between "turrs" as the bird remains motionless.

"Turring" is given by both sexes in a variety of situations. Sometimes the acts performed by the displaying bird following this vocalization seem to indicate a relatively strong attack tendency in conflict with a weaker escape tendency. The following excerpts from my notes typify this.

May 14, 1967, Aviary, St. Bonaventure University. Male YW
"turring," he gives a high pitched (barely audible) "turr-turr-

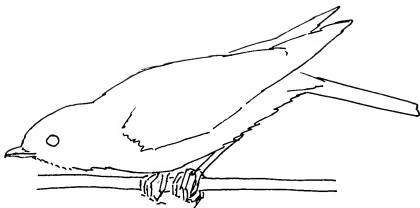


Fig. 12 The Crouch posture of the Eastern Bluebird



Fig. 13 The Alert posture of the Eastern Bluebird, adopted during mild fright

turr" call for 6 minutes from a frozen oblique posture then makes a violent attack upon female W.

April 20, 1967; Wing Hollow. A live decoy is placed two posts away from the nest box of Pair 21S. The female is nest building. Male 21S sits in a tree and preens then flies to a fence post by the decoy and assumes an Oblique Bill-up, pivots, assumes a Head Forward, pivots, then makes ambivalent movements toward and away from the decoy. The male now flies to the top of the cage (decoy inside) and becomes quiet, looks around then gives the high pitched "turr-turr-turr" over and over, then attacks the decoy.

"Turring" is also given during territorial disputes and sometimes, when engaged in a Song Duel, one male will cease Warbling and start "turring." In the wild, "turring" may be given in such a muted form that the observer can only detect it by seeing the pulsating throat feathers every few seconds as the bird remains motionless. "Turring" is frequently heard during early pair formation.

"Turring" is also given in situations that suggest a strong escape tendency thwarted by physical factors, such as a cage or being held in the hand. For example, female DR had laid an egg on the floor of the cage and as I opened the cage to remove it she flew out. After much effort the female was caught and returned to the cage. She then assumed a frozen oblique posture and kept giving the single high pitched soft "turr" over and over (13 "turrs"/minute). Sometimes birds that have just been caught and are being hand held will give this soft "turring." In this situation there are no pauses between each "turr."

It may be possible to subdivide "turring" on the basis of form and function into different vocalizations when more observations are available.

Chatter

Chatter is a loud continual "chit-chit-chit" uttered in rapid succession but can, during mild alarm, be given as a single harsh "chit." Chatter has a low alarm threshold and may be given in response to any general disturbance, e.g., ground predators (cats, dogs, *Elaphe obsoleta*, *Peromyscus* sp., mounted saw-whet owl); novel stimuli introduced into the cage (aquarium, sumac); disturbances around the nest boxes (humans, starlings, cows). Chatter given in these contexts seems to indicate a stronger escape tendency in conflict with a tendency to approach (novel stimuli) or to attack (predators). The birds will Chatter as they hover over the form of stimulus or will fly rapidly to the top of the cage, clinging to the wire and Chattering.

Chatter is also given by both sexes in intraspecific encounters. In this context Chatter usually accompanies Wings-flicked and Tail-fanning Display but may, depending on the motivation, be associated with Bill-raised Display, Supplanting Attack, or Chasing. In these situations Chatter seems to indicate a stronger attack tendency in conflict with a weaker escape tendency. This was especially evident in captivity where dominant birds would harass subordinates by repeated Supplanting Attacks preceded by Wings-flicked, Tail-fanning, and Chatter.

Territorial males, involved in disputes with neighboring males or a new female will Chatter in flight as they fly to a nest box, song perch, or territorial boundary. Chatter in these instances can precede and become continuous with Warble.

Chatter was observed to be associated with panicking only once. A live Cooper's hawk (*Accipter cooperii*) was brought into the indoor aviary and all eight captive bluebirds immediately panicked. There was an outburst of wild activity as the birds flew around and around the cage, often striking the sides. Chatter was given continuously.

Scream

Scream was only heard to be given by a captured bird. While being held in the hand for banding or examination the bird uttered a loud harsh Scream. Scream may be associated with an attack tendency for while Screaming, the struggling bird will often bite the captor's finger. Also, Wings Out Display, associated with a high attack tendency, was the only display seen in response to Scream.

ALARM BEHAVIOR

Crouch

Young bluebirds inside the nest box will Crouch as a response to the parent's Chatter, jarring of the nest box, and opening of the top. They flatten themselves against the bottom of the nest, close their eyes, and remain motionless. If removed for banding, they immediately assume this posture when placed back in the nest.

Captive adults may Crouch while giving the Flying-predator Alarm Call, when frightened, or when unable to locate a source of disturbance. The body is lowered as the legs are flexed, neck extended below the body level, throat fluffed, plumage relaxed to sleeked. Birds in indoor flight cages often adopt this posture as they peer out windows or try to locate unusual noises.

Crouching has also been observed in the wild. Females when incubating or brooding will Crouch as the top of the box is opened and both males and females, after being trapped inside the box, will flatten themselves against the bottom of the box before being removed for banding. Birds on utility lines will sometimes Crouch as they appear to scan the horizon. During early pair formation, when the males are extremely aggressive toward the females, the female sometimes will, upon seeing the male approaching, Crouch with sleeked plumage as the male lands on her back and violently Pecks her head. During interspecific encounters bluebirds sometimes combine Crouch with elements of attack when showing defensive threat (see page 29 for explanation of defensive threat). When being mobbed by tree swallows (*Iridoprocne bicolor*) bluebirds will Crouch on the top of the nest box, Gape, and Bill Snap (both elements of attack) as the swallows dive at them.

In captivity, where escape is impossible, they sometimes show a strong but thwarted escape tendency. The bird will Crouch and flatten itself on the perch, head extended and slightly raised, eyes bulged, plumage extremely sleeked with the lateral breast feathers ruffled over the tightly retracted wings. The bird remains motionless peering at the source of stimulation. If startled or approached, the bird will fly explosively, hitting the sides of the cage hard.

Crouching is similar to the Freezing posture described by Dunham (1964) for the rose-breasted grosbeak (*Pheucticus ludovicianus*) and by Ficken (1962a) for the American redstart (*Setophaga ruticilla*). An alarmed bluebird may also Freeze. Usually the body is held in an oblique position, plumage compressed, legs flexed, bill up somewhat, and eyes bulged (see Eaton, 1914, pg. 538 for a picture of young Freezing). However, many times there is no characteristic Freezing posture as the bird remains motionless for varying lengths of time.

Sleeking of the plumage and Crouching are both flight intention movements and exophthalmos may increase the field of view (Marler, 1956).

Alert

Alert is an expression of mild fright and appears to indicate a conflict between the tendency to flee and the tendency to remain. The alarmed bird stands very erect with body feathers sleeked, pronounced extension of the neck, wings somewhat raised from the supporting feathers. The bird is silent, makes ambivalent movements, and may

alternate between a strict vertical and a horizontal position as it peers in the direction of the disturbance.

This posture is assumed when the bird is confronted with a novel situation and upon habituation, gives way to a more relaxed position.

Dunham (1964) pointed out the biological significance of this display. He felt that it minimizes deleterious consequences and maximizes possible advantages of novel situations.

Wing-flashing

Wing-flashing (sensu Hailman, 1960; Horwich, 1965; Selander and Hunter, 1960) observed in captive birds, is similar to Wing-flashing in the mockingbird (*Mimus polyglottos*) except, in the bluebird, the wings are not "flashed" in a series of hitches. Monroe (1964) observed Wing-flashing in the foraging behavior of the red-backed scrub-robin (*Erythropygia zambesiana*). This was the first report of Wing-flashing in the Turdidae that was identical to that in the Mimidae. Dilger (1956a) reported Wing-flashing in the *Catharus* sp. he studied but this appears to be quite different from Wing-flashing in the Mimidae both in form and context.

The bluebird's body is held in a normal position, head slightly extended, wings somewhat drooped. Both wings are brought up in a deliberate manner and fully extended horizontally or vertically, level with, or just above the body, held in this position for a second or two, then returned quickly to the sides. The tail may be slightly lifted and spread.

Wing-flashing was first observed in captive birds, 4 months old when sumac (*Rhus typhina*) was introduced into the flight cage. The birds became frightened and began to Chatter and mob the sumac. They approached the sumac in an Alert posture with a hesitant manner, Wing-flashed, and finally Pecked at and ate the sumac.

In captivity, this behavior was observed in many different situations. Birds Wing-flashed to a variety of familiar and unfamiliar objects. The following, taken from my notes, will serve as examples.

December 8, 1966; St. Bonaventure Aviary; 12:00 noon. Nailed a branch of sumac to the feeding table. The birds were in the outside aviary and came in immediately. All line up on the wire perch and give Chatter. Females W, R, DG, Wing-flash. Female DG Wing-flashes as she lands on a window ledge, water tray, stove pipe, and perch. Others Wing-flash as they land to feed. 12:30 p.m. Birds appear habituated to sumac.

February 2, 1967; St. Bonaventure Aviary; 12:00 noon. A funnel trap with a song sparrow (*Melospiza melodia*) inside is put on the floor inside the aviary. Female DG hovers over the cage, lands next to it and Wing-flashes four times in a row, then bends over

and picks something off the floor, hops, Wing-flashes, hops, Wing-flashes, lands on top of the trap, Wing-flashes, flies to a perch and ruffles and shakes the body feathers.

February 21, 1967; St. Bonaventure Aviary; 10:15 a.m. Put a live black rat snake (*Elaphe obsoleta*) inside the flight cage. Female DG lands on wire above snake and Wing-flashes. Female DR lands on top of nest box and Wing-flashes, flies to perch and Wing-flashes. 10:30 a.m. The snake is removed and male YW goes to perch where the snake had been and Wing-flashes twice. Birds keep hovering and looking in box 3 where snake was last seen.

Although I looked for this behavior in wild bluebirds, it was seen only once. On January 16, 1967, in Wakulla County, Florida, a female bluebird, feeding along the berm of the highway, Wing-flashed then seized an insect in the grass.

The function and biological significance of this display, or whether, in fact, it even exists in the behavioral repertoire of noncaptive bluebirds, remains obscure. In captive birds, Wing-flashing is sometimes given as an alarm reaction when the birds are confronted with strange objects or unfamiliar situations. It has also become individually conditioned and is given irrelevantly without being associated with alarm or fear situations.

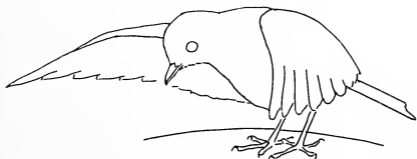


Fig. 14 Captive Eastern Bluebird Wing-flashing to sumac (*Rhus typhina*)

Mobbing

Captive bluebirds less than a year old were observed to show Mobbing behavior in response to the following objects:

- a. High intensity Mobbing response shown to:
 - Live black rat snake (*Elaphe obsoleta*)
 - Mounted saw-whet owl (*Aegolius acadica*)
 - Dead deer mouse (*Peromyscus* sp.)
 - Sumac (*Rhus typhina*)
- b. Low intensity Mobbing response shown to:
 - Mounted tree swallow (*Iridoprocne bicolor*)
 - Mounted eastern bluebird, male (*Sialia sialis*)
 - Mounted great horned owl (*Bubo virginianus*)
 - Mounted red-winged blackbird (*Agelaius phoeniceus*)

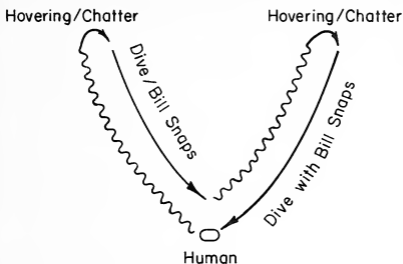
The first reaction during a high intensity response is immediate Chatter as the birds fly rapidly around the cage. As the escape tendency becomes less motivated the birds come to rest on a perch above the object. The plumage is sleeked and the birds may make constant restless movements as they pivot and fly to another perch or they may remain motionless and peer down at the object. Wing-flicking and Tail-fanning can be given as the birds start to hover above the object, uttering Chatter, then flying to a different perch. Diving attacks may be made.

Sometimes subordinate birds would not participate in Mobbing but would assume a Fluffed posture and watch from a high perch in the cage. Females were more responsive than males, as males appeared more fearful of the objects and sometimes completely avoided them. When a bird finally did approach the object, it was slow and from the Alert posture; there would be incomplete intention movements to fly and finally the object would be Pecked. Displacement feather-ruffling was common and Wing-flashing sometimes occurred.

Chatter in low intensity response, if given, was weak and intermittent. A few birds would perch above the object, hover, then lose interest. Often one would approach in an alert posture, Peck the object, then avoid it.

I never observed Mobbing (involving more than one pair of birds) in the wild, yet Sindelar (1967) reported that several eastern bluebirds dive-bombed a meadow vole until it took shelter. However, when I stood by a nest box after the young had hatched, the adults often delivered an aerial attack. This took the form of a Pendulous Display as the bird would hover in midair Chattering, then dive and

give Bill Snaps, return to a point in midair on the other side of me, and repeat the attack. To show this diagrammatically:



Thomas (1946) mentions that bluebirds respond to the distress of other species (“. . . He will join a robin, *Turdus migratorius*, in attacking a blue jay near the robins’ fledgling.”) but I have never observed this.

DISPLACEMENT BEHAVIOR

Tinbergen (1952) defines a displacement activity as “. . . an activity belonging to the executive motor pattern of an instinct other than the instinct(s) activated.” The problem of displacement is very complex and several hypotheses (Tinbergen, *op. cit.*; van Iersal and Bol, 1958; Rowell, 1961) have been presented concerning its cause.

Several times throughout this study, bluebirds in agonistic encounters performed “activities” that were irrelevant and out of context, especially during experiments with live decoys conducted on territorial birds.

It is difficult to know when one is observing displacement activities (Dilger, 1956a) so these observations are tentatively considered as such because they were performed during a conflict situation and were typically incomplete and out of context.

Displacement Bill-wiping

Commonly seen in agonistic situations, the movement is often incomplete with the bill not touching the perch.

Displacement Preening

Any part of the plumage may be preened in a nervous, jerky manner. Usually the feathers are not ruffled (as in preening) or drawn through the bill. The bird may make quick "swipes" at the feathers. Often the head remains sleeked and the bird may give Muted Warble.

Displacement Feather-ruffling

This is similar to the Spread Display of *Hylocichla mustelina* (Dilger, op. cit.) but is not ritualized to serve as a display (see pg. 15).

Displacement Nodding

This is a downward movement of the head varying from a deliberate nod to an obvious lowering of the head with the bill touching the perch. The nod may be held momentarily as the bird wipes the bill, pecks at the feet, or touches the lower breast feathers. Sometimes the bird will deliver several Pecks at the perch.

It is quite possible that nodding is not a displacement activity but has some appeasement value by concealing the bill from direct view of the opponent (it is the opposite of the Oblique Bill-up). However, the nod is seldom directed toward the opponent and often occurs before or after agonistic encounters, when the opponent is no longer present.

Displacement Yawning

Dilger (1956a) mentioned yawning as a possible displacement activity in *Catharus fuscescens*. In the bluebird, yawning was not observed to occur in conflict situations.

Displacement Bathing

Bathing, as a possible displacement activity, was seen twice. On both occasions a male, engaged in a boundary dispute, interrupted fighting and bathed in a creek that flowed along his territorial boundary.

The following extract from my field notes will serve as characteristic examples of displacement activities during conflict situations. Displacement activities are underlined.

June 30, 1967, Wing Hollow; 11:00 a.m. Territory of pair 3S; Nest destroyed by predator. A live decoy (male GY) is placed on a fence post 30 yards from the nest box. Male 3S flies to telephone pole then nods, assumes Oblique Bill-up, pivots, preens nervously around neck, breast, and wing (feathers not ruffled, head is sleeked). Male now flies close to the cage (decoy inside), assumes Oblique Bill-up, keeps his posture and makes a circle on the fence post, nods from Oblique Bill-up and touches tarsus; assumes Head Forward and flies closer to the cage. Feather-ruffles and shakes the plumage, turns away, assumes Oblique Bill-up, nods, nods (both from Oblique Bill-up), nervously preens back and breast etc.

11:15 a.m. Decoy is removed. Pair 3S come to where cage was. Both are excited and male starts "turring." Now both start nodding with the bill touching the perch as they look all around. Male preens very erratically then looks all around, male gives Rapid Warble, Wing-lifting Display, nods from a fluff, and touches bill to post.

11:26 a.m. Male comes back to post where decoy was and hovers, lands, nods, Feather-ruffles, looks around, nods over and over, leaves.

11:30 a.m. Male comes back to where the decoy was, looks around, bill-wipes, then leaves.

Displacement feeding, pecking, and/or collecting nest material

This is usually seen during agonistic encounters between pairs at a territorial boundary. When the birds meet, the encounter is often interrupted as one or both glide to the ground to feed, peck at grass, or make intention movements to do either one. Often intense Fighting is broken off as the birds leave the fence line, glide to the ground, look around, and return to the fence line. This can be repeated several times.

Thomas (1946) mentioned this behavior in bluebirds and made the following statement ". . . the pecking at the ground and tossing of leaves was apparently substitute behavior for fighting at a boundary line."

My observations agree with this.

May 16, 1967; Wing Hollow; Boundary dispute between Pair 19N and 10N. Male 10N advances from bush to bush, he keeps going to the ground as if to feed or pick up nest material; male 19N does the same except he keeps his back to 10N. Now 19N goes to the ground and pecks (pulls?) at grass over and over then flies up to a tree. Male 19N now has a small piece of nest material in bill as he goes from tree to tree. Both birds keep

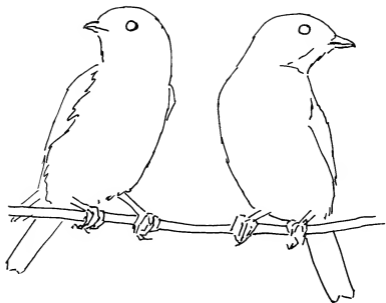


Fig. 15 Two captive Eastern Bluebirds showing Turning-away (appeasement behavior). The bird on right is more submissive.

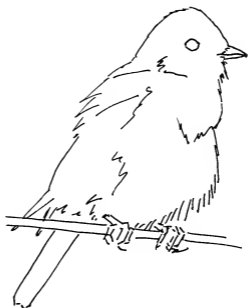


Fig. 16 The Fluffed posture of the Eastern Bluebird

going to ground, sometimes feeding, other times not. Now 19N makes a Supplanting Attack upon 10N.

APPEASEMENT BEHAVIOR

These are displays "designed" to prevent attack by directly reducing the actual and relative strength of an opponents attack tendency, without provoking escape by the opponent or any general reaction by neighbors and companions (Moynihan, 1955b). Smith (1966) stressed their importance as a major feature in loosening the phenomenon of individual distance during pair formation.

In the bluebird two postures were observed that appeared to have an appeasement function.

Turning-away

Turning-away is usually seen during agonistic encounters between members of a pair. It may be observed during boundary disputes between males. It usually consists of fluffing the body feathers and then turning the head away from the opponent. Turning-away may, however, involve the whole body as the bird turns its back on the opponent. When engaged in Song Duels at territorial boundaries the males sometimes perch with their backs to one another as they sing.

In the early stages of pair formation Turning-away is frequently seen when members of a pair are in close contact. This is especially evident during the advent of courtship feeding; if the male does not immediately leave after he feeds the female, either one or both birds will Turn-away as they perch together.

This probably signifies a weak escape tendency, giving the bird a nonaggressive appearance, therefore quelling any agonistic encounters.

Fluffed Posture

The bird perches in a normal position, head retracted, and plumage fluffed. The eyes may be closed and the bill pointed slightly upward. This is similar to the resting posture but differs in context. The Fluffed posture shows an absence of aggressive tendencies and a lack of readiness to act and, in some instances, was observed to reduce the likelihood of attack by another bird. The fluffing of the plumage is associated with the escape tendency, can be considered a submissive display, and in some instances may serve an appeasement function.

This posture is assumed by subordinate birds, by females during pair formation, and, at times, by one or both members of a pair when close together. Often this served as appeasement but several instances were observed where the aggressor attacked even though the attacked bird remained in the Fluffed posture.

It appears, therefore, that in the bluebird the Fluffed posture is not a ritualized appeasement display. It may also occur when the escape tendency is thwarted by an incompatible tendency (feeding, sexual) or by the inability to flee due to confinement.

December 23, 1966; Indoor flight cage; St. Bonaventure University Aviary. Male Y is in a submissive Fluffed posture with the bill slightly raised. He looks at male GY (despot), who is 2 feet away, and closes his eyes. GY Faces Y, gives Rasp twice, then leaves. Now male DY lands on one side of Y and female DG on the other side (both dominant to Y). Y remains in Fluffed posture and looks toward DY then toward DG. Y remained in Fluffed posture for 6 minutes and was not attacked.

January 16, 1967; Wakulla County, Florida. 3:30 p.m. A male assumes an Oblique Bill-up then flies at and Supplants another male who moved only 2 feet and immediately assumed the Fluffed posture with bill slightly raised. The dominate male again assumes an Oblique Bill-up and Supplants the Fluffed male who again moved 2 feet and assumed the Fluffed posture. The male while in a Fluffed posture was Supplanted 20 times in a row by the dominate male. After each attack the Fluffed posture was assumed. These 20 attacks occurred within 3 minutes as the birds moved along a fence line.

May 4, 1967; Wing Hollow. Pair formation between male and female 5N. 4:30 p.m. After being violently Chased by the male, the female goes to a hedgerow and assumes the Fluffed posture (female looks like a round ball with the head drawn in). Male gives Chatter then flies at the female, knocking her from the tree and Chasing her through a hedgerow. The male goes to box 5N; the female to a tree and assumes the Fluffed posture.

Bluebirds also combine the Fluffed posture with elements of attack when showing defensive threat. The body is fluffed with the head retracted but the bird Faces and Gapes at the opponent (both elements of attack).

December 20, 1966; Indoor flight cage; St. Bonaventure Aviary. Female R bathes and on leaving the water is Chased four times by female DR. Now male YW Chases her, hits her in midair and both DR and YW drive her to a corner of the cage where she assumes a Fluffed posture with head retracted but Faces and Gapes at DR who finally leaves. R stayed in this position for 3 minutes.

Dilger (1960) noted that redpolls (*Acanthis flammea*) in captivity, when subjected to persistent attacks by dominate birds, and escape was impossible, showed defensive threat. He pointed out the biological advantages gained by defensive threat. The bird indicates fear but also a willingness to attack if further molested, and if this information is communicated to the aggressor, further attack may be avoided.

REDIRECTION ACTIVITIES

If two or more incompatible drives are strongly and simultaneously activated by the same stimulus (or complex of inseparable stimuli, such as those provided by the mere appearance of an animal or object), the conflict of drives may be resolved by the animal "venting" one of these drives upon some third animal or object (Bastock, Morris, and Moynihan, 1953).

Here the motor patterns appropriate to one of the conflicting tendencies are shown, but are directed toward an object other than that which elicited the conflict. This behavior was seen in captive and wild bluebirds during the reproductive season.

Four pairs of bluebirds were housed in separate (8' x 6' x 8') cages, in the same room, so the pairs could see and hear one another. Redirection was observed when males in adjoining cages engaged in a Song Duel which intensified gradually until the male attacked his own mate instead of the other unavailable male. After such an attack the male would resume the Song Duel and again Warble would intensify to a certain threshold whereupon he attacked the female. One particular instance is worth mentioning:

April 13, 1967; St. Bonaventure Aviary. Pair YW and W. Male YW's Song Duel with the male GY reaches a peak and he starts Wing-lifting and looking around for female W (who is inside the nest box). Finally the Song Duel reaches such a high intensity that male YW flies to the nest box and starts pecking rapidly at the hole. He returns to the wire and starts answering GY again. This reaches a peak and as female W comes out of the box the male attacks, driving her to the floor, Pecking her head over and over.

In this situation it is difficult to imagine that the male's escape tendency is also strongly activated and in conflict with the attack tendency. However, Bastock et al. (1953) mention that, although most redirection activities seem to have resulted from conflicting drives

within an animal, such activities may also occur when a single drive (tendency) is strongly activated and then thwarted.

This appears to be the case in the preceding example. Male YW's attack tendency was strongly activated (due to the Song Duel with GY) and then thwarted (due to captivity), hence the bird attacked its mate. Of the four pairs of bluebirds in captivity, two showed this type of redirection during early pair formation. Kortlandt (1940) mentioned that when an intervening fence prevented two angry animals from attacking one another, one or both would often turn and attack other animals.

In the wild, during spirited boundary disputes, females often showed possible redirection activities. This usually involved a female directing her attack upon her mate.

June 24, 1966; Wing Hollow; Boundary dispute between pair 21S and 20S. ". . . males are now close together on the fence line with their females behind. Now both females go to the ground Fighting. The males remain on the fence posts and wave both wings. The females stop Fighting and return to the fence line and then the males go to the ground Fighting. As the males return to the line there are a lot of Supplanting Attacks. Female 21S keeps Supplanting her mate (male 21S) as they move down the fence line. Male 20S ruffles the feathers, then female 20S does the same, nods, false preens, then her male comes and lands next to her. Rapid Warble is given by both pairs. Female 21S again starts Supplanting her male driving him back up toward the other pair. Female 21S keeps up these Supplanting Attacks on her mate. . ."

This behavior was also observed when both members of a pair were attacking a decoy. As the female was pecking the decoy she would turn and attack her mate. Indeed some females became so aggressive toward the decoy, the mate would be attacked whenever he approached.

It is difficult to label this female behavior as redirection because the attacked male was previously showing threat behavior and may have provoked the female attack. This would also hold true for the female but a male rarely attacks his mate during a boundary dispute or during an attack upon a decoy. It may be that this female display of dominance in conflict situations may strengthen the pair bond.

FLOCK BEHAVIOR

Bluebirds in the nest box form social bonds to one another and will, if separated, crawl together again. Heinroth (1924) points out that nestlings of some species (i.e., chats wheatears, thrushes) lose this

first bond to one another when they first leave the nest and seek separate perches. This is not the case with fledged bluebirds for the young remain together in a close family unit, sometimes loafing and preening side by side and even roosting together the first night out of the box. In captivity, young of the same brood would sometimes roost side by side up to 155 days of age. Low (1934) mentioned the persistence of family groups and reported several instances of trapping young of the same brood a month or two after leaving the nest.

Sometimes the social bond between the parents and young remained through a second nesting with the juveniles helping to feed the second brood (Hamilton, 1943; Laskey, 1939; Wetherbee, 1933; pers. obs.).

In this study juveniles from different family units joined together to form small mobile flocks in late summer. Agonistic behavior then became fairly common, usually consisting of Supplanting Attacks and Chases that occasionally developed into actual combat. Incipient reproductive behavior was also common with females pecking at and mandibulating nest material or males attempting copulation. Juveniles of both sexes eagerly participated in nest inspection. Table 3 shows the size and composition of these small mobile flocks in the Wing Hollow area.

TABLE 3

SIZE OF		COMPOSITION	BEHAVIOR
DATE	FLOCK		
1966			
8/29	4	adult male and female; two young (migrants)	maintenance activity on utility line
	5	female 7N; female 10N; female 20S; two young 10N	one young attempts to copulate with other young
9/12	6	?	feeding along hedgerow
	3	male 7N; female 17S, female ?	nest inspection
	5	?	feeding
	5	male, female 23N; male and two females banded but not identified	maintenance activity on utility line
	11	?	seen by S. W. Eaton on utility line
9/13	5	female, young 10N; male, young 10N; other young ?	nest inspection, much chasing

TABLE 3 (cont.)

DATE	SIZE OF FLOCK	COMPOSITION	BEHAVIOR
	3	male young 10S; female young 21S; female young 10N	nest inspection
	4	young 1N; other young ?	nest inspection
	10	?	on utility lines and left right away
	5	male and female 40S; male and two females (migrants)	nest inspection
9/16	3	young 7N; (one male, two females)	nest inspection
	6	?	feeding on <i>Prunus virginiana</i>
9/24	4	adults; one female banded	maintenance activity, then left
	4	male 40S; male and two females (migrants)	nest inspection
9/25	5	two males; three females	nest inspection
9/28	2	male young ?; female young 10N	nest inspection
	4	male 17S; female 40S; male and female ? (migrants)	nest inspection
	2	female 23N; male young 7N	nest inspection
10/8	4	male and female young 10N; male and female young 10S	nest inspection
	4	two male young 7N; female young 7N; young ?	nest inspection
10/9	2	male 17S; female ? (migrant)	feeding in upper pasture
	1	male 12S	feeding from utility line
	4	two females, young 10N; two males, young ?	feeding along fence line

The size of migrant flocks of bluebirds is quite variable. Bent (1949) reports some flocks with only six birds while other contained "some hundreds" of birds. In southwestern New York, migrant flocks of one to 30 have been seen (Eaton, pers. comm.; pers. obs.). Buck and Bates (1962) report four separate flocks of 50 birds each in the area just north of St. Bonaventure University.

In the winter of 1967, wintering flocks were studied in the vicinity of Tallahassee, Florida. As many as 100 bluebirds (both sexes about equal) could be counted along a 3-mile stretch of highway. I interpreted this to represent several subgroups acting somewhat independently of the main group. These subgroups contained two to 40 birds with the number continually changing as birds moved independently to feeding areas.

Thomas (1946), studying a nonmigrant population, stated that the size of a winter flock was determined by the number of nest sites (boxes) in a locality and the bluebird population of the surrounding country. I did not find this to be the case in a migrant population. To see if wintering birds in the Tallahassee area would show any interest in nest boxes, two were placed on telephone poles where the flock normally fed. Although the boxes were present for 10 days and the birds were always feeding in close proximity to them, no bluebird ever showed an interest (i.e., nest inspection) in them or, in any natural nesting holes.

The noteworthy behavior of these wintering flocks was the relative paucity of agonistic encounters. When feeding, bathing, preening, or loafing, bluebirds showed little aggressiveness toward conspecifics (even when in such close association as feeding upon sumac and mistletoe). Most agonistic encounters recorded involved direct attack on the opponent rather than attack when individual distance was violated.

I had determined that a relatively strong social bond remained among fledgling nest mates so an investigation was made to determine what type of social structure existed in a group composed of birds from different broods. These observations were made on juvenile birds, hand-raised from 8 days of age, and may not be representative of wild bluebirds.

Subgroup 1 consisted of two males (DY, Y) and two females, (W, R) all from the same brood; subgroup 2 contained two males (YW, GY) and two females (DG, DR) from the same brood except male YW.

The two subgroups were housed in separate (3' x 3' x 6') cages until approximately 60 days old. On September 21, 1966, both sub-

groups were placed in a 10-cubic-foot flight cage. Recorded observations were begun a week later and the social hierarchy was determined by examining conflicts involving dominance between caged individuals. A bird was considered the winner of an encounter if its opponent retreated. Between October 1, 1966 and April 1, 1967, 1,480 agonistic encounters were recorded in approximately 76 hours of observations distributed over 82 days.

Table 4 shows the social structure of each subgroup over a 6-month period. Both subgroups were organized in a peck-dominance hierarchy where the relationship between any two birds is determined by which bird wins the majority of encounters. In subgroup 1 the males dominated the females whereas in subgroup 2 the females dominated the males.

TABLE 4

Social Hierarchies of Subgroups 1 and 2 for a 6-Month Period

SUBGROUP 1				SUBGROUP 2					
	DY ♂	Y ♂	W ♀	R ♀	DG ♀	DR ♀	GY ♂	YW ♂	
DY ♂		6	23	6	DG ♀		22	31	26
Y ♂	10		3	2	DR ♀	6		16	19
W ♀	7			3	GY ♂	8	14		72
R ♀	1	1	1		YW ♂	11	3	1	

October 1, 1966 to April 1, 1967

TABLE 5

Social Hierarchy of the Flock (Both Subgroups) for a 6-Month Period

	DG ♀	DR ♀	GY ♂	YW ♂	DY ♂	Y ♂	W ♀	R ♀	
DG ♀		22	31	26	14	17	167	31	pecks: 6
DR ♀	6		16	19	9	9	52	80	5
GY ♂	8	14		72	271	42	85	37	5
YW ♂	11	3	1		121	19	47	33	4
DY ♂	74	55	1	15		6	23	6	4
Y ♂	2			4	10		3	2	3
W ♀					7			3	1
R ♀				3	1	1	1		0

October 1, 1966 to April 1, 1967

Read from left to right in the horizontal rows. The numbers indicate the number of wins by the bird in question. For example in the first hierarchy, DY won six observed agonistic encounters with Y.

Based on the number of encounters, members of subgroup 1 were not as aggressive toward one another as were the members of subgroup 2.

Table 5 shows the social structure of the flock (now considering both subgroups as a single flock) over the same 6 months. The flock was generally organized in a peck-dominance hierarchy but the two subgroups never became integrated. Thomas (1946) reported that winter flocks rarely mingled in the area of their nest sites; in bitter winter weather small flocks might join together but with return of mild weather the newcomers were driven off by the resident birds.

Subgroup 2 completely dominated subgroup 1, especially during social activities such as nest inspection. Nest inspection was a social affair with all members of subgroup 2 participating. The birds derived much excitement from this activity and at times appeared playful even though agonistic encounters were frequent. Members of subgroup 1 were never allowed to participate and if they tried, were immediately Chased. The aviary contained five nest boxes and usually when subgroup 2 was participating in nest inspection at one box, a single member of subgroup 1 would inspect a different box. At times this would be tolerated, but nest inspection never became a social affair for subgroup 1. The following notes typify nest inspection. Members of subgroup 1 (subordinate) are underlined.

November 5, 1966; St. Bonaventure Aviary. Members of subgroup 2 are at box 3 participating in nest inspection. Male DY looks in and is Supplanted by male YW. Male GY rocks, goes in, YW is on top. Female DG goes in with GY, now YW goes in. All three inside the box when GY comes out, lands on a post, YW follows and tries to copulate with GY but GY Gapes and YW leaves.

February 2, 1967; St. Bonaventure Aviary. Members of subgroup 2 at box 5. YW inside box, DG, DR both at hole, DR and YW keep Pecking at each other. YW comes out and pushes past DR who then rocks, DG goes to top of box. Now all leave and go to box 4. DR rocks, goes in, DY lands on top but is Supplanted by GY. Now YW rocks, goes in, DG comes, rocks, goes in, GY comes, looks in (other three inside). YW pushes past GY, W comes to box top and is Chased by GY. DR comes out, GY comes, looks in, rocks, DR Supplants GY at the hole, W goes to box 2, looks in, then leaves right away. R goes to box 5, looks in, leaves. DG still inside box 4, GY comes, rocks, DR Supplants GY at hole. DG comes out and now birds go and feed.

Subgroup 2 also expressed its dominance over subgroup 1 in other social activities, such as preroosting behavior. To typify this:

November 1, 1966; St. Bonaventure Aviary. DG, YW, GY are in the corner of the cage pushing and shoving under and over one another. DR comes in and lands on the back of YW and pushes in between the two birds. Now all either shove under or over one another as they change positions. W and DY now go to opposite corner of cage and start to do the same thing. YW comes and Supplants both of them.

Members of subgroup 1 never roosted next to members of subgroup 2. Birds of subgroup 2 would occasionally roost side by side, but those of subgroup 1 roosted alone throughout the cage.

Group dominance was not expressed toward objects inside the aviary except nest boxes. The members of dominant subgroup 2 defended no special perches, roosting sites, or feeding areas.

Marler (1955) and Dilger (1960) studied the effects of starvation on the social order of chaffinches (*Fringilla coelebs*) and redpolls (*Acanthis flammea*). They found that when starved, less dominant birds became more "reckless" about violating the individual distance of more dominant birds. The same may be said for bluebirds although I did not design specific experiments to show the effects of starvation. Bluebirds are extremely fond of mealworms (*Tenebrio* sp.) and were fed them only once every 2 weeks. At this time (starved in the sense of mealworms) subgroup 1 would usually feed first, followed by subgroup 2. It was not unusual to have both subgroups feeding together, side by side, all uttering a soft, hardly audible "pump handle-like" call with little or no agonistic encounters.

Although both subgroups were organized in a peck-dominance hierarchy, because they were not integrated, a complex peck order, resulted, maintained by both peck-dominance and peck-right. Members of the dominate subgroup 2 held peck-right relations over all or some of the birds in subgroup 1; subgroup 1 lacked peck-right relationships. Table 5 shows this but the following arrangement gives a better indication of peck-right and peck-dominance relationships.

		<u>Peck-Right</u>
<u>GY</u> ♂	*dominates	<u>YW</u> ♂, <u>DY</u> ♂, Y ♂, W ♀, R ♀
<u>DR</u> ♀	"	Y ♂, W ♀, R ♀
<u>DG</u> ♀	"	W ♀, R ♀
<u>YW</u> ♂	"	W ♀, R ♀

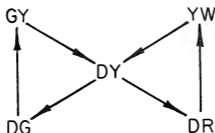
Peck-Dominance

<u>DG</u> ♀	dominates	<u>DR</u> ♀, <u>GY</u> ♂, <u>YW</u> ♂, <u>Y</u> ♂
<u>DY</u> ♂	"	<u>DG</u> ♀, <u>DR</u> ♀, <u>W</u> ♀, <u>R</u> ♀
<u>YW</u> ♂	"	<u>DY</u> ♂, <u>Y</u> ♂
<u>DR</u> ♀	"	<u>GY</u> ♂, <u>YW</u> ♂
<u>Y</u> ♂	"	<u>DY</u> ♂
<u>W</u> ♀	"	<u>R</u> ♀

* Underlined birds are members of dominate subgroup 2.

Note that male GY held peck-right relationships with all members of the flock except his two nest mates, females DR and DG, who both dominated him. Male YW, although a member of subgroup 2 (but never a nest mate for he was from a different brood) was never completely accepted into the group for male GY held a peck-right relationship with him.

Table 6 shows the flock's social structure for each month of the investigation. Because both complete and partial dominance relationships were formed, the flock showed both triangles and dominance reversals. Two of the most notable triangles involved male DY. He was dominated by males GW and YW; yet he dominated both females (DG and DR) that dominated these two males (see below).



Early in the investigation females DG and DR both dominated male DY but he reversed this dominance and by the end of the study completely dominated both females. No evidence indicated that this reversal was due to redirection (*sensu*, Bastock, Morris, and Moynihan, 1953) by male DY because he was completely harassed by males GY and YW.

Figure 17 shows the aggressiveness of each individual over a 6-month period. The relative aggressiveness of each bird was measured by the number of encounters it won per hour of observation each month. Aggressiveness reached its peak during the winter months and declined with the advent of the breeding season (Figure 18). There was no shift (i.e. change in agonistic relations of the sexes as they came into reproductive condition) in dominance such as reported by Hinde (1955-56), Dilger (1960), and Coutlee (1967). This is natural for wild bluebird pairs have an incomplete dominance relationship.

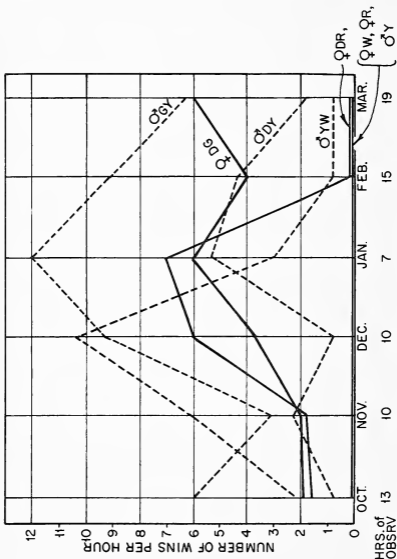


Fig. 17 Seasonal variation in the aggressiveness of individual caged male and female Bluebirds in 1966-67.

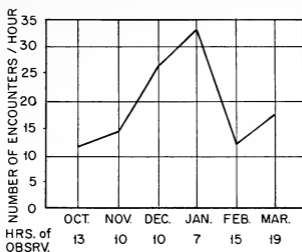


Fig. 18 Seasonal variation in total aggressiveness for the captive flock of Bluebirds in 1966-67.

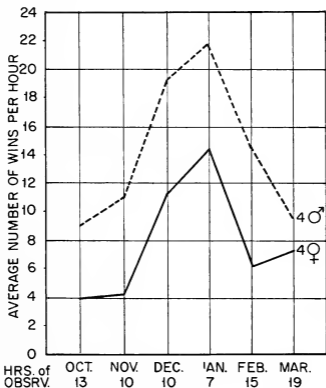


Fig. 19 Seasonal variation in the total aggressiveness of eight caged male and female Bluebirds in 1966-67.

Five members of the flock showed a cyclic aggressiveness phenomenon while the three totally subordinate birds showed none. In general the position in the hierarchy corresponds to the relative aggressiveness of each individual.

Figure 19 shows that males were generally more aggressive than females.

It can be concluded that the social structure in the juvenile captive bluebirds studied, consisted of both peck-right and peck-dominance relationships. Indeed, Marler (1955) in quoting Ritcheny (1951), stated "that it is possible to obtain an apparent "peck-right" relationship in a society that is actually organized in a "peck-dominance." In the bluebird this complex social structure resulted from subgroup 1's inability to integrate with subgroup 2 suggesting that members of a brood (in captivity) retain a social bond to one another and that complete dominance is attained only over members from different broods.

TABLE 6

Social Hierarchy of the Flock (Both Subgroups) for Each Month of the Investigation Period

October 1966								
DG ♀	GY ♂	DR ♀	YW ♂	DY ♂	Y ♂	W ♀	R ♀	
DG ♀	1		2	5	3	8	4	pecks: 6
GY ♂		2	13	16	4	24	17	6
DR ♀			2	5	2	7	9	5
YW ♂				6	2	5	11	2
DY ♂	2		6		2	2	4	2
Y ♂	1		3	1		1	1	1
W ♀				2			2	1
R ♀			3	1				0

TABLE 6 (cont.)

November 1966

	DG ♀	GY ♂	YW ♂	DY ♂	DR ♀	Y ♂	W ♀	R ♀	
DG ♀		1	5	6	1	1	6	3	pecks: 7
GY ♂			6	4	1	5	6	6	5
YW ♂	1	1		16	2	8	16	14	4
DY ♂	1	1	2	1	7	3	5	1	4
DR ♀		1	2	2			5	6	2
Y ♂			1				1	1	2
W ♀				1				1	1
R ♀									0

December 1966

	GY ♂	YW ♂	DY ♂	DR ♀	DG ♀	Y ♂	W ♀	R ♀	
GY ♂		16	21	3	4	14	21	6	pecks: 7
YW ♂			73		5	8	6	3	5
DY ♂				3	5	1	3	1	5
DR ♀	2	3	2		2	3	7	41	4
DG ♀	1	1	3	2		5	25	5	3
Y ♂									0
W ♀			1						0
R ♀									0

January 1967

	DR ♀	DG ♀	GY ♂	YW ♂	DY ♂	Y ♂	R ♀	W ♀	
DR ♀		4	6	5		2	18	17	pecks: 6
DG ♀	2		6	5		4	14	13	5
GY ♂	3	2		12	44	12	7	7	5
YW ♂					11	1	3	6	4
DY ♂	12	17		1				2	4
Y ♂					9			1	2
R ♀						1			1
W ♀									0

TABLE 6 (cont.)

February 1967

	DG ♀	GY ♂	DY ♂	DR ♀	YW ♂	R ♀	Y ♂	W ♀	
DG ♀		10		5	6	5	4	32	pecks: 6
GY ♂	2		101	6	9	1	7	9	6
DY ♂	29			19	3			4	4
DR ♀		3			4	6	2	5	4
YW ♂	5		7	1		2		6	3
R ♀								1	1
Y ♂	1								0
W ♀									0

March 1967 (R and Y removed)

	DG ♀	DR ♀	GY ♂	DY ♂	YW ♂	W ♀	
DG ♀		12	12		7	83	pecks: 4
DR ♀			4		3	11	3
GY ♂				85	16	18	3
DY ♂	20	14			3	7	3
YW ♂				8		8	2
W ♀				3			0

TERRITORY

I follow Noble (1939) in defining territory as "any defended area." The territory of the Eastern bluebird can be classified as Hinde's (1956) Type A. This is a large breeding area in which nesting, courtship, mating, and most food-seeking occur. Powers (1966) found the territory of the mountain bluebird to be Type A.

PHYSICAL ASPECTS OF THE TERRITORY

The nest box or natural cavity is the most important element in the selection of the territory. After selecting a nest hole the male establishes a rather large territory around it. Other thrushes (ex. American robin; Young, 1951) occupy a territory first and then choose a suitable nesting place.

Von Haartman (1956) stated that a suitable hole seems to be the key-stimulus for inducing hole-nesters to choose a territory and that the terrain in which the hole is situated is of slight importance. Again, the bluebird differs, for the terrain in which the hole is located is extremely critical. The territory must contain open fields or abandoned orchards with many perches that can be used for singing, feeding, and display. Grazed pastures are preferred to planted fields. Streams and stands of sumac (*Rhus* sp.) are also important for they assure a food supply (e.g., adult stoneflies and sumac fruit) during early spring snow storms. Bluebirds cannot be induced to nest just by putting up nest boxes and disregarding the terrain.

The number of nest boxes a territory contains has some influence on the maintenance of the territory and hence, maintenance of the pair bond. Once males have established territory, the attachment is steadfast and abandonment is rare. In early pairing-behavior, the male's attachment to the territory (nest box) remains stronger than his

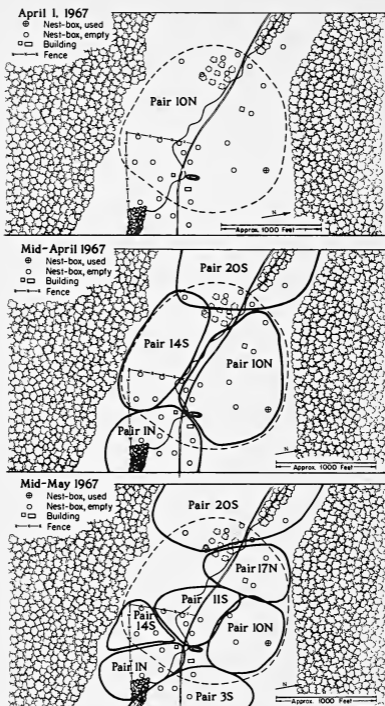


Fig. 20 Territorial changes, Wing Hollow study-area, 1967.

bond to the female. If, for some reason, the female abandons the nest site early in the nesting cycle the male will remain and start advertising again. Some males have mated with as many as four females before a successful nesting was accomplished. Therefore the number of nest boxes during early prenesting is of little importance in maintaining the pair bond. However, once the bond is more firmly established and the pair are midway through the nesting cycle (i.e., incubating or feeding young) other nest boxes within the territory take on added importance in its maintenance. If this nesting is prematurely terminated, the pair usually will remain and renest if other nest boxes are available, maintaining the territory and hence the pair bond. Pair 17S (1966) had five empty boxes in their territory, lost their young on June 7, and maintained their territory for the next 46 days without renesting. Maintenance was carried out mainly by the male leading the female daily from box to box and going through the Nest Demonstration Display while the female watched nearby.

If the territory lacks other nest boxes the male will either abandon the territory or the female, for females rarely will renest in the same box. Although quantitative data are lacking, the male's attachment to the female at this stage appears to be stronger than his attachment to the territory; hence the pair desert the territory and the area completely.

Nest boxes are also instrumental in determining the size, shape, and boundary changes of territories. When first establishing a territory bluebirds do not just select and defend one "box." Depending on the population density they inspect all boxes in the vicinity, using these for Nest Demonstration Display. The general procedure is for early arrivals to frequent a much larger area than they will later defend. Once the female starts to build, the pair confines its activities to one box, but will still defend other boxes in its territory. As the population density increases, nesting bluebirds will surrender certain boxes in the marginal areas of their territory to new arrivals. This results in many boundary changes throughout the breeding season.

Figure 20 shows some territorial changes that took place in Wing Hollow during 1967. Pair 10N were the first arrivals and frequented a large area. By mid-April, males 20S, 14S, and 1N had established territories along the margin of 10N's original area, thus reducing its size considerably. By mid-May, males 11S, 17N, and 3S had carved out territories in the center of the breeding population thus reducing the size, shape, and boundaries of 10N's, 14S's, and 1N's territory.

This figure illustrates several important factors about bluebird territories:

1. Bluebirds frequent a much larger area than they will later defend.
2. Bluebird territories are compressible but their compressibility has definite limits.
3. There appears to be a minimum territorial size and any encroachment is strongly resisted.
4. Unlike most hole-nesters that defend only a nest hole (Von Haartman, 1957), bluebirds defend a relatively large area surrounding their nest cavity.

Von Haartman (op. cit.) also stated that one is able to increase enormously the number of most hole-nesting birds by putting up nest boxes. He increased his population of pied flycatchers (*Muscicapa hypoleuca*) from 10 to 70 pairs in the same study area. Once again the bluebird differs. Figures 21, 22, and 23 show the increase in bluebird population at Wing Hollow from 1965 to 1967. In 1965, 10 boxes were available with five pairs nesting, in 1966 the number of boxes was increased to 35 with nine pairs nesting, and in 1967, 43 boxes were available with 10 pairs nesting.

The most apparent reason for the moderate increase in population was not the increased number of boxes, but rather the selective placement of boxes throughout the hollow, thereby covering all available habitat. The five territories maintained in 1965 remained approximately the same in 1966 and 1967 with some having as many as four empty boxes. New territories were usually established in favorable terrain that lacked boxes in 1965. This same trend prevailed in the other tributary valleys studied.

Bluebird populations, in a given area, cannot be prodigiously increased by just increasing the number of nest boxes. Bluebirds have certain behavioral mechanisms that prevent crowding; namely, the vehement defense of a relatively large area around the nest box rather than just the nest box itself.

Once established, territorial boundaries not containing nest boxes remained fairly rigid. These were formed where there were satisfactory perches for carrying out territorial defense patterns. Early in the season, stretches of bad weather weaken territorial behavior and pairs tend to wander in search of food with hostile encounters when pairs meet.

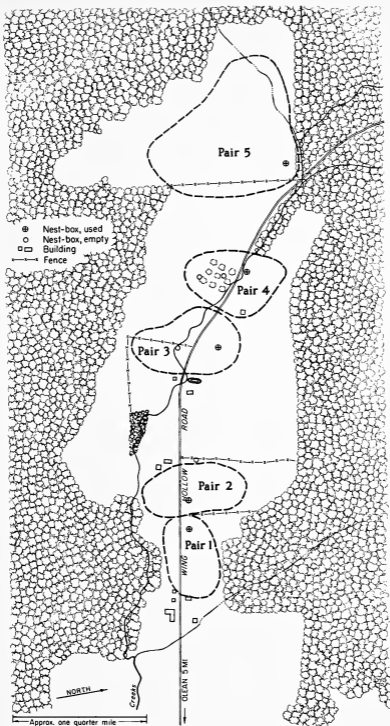


Fig. 21 Territories of *Sialia sialis*, Wing Hollow study-area, 1965.

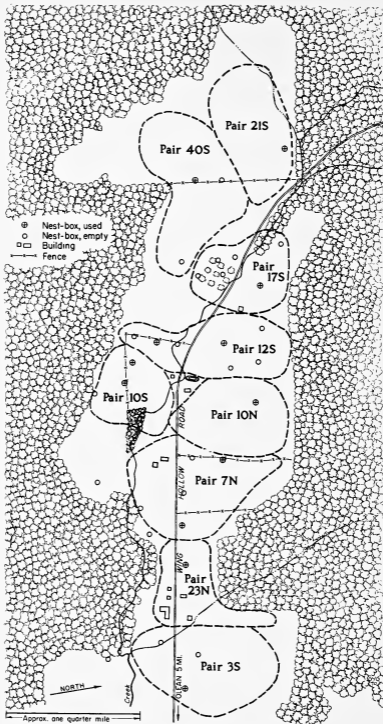


Fig. 22 Territories of *Sialia sialis*, Wing Hollow study-area, 1966.

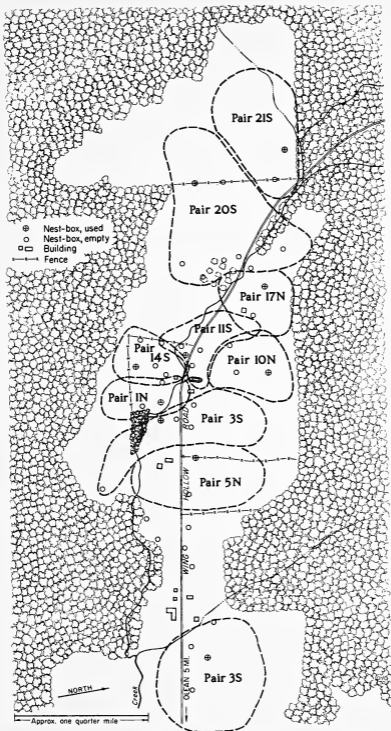
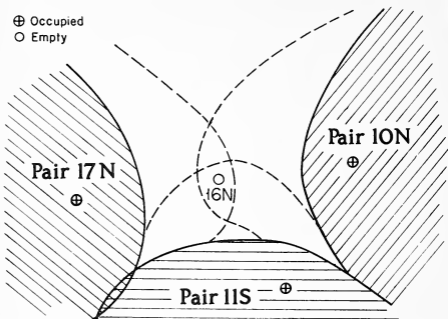


Fig. 23 Territories of *Sialia sialis*, Wing Hollow study-area, 1967.

However, boundaries containing empty nest boxes remained rather fluid (*sensu*, Howard, 1920) with ownership going to the neighboring male or pair in the prenesting phase of the breeding cycle. To show this diagrammatically:



When the pairs were nesting, they ignored this fluid area and maintained a rigid territorial boundary as indicated by the solid lines. If, however, a male lost his mate or a pair had an unsuccessful nesting, they would extend their territory to include the fluid area around the empty nest box, both defending it and using it for display. This situation existed through most of the nesting season in 1967 among pairs 10N, 17N, and 11S. The area around box 16N remained fluid, with ownership continually changing.

Territories were mapped after becoming fairly stable as determined when the female started to carry nest material, concentrating most activities around one box. Field sketches were made of each pair's activities and plotted on an aerial map with size determined by the square grid method (Stains, 1962).

The average size was 15.1 acres in 1966 and 12.1 acres in 1967 (table 7). Figures 22 and 23 show the distribution of territories. In 1966 and 1967 the territories in the center of the study area became smaller and more compact while those at both ends remained approximately the same. This was because the males spread out themselves in early April as seen in figure 20. As the season progressed, late arriving, unpaired males established territory in the center of the popula-

tion rather than at its ends; apparently attracted by the frenzy of continual courtship display. This was especially noticeable in 1967 when males 3S, 17N, and 11S, all late, single male arrivals carved out territories in the middle of the population, rather than at its ends where plenty of empty nest boxes were available. In fact, the area between territories of pair 5N and 3N (see figure 7) contained five empty nest boxes and remained vacant all season.

Late arriving pairs, however, never attempted to "carve out" territories in the center of the population. They always established territories at the ends or extreme margins of the population, slipping in unnoticed with little advertisement.

TABLE 7

Approximate Size of Bluebird Territories, Wing Hollow,
1966 and 1967

Territory 1966	Size	Territory 1967	Size
Pair 10S	8.9 acres	Pair 14S	5.1 acres
Pair 23N	9.9 acres	Pair 1N	5.3 acres
Pair 17S	12.8 acres	Pair 11S	5.5 acres
Pair 12S	15.0 acres	Pair 17N	6.2 acres
Pair 10N	15.7 acres	Pair 10N	8.4 acres
Pair 21S	15.9 acres	Pair 3S	9.9 acres
Pair 3S	18.7 acres	Pair 5N	14.6 acres
Pair 7N	19.4 acres	Pair 21S	16.9 acres
Pair 40S	19.8 acres	Pair 3N	20.5 acres
		Pair 20S	28.7 acres
Mean	15.1 acres	Mean	12.1 acres

ARRIVAL AND ESTABLISHMENT OF TERRITORY

In the North American thrush genera *Hylocichla*, *Catharus* and *Turdus*, the males of the species arrive on the breeding grounds before the females and set up and defend territories against birds of their own species (Dilger, 1956a; Young, 1951). Despite observations to the contrary (Bent, 1949; Todd, 1940) I found that arrival of bluebirds in the Wing Hollow area differs from this thrush pattern (see table 8). Males do not always arrive first, followed by the females. The general pattern was a staggered arrival of male and female birds from mid-March to the beginning of June. As table 8 shows, some birds arrived already paired, especially in 1967; others unpaired. Cold

weather late in March held up the advancing birds farther south, resulting perhaps in pair formation south of their breeding territories.

Most bluebirds that arrived in Wing Hollow stayed throughout the breeding season. The reappearance of both young and adults banded in previous years indicated a tendency to return to the same general area. Kibler (in lett.) however, informed me of a male bluebird he captured for 2 consecutive years in the Jamestown, New York area that was banded as an adult in the Ithaca, New York area some 200 miles east.

Thomas (1946) asserted that at the start of the season unmated males do not take up territory; in Wing Hollow this was not the case. After arrival, the male selects a suitable nest box and confines his activities to its immediate area. At first he is quite secretive, mostly foraging and silently inspecting the nest box. Warble is weak and seldom given although Location Calls are frequent. After a day or two he becomes more conspicuous and starts to advertise the territory in earnest. He becomes very aggressive, continually challenging neighboring pairs. At this time the male enlarges his territory almost daily, taking over as many nest boxes and suitable terrain as the

TABLE 8

Arrival Dates and Pairing Status of Bluebirds, Wing Hollow, 1966-67

Bird	Arrival Date	Status When First Seen	Previous History
Male 10S	March 19, 1966	Paired	Banded as adult, 1965
Female 10S a	March 19, 1966	Paired — left	
Female 10S b	?	Unpaired *	
Male 40S	April 14, 1966	Unpaired	
Female 10S c	?	Unpaired	
Male 10N	March 21, 1966	Paired ?	
Female 10N	March 21, 1966	Paired ?	
Male 12S	March 22, 1966	Unpaired	Banded as adult, 1965
Female 12S	March 23, 1966	Unpaired	
Female 12S a	June 14, 1966	Unpaired	
Male 1N	March 23, 1966	Unpaired	
Female 1N	March 30, 1966	Unpaired	
Male 3S	March 23, 1966	Unpaired	
Female 3S	April 14, 1966	Unpaired	
Female 3S a	June 17, 1966	Unpaired	
Male 38S	March 27, 1966	Unpaired — left	

TABLE 8 (cont.)

Male 7N	April 11, 1966	Unpaired	
Female 7N	April 15, 1966	Unpaired	— left
Female 7N a	May 24, 1966	Unpaired	
Male 17S	April 26, 1966	Unpaired	
Female 17S	April 29, 1966	Unpaired	
Male 23N	May 6, 1966	Paired	
Female 23N	May 6, 1966	Paired	Banded as adult, 1965
Male 21S	June 10, 1966	Paired	
Female 21S	June 10, 1966	Paired	
Male 3N	March 29, 1967	Paired	
Female 3N	March 29, 1967	Paired	— left
Female 3N a	June 17, 1967	Unpaired	Banded as adult, 1966
Male 10N	March 29, 1967	Paired	
Female 10N	March 29, 1967	Paired	Banded as adult, 1966
Male 1N	April 2, 1967	Paired	
Female 1N	April 2, 1967	Paired	Banded as adult, 1966
Male 22S	April 2, 1967	Paired	
Female 22S	April 2, 1967	Paired	Banded as young, 1966
Male 20S	April 8, 1967	Paired	
Female 20S	April 8, 1967	Paired	
Male 14S	April 9, 1967	Unpaired	
Female 14S	April 27, 1967	Unpaired	
Male 5N	April 28, 1967	Unpaired	
Female 5N	May 4, 1967	Unpaired	Banded as adult, 1966
Male 19N	May 13, 1967	Unpaired	
Female 19N	May 18, 1967	Unpaired	
Male 17N	May 20, 1967	Unpaired	
Female 17N	May 21, 1967	Unpaired	Banded as adult, 1966

TABLE 8 (cont.)

Male 11S	May 21, 1967	Unpaired
Female 11S	May 25, 1967	Unpaired — left
Female 11S a	June 5, 1967	Unpaired — left
Female 11S b	June 26, 1967	Unpaired
Male 3S	May 26, 1967	Unpaired
Female 3S	May 31, 1967	Unpaired

* Bond formed between two birds.

neighboring birds permit. Once territory is established the male restricts all his activity to this area. However, in early spring during adverse weather conditions, there are hours and even days when some males cannot be located. Whether they leave the territory in search of a mate or food is not known.

After the male has established the territory he begins to continually advertise his presence in it. Advertisement is carried out by a variety of displays that function both as epigamic and gamosematic displays.

Birds that arrive already paired, select and establish the territory together.

ADVERTISEMENT OF THE TERRITORY

The displays will be treated here only as they pertain to self-advertisement by the male. Once the female has accepted the territory most of these displays still persist but take on a different function. Therefore, the relationship between the male and female will be treated in detail under Pair Formation.

SONG

Warble does not always begin when the first migrants arrive. Weather conditions play an important role because cold spells inhibit song. The highest perches in the territory (tops of dead trees, utility poles and lines) seem to be preferred but Warble is also given in the box vicinity and along fence lines.

I have observed bluebirds singing from any posture, even during extensive preening bouts. However, Warble usually is given from an upright posture with the plumage somewhat fluffed (especially the throat feathers). When singing the bird may pivot and then sing in the opposite direction. Two movements can be performed by the

singing bird. The tail can be spread with each burst of song or the wing may be lifted rapidly in a vertical plane. Both of these indicate a sexual tendency and consequently the presence of a female in the vicinity.

Saunders (In Bent, 1949) described the advertising song of the bluebird as three to eight notes grouped in phrases of one to three notes, with short pauses between them. In the Wing Hollow area, Warble consisted of two different song types; the "tury, cherwee, cheye-ley" and the "turr, heur, lee, em." The latter can be introduced with either a "turr" or "pew" note. Sometimes "pew" is repeated over and over. Both song types can be alternated. Each Warble lasts about 1 to 2 seconds then is repeated after a short pause. In a random sample of 11 wild, unpaired males, the average number of Warbles per minute was 17 (table 9). Warble in this context functions to attract unpaired females.

TABLE 9

Rate of Song Delivery of 11 Wild Unpaired Bluebirds

Rate of Warble per minute	15	16	17	18	19	20
Number of songs	4	2	3	8	6	3

Male bluebirds use other vocalizations to advertise their presence in the territory. The most notable is Rapid Warble, which sounds like Warble ("tury, cherwee, cheye-ley") without pauses between the phrases. Chatter is also frequently given, usually during Rapid Flight.

Unpaired males frequently give Whisper Song near the nest box, usually in the form of Rapid Warble, but Warble and "turring" are also common. Muted vocalizations appear to have the same form as regular songs but are delivered at much lower volume, scarcely audible. Whisper Song may be detected (at least to human observers) by the pulsating throat of the apparently silent bird. I do not know if Whisper Song in this context functions as advertisement.

AERIAL DISPLAYS

Semicircling

The male flies out from his perch, in a Semicircle and returns farther down the fence or utility line. Circling is usually at the same height as the perch but may be performed by dipping almost to the ground as he flies down the utility line. Rarely is song associated

with Semicircling. This is not the Circling described by Dilger (1956a) in pair formation but is typical of bluebirds as they advertise their presence in the territory. Females were also observed to Semicircle.

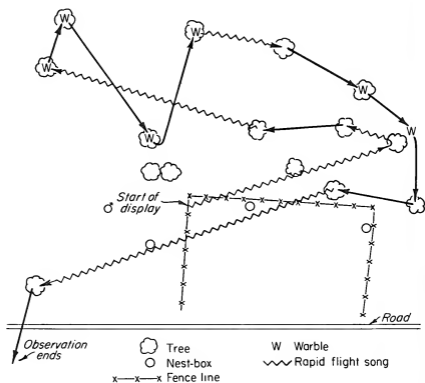


Fig. 24 June 11, 1967. Male 3S giving Warble and Rapid Flight song while advertising his territory after losing ♀ 3S

Gliding Flight

In this display the tail can be spread and the wings are fully extended but not moved as the bird loses altitude. Glides are normally brief (3 to 40 yards) but long flights (over 100 yards) are not rare. In long Glides a few dips or banking movements to either side may be made. Rapid Warble can accompany this display. When landing the wings are held up and out for a brief second then folded to the sides. Gliding is usually used as the bird goes from perch to perch or when approaching the nest box. It is also employed in foraging.

Rapid Flight Song

This display, given by males, is a rapid, straight flight between two perches; one often being the nest box. Normally the flight is well over 30 yards and is accompanied by either Rapid Warble or Chatter, both of which can be given in a continuous or interrupted series. Rarely are the two alternated during one flight. Although given throughout the courtship, it is especially evident during establishment of territory. After losing a female this is a frequent display as the male again advertises his territory (see Fig. 24). Of all the thrush species studied by Dilger (1956a) apparently only *Catharus minimus bicknelli* has a well-developed flight song.

Impeded Flight

Male bluebirds have three impeded flight displays. Hovering accents the presence of the male and nest box in the territory. The bird Hovers in front of the box, body somewhat vertical, wings rapidly beating. The tail is spread and the bird remains stationary in mid-air. A flight toward the nest box may end in a Hover for several seconds before landing at the hole.

During Butterfly Flight the wings are fully extended and the tail is spread. The wings move in large amplitude but slow frequency so that actual flight speed is considerably slower than normal. Usually the flight is straight, between 5 and 20 feet above the ground, but wide circles and zigzags are not rare. Both Warble and Rapid Warble can accompany this display. Butterfly Flight is the most common Impeded Flight Display and usually ends by landing at the nest box.

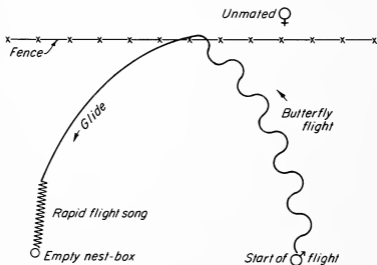
In Lopsided Flight the bird flies slowly, tail spread and both wings out of synchrony as he appears to "flop" along. This seems to be a form of Butterfly Flight with a strong sexual tendency present for

the bird appears to Wing-lift as he flies, resulting in the unsymmetrical flight.

Sometimes bluebirds combine different forms of aerial display giving a rather bizarre aerial performance appearing to function as advertisement. The following two extracts from my notes are characteristic observations involving "bizarre" aerial displays.

June 9, 1967; Wing Hollow; Pair 20S; 11:00 A.M. Pair 17S's nest was destroyed by a predator and male 17S has begun to sing again. Most of the morning he has been intermittently Nest Demonstrating at box 18N and singing from different perches in the territory. Male 20S gives an aerial display along the border between his and 17S's territory. He flies up 300 feet in the air and while singing uses Butterfly Flight, Glides, then gives Lopsided Flight as if Wing-lifting, all the time moving along the territory boundary. He then suddenly "tumbles" down through the branches of a large oak (*Quercus* sp.) tree and lands next to his female.

May 31, 1967; Wing Hollow; Male 3S. Male 3S is not yet mated. A female was seen in the north pasture but has not yet entered 3S's territory. Male 3S gives Rapid Flight Song to the north fence line, Wing-lifts, then leaves and Glides for 100 yards with tail spread (few dips in Glide), lands in tree, and Warbles. Male repeats this again but female still does not follow. Now male uses Butterfly Flight all the way up to the north fence line, turns in midair, and Glides back with many "banks," first one way then the other, then starts Rapid Flight Song, lands at box 10N, and goes in. Female (?) comes to box right away. To show this diagrammatically:



NONAERIAL DISPLAYS

Wing-lifting

Unpaired males rarely Wing-lift unless a female is in the vicinity. Once the male becomes aware of a female's presence he immediately begins a Wing-lifting Display, a particularly sensitive "barometer" in this situation. The wing is lifted away and up from the body in a vertical plane. Depending on the intensity, the wing can remain folded or be unfolded as it is rapidly lifted above the back then back to the side. When highly motivated the display appears almost as a "blur"; low intensity Wing-lifting may be just a quiver with the wing hardly leaving the supporting feathers or a frequent jerk of the wing up to the level of the back. Wing-lifting can involve one or both wings. This display indicates an activated sexual tendency and also makes the male's presence more conspicuous. Wing-lifting can be given in conjunction with other displays such as Warble, and Nest Demonstration. It persists throughout the breeding season, often acting as a greeting between members of a pair.

Wing-waving

This display is also given when a female is in the vicinity. Sometimes Wing-lifting can develop into Wing-waving, especially if the male is highly motivated. Wing-waving may represent Wing-lifting in its highest intensity. Both wings are held out to the sides, fully extended and then moved up and down. The body is in an oblique to horizontal position, the tail is somewhat raised but not spread. Sometimes in its highest intensity the wings are completely unfolded and held above the back for several seconds.

Nest Demonstration

The nest box (hole) is the most important element in the bluebird territory and a ritualized Nest Demonstration Display is used to advertise its presence. Nest Demonstration is the most important advertising display here as in pair formation and courtship. The display will be discussed here only as it pertains to territory advertisement by unmated males. The relationship of the female to Nest Demonstration will be treated in detail on page 114 (pair formation).

Several authors (Burroughs, 1871; Bent, 1949); Thomas, 1946; etc.) have commented on the "male's persistent attempts to persuade a female to accept a nest-hole." Von Haartman (1957), anthropomorphically expressed the display's function in hole-nesting birds

quite well when he wrote: "This behavior evidently functions as an advertisement: good-looking bachelor with own apartment wants a mate."

In the bluebird, the complete display has several elements which can be performed in varying sequences. During high-intensity display (i.e., a female is present in the vicinity) the male flies to the nest box using any one of the aerial displays already mentioned, although Butterfly Flight is the most common. He perches at the hole with tail spread and wings partly open, showing the blue color of the back conspicuously. Wing-lifting or Waving may be given, especially if a female is nearby. While at the hole he may look around and then either peer into the entrance or put his head in and out of the hole in quick succession. The male then starts to rock back and forth, putting his head and shoulders inside with every forward rock, sometimes looking around with the backward rock. Finally the male enters the box, and as he inspects, may peck at the sides and floor. Before leaving the box, the male shows his face at the hole for several seconds often ducking back inside only to face-show again. Face-showing probably has some signal value and appears to be somewhat ritualized. It is most frequently given when a male is highly motivated to entice the female to approach the nest box. For example, within 10 minutes male 17N flew to box 18N and went in and out 11 times, face-showing in the following sequence when inside the box: 4-3-3-9-5-3-4-4-2-1-0.

The male's exact manner of leaving the nest box varies. He may hop from the entrance, turn in midair, Hover, then land at the hole, and repeat the display. Sometimes he flies to a distant or nearby perch and sings, or flies to the top of the box and sings before repeating the display. Often he flies from the hole to another nest box in his territory and performs Nest Demonstration there.

At lower intensities one or more elements of the display drop out and at its lowest intensity the male merely flies to the nest box, look in, and leaves.

The male bluebird usually incorporates song and nest material into Nest Demonstration Display. Both Warble and Rapid Warble can be given during any phase of the display and "turring" is frequently heard. While at and inside the box, Warble and Rapid Warble can be given in a muted form. Sometimes the male stays inside the box for over 3 minutes continuously giving Whisper Warble as he alternates between remaining in the box and face-showing. When face-showing, the pulsating throat is clearly evident. It is difficult to assess the function of Whisper Warble from within the box; espe-

cially during advertisement when the female is not present in the territory. However, during pair formation and courtship, Whisper Warble is a frequent part of Nest Demonstration and probably has some adaptive value in courtship by minimizing the pair's presence to other bluebirds and possible predators. It may be that the unpaired male performs the complete Nest Demonstration Display during advertisement with Whisper Warble taking on meaning only during reactions between the pair during courtship.

The male may carry nest material in the bill during some or all phases of the display. The material is usually obtained from inside the box and the male holds a strand, often mandibulating it, while face-showing. He can, however, obtain the material outside and take it to the box, mandibulating it, throughout the whole display.

The male may also advertise himself and the nest box by dancing on the box top. Dance Display can be continuous with Nest Demonstration or can occur by itself. It is usually given on the box top but may be given on the ground or on a fence post. The male assumes the Oblique-sleek Display with tail spread and wings slightly drooped. He then moves all over the box top dragging the spread tail. He hops in a circle, stops to look around, then hops again. While displaying he may sing or carry nest material in the bill. Wing-lifting can accompany this display.

TERRITORIAL DEFENSE

Territorial studies (Nice, 1941; Tinbergen, 1939) usually conclude that the established bird is nearly invincible in his territory. Indeed, Thomas (1946) stated . . . "I have found that bluebirds are invincible in their territories only in the course of a nesting, not after their young are fledged."

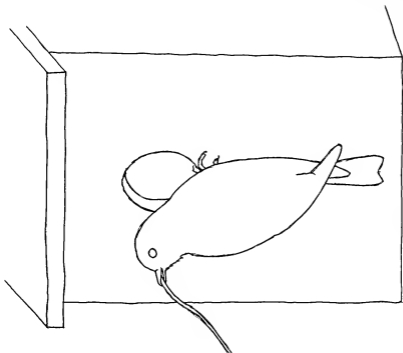
I found that bluebirds in the Wing Hollow area were not always invincible in their territory. Paired males (or females) will sometimes invade and usurp territory holders. The history of one follows:

Wing Hollow, 1966; Pair 10S

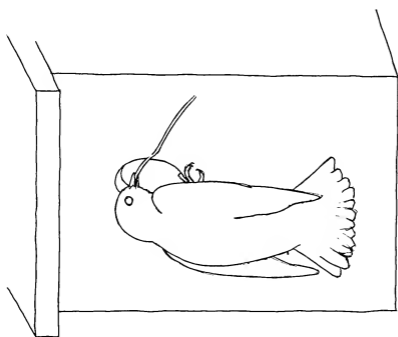
March 19—Male 10S, a return from the 1965 season, arrives already paired with female 10S.

March 25—Female 10S has left. Male 10S showing weak territorial advertisement.

April ?—Female 10Sa arrives and forms a bond with male 10S.

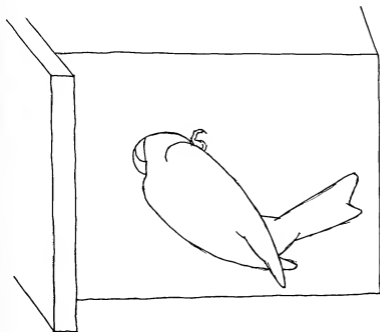


b Looking around

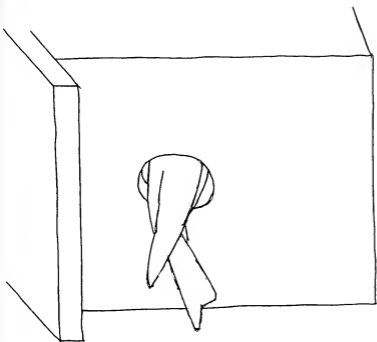


a At hole with nestmaterial; note dropped wings and spread tail

Fig. 25 Nest Demonstration display of male Eastern Bluebird showing several different elements.

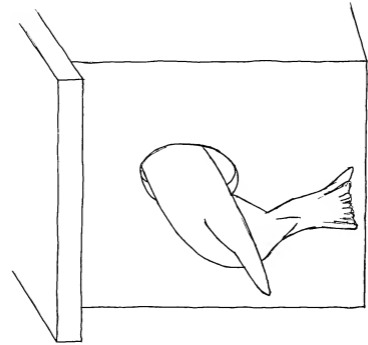


c Peers into entrance

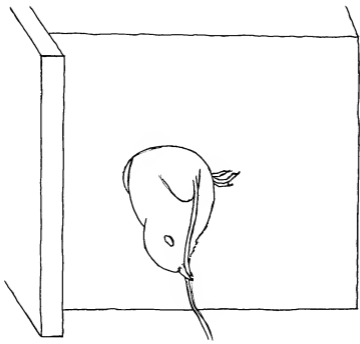


d Begins rocking

Fig. 25 Continued



e Rocking, continued



f Face showing, with nest material

Fig. 25 Continued

April 12 — Female 10Sa is now starting to carry nest material to box 40S. Male 10S singing from different perches within the territory.

April 13 — Female 10Sa building in earnest now. Male 10S stays close to the nest box as female builds.

April 14 — 7:30 a.m. Female carrying nest material to box. Female leaves box and male 10S Chases her across field.

7:45 a.m. A new male (unbanded and unpaired) comes to the nest box, Warbles, goes in box, comes out, and Warbles from top. Male 10S comes immediately and a violent fight takes place in a ditch in front of the box. Female 10Sa comes and Hovers over Fighting males then leaves giving Location Calls.

8:01 a.m. Female 10Sa comes back to the nest box. The males stop Fighting and one Chases the other across the field with the female following.

8:05 a.m. New male and female 10Sa going through Nest Demonstration at box 41S.

April 15 — New male has taken over territory of male 10S and has formed a bond with female 10Sa. Female again carrying nest material.

April 20 — Male 10S has established a new territory in the southern part of the study area.

Pettingill (1936) reported the case of an unpaired female bluebird invading a pair's territory and successfully driving out the resident female.

However, bluebirds were usually successful in defending their territories. Most disputes were settled by display and when actual combat occurred it was usually over a female rather than territory (nest box).

The agonistic behavioral patterns used by bluebirds in territorial defense have been described under Agonistic Behavior. These depend on the male's position in reference to his territory, his mate, and the behavior of the other bird. At territorial boundaries those displays showing conflicting attack and escape tendencies were prevalent, resulting sometimes, in prolonged encounters. In the vicinity of the nest box, the attack tendency was strong and little display was seen as the owner simply attacked the intruder.

Of all the agonistic displays, Warble is the most important in maintaining the territory. It, like that of most song birds (Marler, 1956), has the dual function of attracting females and repelling males. Loud Warble is usually the only display given during intraspecific encounters in the vicinity of the nest box and probably reflects a high attack tendency as shown by the following observations.

When decoys are placed near the nest box Warble is given immediately as the resident male (or pair) attacks the decoy. Males will even attack a microphone emitting Warble in the absence of a decoy.

In captivity, even though visual contact was reduced to a minimum by attaching either 4' x 8' sheets of plywood or large pieces of cloth to the wires separating the cages, my bluebirds were never successful in fledging young. I believe the reason for the nesting failure was that the birds were in constant auditory contact with one another. Regardless of the phase of the nesting cycle, on hearing Warble, a pair would try with great persistence to attack other pairs through small cracks in the cages. This caused a constant turmoil among the caged pairs with incubation and feeding of young ignored or suppressed by the stimulation of the stronger attack tendency.

Mrs. Laskey (personal communication) says that in her experience bluebirds would only nest close together if a natural barrier (such as a hedgerow or barn) separated the nest boxes thereby reducing both visual and auditory contact between nesting pairs.

Hartshorne (1962) successfully bred bluebirds in captivity; however, his birds were kept in sound isolation chambers making auditory (and visual) contact between pairs impossible.

Song Duels between neighboring males were a common display whenever territorial boundaries were in dispute. Normally this involved two males perched at the boundary, rendering Warble, but yet Song Duels often involved more than two birds. If one was unpaired and establishing territory the Duel would develop into a noisy "melee," reminiscent of the communal display of the house sparrow, *Passer domesticus*, especially if the females of the other participating birds were present. The unpaired male would Warble with the greatest volume and frequency and as the Duel intensified it would develop either into a communal Chase with two or three males Chasing a female or actual Fighting between males or pairs. Young (1951) never observed "Song Duels" between male robins (*Turdus migratorius*) but Siivonen (1939) describes a Song Duel between two song thrushes (*Turdus ericetorium*). Power (1966) said of the mountain bluebird (*Sialia currucoides*) . . . "two males would frequently be seen answering each other's song along the common borders of their territories."

When females are present during boundary disputes the males guard them by staying between the female and the other male. If the female flies to the ground the male will follow and Hover over her, returning with her to the perch. Boundary disputes are frequently interrupted by Nest Demonstration. After vigorous encounters between the pairs, one or both will interrupt Fighting, fly back to their nest box, and give Nest Demonstration Display. This was also common during experiments with decoys; the pair would attack the decoy, leave

and give Nest Demonstration Display, only to return and attack the decoy again. The nest box does not have to be the one used for nesting; any box in the territory can be used. Von Haartman (1956) mentioned this same type of behavior in the pied flycatcher (*Muscicapa hypoleuca*) and interpreted it as ambivalent behavior, the male reacting momentarily as if the intruder were a female. Hinde (1952) also mentioned that in the great tit (*Parus major*), hole inspection sometimes occurred during a lull in reproductive fighting. In the bluebird a possible explanation may be that the presence of the intruder (or decoy) was sufficient to stimulate an attack response. After prolonged Fighting (or a lull in Fighting) the attack tendency waned and the presence of both the female and nest box released the next type of behavior for which both internal and external stimulation had reached threshold value, in this case, Nest Demonstration.

Territorial defense does not decline when the female starts to incubate but remains intense throughout the nesting cycle (see table 10). This is important in a species that has special territorial requirements (nest cavity) in short supply. Usurpation is rare and hence the pair are able to raise more than one brood without wasting energy and time trying to locate a new nest cavity.

Bluebirds usually tolerate other birds in their territory except in the immediate vicinity of the nest box. They show a marked antipathy, however, toward other hole-nesters, especially tree swallows (*Iridoprocne bicolor*), house sparrows (*Passer domesticus*), and starlings

TABLE 10
Results of Decoy Experiments

Stage	Reaction of Male or Pair		
	A	B	C
Male unpaired		3*	3
Pre-nest building		2	5
Nest building	1	1	8
Laying	5	1	2
Incubating	9	4	15
Feeding young	2	1	17
Young have fledged.....	8	—	9
Totals	25	12	59

* Number of experiments

A = No reaction, birds ignore decoy

B = Moderate reactions, birds show threat toward decoy

C = Strong reaction, birds attack decoy

(*Sturnus vulgaris*). Sometimes bluebirds use a defensive display when defending the nest box from tree swallows. The bird will enter the box and face-show, while Gaping and Bill Snapping at the diving tree swallows.

Although brown-headed cowbirds (*Molothrus ater*) have been reported to parasitize bluebird nest boxes (Friedman, 1929; Thomas, 1946), this never occurred in the Wing Hollow area. Cowbirds were Supplanted and Chased whenever they came near a nest box. Hamilton (1943) reported a case where two cowbird eggs were deposited in a bluebird's nest and the female promptly covered both with a new lining.

Bluebirds completely ignored the sparrow hawks (*Falco sparverius*) nesting in area. Drinkwater (1953) reported a female sparrow hawk taking young bluebirds from a nest box but he felt this was because the box had a perch in front of the hole.

Bluebirds were seen to Chase the following species from the vicinity of the nest box: robin (*Turdus migratorius*), eastern phoebe (*Sayornis phoebe*), song sparrow (*Melospiza melodia*), and field sparrow (*Spizella pusilla*).

FUNCTIONS OF TERRITORY IN THE BLUEBIRD

Tinbergen (1957) stated that territory is the result of two tendencies in the owner:

1. Attachment to a site.
2. Hostility towards a certain category of other animals, usually members of the same species and the same sex.

The territorial behavior of the bluebird clearly exhibits both these tendencies. Because of its extreme hostility to conspecifics and its tenacious attachment to a nesting site (box) the following functions of territory are suggested.

The male's vehement defense of the nest site has selective advantages for the nest site plays an important role in pair formation. Bluebird nest sites are scarce; therefore it is advantageous for females to pair with males who already possess one.

The male's advertising within his territory makes him more conspicuous to roaming females, thus helping to bring the sexes together and form sexual bonds. The pair's aggressiveness toward conspecifics and other hole-nesters secures a nest site (box) for the pair and the attachment to this area helps maintain the pair bond. Strong territorial defense also reduces the likelihood of interference with coition.

Males from adjacent territories are attracted to the intense courtship activities of the pair and sometimes are successful in interfering with copulation.

By defending the territory *per se* instead of just the nest cavity the population density can be somewhat limited thereby securing for the pair a certain food supply and allowing them the opportunity to raise more than one brood.

PAIR FORMATION

Lack (1940b) in his review of the literature stated that in many species, pair formation occurs in the territory, while in others, it occurs in the flocks. Pair formation in the bluebird apparently occurs in both situations for some birds returned to Wing Hollow already paired. However, it will only be discussed as it occurred within the territory of unpaired males in the Wing Hollow area. In all, 10 natural pair formations were observed and these were supplemented by introducing live caged females into the territory of four unpaired males.

THE MECHANISM

A typical sequence when an advertising male detects a female in his territory follows.

On seeing a female in his territory, an advertising male immediately begins Wing-lifting Display and Rapid Warbling. He may then fly toward either the female or the nest box, using Impeded Flight and uttering Rapid Warble. He ends up at the nest box and assumes the Oblique Sleek Display (see pg. 101) with continual Rapid Warble or performs Nest Demonstration Display. He lands at the hole with tail spread and wings partly spread, starts Wing-lifting and Waving, rocks, then enters. While inside he continues to Warble, face-shows several times with nest material, comes out to the top or nearby perch, and mandibulates the nest material as he Wing-lifts and Rapid Warbles.

If the female does not approach the nest, the male may:

1. Repeat Nest Demonstration Display,
2. Perch on or by the nest box (often in Oblique Sleek), and give a variety of vocalizations such as Warble, Rapid Warble, or "turring" as he continually Wing-lifts,

3. Fly with Impeded Flight and Rapid Warble to another nest box in the territory and give Nest Demonstration Display,
4. Fly toward the female and repeat the aerial display back to the box,
5. Chase the female.

The continued aerial and Nest Demonstration performances with intermittent Chases accentuate the presence of the male and the nest box and stimulate the female to approach the nest hole. Depending on the female's motivation this may take minutes or several hours, but the female eventually approaches, either by following the male or coming while he is displaying at the box. Whatever the approach, the male immediately goes inside the box and begins Rapid Warbling (usually in muted form) and face-showing with nest material. The female may remain passively perched by the box in a Fluffed posture and appear to ignore the displaying male. If she does fly to the hole she is very tense as witnessed by her withdrawn posture with her body held way back and turned slightly sideways to the hole, the head sleeked and drawn in between the shoulders. One foot holds to the hole, the other near the base of the box and she keeps looking away as if she will flee at any moment. This is a critical moment for the female *must* enter the nest box while the male is inside to insure the establishment of the pairing bond. However, she seldom enters on her first approach to the hole. Usually she flies rapidly from the box but does not leave the territory. She remains perched (frequently in thick foliage such as a hedgerow or tree) in the Fluffed posture and may perform maintenance activities. The male continues his aerial and Nest Demonstration Displays and the female occasionally warbles and moves closer to the nest box. At this time the male commonly shows Wings-raised Sleek Display which develops into either Nest Demonstration or a violent Chase of the female ending with the male using Butterfly Flight and Rapid Warble back to the box; the female remains Fluffed on some perch within the territory. If, in the interim, the male is not present at one of the boxes, the female may suddenly fly to the box, go inside, remain a few seconds, then leave.

Eventually the female approaches the nest again and remains Fluffed by the box as the male is inside giving Rapid Warble and face-showing. She may give a weak Wing-lift, Rapid Warble, fly to the hole and look in, engage in Mutual Warbling with the male, then return to her perch and again assume the Fluffed posture. When the male comes out he goes to the opposite side of the box and shows the Oblique Sleek Display (see pg. 101) with his back to the female. The female may then go to the hole and look inside. This causes the male to become greatly excited and while still in the Oblique Sleek he begins

to quiver and lift the wings as he shows intention movements to both leave and approach the box while uttering Rapid Warble and Squeals.

This interplay between the two continues as the female begins to look in the nest box more often and starts to show signs of sexual excitement herself. Her tendency to flee lessens and the male's Wings-raised Sleek Display now develops into actual attack as he lands on her back and Pecks her head.

The crucial time comes when the female finally enters the nest box while the male is inside. After she enters, the male always comes out first and lands near the box usually in an Oblique Sleek with his back to the nest. The female follows and directly *Supplants* the male. Now the female takes an active part in Nest Demonstration as she follows the male to the different boxes in his territory. She shows reduced fear of the male and increases her Supplanting Attacks upon him. As the pair continue Nest Demonstration Display, one gets the impression (as did Meyerriecks in his study of the green heron, *Butorides virescens*, 1960) that the male is now the intruder!

The female can Supplant the male in any of the interactions between them while in the immediate vicinity of the nest box but it usually occurs as just described. I feel this act of dominance by the female is of prime importance in establishing the pair bond. Some evidence exists that the female dominates the male as soon as she enters the nest. When observing pair formation in captive birds the female would start Pecking the male as soon as she entered the box to the extent that the male would sometimes get confused and try desperately to leave through the side observation glass in the box.

To show the importance of the Supplanting Attack by the female, the following section from my field notes is given:

May 4, 1967, Wing Hollow. Pair formation between male 5N and migrant female.

Female has not yet come to box.

3:15 p.m. Male gives Butterfly Flight with Rapid Warble to box 9N, looks in, goes in, face-shows with nest material, comes out, turns in midair, lands at the hole with tail spread, looks in, goes to top with nest material, Wing-lifts, Hovers, looks in, goes in, comes out with nest material to the top and moves all over touching nest material to the top, Hovers, looks in, goes in, comes out with nest material, Wing-lifts . . . keeps up the same pattern and goes in the box at least 12 times. Now a female flies across the road and the male goes very fast, cuts her off, and he lands at box 8N, female goes to utility line.

3:50 p.m. Female still has not come to the box. Female on utility line and male assumes Wings-raised Sleek, Chases female,

turns, and uses Butterfly Flight with Rapid Warble to box 8N. Males goes in

4:35 p.m. Female nervously preens in hedgerow, male gives Rapid Warble, flies right at the female and Chases her among the trees, then goes to box 8N and Nest Demonstrates. Female remains in tree in a Fluffed posture

5:40 p.m. Male inside box, female Fluffed nearby and Wing-lifts a few times, goes to hole with leg down and head back, looks in, back to wire. Male face-shows with nest material, comes out, Hovers, lands at hole, back in, face-shows with nest material (female looks towards box) three times, out, Hover, right back in. Female still in Fluffed posture. Male face-shows four more times, goes to wire on opposite side of box, and assumes Oblique Sleek. Female goes to hole, looks in, male Wing-lifts and female leaves the hole and *Supplants* the male. Male leaves and female looks in, goes to wire. Male Butterflies to the hole, goes in, much Whisper Warble heard. Female looks in, goes in (both in), male face-shows and out immediately with nest material and assumes Oblique Sleek on the wire. Female comes out and *Supplants* the male, male goes back in, female looks in, goes to wire. Male out with nest material and in Oblique Sleek, female in Fluff and Wing-lifts, male back in, out to opposite side of the box. Female goes and *Supplants* male, male doesn't leave so female Gapes and bites him

5:50 p.m. Female comes toward box, male assumes Oblique Sleek and goes in, face-shows, female on wire, male out to the opposite side and female goes and *Supplants* him. Female now looks in, Wing-lifts, male comes to post and female *Supplants* him then keeps *Supplanting* him in rapid succession

This partial dominance at the nest box is extremely important. The box is the most important element in the male's territory and his defense of it is most vehement. Thus if the female is going to be accepted, she must show some form of dominance in its vicinity to reduce the likelihood of attack by the male. Therefore the extent of the male's aggressiveness partly depends on the degree of dominance exerted by the female at the nest box.

DOMINANCE RELATIONS

From the preceding discussion one would expect that a reversal of dominance in the sexes occurs during pair formation and that the female establishes a microterritory around the nest box. Yet this is not the case, for when the dominance relations between the pair

are considered for the entire courtship it becomes evident that neither sex completely dominates the other; a partial or sometimes incomplete dominance exists. This is shown in table 11 where, of 255 recorded encounters, the males were dominant only 54 percent of the time.

TABLE 11

Agonistic Encounters in Wild Pairs of *Sialia sialis*
Wing Hollow, 1966-67

Pair	Number of Encounters	Male Wins	Female Wins
<u>1966</u>			
3S	16	14	2
7N	12	7	5
10N	2	2	0
10S	1	1	0
12S	15	10	5
17S	18	7	11
23N	1	1	0
40S	25	14	11
<u>1967</u>			
3N	10	1	9
3S	11	9	2
5N	21	6	15
1N	15	5	10
10N	21	8	13
11S	37	33	4
14S	3	1	2
19N	2	2	0
20S	18	9	9
22S	4	0	4
17N	23	6	17
Totals	255	136	119

Note the variation in the dominance relations between different pairs. In some relationships the males were extremely aggressive (35S, 11S), in others, the females (5N, 17N) were. Those birds that arrived already paired showed little aggression.

Table 12 shows the types of agonistic displays used in the interactions between the pairs during courtship.

TABLE 12

Types of Agonistic Displays Used in Interactions Between Pairs

Male Display	Stage	Number of Encounters
Chase	A	43
	B	19
	C	14
Attack	A	9
	B	5
	C	34
Supplanting	A	4
	B	4
	C	2
Diving at	A	—
	B	—
	C	2
Female Display	Stage	Number of Encounters
Supplanting Attack; at nest box	A	18
	B	48
	C	12
Supplanting Attack; away from nest box	A	2
	B	3
	C	2
Supplanting Attack; during boundary dispute	A	8
	B	5
	C	2
Face-Gape-Peck	A	3
	B	8
	C	8
A = Pair formation	B = Prenest building	
C = Nest building		

Males mainly intimate females by Chasing but as courtship continues the female's tendency to flee becomes inhibited and actual attacks become predominant. Attacks were always expressed by the male Pecking the female's head and occurred mainly during nest building.

The female reveals her dominance by Supplanting Attacks which usually (65 percent) occur at the nest box. These are most frequent

during pair formation and prenest building then are reduced during nest building. Therefore the female does not establish a microterritory around the nest box that excludes the male. Throughout courtship the male is ever present at the box and he rarely shows fear when approaching it.

SEXUAL RECOGNITION

Bluebirds are sexually dichromatic and when a territorial male meets a male intruder he reacts aggressively, but when a female intrudes his first reaction is overtly sexual. Instead of Warbling, flying directly at the female, and delivering a series of Supplanting Attacks (as he would to another male), he immediately starts Wing-lifting, shows Impeded Flight with Rapid Warbling to the nest box where he gives Nest Demonstration Display. This indicates the male is able to recognize the female as distinct from the male and suggests that morphological rather than behavioral characteristics are used in sexual recognition. This is also supported by the fact that in four experiments in which a caged live female was introduced into the territory of an unpaired male, the male's first reaction was always sexual (as above) rather than aggressive. This was also true when mounted female decoys were used. For example:

May 27, 1966 — Wing Hollow. Male 7N is unpaired. I put a mounted male and female bluebird on a fence line 3 feet from male 7N's nest box. Warble is played through the tape recorder.

. . . . Male 7N Warbles and flies close to the decoys. Male Warbles then goes to box and gives Rapid Warble, goes in box, face-shows, back in, stays inside 3 minutes and gives Whisper Rapid Warble, face-shows, looks toward decoys, comes out, lands by box, and assumes Oblique Sleek Display.

Now I play tape recording.

. . . . Male flies up and over the male decoy and lands on other side. He assumes Head Forward, Oblique Bill-up, then attacks the male decoy violently and knocks it to the ground. Male regards the female decoy, gives Whisper Rapid Warble, goes to the ground, and pulls feather off the male decoy.

I remove male decoy.

. . . . Male moves closer to female then goes to ground where male decoy was and pecks ground. Male back by female decoy, regards it, Warbles, goes to box, looks in, goes in, out to fence line and Warbles, preens nervously, Wing-lifts. Male now Warbles from Fluffed posture then starts to preen.

I play recorded Warble and male moves away and gives Whisper Warble then feather-ruffles, goes to ground, back to fence line. Now male goes to ground where male decoy was, looks around, then back to fence line.

Thus pair formation in bluebirds is quite different from the *Hylocichla* and *Catharus* thrushes studied by Dilger (1956a). He found males initially react aggressively toward females entering their territory, much as they would to intruding males. Thus in these thrushes there are no special displays associated with pair formation like those in the bluebird.

MOTIVATION OF THE SEXES

When the male first detects the presence of the female, the sexual tendency is clearly predominant. He shows Wing-lifting, Rapid Warbling, Impeded Flight, and Nest Demonstration; all sexual displays. The attack tendency is not shown at first, but in later encounters becomes clearly evident by the appearance of the Wings-raised Sleek Display, Sexual Chasing, and attacks upon the female. The escape tendency, though weakly activated, is betrayed by the Oblique Sleek Display given when the female is at the box.

The female at first shows no aggressive tendency and usually remains in the Fluffed posture. With increasing visits to the nest box her sexual tendency rises as she shows Wing-lifting, Rapid Warbling, and an interest in the nest box. Finally, she takes an active part in Nest Demonstration and becomes increasingly aggressive as shown by her frequent Supplanting Attacks upon the male.

Since pair formation seems to increase the relative strength of the attack tendency in both sexes, a principal function of bluebird courtship is to suppress this attack tendency in the sexual partners. This is achieved by much mutual sexual displaying between the pair during the courtship period with Nest Demonstration and courtship feeding being especially important.

COURTSHIP

I follow Morris (1956b) in defining courtship as "the heterosexual reproductive communication system leading up to the consummatory sexual act." This includes the activities from pair formation through copulation. It has now been established that in both sexes there is a three-point conflict between the incompatible tendencies to flee, attack, and mate (Hinde, 1952, 1953; Marler, 1956; Morris, 1954, 1956b; Tinbergen, 1952). Courtship, therefore, does not involve a single sexual activity, but also the tendencies to attack and to flee from the sexual partner. In the sexual behavior of the bluebird all three tendencies are expressed but the bird is principally under the influence of conflicting tendencies to attack and behave sexually towards the mate.

MALE DISPLAYS

Oblique Sleek Display

This is a variable display with many possible combinations of components. It is similar to the Oblique Bill-up Threat Display and may be derived from it. In its lowest intensity the body is held in an oblique position with the plumage sleeked. This is especially noticeable when the male is advertising his territory. However, most pair formation and early nesting behavior involve the full (more intense) Oblique Sleek Display, usually in the vicinity of the nest box. As the female approaches the box (or comes out of it) the male turns his back to her and assumes the Oblique Sleek with wings drooped, bill slightly raised, and tail maximally spread. The male thus presents a "mass of blue" to the female as she either Supplants him or he moves away. As courtship continues and the motivation levels of the different tendencies shift, the male incorporates more components

into the display. He may remain stationary (and tense) and lift or quiver the wings instead of drooping them. Vocalizations indicating a sexual tendency can be given: Rapid Warble, "turring," and Squeal. Orientation may change as the male no longer turns away from but either faces or glances over his shoulder at the female. Some even pivot or turn in a complete circle showing alternating movements to approach and flee from the female.

A number of facts suggest this display is due primarily to conflicting escape and sexual tendencies. The oblique posture, sleeking of the feathers, and flexing of the legs are all flight intention movements and coupled with the male turning his back to and showing movement away from the female suggest a strongly activated escape tendency. Turning the back is a "reversed movement" (e.g., Marler, 1956), that is, the opposite in form from the posture of a bird which is ready to attack. Sometimes, when displaying, the male will even fly before the female makes the Supplanting Attack. The spread tail, movements of the wings, vocalizations, and the occasional attempts at rape all represent a sexual tendency. Also the male will sometimes mandibulate nest material while displaying. Yet the attack tendency is also weakly activated as evidenced by the sometimes open bill (Gape), change in orientation, and rare attacks on the female. Vocalizations indicating an attack tendency such as Warble and Chatter can be given.

In captivity where escape was impossible this display sometimes developed into a forced rape of the female. For example:

May 14, 1967. St. Bonaventure Aviary. Pair YW and Y. Female is nest building. Male is in the corner of the cage in a frozen Oblique Sleek. He keeps "turring" for 6 minutes then makes a violent rape of the female. For the next 45 minutes he assumes the Oblique Sleek Display (full intensity), keeps his back to the female most of the time, and repeatedly gives Rapid Warble as he flies around the cage rapidly as if trying to get out. Within this period though he attacked and raped the female seven times, each time trying desperately to copulate.

Isenberg (1953) bred the loochoo robin, *Icoturus komadori komadori* (*Erithacus komadori komadori*, Peters, vol. 10, pg. 39, 1964) in captivity and reported a similar display. He wrote ". . . he struts, not unlike a Turkey, with lowered wings, tail fanned out and held up over his back the while a torrent of lovely song pouring forth."

Sometimes during periods of intense courtship neighboring males will perform a very exaggerated form of the Oblique Sleek at the territorial boundary. The display appears to be directed toward the neighboring female and includes ambivalent movements, postures,

and displacement activities. The duration of the display is much longer (giving the impression of a dance) and the body can alternate between an oblique and horizontal position. These were observed eight times in the wild and they always occurred either at the boundary or within the neighbors' territory. A typical example is taken from my field notes:

June 17, 1966. Wing Hollow. Male 11S (not paired) is invading (establishing territory?) the territory of pair 12S during the courtship period. He appears very nervous and flies to the telephone crossbar and assumes a horizontal sleek and walks along dragging the depressed and fully spread tail. Now he flies to a post and Warbles . . . male flies back to crossbar and assumes an Oblique Sleek, tail spread and wings drooped, then walks along dragging both tail and wings, bows, leaves . . . flies back to the crossbar, assumes Oblique Sleek, tail spread, droops wings then walks fast with head down one way, pivots, walks the other way (head still down), bill wipes, giving Rapid Warble constantly, feather ruffles, back into Oblique Sleek, tail spread, wings drooped, and walks along crossbar, Warbling.

Thus, in this exaggerated Oblique Sleek, the bird has a strong tendency to behave sexually and also a strong tendency to flee, the conflict being revealed by the walking movements, displacement activities, and the obvious ambivalence. The walking is probably an ambivalent movement that rapidly alternates between intention movements to approach and flee. As far as I know this is the only situation in the bluebird's life where it walks (see locomotion, p. 2). Two displacement activities are seen in the display, bill-wiping and feather-ruffling. I am uncertain of the Oblique Sleek posture with the head down. It might be an ambivalent posture with the Oblique Sleek being a flight intention movement and the head down an intention movement to peck.

Wings-raised Sleek

In this display the male faces the female. In its most intense form the body is horizontal, plumage sleeked, and the wings raised to or above the shoulders with a slight downward rotation relative to their articulation with the body. The tail is maximally spread and arched downward, legs flexed, and the bill open and slightly raised. The variable components are the wings which can be stationary when raised or quivered, lifted, or waved. The bill is usually closed and directed forward and nest material can be carried in it. Whisper song often accompanies this display and Squeals may be given. The duration of the display is very short, rarely lasting more than 5 seconds.

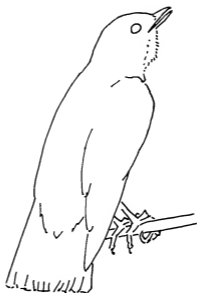


Fig. 26 The Oblique Sleek display of the Eastern Bluebird accompanied by Rapid Warble. Dotted line indicates pulsating throat



Fig. 27 The Wings Raised Sleek display of the male Eastern Bluebird

Wings-raised Sleek was observed 37 times in the wild, often near the nest box. Table 13 shows the behavior of the male immediately following the display.

TABLE 13

Wings-raised Sleek Display:

Behavior of the Male Immediately Following the Wings-raised Sleek Display

Stage	None	Nest demon- stration	Chase	Chase- attack	Attack	Copula- tion attempt
Pre-pair Formation (female in vicinity)	4	4				
Pair formation	1	6	2	2(1)	1	
Prenesting building			1		4(1)	
Nest building			1	2(1)	(6)	(1)

Numbers — the number of observations.

() — number of observations when display was preceded by Song Duel or Whisper Rapid Warble.

When neighboring or migrating females are in the immediate vicinity of an unpaired male's territory he may show a low intensity Wings-raised Sleek and then give Nest Demonstration Display. During early pair formation the same holds true but once the pair bond is formed this display leads to increasing attacks on the female, especially in the nest building period. On five occasions it appeared to be initiated by intense Song Duels with neighboring males, perhaps as a result of redirection. On five other occasions it was preceded by Whisper Rapid Warble which would increase in frequency until the male would suddenly assume the Wings-raised Sleek and violently attack the female.

Table 14 shows the context of the display in the wild for one male during different stages of courtship.

TABLE 14

Context of Wings-raised Sleek During Different Stages
of Male 11S Courtship Period

Stage	None	Nest demon- stration	Chase	Chase- attack	Attack	Copula- tion attempt
Pair For. June 5 345 minutes**	5	1-2-3-4*	6-10	8	7-9	
Nest build June 6 240 minutes					1-2-3-4-5	
Female leaves June 7						
Female No. 2 Pair For. June 20 315 minutes	1-3	2				
Female leaves June 21						
Female No. 3 Pair For. June 25 — no observations						
Nest build June 26 300 minutes					1-2-3	
Nest build June 27 180 minutes					1	
Nest build June 28 30 minutes					1	

* NOTE: The numbers indicate the sequential pattern of change in the males' behavior following each display and therefore refer to one observation, not to the number of observations.

** Total period of observation.

In the beginning of pair formation before the female has entered the box, the male does not attack the female from the Wings-raised Sleek but gives Nest Demonstration. Once the female has entered (and accepted?) the nest box, the male becomes more aggressive and this behavior leads to Chases or Attacks on the female. When the female starts to carry nest material she no longer flees in response to Wings-raised Sleek but remains and sometimes give a low intensity Solicit; yet the male still attacks.

The evidence (tables 13 and 14) indicates that the Wings-raised Sleek primarily involves a strong tendency to attack the mate. However, when observing this display in captivity it becomes evident that a strong sexual tendency is also activated. Table 15 shows the ontog-

eny of this display in one pair of captive birds. During early courtship the display leads to attack but as courtship continues Wing-raised Sleek becomes a precopulatory display. To cite typical examples :

April 12, 1967. St. Bonaventure Aviary. Pair DY and DG. Male assumes Wings-raised Sleek and female Solicits. Male mounts and copulates, hops off, Faces the female and gives Wings-raised Sleek, mounts female and copulates, then leaves.

April 14, 1967. 1:10 p.m. Male is Fluffed on the stove pipe, Female flies up to the male and Solicits. The male shows Wings-raised Sleek, mounts female and copulates, then leaves.

1:15 p.m. Male assumes Wings-raised Sleek, faces female who Solicits and Squeals, male mounts and copulates. Male does this twice then leaves.

1:19 p.m. Male copulates with female without showing Wings-raised Sleek.

However, in the wild, Wings-raised Sleek was never observed to function as a precopulatory display. Note also that in the 11 displays that led to attack, seven were preceded by Song Duels between the captive birds.

TABLE 15

Wings-raised Sleek Display by Male DY in Captivity, 1967

Stage	Prenest Building		Building						
	7	8	9	10	12	13	14	17	18
Behavior of male following display									
None					1				
Attack	1* (1)**	2	4 (4)	3 (1)	1 (1)				
Copulation attempt				1	3	4		1	
Copulation without display									Starts →

* number of observations

**display was preceded by Song Duel

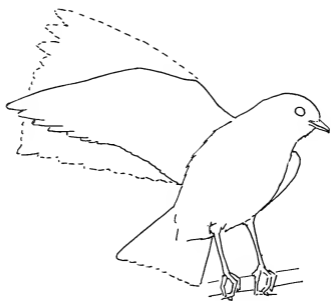


Fig. 28 Male Eastern Bluebird showing Wing-lifting display

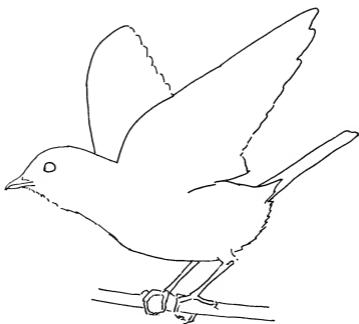


Fig. 29 The Wing-lifting Tail-up display of the female Eastern Bluebird

Not only does this display often lead to actual attacks or Chases (59 percent in the wild) but it resembles both the Head Forward and Wings Out Threat Displays. The elements of horizontal body, sleeked plumage, raised wings, and frontal orientation all are intention movements of attack. Wing quivering, lifting, and waving, all important elements in the display, occur only in the breeding season. The depressed spread tail is a common element during copulation as is Squeal. Hence these elements, plus the wing movements, probably all denote a sexual tendency.

It appears therefore that the Wings-raised Sleek involves a strongly activated attack tendency, a fairly strong sexual tendency, and a relatively weak tendency to flee.

Fluffed Posture

This is similar to the Fluffed posture used in agonistic situations (see pg. 49), but usually is more marked. In its more intense form during courtship the body feathers are fluffed, neck withdrawn, wings slightly drooped below the tail, and the crest and rump are ruffled. This posture is frequently used, along with tail spreading, when rendering Warble. It is frequently seen in situations when the escape tendency would be expected to be relatively high, for example after pair formation when the female becomes more aggressive toward the male around the nest box. At this time the male usually sits by the box, in a Fluff, watching the female build.

The Fluffed posture often involves an activated sexual tendency as the male gives Wing-lifting (or Waving) and Rapid Warble.

In this posture the tendency to attack the mate is relatively low. However, when accompanied by Whisper Rapid Warble the male sometimes attacks the female. To cite one example:

June 28, 1967. Wing Hollow. Male 11S is in an oblique Fluffed posture. He Wing-lifts and gives Whisper Rapid Warble faster and faster. He now pivots on the perch and the Wing-lift changes to Wave, the Whisper Rapid Warble becomes more intense, and then the male flies 50 yards, lands on the female's back, and Pecks her head violently.

It appears that Whisper Rapid Warble and Wing-lifting raise the relative strengths of the sexual and attack tendencies, and on close contact with the female, the attack tendency is expressed.

The Fluffed posture is also frequently shown between paired birds just prior to copulation. The birds remain immobile and quite passive for long periods of time.

The Fluffed posture is opposite in form to the two sleeked displays just described and probably functions as appeasement by signaling the submissiveness of the bird.

Wing-lifting and Waving

These are both very common displays during courtship and are associated with an activated sexual tendency. Both are discussed on pg. 81.

Symbolic Nest Building

This is the manipulation of nesting material by a member of a pair which does not ordinarily help construct the nest (Nice, 1943). It is a very common display in the bluebird, especially during Nest Demonstration. The male will hold a piece of nest material in the bill, sometimes mandibulating it, as he proceeds through the different phases of Nest Demonstration. Usually he gets the material from inside the nest box but will occasionally carry it to the box. It almost always occurs during pair formation and continues well into the nest building period.

On two occasions, captive males were observed to go through nest-shaping movements while inside the nest box. This same behavior was also noticed by Hartshorne (1962). Power (1966) observed symbolic nest building in *Sialia currucoides* where the male went through all the motions of picking up nest material but did not actually pick up anything. Curio (1959), in describing the behavior of the male semicollared flycatcher (*Ficedula semitorquata*) at the nesting hole, stated that the male brings out nest material (left by starlings) but he called this cleaning.

Although the female constructs the nest (Hartshorne, 1962; Thomas, 1946; pers. obs.), there are reports of males sometimes participating in this activity (Bent, 1949; Hamilton, 1943; Hartshorne, 1962; Knight, 1908). Manipulation of nest material may be a vestige of behavior of a former time when the male may have had a more important role in nest building.

This behavior may stimulate the female to approach the nest and/or to build. When the nesting cycle is interrupted (predators, etc.) the male will almost always resume Nest Demonstration Display while carrying nest material in his bill. One such male gave Nest Demonstration Display 38 times in 1 hour; most of the time with nest material in the bill. Incomplete activities often have great importance because of their signal significance or stimulatory effect upon the mate (Tinbergen, 1951).

Flight Display

Male bluebirds have several flight displays to advertise their territory (see pg. 77 for description). These persist after the female has entered the territory and becomes a definite part of courtship. Table 16 shows the occurrence of such displays throughout the courtship period. The displays are performed during advertisement (24 percent), reach a peak during pair formation (53 percent), and then occur sporadically through nest building.

TABLE 16

Occurrence and Number of Observations of Flight Displays
by Male Bluebirds During the 1967 Breeding
Season, Wing Hollow

Flight Display	Stage			
	Not Paired	Pair Formation	Prenest building	Nest building
Butterfly Flight directed toward	19**	38	6	4
box	12	36	5	1
perch	7	2	1	3
Gliding Flight directed toward	7	24	9	8
box	5	19	9	6
perch	2	5	—	2
Lopsided Flight directed toward	5	7	2	—
box	3	6	—	—
perch	2	1	2	—
Butterfly/Glide	1	2	—	—
Total of all flight displays	32	71	17	12

** Number of observations.

Of the 132 flights that I observed (1967), 104 (78 percent) were directed toward the nest box, almost always ending in Nest Demonstration Display.

These flights show (to the female) the presence of the male and the location of the nest box. They are primarily gamosematic displays (see Lack, 1940b, pg. 281) by assisting the members of a pair to find one another and probably influence the female in selecting a mate at pair formation.

FEMALE DISPLAYS

Sleeked Display

Females were never observed to give Oblique Sleek or Wings-raised Sleek. During pair formation, however, they sometimes sleek the head while at the nest box.

Fluffed Posture

This is similar to that given by the male but not as marked. It is usually associated with a thwarted tendency to flee and probably functions as appeasement. It is especially evident during pair formation.

Wing-lifting and Waving

Similar to the male.

Symbolic Nesting

During Nest Demonstration the female may carry nest material in the bill. However, in the female it may result from low motivation for nest building.

Solicit

This is a stationary display and at low intensity the female crouches with plumage compressed, head drawn in, and bill slightly raised. The wings are drooped with their tips below the base of the tail; the tail is slightly raised (also see Hartshorne, 1962). Low intensity Soliciting can be given in early courtship in response to approach by the male. This rarely leads to successful copulation but rather results in threat or even attack; the female maintains the Solicit as the male lands on her back and repeatedly Pecks her head. Occasionally the attack tendency is expressed in the female as she Faces, Gapes, Rasps, and sometimes Pecks the male.

At higher intensity (usually when the nest is completed) the female crouches in a horizontal position, plumage compressed, with the feathers of the crown and back especially sleeked. The bill is slightly raised and the tail is raised markedly. The wings are drooped and can be quivered. Usually Squeal and peeps are given.

The Soliciting posture is the preliminary to actual copulation and clearly involves a strong tendency to behave sexually (Hinde, 1954). In the bluebird the attack tendency is also weakly activated as shown by the occasional threat toward the male. Rarely does the female flee.

Wing-lifting Tail-up Display

The body is held in a horizontal position with the plumage either fluffed or compressed. The legs are slightly flexed and the tail is raised markedly but not spread. The head is raised but can (rarely) be lowered in a bow. The wings are continually lifted or even waved and the bird may move by pivoting or hopping. A variety of vocalizations can be given — Rapid Warble, Squeal, “whines,” or Peeps.

In 1967 this display was seen 14 times in the wild and in two of these situations it was repeated 10 and 12 times in succession. In 10 cases it was the female who displayed; three cases, the male; once, both displayed. The display was observed when the bird was greatly excited and usually in a conflict situation as shown by the following figures:

1. Boundary disputes	6 cases
2. Courtship feeding	4 cases
3. Nest Demonstration	3 cases
4. Soliciting	1 case

In addition to these it was observed in captivity.

The Wing-lifting Tail-up Display resembles the female precopulatory display of other passerines, e.g. the chaffinch, *Fringilla coelebs* (see Andrew, 1961, pg. 345). In the bluebird it may be the highest intensity of the Solicit posture, yet it differs from the Solicit in many ways:

1. it (usually) is not a stationary display
2. Wing-lifting and Waving occur
3. it never resulted in copulation (or even an attempt)
4. it is usually given in situations that suggest conflict

Five typical Wing-lifting Tail-up Display situations from my field notes are described below:

1. Pair 5N are excited around their nest box. The female flies to a tree and gives Wing-lifting Tail-up Display. Male follows and lands by female who then Supplants him. Female remains in Wing-lifting Tail-up Display and flies from branch to branch, male gets excited and female Supplants him.
2. Male 12S and 11S fight at the territorial boundary. Female 12S gets excited and gives Wing-lifting Tail-up Display on wire above Fighting males. Female pivots on wire as she displays. . . .after more disputes the male is guarding the female when she flies to ground, returns, and lands close to the male. The male then gives Wing-lifting Tail-up Display toward his female. Male 11S comes and both males fall to ground Fighting.

3. I put a decoy eight feet from the nest box (young 3-days old) of pair 2S. Male comes immediately and attacks decoy so I remove it and just play song. Male and female get excited and go to the nest box. On top, the female assumes the Wing-lifting Tail-up Display while turning and Squealing. Male approaches, hovers over the female but does not mount. As I play song the female does this 12 times in a row each time the male hovering but never mounting.

4. Male 1N is banging a large caterpillar on the fence post. Female 1N assumes Wing-lifting Tail-up Display, flies to male, and gives Wing-lifting Tail-up Display in front of him. The male keeps moving away and 10 consecutive times the female flies to him and gives Wing-lifting Tail-up Display. Male finally leaves and female goes back to nest box.

5. Male 11S forms a bond with female 14S who has a broken lower mandible. Female apparently cannot carry nest material. Female is on the fence line and assumes Wing-lifting Tail-up Display and male comes and feeds her.

When observing this display one gets the impression that the female is highly motivated and in some situations invites copulation, in others, feeding. Yet in all observations she achieved neither (except number 5 above). Morris (1954) stated that in some species the female's invitation-to-copulate display is identical with the juvenile food-begging display. In the bluebird, the Wing-lifting Tail-up Display definitely resembles both the female's Solicit and food-begging posture, yet differs from each. In Soliciting the wings are not lifted or waved and in food-begging (courtship feeding) the tail is not raised.

Since sufficient observations are lacking the function and significance of this display remain obscure. Both a highly activated sexual and feeding tendency are involved and when the display occurs during boundary disputes it may possibly be a displacement activity. The occurrence of this display in the male (four cases) may be due to a thwarted sexual tendency and hence a pseudo-female display (see Morris, 1955).

MUTUAL DISPLAYS

Nest Demonstration

This is the display that the male uses to advertise himself and the nest box to the female (see pg. 81) for complete description. During this display the pair bond is formed. The female takes an active part in the display and can perform all its components. After pair forma-

tion and throughout courtship the pair still perform the display. In this context it probably functions to sexually stimulate both members of the pair and to strengthen the pair bond by suppressing the agonistic tendencies of each. This is also evidenced when a nesting is terminated; Nest Demonstration again becomes predominate. This appears to be a critical test, for if the female will not participate in the display and therefore not accept the nest box, either the female or the pair will leave the territory. Usually, the female does participate (especially if other nest boxes are in the territory) and the pair re-nest. However, if she does not participate and leaves, the male's attachment to the territory is usually stronger than the pair bond and he remains and starts to advertise again. John Burroughs (1871) recognized this when he wrote:

"...He (Eastern Bluebird) thought the box just the thing, and that there was no need of alarm, and spent days in trying to persuade the female back. Seeing he could not be a stepfather to a family, he was quite willing to assume a nearer relation. He hovered about the box, he went in and out, he called, he warbled, he entreated; the female would respond occasionally and come and alight near, and even peep into the nest, but would not enter it, and quickly flew away again. Her mate would reluctantly follow, but he was soon back, uttering the most confident and cheering calls. If she did not come he would perch above the nest and sound his loudest notes over and over again, looking in the direction of his mate and beckoning with every motion. But she responded less and less frequently. Some days I would see him only,...."

Sexual Chasing

Sexual Chases in the bluebird involve a rapid pursuit of the female by the male. Most occur during the pair formation and prenesting period. The motivation of the male is variable. Sometimes Chases were preceded by some form of aggressive display. For instance, on 11 occasions the male assumed the Wings-raised Sleek (strong attack tendency) and moved toward the female who responded by flying off rapidly with the male in close pursuit. Chases could also be preceded by signs of sexual excitement. The pair could be actively involved in Nest Demonstration when a Chase would suddenly develop or the male could give Rapid Warble with Wing-lifting Display then chase the female. Some Chases appeared to develop "spontaneously"; the pair inactive when a rapid Chase would suddenly take place.

The Chase is a rapid, sometimes twisting flight, yet in only one Chase did the male actually catch the female. A variety of vocalizations can be given, especially Chatter (attack tendency), Rapid

Warble, and Squealing (sexual tendencies). Chases always occur within the territory and the female may only leave its boundaries during pair formation. On two occasions the male overtook the female and both times he landed at the nest box and performed Nest Demonstration.

The pair rarely end the Chase close together; the male usually lands several feet from the female. The female usually assumes the Fluffed posture, the male the same or the Oblique Sleek. Table 17 shows that 68 percent of the recorded Chases ended with no interaction between the pair. However, in 21 cases, after the female landed, the male went directly to the nest box and gave Nest Demonstration.

In the bluebird, it appears that Sexual Chases can be an expression of either an aggressive or sexual tendency in the male. At their termination though these tendencies usually become inhibited by the escape tendency. While the male shows either an activated attack or sexual tendency at the beginning these are rarely expressed at the end by actual attack (1 case), or copulation attempts (2 cases); usually he lands several feet from the female (escape tendency being predominant). However, the male may still show sexual excitement at the end by giving Nest Demonstration Display. In the 11 Chases preceded by the Wings-raised Sleek, five ended in Nest Demonstration; the male's apparent motivation changing from aggressive to sexual.

It appears therefore that during the Chase either the male's (depending on the motivation at the start) attack or sexual tendency is lowered. This is advantageous to a species that has a strong aggressive element in its courtship. Sexual Chasing then may provide a pro-

TABLE 17
Occurrence of Sexual Chasing and Resultant Pair Behavior

Stage	Chase ends in					
	observa- tions	attack	copula- tion	nest demon- stration*	breaks off	termi- nates in dense foliage
Pair formation	39	1	0	11	19	8
Prenest building	22	0	0	9	9	4
Nest building	15	0	2	1	8	4
Totals	76	1	2	21	36	16

*only the male participates

visional outlet (as suggested by Marler for the chaffinch, 1956) for high copulatory or attack motivation thus allowing the mating activities of the male and female to become better synchronized.

The effects of Chasing on the female are not clear. The escape tendency is certainly activated yet she seldom leaves the territory. She certainly benefits from those Chases preceded by aggressive display by avoiding an actual attack.

Courtship Feeding

Fully developed courtship feeding actively involves both mates; the male gives the prefeeding call and brings the food to the begging female. There is, however, much variation in the pattern, depending on the level of motivation of each sex and on the conflicting agonistic tendencies associated with the sexual and feeding tendencies. In its early stages it may be incomplete and sometimes results in agonistic encounters between the pair. The male usually initiates courtship feeding with the female generally responding in one of four ways:

As the male approaches with food the female may

1. flee (rarely)
2. threaten him
3. remain passive and accept the food, or
4. adopt a begging posture similar to that used by young bluebirds.

When actively begging, the body is in a horizontal to oblique position, plumage somewhat fluffed, one or both wings lifted in rapid succession, and begging calls are given.

In some cases (especially in captivity) courtship feeding first involved fleeing or threat, then passivity, and finally active begging by the female. However, in the wild it was extremely variable with some females actively begging all the time.

Later in the courtship period the female may start to beg even before the male captures the prey or else fly to him and beg as he mouths the prey in his bill. During incubation, apparently without stimulus from the female, the male feeds the female inside the box.

Evidence exists that the male's feeding tendency is waxing (especially in late arrivals) before and during pair formation. An unpaired male was observed giving the prefeeding call as he mandibulated an insect before swallowing it, and during symbolic nest building males will sometimes work nest material as if it were an insect. In one unusual case male 5N, who had recently (approximately 4 hours) formed a bond with female 5N, was observed to perform a possible overflow activity. Overflow activities (vacuum activities of Lorenz, 1937) occur when an animal has one drive strongly activated and the

releasing stimuli, indispensable for the performance of the executive motor patterns of the drive, are inadequate. They are apparently nothing but reactions to suboptimal stimuli (Bastock, Morris, and Moynihan, 1953). Male 5N was on a fencepost 10 yards from the nest box. He bent over in a horizontal position and moved the bill as if "working" an insect. Yet the bill was empty! He touched the bill to the post and then banged it one way then the other as he worked the invisible insect.

Feeding the female by regurgitation was only observed in captivity. This may occur in the wild for one pair was observed to engage in billing where both mates faced each other in Fluffed postures as they touched bills. The male left, returned immediately, and repeated the same performance. This is the only time billing was observed in the wild but captive young birds will often touch bills and then gently Peck one another. In *Myadestes unicolor* (grey solitaire) Isenberg (1948) reported that the male feeds the female by regurgitation.

In the Wing Hollow population, courtship feeding is a common and necessary part of courtship and appears to serve two major functions:

1. to maintain and strengthen the pair bond, and
2. to reduce the agonistic tendencies between the pair.

Evidence for the former is that courtship feeding occurs in all phases of the reproductive cycle (table 18). The male also frequently feeds the female

1. during lulls in boundary disputes,
2. after attacks upon her,
3. during the interval before reneating after an aborted attempt.

Regarding the latter function, the bluebird in the Wing Hollow area has a strong aggressive element in its courtship. Throughout the courtship period the male makes repeated attacks upon the female whereas the female makes Supplanting Attacks upon the male in the vicinity of the nest box. It is suggested therefore that courtship feeding may suppress the agonistic tendencies in the pair by permitting each bird to become habituated to the proximity of its mate. For instance, a male aggressive to its mate at one moment will, in the next moment, approach and feed the female with no sign of aggressiveness. This is best illustrated by the following field observation:

Wing Hollow, June 6, 1967; Pair 11S.

11:25 a.m. Female comes to fence line by the box, male turns toward her, assumes Oblique Sleek, shivers the wings, female goes in box. Female comes out and lands in front of box. Male (with no display) comes at and hits her with his feet, then Pecks

her head, hops up in the air and repeats this 8 to 10 times finally knocking female upside down on the fence line. Male leaves and female goes back to nest building.

11:28 a.m. Male comes with insect and sidles up to female and feeds her; both face away, male leaves.

Also when the male approaches the female with food his feeding tendency dominates both the attack and escape tendencies. In well over 100 observations I have never seen a male display strong aggression during courtship feeding. Likewise, while studying the relationships between agonistic behavior and the social hierarchy in captive bluebirds, out of more than a thousand encounters, very few occurred over food. Dominant and subordinate birds often would feed together. Therefore, despite threat or even fleeing by the female the male is persistent in his attempt to feed her.

TABLE 18

Occurrence of Courtship Feeding During the Different Phases of the Nesting Cycle

Stage	Number of observations
Pair Formation	11
Pre-nest Building	24
Nest Building	66
Incubation	frequent

Lack (1940a), in his review of the literature, stated that the eastern bluebird's habit of courtship feeding is rare and many individuals apparently do not show it. Thomas (1946), in her 14-year study of an apparent nonmigrant population in Arkansas, found that courtship feeding did not occur at all, nor were females ever observed to beg during the courtship period. Yet both Hartshorne (1962) and I (working with migrant populations) found courtship feeding common.

It is possible that courtship feeding occurs prominently in social interactions between the pair in a migrant population but is apparently rare or nonexistent in some nonmigrant populations. Thomas (*ibid.*) did not mention any aggressive element during the courtship period. She stated that most pairs were formed between November and the last of January, nesting started approximately March 7, and in old mates there appeared to be a real bond the year around. Nonmigrant populations may have no need for a mechanism such as courtship feeding to reduce the agonistic tendencies between the pair during courtship. Apparently this is resolved before nesting begins, possibly

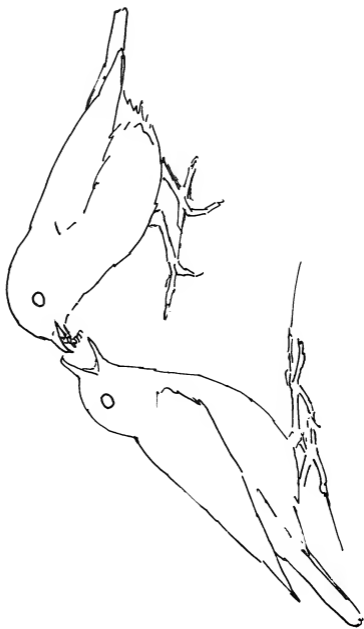


Fig. 30 Courtship Feeding in the Eastern Bluebird. Male is on right.

by Nest Demonstration Display which, according to Thomas, occurs throughout the nonbreeding season.

The Wing Hollow population not only incorporated courtship feeding into their reproductive cycle, but also had "helpers at the nest" (i.e., young of first brood help feed young of second brood). Thomas (op. cit.), never observed feeding or helpers at the nest.

Copulation

Successful copulation is sometimes initiated by the male; he flies toward the female who adopts the Soliciting posture as the male lands on her back. Usually though the female initiates copulation by giving a marked Soliciting posture. The male flies either directly to her back or else lands beside her, then up and on.

During copulation the male waves his wings as the tail is brought down and cloacal contact is made. Two vocalizations can be uttered, Squeal by either partner and Peeping by the female.

No post-copulatory displays were noted. Successive mountings were seen only in captive birds. Once the male mounted two times, and twice, three times before leaving. Copulation attempts may begin before nest building and terminate part way through the incubation period. They can occur on any convenient perch within the territory.

In most copulation attempts observed (both in the wild and captivity) the male was influenced by conflicting tendencies to attack and behave sexually with the female. The attack tendency was almost always expressed by Pecking the female's head while standing on her back. It was frequently difficult to determine if the male was actually attempting copulation or just attacking the female. Only if the male depressed the spread tail was it considered a copulation attempt. In the wild, 19 such attempts were recorded and in 14 the male Pecked the female's head. Only once did the female Peck the male and this occurred after a successful copulation. In captivity, attacks on the female during copulation were common. For example:

Nest box has two eggs. Male goes in the box and female Squeals. Male comes out with nest material in bill, Wing-lifts and gives Rapid Warble, now he approaches female who is Soliciting. Male lands on her back and Pecks her head over and over with tail spread and waving both wings. Male now stops Pecking and depresses his tail as if to copulate. Male leaves and then returns and feeds female.

Hartshorne (1962) saw one of his laboratory males Peck the head of the female during copulation but did not see this in other bluebirds.

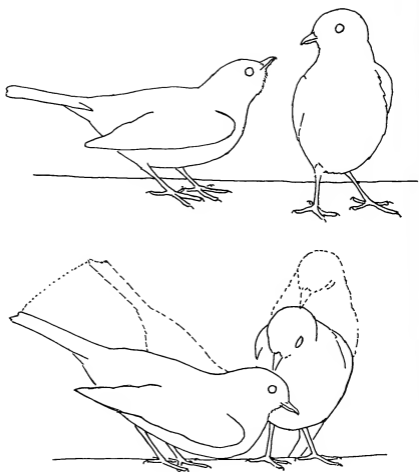


Fig. 31 Female Soliciting and male attacking behavior. In upper figure the female (on left) is giving a low intensity Solicit as the male is about to attack. The lower figure shows the male now violently attacking the female by pecking her head.

On four occasions neighboring males interrupted copulation attempts by attacking the copulating pair. I never observed reverse mounting but Pearse (in Bent, 1949) reported this in the western bluebird (*Sialia mexicana*); the male mounted the female and then the female mounted the male.

SYNOPSIS OF THE COURTSHIP PERIOD

The length of the bluebird's courtship period varies. In birds that pair early in the season (late March-early April), four weeks may elapse before successful copulations take place whereas in late pair formations (early June) only 24 hours may elapse. Weather is an important factor, for during a period of low temperatures, courtship activity ceases and the pairs become inactive and difficult to locate.

Before actual nest construction begins the male still Warbles and patrols the territory. The pair forage and move about the territory together keeping in contact by calling "tu-a-wee," yet individual distance remains strict. Boundary disputes are common and both members actively defend the territory. Most sexual behavior is centered around the nest box. The male takes the initiative and displays at the box showing Wing-lifting, symbolic nest building, Rapid Warble, and Nest Demonstration. Shortly, the female takes an active role and the frequency of her Supplanting Attacks on the male increase. Nest Demonstration now becomes the principal display as the pair inspect (with either sex leading) all the boxes in the territory.

While at the boxes the female may show searching behavior (Hinde, 1954, pg. 229) by hopping along the ground and going through the motions of looking for nest material but not actually picking any up. Later she may start to carry pieces of grass into and sometimes out of the nest boxes. The male still Chases the female but she never leaves the territory. Later still the pair center their activities around one box and engage in much mutual sexual display.

Finally the female starts to build and this causes a rise in the male's sexual and attack tendencies. He remains close to the box and may inspect the nest in her absence, often bringing nest material out, or he may fly inside and face-show as she approaches. Some males follow the female back and forth to the box or Chase her as she comes out. Low intensity Solicits are frequent and courtship feeding is common.

At this time the female's Supplanting Attacks on the male decrease and the male becomes more aggressive and increases his attacks on

the female. As the nest nears completion these attacks become more associated with copulation attempts as the male rapes the female. When the nest is completed the pair spend little time near the box. They remain together and retire to the shrubs and trees in the territory, spending considerable time in maintenance activities. Both show the Fluffed posture, the male feeds the female quite regularly now and there are bursts of sexual excitement as copulation takes place with no aggressiveness between the pair.

During the parental phase some of the courtship displays can be given in certain situations. Wing-lifting remains prevalent and is a mutual display given much like a "greeting" when the pair meet after a sustained absence. For example, if one bird is perched and the other, after an absence, lands close by, both start Wing-lifting as they perch close together. This may be a form of reassurance (*sensu*, Smith, 1966) in which each bird communicates that it will not likely attack the other.

SUMMARY

The general behavior of the eastern bluebird, *Sialia sialis*, was studied for 5 years, the last two primarily devoted to agonistic and courtship behavior of both captive and wild color-banded birds in western New York State. Eight nestlings were reared by hand and observed in captivity for 2 years. Observations on wintering bluebirds were made in the vicinity of Tallahassee, Florida.

Maintenance activities and the behavioral patterns associated with agonistic and courtship behavior are described in detail. Interpretations are offered for the functions, motivations, derivation, and biological significance of some of these behavioral patterns. Comparisons and homologies are made with behavioral patterns of other species, especially other chat thrushes and true thrushes (Ripley, 1952).

Previous studies such as those of Laskey (1939, 1940, 1943), Thomas (1946), and Hartshorne (1962) have stressed different aspects of bluebird behavior. The information summarized here is either new or reinterpreted in the light of recent ethological thought (see Dilger, 1962).

Maintenance Activities

Maintenance activities of the bluebird were studied in the field and in captivity and resemble those of most passerines that have been studied. They have been described and their ontogeny traced whenever possible.

Care of the body includes 12 activities. Head-shaking is common in adults and is associated with other toilet (for use of this term see Andrew, 1956) behavior. The head is scratched indirectly. The three stretching movements are similar to other North American *Hylocichla* and *Catharus* species but the sequence is different. Both wings down occurs only in nestlings and is not a transition movement.

Two methods of bathing are used and alternate wing movements (motion 3 of Nice, 1943) do not occur. Preening, bathing, and sunning all have social qualities.

Typically the species forages by scanning the ground from elevated perches. Midair catches are made and food may also be obtained by hopping along the ground. Preparation of prey before swallowing is by "scissoring" and/or "hammering." Both animal and vegetable matter are consumed, the latter mainly in the winter.

The ontogeny of locomotion is given. Movement along a perch is by hopping, sidling, or pivot-hopping. Pivoting is a common movement while perching.

The behavior and location of communal roosting, during adverse weather, is described.

Agonistic Behavior

Agonistic behavior in captive and wild bluebirds generally resembles that of other North American thrushes studied but differs in detail. Four attack responses are described: Supplanting, Chasing, and Fighting are associated mainly with territorial defense, and Pecking when individual distance is violated. The threat code consists of seven displays which showing varying intensities of the attack and escape tendencies. In *S. salis*, Wings-flicked reflects a high attack tendency and is accompanied by Tail-fanning in a horizontal plane rather than Tail-flicking in a vertical plane as in *Hylocichla* and *Catharus*.

Wings-out was only given in response to Scream and was not directed toward conspecifics. Bill-raising has two intensities and incorporates ambivalent movements and feather adjustments. Eight vocalizations accompanying agonistic displays are described.

Crouch and Alert are adaptive responses to unfamiliar stimuli. Wing-flashing, which occurs frequently in captive birds in response to novel stimuli, was only observed once in the wild.

Feather-ruffling is a common displacement activity and is similar to the Spread Display of *Hylocichla mustelina* but differs in not being ritualized to serve as a display. The Fluffed posture seen in pair interactions is not a ritualized appeasement display. In captivity redirected attack occurred as a result of intensive song duels between males in adjoining cages.

On leaving the nest, young bluebirds remain together in a close family unit and may help to feed the young of the second brood. In late summer, juveniles from different family units join together to form small mobile flocks with the individuals showing much agonistic and incipient sexual behavior. The size of migrant flocks is variable and

on the wintering grounds a flock of 100 or more bluebirds represents several subgroups. Nest inspection was not part of the behavior of wintering flocks but was common in captive birds during the nonreproductive season.

In captivity young from two different broods (subgroups) were kept together from October to March in a large 10-cubic-foot aviary. Both subgroups were organized in a peck-dominance hierarchy; the males in one were dominant over the females but in the other subgroup the females were dominant. The subgroups never became integrated, as one subgroup completely dominated the other. This resulted in a complex peck order maintained by both peck-dominance and peck-right. It is suggested that (in captivity at least) the members of a brood retain a social bond to one another based on incomplete dominance. Complete dominance is only attained over members from different broods.

Territory

Bluebirds defend large territories in which courtship, mating, nesting, and most food-seeking occurs. Possession of a nest cavity in open terrain is a prerequisite before the territory can be established. Nest cavities are in short supply and both interspecific and intraspecific competition for ownership is intense. As a result, aggressive behavior is employed by males in acquiring nest cavities, which provide the opportunity to mate and begin nesting. It is important to both the maintenance of the territory and the pair bond that the male select and defend more than one nest box. Nest boxes are also instrumental in determining the size and shape of the territory. As the population increases some territorial boundaries are frequently changed. The changes are caused by early arriving males (or pairs) taking possession of a very large territory, and then being forced to yield parts of it to new arriving males. Boundaries that contain empty nest boxes remain rather fluid with possession determined by variations in the breeding activities of the neighboring pairs. Territories in the Wing Hollow area average 13.6 acres in size, but they vary all the way from less than 5.3 to 28.7 acres. The population could not be increased significantly by putting up more nest boxes.

The males do not always arrive first. Arrival is a staggered affair with male and females arriving from mid-March to early June. Some birds arrive already paired. The territory is advertised mainly by Warble, six Aerial Displays, Wing-lifting and Waving, and Nest Demonstration Display. Warble is the principal display in main-

taining the territory and Song Duels between neighboring males are common. At the territorial boundaries, displays showing a conflict of attack and escape tendencies are prevalent, especially the Oblique Bill-up Display. When conspecific intruders come within the territory and near the nest box the resident males usually react with Supplanting Attacks or displays showing a strong attack tendency. Bluebirds in Wing Hollow usually maintain the territory throughout the breeding season. Experiments with decoys showed that the territory, *per se*, and not just the nest box is defended and defense continues throughout the nesting cycle. This allows more than one brood to be raised and has certain selective advantages. The birds do not have to waste time and energy locating new nest cavities (which are in short supply) and reestablishing territory.

The nature of territory in the bluebird is applicable to Tinbergen's (1957) concept that territory results from two tendencies in the owner, site attachment and hostility. Natural selection would favor these two in the bluebird which has special territorial requirements (nest cavity) in short supply and no hole-forming capabilities, as with the titmice, to compensate for the lack of nest cavities.

The most important functions of territory in the bluebird are the facilitation of pair formation and maintenance of the pair bond.

Pair Formation and Courtship

The mechanism of pair formation as it occurs within the territory of unpaired males is described. In the developing pair bond, the female must take an active part in Nest Demonstration Display and enter the nest box while the male is inside. To insure the establishment of the bond, she must express her dominance by making Supplanting Attacks on the male in the vicinity of the nest box. After the pair bond is formed, its structure is based on incomplete dominance between male and female. Bluebirds are somewhat sexually dichromatic, so the male can recognize the female as distinct from other males and reacts aggressively to a male and sexually to a female intruder. Pair formation increases the relative strength of the attack tendency in both sexes and a main function of courtship is to suppress this attack tendency. This is achieved by much mutual sexual displaying in which Nest Demonstration Display and Courtship Feeding are especially important.

Six male displays are described. The Oblique Sleek Display, seen primarily in early courtship, includes many variable elements. It reflects a strong sexual tendency in conflict with the escape tendency and when given at territorial boundaries may develop into a dance.

The Wings-raised Sleek Display involves a strong attack tendency and during the nest-building period develops into attacks on the female. In captivity this display developed into a precopulatory display resulting in successful copulation without aggressive tendencies. Symbolic Nest Building probably has some stimulatory effect on the female. Butterfly, Gliding, and Lop-sided Flight are primarily gamosematic displays.

The primary female display is the Solicit which has two intensities. Wing-lifting Tail-up Display resembles both the female's Solicit and food-begging posture yet is different from each. The function and significance of this display is not known. Sexual Chasing is an expression of either an aggressive or sexual tendency in the male and functions by lowering such tendencies. Nest Demonstration is a variable display and when mutually performed functions to stimulate the pair sexually and helps to strengthen the pair bond by suppressing their agonistic tendencies. Courtship Feeding occurs throughout the courtship period and serves to maintain and strengthen the pair bond and to reduce aggressiveness by allowing each bird to become habituated to the proximity of its mate. The ontogeny of courtship feeding is described. Copulation can be initiated by either sex and may occur without preliminary display by the male. Most copulation attempts in the wild involved an aggressive element as the male pecked the female's head.

A synopsis of the courtship period is given.



Fig. 32 Wing Hollow, looking east, April 29, 1970

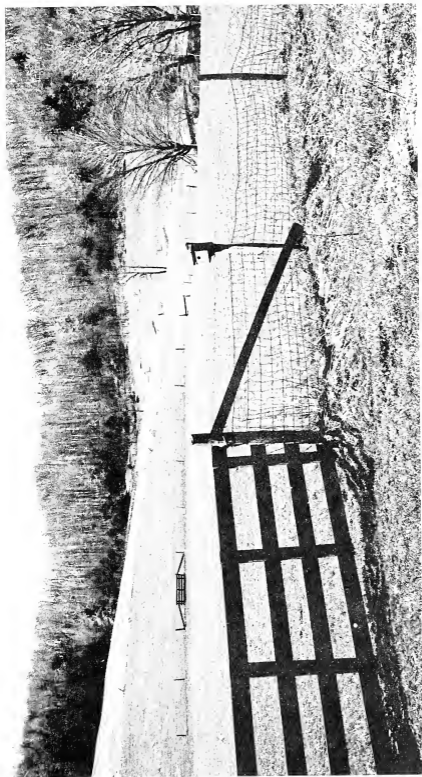


Fig. 33 Typical Bluebird nesting habitat, Wing Hollow, April 29, 1970

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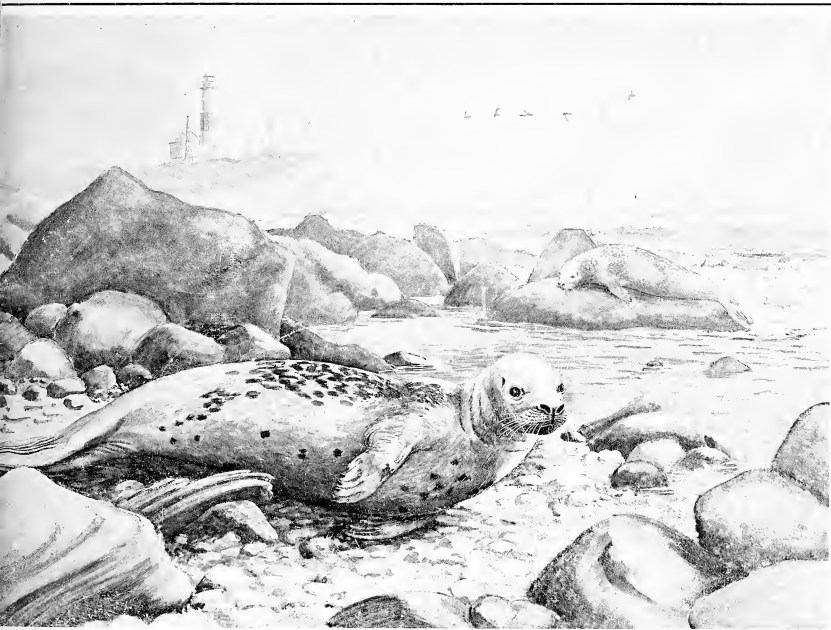


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The Mammals of Long Island, New York

by **PAUL F. CONNOR**
Scientist

New York State Museum & Science Service



Harbor Seals at Montauk Point

by Robin Rothman

BULLETIN 416

New York State Museum
& Science Service



*The University of
the State of New York*

ALBANY, N.Y. 12224

The State Education Department

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ACKNOWLEDGMENTS

The small mammal survey is under the direction of Ralph S. Palmer, State Zoologist. Donald H. Miller co-operated as field assistant during the summer of 1961. Special thanks are extended to Roy Latham of Orient who was exceedingly generous in furnishing information on mammals, in letter form, from his extensive notes on the natural history of eastern Long Island; this valuable information is included in the bulletin under the various species accounts. Recently (in 1969) he donated his mammal collection to the New York State Museum. Other Long Island naturalists were very helpful during our stay on the island, and Christopher McKeever of Water Mill, Charles Raynor of Shelter Island, Gilbert S. Raynor of Manorville, and LeRoy Wilcox of Speonk kindly provided information concerning the fauna and local areas. State Conservation Department people provided much helpful information, especially Anthony Taormina and John Renkavinsky, but also Windsor Gow, Donald Greeley, Stanley Grom, and others.

Richard H. Manville and John L. Paradiso of the

Bird and Mammal Laboratories at the U.S. National Museum kindly made available various records on file pertaining to Long Island mammals. Richard Van Gelder helped ease my way through the mammal collection at the American Museum of Natural History, New York City, and also spoke of his experiences with various mammals on the island. Valuable comments were received from Robert Cushman Murphy, also of the American Museum, and a native Long Islander. William J. Hamilton, Jr., was helpful in connection with a visit to the Cornell University collection, and in other ways. Especially informative were letters dealing with marine mammals from the following persons: Joseph C. Moore of the Field Museum of Natural History, Robert A. Morris of the New York Aquarium, Carleton Ray of The Johns Hopkins University, James W. Romansky, Jr., of Bay Shore, and William E. Schevill of Woods Hole Oceanographic Institution. Most helpful were Mrs. Charles E. Gillette, who drew the maps and Harold Furlong, who prepared the photographs.

The Mammals of Long Island, New York¹

by PAUL F. CONNOR

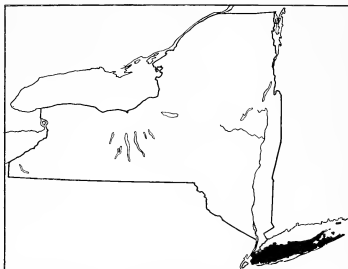
INTRODUCTION

Long Island at the time of the first white settlers abounded in a wonderful variety of wildlife in pleasant surroundings. The various woodland, grassland, and marsh habitats provided homes for most, although not quite all, of the mammals found on the adjacent mainland, while in the ocean and in the many sounds and bays of the area were numerous whales and smaller marine mammals. As the island was settled and tamed from one end to the other, all of the larger species suffered a drastic reduction in numbers, and the large land carnivores were exterminated. However, many small mammals (insectivores, bats, rodents, etc.) and several species in the muskrat-to-fox size range which survived the bounties and other persecutions of early days, and years of fur trapping, are still surprisingly common in much of central and eastern Long Island. Deer, too, are numerous again.

Nevertheless, Long Island today is in a period of incredibly rapid human exploitation. According to Stout (1958) and others, land use on the island is the most swiftly changing in the State as New York City exerts a constant pressure on farm and forest lands for residential development; with a soaring population and a thick network of roads much of the island is rapidly becoming a suburban area. Thus it seemed important to extend the State Museum's continuing small mammal survey to this area at an early date, before further loss of natural areas and habitats occurred.

Field Survey

The field survey was started in the fall of 1960 and continued through the summer of 1963. This work was concerned mainly with collecting small mammals from shrew to squirrel size, preparing study skins and skeletal material, and obtaining information on the local distribu-



MAP 1. MAP OF NEW YORK STATE SHOWING LOCATION OF LONG ISLAND

tion and habits of the various species. All study skins and other preserved material, and field-data sheets for most of the individuals examined are at the New York State Museum, Albany. Concurrently with this survey, other field work was done in cooperation with the New York State Department of Health and other agencies which had initiated a survey of arthropod-borne viruses on Long Island. This work mainly involved collecting migratory blackbirds and some other common vertebrates in Suffolk County. Material preserved, such as bird spleens and blood samples, was tested primarily by the State Department of Health and the information published elsewhere.

Small mammal collecting was confined almost entirely to Suffolk County, a large area consisting of approximately the eastern two-thirds of Long Island (map 2). Field headquarters was located at Hampton Bays during most of the period. Collecting was concentrated in certain regions, especially south and southeast of Riverhead, a relatively wild area for Long Island, with a variety of natural habitats, and in the region of Hither Hills and Napeague Meadows, which are well out on the southern

¹Manuscript submitted for publication August 28, 1970.

fork of eastern Long Island. Trapping was also undertaken at various points along the south shore from Montauk Point to Babylon; on the north shore from Orient to the Nissequogue River; and at some other places such as Shelter Island, and scattered interior localities west to the region of Mineola in Nassau County. These and most of the other places mentioned in the text are shown on map 3. *

Other Information

This bulletin is based primarily on the small mammal collecting program, but I have also attempted to assemble information on the occurrence of the other land mammals and the marine mammals. For this region of the State, there is a rather extensive and scattered natural history literature going back many years; mammal specimens and records are located in various museums and private collections. Long Island has been well endowed with many resident and visiting naturalists, collectors, and students. A more intensive search of these sources would reveal additional information and records of interest. However, it seems worthwhile to summarize the published and unpublished information now available to me on the status of the various mammals, as well as our own findings in the field.

The most important published accounts of Long Island mammals in general are by Helme (1902) and Hamilton (1949). Publications dealing exclusively with the bats of this area are by Murphy and Nichols (1913) and Nichols and Nichols (1934). A recent publication of the Nature Conservancy (Anon., 1968a) has interesting firsthand accounts of the larger land mammals. Other Long Island naturalists who have considerable knowledge of the subject and who have made collections of mammals include William T. Helmuth of East Hampton (deceased), Roy Latham of Orient, and Gilbert S. Raynor of Manorville.

The accounts of species in the present paper deal mainly with the native and naturalized wild mammals which now occur on Long Island and in its adjacent waters, or for which there are at least occasional recent records. Available records of interest concerning mammals on outlying islands such as Gardiners Island, Fishers Island, and Staten Island, have been worked into the species accounts. My information on the status of most species in these peripheral areas is less complete than for Long Island proper. Additional species, such as some which have been extirpated on the island, introduced forms of temporary or local occurrence, and certain small mammals of the nearby mainland which have not been

found on Long Island, are discussed briefly under "Other Mammals" following the species accounts. Extinct species, such as the mastodon, are not discussed.

Maps of eastern United States and North America in several books which show ranges of species of mammals by shading are deceptive as far as Long Island is concerned and are puzzling to many people. Such maps may be large enough to show Long Island as a discrete area, yet the island may be incorrectly shaded in or left blank for certain species. This probably happens from lack of local information, through oversight, or because the area seems insignificant in size.

Most of the mammals living on Long Island at the present time probably were on hand to greet the first white settlers from Europe in the 1600's. Denton (1670), for example, lists muskrats, foxes, raccoons, skunks, otters, and deer among the "wilde beasts" of Long Island. At several Indian archaeological sites on Long Island, with radiocarbon dates ranging between 1043 B.C. and 763 B.C., bones of woodchuck, gray fox, raccoon, mink, white-tailed deer, and various small rodents have been found, and at later prehistoric sites, muskrat, raccoon, whale, and deer have been reported (Ritchie, 1969).

Roy Latham (personal communication) has records from about 100 excavated Indian camps and village sites from Montauk and Orient to Riverhead. At these sites he found the same species mentioned by Ritchie, and also discovered the remains of cottontail (*Sylvilagus* sp.), Eastern chipmunk, gray squirrel, flying squirrel (Riverhead only), red fox, weasel (*Mustela* sp.), striped skunk, and harbor seal. This material was identified by Roy Latham and authorities at the United States National Museum, Washington, D.C., and other museums. Also small bones of mice, moles, and bats were collected but no attempt was made to name them. Evidently only a very few of the established species, as mentioned elsewhere, have arrived since the time of the first European settlers.

Marine Mammals

The accounts of marine mammals are based mainly on a brief survey of the literature and museum collections, and correspondence with a few observers. But it is hoped that all species known from Long Island and its offshore waters have been included. Cetaceans travel widely, and additional species may eventually be recorded from the area. Stranding records include species which regularly frequent coastal waters and those which normally live farther out. Some strand alive for one reason or another, but certain species seem more careful in avoiding this; some float in after death or disablement,

but many species are likely to sink when dead. All strandings are considered local records, but I have indicated, when known, if the animals were actually alive when found on the shore.

There are no separate species accounts for those marine mammals which have been reported only north or south of Long Island, but some which approach the area quite closely are mentioned under accounts of related species. A few species for which I have no firm Long Island records, but which have been recorded nearby to the north and south of the island, or well offshore, have been included as complete accounts; for these, the Long Island coast is considered to be at least on the edge of their range or occasionally visited. Marine mammals in general; i.e., all the large whales, dolphins, porpoises, and the seals, were very numerous originally, but have been greatly decimated in this area and occur at only a very small fraction of the population present before the heavy settlement of the coast and the era of whaling. Several of the small, little-known whales, however, have never been common. As far as I know, there has not been a general report on the cetaceans of Long Island since the brief statements on a few species by Miller (1899) and Helme (1902).

Checklist

The species accounts, as listed in the Contents, may be considered a checklist of known present-day native

and naturalized mammals of Long Island, with certain qualifications in the case of the marine species. This list totals 59 species. Of these, 35 are land mammals, collected on this survey or examined as museum specimens except for gray fox and short-tailed weasel (published records exist for these). Marine species total 24, and at least 14 of these are represented in museums by Long Island specimens (strandings or killed near shore). I was unable to locate specimens of the other 10, as follows—killer whale, little piked whale, blue whale, and humpback whale, for which there are published records of occurrence; white whale, with one probable sight record, not previously published; gray grampus, sei whale, hooded seal, harp seal, and gray seal, species which have been found both north and south of this area, and also within a very few miles of our coast or directly offshore (details given in text). The author would be very pleased to receive additional records or information concerning land and marine mammals in the Long Island area.

Little attention was given to the question of subspecies, and most of the subspecies names used are merely those of the forms which would, on geographical grounds, be expected to occur; in some especially doubtful cases no subspecific name is given.

Accounts of various species have been handled somewhat differently; for example, information on the small mammals we collected is arranged under subheadings for convenience, and the marine mammals have very brief, general descriptive information for the benefit of readers unfamiliar with these animals.

DESCRIPTION OF REGION

Location

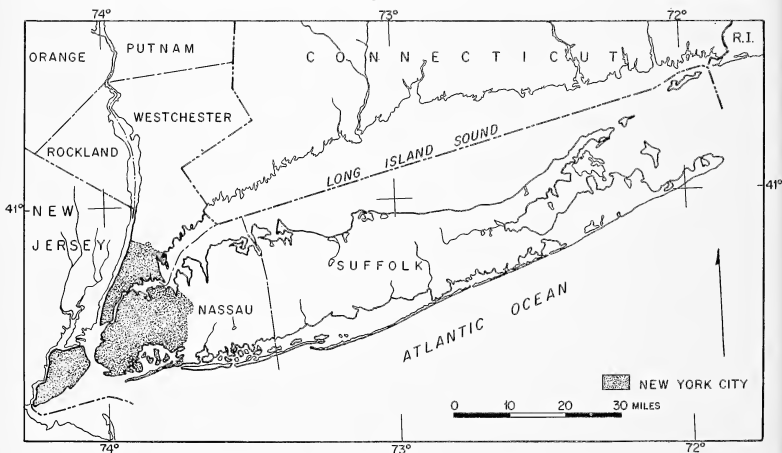
Long Island, approximately 118 miles long and 12 to 20 miles wide for most of its length, is the largest island adjacent to the eastern coast of the United States. A coastal-plain extension of New York State south of Connecticut, Long Island is surrounded by salt water, primarily the Atlantic Ocean and Long Island Sound. At its western end it is narrowly separated from other portions of New York: from the Bronx mainland and Manhattan by the East River, a tidal channel or tidal strait partly occupying a passage cut in rock, and no more than one-half mile wide in places, and from Staten Island by The Narrows, about 1 mile wide. New Jersey is about 2 miles away across the waters of Upper New York Bay. The principal political units of Long Island are the counties of Nassau and Suffolk, and the New York City boroughs of Brooklyn and Queens. Suffolk County, the largest unit, also includes various islands off the east end of Long Island; the most remote is Fishers Island, which is closer to Rhode Island and Connecticut than to Long

Island. Staten Island (borough of Richmond), the least developed part of New York City, together with Long Island and its small outlying islands, make up the coastal-plain portion of New York State.

Topography and Geology

Long Island is mostly flat and elevations are low. High Hill, south of Huntington, about 420 feet above sea level, is the highest point. Aside from a few small outcrops of ancient bedrock near the East River in Queens, the island is composed of unconsolidated materials. The basal layers are Cretaceous in origin, but these are covered nearly everywhere by glacial deposits of gravel, sand, clay, boulders, and till. Long Island was built primarily by the glacier; that is, without the extensive deposits left by the ice, the area above sea level today would be much smaller.

Long Island and Staten Island mark the southern limit on the coast of the Wisconsin stage, the most recent advance of the Pleistocene ice. Two distinct terminal



MAP 2. RELATION OF LONG ISLAND TO THE NEARBY MAINLAND

moraines (accumulations of debris dropped by the ice) were formed at the melting edges of the halted ice margins during two different substages of the Wisconsin. These moraines, existing as two ranges of low hills, are prominent topographic features of Long Island. The older moraine runs through the center of the island and then east along the south fork to Montauk Point and islands beyond. Later, another moraine was developed. On western Long Island this moraine overlaps the earlier one, but eastward the ice did not reach as far south and the moraine forms most of the hilly north shore and extends on to Fishers Island and Cape Cod.

Much of Long Island's surface consists of outwash sediments which form extensive, flat, and often sandy plains south of the moraines. Lesser, but striking, reminders of the glacier are the occasional large boulders, or erratics, some as big as a house, which were carried down from farther north, and the numerous kettle holes (now ponds or hollows) which formed where detached blocks of ice, partly or completely buried, finally melted away.

The sea level fluctuated during the Pleistocene. Marine waters covered most of the Long Island area prior to the Wisconsin advance. Later, during the Wisconsin glacial stage of low sea level (within the last 25,000 years), much of the present continental shelf was evidently a broad emerged coastal plain; teeth of mastodons (*Mammuth americanum*), mammoths (*Mammuthus* sp.), and remains of other large Pleistocene mammals which lived on the plain have been dredged up by fishermen south of Long Island (off New Jersey), and east of Long Island (on the Georges Banks) (Whitmore et al., 1967). With the melting of the ice, the sea level rose again. The Long Island area was probably freed of ice by about 15,000 years ago. The gradual post-glacial submergence of the coastline, which followed, formed Long Island Sound, New York Bay, and Raritan Bay, and also flooded the narrow valley of the East River (Schubert, 1968). The approximate present outline of Long Island thus was established.

Besides land erosion by streams and wind in post-glacial times, the shape of the coastline has been greatly modified by the actions of ocean waves, shore drifting, and tidal currents; this has caused, for example, much land loss at Montauk, and the buildup of miles of barrier beach islands along the south shore. The construction of these low, sandy beaches and the growth of salt marshes behind them have added many square miles to the island in recent times, although probably more than counterbalanced by land lost to erosion and subsidence (Fuller, 1914). Where higher ground meets the coast, as on the north shore, the shores between the forks, and in

the Montauk region, bluffs and rocky beaches face the water.

Plant life covered Long Island following the melting of the ice, the species composition changing as the climate ameliorated (temperate conditions may have arrived about 9,000 years ago). Mammals could have reached the island in various ways, such as by swimming, flying (bats), being transported on floating debris or by man, and walking across seasonally frozen bodies of water and early land connections. A broad expanse of the coastal plain now under water probably remained exposed for a while after the ice front receded, and this would have permitted rapid invasion of the Long Island area. But the rising sea level eventually flooded the shelf and finally severed all land connections between the island and the mainland.

Surface soils of the island, which are well to excessively drained, and tend to be acid, vary from gravels to sands to silt loams. Although the climate (temperature, precipitation) is generally quite favorable, about one-half of the soils are so sandy and porous and of such low water-holding capacity that they are nonagricultural (Cline, 1955; Free et al, 1957). The extensive pine-oak barrens and abandoned fields of central and southern Suffolk County are on such soils. The more fertile areas are on the western end (now under intensive urban pressure) and along the north shore. The production of potatoes is an important industry on soils with good water-holding capacity in northeastern Suffolk County, and locally elsewhere.

There are no large streams on Long Island. Much of the rain water sinks through the deep, porous ground materials to form ground water. The Peconic River, flowing east into the depression between the north and south forks, is the largest stream. Ponds and swamps are rather numerous, however. The coast is indented with many tidal inlets, bays, and estuaries.

Climate

Much of the following is from Taylor (1927). Long Island has a milder climate than the remainder of New York State, and has a long growing season which averages between 180 and 210 days in length. The climate in general resembles that of the nearby mainland, but the ocean has a moderating influence here, reducing to some extent the extremes of summer heat and winter cold. The climate differs somewhat at the two ends of the island. Spring is later on the eastern end, where the influence of the cold ocean water retards the growth of vegetation (leafing of trees, etc.), and this difference,

which may be as much as 2 weeks, is very noticeable if one travels from Brooklyn to Montauk at this season. There is, however, a long frost-free season on the east end, since killing frosts rarely occur late in spring, and the moderating effect of the ocean also tends to delay fall frosts. Central Long Island occasionally experiences very hot periods in summer; the heat may be especially oppressive in the pine barrens where the open canopy lets down much more sunlight than other forest types.

The average annual precipitation is 40-50 inches over most of the island, and somewhat less than 40 inches in the Napeague-Montauk region. Snowfall averages about 20-40 inches, less than mainland New York, and a snow cover rarely lasts because of the relatively mild climate (winter of 1960-61 unusually severe). There is a good deal of rain during the winter. Summer months are the driest, the lack of rain producing occasional droughts destructive to plants on the highly porous soils, especially when combined with high temperatures and winds.

Long Island is a windy place, and where there are no obstructions, as at Montauk, Shinnecock Hills, and along the outer barrier beaches, wind has a pronounced local effect on the vegetation. In such areas during winter the wind makes it feel much colder than the thermometer indicates. Weather Bureau records show that Montauk Point is one of the windiest spots along the Atlantic Coast. In summer, regular, cooling "sea breezes" make eastern Long Island and the outer beaches pleasant.

Severe coastal storms such as hurricanes (usually in late summer) and northeasters (usually in winter), occasionally batter the coast. At times they break through the outer beach strip to create new tidal inlets, which may increase the salinity and affect the life of the bays. The inlets may become sealed off again naturally or shift from east to west; man has worked to keep some of them open for boating by building jetties and dredging. Some of our field work was conducted in the vicinity of Shinnecock Inlet, which was created during the exceptionally destructive hurricane of September 21, 1938, and Moriches Inlet, which was opened during a storm in March 1931. Helmuth (1954) wrote a fascinating account, based on his personal field observations, of the great hurricane of 1938 on eastern Long Island and its effect on the bird and small mammal populations of the area.

Western Atlantic coastal waters between far northern and tropical seas may be considered to belong to three main zones or faunal provinces, significant in the distribution of many marine invertebrates and vertebrates. There is a cold-water zone north of Cape Cod and a warm-water zone south of Cape Hatteras; Long Island is in the northern part of the temperate-water zone between the two capes.

Vegetation

The vegetation of Long Island has been profoundly affected by the activities of modern man, especially on the urbanized western end, where very little remains of the original flora. Indians had been living on Long Island for many centuries prior to the arrival of the white men. Undoubtedly the former had some effect on the vegetation through their deliberate burning of the woods, helpful in hunting game, and their clearing of the ground to plant corn and other crops. But the big change began in the 1600's when the whites replaced the aboriginal inhabitants. The first Dutch farm was established in what is now Brooklyn in 1625, and English settlers, by way of Connecticut, arrived on eastern Long Island in 1640. The English spread west rather rapidly along the coasts of Long Island, while the Dutch for a time controlled the western portion.

By 1670 Denton was able to write: "Long Island . . . is inhabited from one end to the other. On the west end is four or five Dutch towns, the rest being all English to the number of twelve, besides villages and farm houses." He also wrote of meadows and hayfields which supported a plentiful supply of cattle and other livestock. As for the Indians, Denton stated that in his own time they were reduced from six towns to two small villages, although the survivors still went hunting and fishing and raised crops of corn.

Svenson (1936) discussed the early vegetation of Long Island, quoting extensively from Denton (1670) and other writers of long ago. In early Colonial days there were tall and impressive stands of timber, especially on the western end and along the north shore; tall red oak, white oak, hickory, black walnut, American chestnut, and beech abounded. Much of the valuable timber was removed very early. Long Island was praised by the settlers for its wild fruits, an abundance of strawberries, blueberries, huckleberries, cranberries, grapes, and beach plums; the wild strawberries were large and eagerly sought.

The vast pine and oak barrens, typical of central and southern Long Island today, were mentioned by early travelers. Apparently much of this forest became degraded, however, by heavy cutting and ever more frequent fires. Swamps of southern white cedar formerly were much more widespread than at present, and typically bordered the heads of tidal streams all along the south shore. The Hempstead Plains, unusual in being considered a true natural prairie in the East, originally comprised an area 16 miles long, covered with tall grass. Denton (1670) stated that it was being mowed for hay, and used to graze sheep and other livestock and for rac-

ing horses. A sizable portion of the Plains remained until a few decades ago, but now only a small remnant has survived the spread of suburban housing. According to Taylor (1923), early Colonial documents described the hilly coastal grasslands still existing in the windy Montauk area, known as the Montauk Downs. The grassy, rolling Shinnecock Hills apparently are more stabilized than formerly; older writings refer to a lack of vegetation and drifting sand in this area. The woods of Gardiners Island reportedly grew the largest trees in all of the Long Island area up until the destructive hurricanes of 1938 and 1944. According to Taylor (1923), woods in a relatively sheltered area near Montauk Point had trees as large as those of Gardiners Island before a severe storm in 1815. The barrier beach and salt marsh habitats, once relatively inaccessible, are endangered by steadily increasing recreational use of the entire south shore.

The climate and elevation are fairly uniform throughout Long Island and small differences are of minor importance in the distribution of plants. Underlying geological materials, soil types, and moisture are significant. The pine barrens, for example, grow largely on the sandy, gravelly outwash plains, while a mixed deciduous forest covers richer, moister sites on the north shore moraine. Brodo (1968) points out that there is a strong correlation between soil types and vascular vegetation on the island. Fires play an important role in the barrens, favoring fire-resistant pitch pine and scrub (bear) oak; where fires are especially frequent the pines and oaks are low and shrubby.

Brodo (1968) described the vegetation types of Long Island, and referred to the many botanical papers dealing with local areas and plant associations. Peters (1949) gave an account of the dominant types of vegetation. A brief and sketchy classification, based on these and other references and my own field work is given below. All of the 14 major categories listed were searched for small mammals except for the nearly vanished Hempstead Plains; some of the study areas were in miscellaneous or edge habitats not resembling any of the major types. Habitats where the various mammals were found are mentioned in the species accounts, and some of the collecting areas are shown in the photographs (figures 1 to 26).

Mixed deciduous forests. The forest of the richer soils of western Long Island (now surviving only in parks and other small areas) and also on the north shore (in estates and woodlots). Large trees, growing especially tall in the western areas—black oak (*Quercus velutina*), white oak (*Q. alba*), red oak (*Q. rubra*), beech (*Fagus grandifolia*), tuliptree (*Liriodendron tulipifera*), black birch (*Betula lenta*), hickory (*Carya* spp.), and others.

Oak forests. These occupy extensive areas on drier soils in central Long Island and on the south fork (both west and east of the pine barrens, and elsewhere). Scarlet oak (*Q. coccinea*), black oak, white oak, and other oaks.

Pine barrens (or Pine-oak barrens). The typical pine barrens on Long Island consist of nearly pure stands of pitch pine (*Pinus rigida*), with an extensive undergrowth of scrub oaks, especially the species known as bear or barren oak (*Quercus illicifolia*). Also blueberries, huckleberries, and the low ground cover, bearberry (*Arctostaphylos uva-ursi*) may be found. This habitat is especially characteristic of dry, very well-drained soils, and high incidence of fire. Areas where all the vegetation is low and scrubby are sometimes called "pine plains" or "oak brush plains." The pine region extends from eastern Nassau County east to Riverhead and Hampton Bays.

Pine-oak forest. Similar to the pine barrens, but more mature, with older trees and a large proportion of tree-sized oaks, such as white oak and scarlet oak. Pitch pine, the dominant conifer of Long Island, and the various scrub and tree oaks, the dominant deciduous trees, also are found growing in all sorts of complex combinations. The predominantly oak woods in turn merge with the mixed deciduous forests.

Other forests. Of interest are certain woodlands near the coast of eastern Long Island and on the outer barrier beach, which are relatively small in extent but apparently long-established and unlike woods elsewhere. Most publicized is the Sunken Forest, where holly (*Ilex opaca*), tupelo (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), shadbush (*Amelanchier*), and other species form a deeply shaded woodland sheltered behind the inner dunes on Fire Island. In Hither Hills there is a woodland ("Hither Woods") of old oak trees somewhat dwarfed by the wind and formerly festooned with lichens. A stretch of woods near Montauk Point ("Point Woods") contains a beautiful stand of beech, oaks, holly, red maple, etc. Other rich woods with large beech and oaks on eastern Long Island are on Shelter Island and Gardiners Island. On the survey, we collected in the woods of Hither Hills, and to a lesser extent in the woods of Montauk and Shelter Island, and only visited the Sunken Forest and Gardiners Island.

Southern white cedar swamps. Coast or southern white cedar (*Chamaecyparis thyoides*), growing closely together, is the dominant tree. Ground cover consists of sphagnum moss. Now of very limited distribution on Long Island, cedar swamps are found mainly near ponds and streams in the eastern part of the pine barren region.

Red maple swamps. This is the most frequent type of swampy woods; common along streams throughout

the island. Red maple (*Acer rubrum*) is numerous, and tupelo is often present.

Sphagnum bogs. Small areas of leatherleaf (*Chamaedaphne calyculata*), sedges, sphagnum, and other bog plants are found in wet areas of the pine barrens and eastern Long Island. *Chamaecyparis* may be present as scattered trees or along the edge. Abandoned cranberry bogs also are present locally.

Fresh marshes. Fresh-water marshes, with grasses, sedges, cattails, and the like, are found mainly along south shore streams, around ponds, and in kettle holes.

Hempstead plains. This natural prairie land, formerly extending across much of central Nassau County, is (or at least was) dominated by a species of beardgrass (*Andropogon scoparius*).

Downs (grassy coastal uplands). The Montauk Downs, described in detail by Taylor (1923), are grassy, rolling hills with occasional islands of shrubs and a very few widely scattered trees. Here the wind seems to be principally responsible for preventing or greatly slowing down the development of trees. The Shinnecock Hills are somewhat similar and are exposed to winds blowing across the ocean and Great Peconic Bay. The vegetation consists of *Andropogon* spp. and other grasses, with clumps of bayberry (*Myrica pensylvanica*), beach plum (*Prunus maritima*), etc., and some scattered trees (pitch pine, red cedar).

Dunes (grass and thickets). Sand dunes are the backbone of the outer beach strip, and also occur in

some other areas. Probably the largest dunes on Long Island are the spectacular moving or "walking" dunes on the east side of Napeague Harbor. Desert-like conditions prevail on the dry sandy dunes; beachgrass (*Ammophila breviligulata*) is the most vigorous dune plant in exposed situations, while certain shrubs (bayberry, beach plum) are frequent. Along the ocean, primary or outer dunes lie just behind the beach, while a bit farther back are the more stable secondary or inner dunes. In the interdune valleys, and in depressions and hollows, may be found moist, protected situations where the vegetation is relatively dense (and small mammals numerous).

Salt marshes. Located primarily in the bays along the south shore, these marshes are still fairly widespread. They are covered periodically by salt water during very high tides, and contain certain plants, such as salt-meadow grass (*Spartina patens*) and marsh-elder (*Iva frutescens*), not found in other habitats.

The extensive Napeague Meadows, situated between Napeague Harbor and the ocean dunes, does not seem to fit any of the above categories exactly. Quite a few small mammals were collected in this flat, open, maritime area containing both moist meadow (fresh to salt) and dry sandy ground.

Abandoned fields. Dry, sandy, abandoned farm fields with grasses (especially *Andropogon virginicus*) and various weeds, are frequent on the poor soils of central Long Island and were covered in this survey.

ACCOUNTS OF SPECIES

Opossum

Didelphis marsupialis virginiana Kerr

The opossum is generally common on Long Island, but apparently it has been a resident here only during the past 100 years or so. It became established late in the 1800's, probably as the result of repeated accidental introductions and releases. Seemingly contrary to the prevailing evidence is a statement by Denton (1670) naming the opossum as a food of Long Island Indians; however, Denton did not include this marsupial in a list of Long Island mammals presented elsewhere in his publication.

Audubon and Bachman (1851) predicted that the opossum would in time become established on Long Island, and in other areas east of the Hudson River, because the living animals were constantly being carried there. Helme (1902) mentioned accumulating reports of opossums in the early 1880's and stated that in a few years they became common with a wide distribution the full length of the island. Opossums were quite common at Montauk in 1893, but had become common there only a few years earlier (Dutcher and Dutcher, 1893). By the late 1880's several towns were paying bounties for the destruction of opossums, but this seemed to have no appreciable effect on their abundance, even though thousands were reported killed in some years.

Nowadays, this is one of the mammals frequently found dead along many of the highways on Long Island, indicating a high population present. The opossum seems to thrive in the more thickly settled areas, and is even found within the limits of New York City. In our field work, this species was frequently noted along the south shore, throughout much of the south fork, in the central pine-oak region, and in some north shore areas. We regularly saw opossums in sandy and marsh-edge habitats on the outer barrier beach between Moriches Inlet and Shinnecock Inlet.

However, in comparing today's abundance with that suggested in the early reports, and judging from the records of experienced observers extending over many years, there are fewer opossums in some sections of the island at present than during their first decades of explosive increase. Roy Latham (personal communication) writes that opossums were common in Orient and throughout the north fork from 1900 to 1930, but have become

scarce within the past 10 years, while red foxes and raccoons have increased dramatically since 1930. Our field work in 1963, and conversations with local residents, indicated opossums to be quite rare on Shelter Island; opossums were formerly common there, according to Latham, and he has records for Shelter Island up to 1943. The opossum seems to have had a checkered career on Staten Island, including a marked increase late in the past century.

Masked Shrew

Sorex cinereus cinereus Kerr

Distribution and habitat. The masked or common shrew is rarely seen and is not as familiar to Long Island residents as the eastern mole, short-tailed shrew (also often called "mole"), and the various kinds of mice. Nevertheless, it is quite possible that this is the most numerous mammal on Long Island. Trapping results indicated this to be the case at least for the less developed areas of Suffolk County. *Sorex* was outnumbered in our total Long Island catch by *Blarina*, *Peromyscus*, and *Microtus*, but these last three are more easily trapped than this tiny *Sorex*, which, when it does encounter a trap may often escape untouched or fail to spring it. Furthermore, on Long Island this species is found in a great variety of environments, as discussed below. This is the smallest mammal found here; in New York State only the pigmy shrew (*Microsorex*) is smaller, and it is not known to occur on Long Island.

Trapping results indicated the presence of this species in just about every habitat on Long Island with sufficient ground cover, including both damp and dry situations, and areas with or without woody growth. Grasslands of every description, except where the grass was too sparse, were especially productive: over half of the specimens were taken in grass. Such habitats included abandoned fields, the Shinnecock Hills, fresh marshes (along streams, etc.), salt and brackish marshes, moist and dry grassland at Montauk Point, and dry sandy places near the shore (such as depressions among the dunes, meadows at Napeague, etc.). In these habitats various shrubs, sedges, and miscellaneous herbs were often present, but grass of

one kind or another was the dominant feature. This shrew and *Microtus* were frequently found together, the former often traveling the runways of the latter.

This little shrew occurs all along the outer barrier beach of the south shore, such as Jones Beach, Fire Island, and between Moriches and Shinnecock inlets. Individuals have been found under old logs and other driftwood on the upper beaches of both the north and south shores and at Montauk Point.

Sorex cinereus was also common in the woods. Oak woods, mixed deciduous woods, pitch pine barrens, swampy woods of red maple and other trees, southern white cedar swamps, and both dry and damp coastal woods near Montauk Point, all yielded their quotas of this shrew. Probably it occurs in the Sunken Forest on Fire Island, although we did not trap that part of Fire Island. In the woods the shrews were trapped under the leaf litter and fallen branches, about stumps and logs, in mole tunnels, and in mossy cavities in maple swamps and at the base of cedar trees (figure 8). Hamilton (1949) wrote of trapping many in woods at Roslyn (north shore of Nassau County), and they are still found in wooded parks in eastern Queens.

Sphagnum bogs were also good for finding *Sorex* (figure 9). Here, leatherleaf, other shrubs, and sedges grow above the thick sphagnum carpeting the ground; the shrews were found in runways and cavities on and under the moss. In several of the cool cedar swamps and sphagnum bogs *Sorex cinereus* was the only species of small mammal collected. These habitats are very reminiscent of areas in the New Jersey pine barrens, many of the same plants being found in both regions. But the New Jersey region has a richer mammal fauna in that the cedar swamps and sphagnum bogs there are inhabited also by the red squirrel (*Tamiascus*), red-backed mouse (*Clethrionomys*), bog lemming (*Synaptomys*), and meadow jumping mouse (*Zapus*) which do not occur on Long Island, except for the jumping mouse, which is scarce.

Sorex cinereus is present on Staten Island and Shelter Island. I do not know of any records of this shrew on Gardiners Island, Plum Island, or Fishers Island, but would not be surprised if it was found on these islands off the east end of Long Island.

Reproduction. Masked shrews were found to produce young on Long Island for at least half the year, from April through October. On April 27, one female examined was carrying seven embryos, while five other females in April were already nursing litters—April 18 (1), April 26 (3), and April 27 (1). Reproduction continued through the summer and in October as well, although at a

reduced rate since there was evidence of fewer pregnancies after June. On October 14, a female carried six quite small (about 2.5 mm.) embryos, and another one on October 20 was lactating. Litter size based on eight embryo counts averaged 5.9 (range four to seven); embryo size ranged from about 1 mm. (diameter of swellings) to 11 mm. (crown to rump length). Adult males in evident breeding condition (reproductive structures markedly enlarged) were collected from March 18 to October 14. The first juveniles out of the nest were trapped June 7 and 8.

Measurements. Forty adult males, collected from March to October at various localities in Suffolk County, and all in apparent breeding condition, average: weight, 4.7 grams (3.4-6.4); total length, 99.3 mm. (92-105); tail, 38.7 mm. (35-42); hind foot, 12.0 mm. (11-12.5). Females are closely similar in size and 30 adult females (eight with embryos) from March to November (same localities) average: 4.8 grams (3.2-7.9); total length, 99.2 mm. (92-105); tail, 38.2 mm. (33-41); hind foot, 11.9 mm. (10-12.5). If the eight pregnant females are excluded, the 22 remaining adult females weigh slightly less, averaging 4.5 grams (3.2-6.0).

Individuals taken. 216

Short-tailed Shrew

Blarina brevicauda talpoides (Gapper)

Distribution and habitat. On Long Island, *Blarina* is distributed from Brooklyn to Montauk Point and on some of the offshore islands. This large shrew is generally abundant in many different habitats throughout its range, which blankets much of eastern North America. On the island we found *Blarina* most numerous in woods with deciduous trees (133 taken), such as oak or mixed deciduous woods, oaks with pines, and red maple swamps; and in inland fields (91 taken).

Only a relatively small number (26), were taken in all other habitats, that is, seven or less were taken in each of the following: pine barrens, southern white cedar swamps, sphagnum bogs, fresh marshes, salt marshes, and coastal dunes and grasslands. Several extensive traplines in these habitats did not yield a single specimen, and also we failed to find any at our outer barrier beach localities.

This was quite different from our experience with *Sorex cinereus*. Especially in sandy grasslands near the shore (including the outer beaches), in salt marshes, and in sphagnum bogs, *Sorex* was much more numerous than *Blarina*. The following are some examples of this among trap returns in the period 1961-63: Napeague Meadows

on the south fork (traps mostly in dry sandy grassland)—40 *Sorex*, no *Blarina*; Hither Hills (in grassy depressions near Napeague Harbor)—28 *Sorex*, two *Blarina*; various sphagnum bogs—17 *Sorex*, four *Blarina*. Many of the traps were set in *Microtus* runways in these areas. On the other hand, in woods and also in many fields away from the immediate vicinity of the coast *Blarina* seemed to be the more numerous shrew. *Blarina* was common on wooded bluffs of the north shore, overlooking Long Island Sound.

In woods and fields, short-tailed shrews were frequently taken in close association with pine mice, in the same burrows in the humus or sandy soil. Also, mouse traps set in tunnels of the eastern mole took many of these shrews. Nineteen were caught in star-nosed mole tunnels in red maple swamps at Belmont Lake State Park, Babylon. Of course, being so numerous in general *Blarina* was also found living together with the other small mammal species in one area or another.

Blarina was common during this survey in 1963 on Shelter Island, in both woods and fields. Richard Van Gelder (verbal communication) has trapped this species on Gardiners Island. The short-tailed shrew occurs at Orient Point and also on Fishers Island, but I do not know of any records for Plum Island. This island is a quarantined animal disease laboratory and few naturalists visit. *Blarina* is common on Staten Island, where the least shrew (*Cryptotis parva*) also occurs.

Reproduction. Only five pregnant females were taken, the earliest on March 22. Embryo counts ranged from five to eight (average 6.7). Males in apparent breeding condition were collected from January 16 (1962) and March 9 through the first half of October.

Measurements. Fifty adult males from various months average: weight, 17.9 grams (13.4-24.1); total length, 119.4 mm. (109-129); tail, 24.9 mm. (21-30); hind foot, 14.2 mm. (13-16). Twenty nonpregnant adult females (various months) average: weight, 16.1 grams (12.9-20.9); total length, 119.5 mm. (112-128); tail, 25.4 mm. (23-28); hind foot, 14.3 mm. (13-15).

Individuals taken. 250

Eastern Mole

Scalopus aquaticus aquaticus (Linnaeus)

Distribution and habitat. This is the common species of mole on Long Island, and it is also present on Staten Island. The hairy-tailed mole (*Parascalops*) which is the

common mole in woods and drier ground in most of "upstate" or mainland New York, has not been found in this region.

The eastern mole occupies most of Long Island where the ground is not too wet. Probably it is most numerous in some of the mixed deciduous woods along the north side of the island where richer soils accommodate high populations of invertebrates. However, the mole also occurs in the sandy ground throughout the pine and oak areas, and in abandoned fields, of the central and south shore portions of Suffolk County. The conspicuous ridges, marking the course of the shallow subsurface tunnels, may be seen even in exceedingly barren situations, such as under scrubby waist-high "pine plains" vegetation south of Riverhead. The mole also invades suburban yards, where its tunnels and mounds disfigure lawns to some extent.

East and west, its range extends nearly the full length of the island—from parks within New York City limits to well out on both the northern and southern peninsulas, or forks, of eastern Long Island. On the north fork a mole was collected within 3 miles of Orient Point. On the south fork we did not find the eastern mole in the immediate vicinity of Montauk Point, but it was common in the Hither Hills region a few miles from the point. In their mammal survey of the Montauk region before the turn of the century, Dutcher and Dutcher (1893) wrote: "No moles of any kind were observed east of Napeague Beach, although careful search was made, nor did we hear of any mole ridges ever being seen on Montauk. Napeague seems to them to be an impenetrable barrier." In the present survey (early 1960's) we found mole tunnels numerous at Hither Hills, which is east of the narrow neck at Napeague. Perhaps *Scalopus* is extending its range eastward in this sector.

Scalopus is present on Shelter Island, according to Roy Latham (personal communication). Moles have not been collected or reported on Fire Island, Gardiners Island, Plum Island, or Fishers Island, as far as I know. It seems likely that moles are absent from some if not all of these islands.

This mole frequently digs through pure sand in the vicinity of tidal water. The tunnel ridges may be seen in sandy ground along the very edge of salt marshes or meandering across dunes near the ocean. Such areas seem insufficiently provided with food, and are probably not permanently occupied by the moles, but the tunnels in these situations are conspicuous. Near Moriches Bay (in April) I noted a mole tunnel in a rather high, sandy bank bordering a salt marsh stream. Long, raised mole tunnels across the surface of the smooth sand are fre-

quent in the moving dunes area at Hither Hills State Park. At nearby Napeague Harbor in June, mole tunnels were seen which traversed the rolling surface of beach dunes and wandered over the level upper beach. Near East Hampton I trapped a mole during December in a sand tunnel on inner dunes about 800 feet from the ocean; cover consisted of bare sand alternating with patches of woody *Hudsonia tomentosa* and lichens. A remarkable spot to see a mole tunnel was on a sandbar about 1,000 feet long separating Peconic Bay from a pond and salt marsh. Here (in March) a mole had tunneled for hundreds of feet through low sand dunes, with beach-plum (*Prunus maritima*) and beach-grass (*Ammophila*) for scattered cover. The mole finally stopped upon encountering an outlet stream which crossed the beach. Some of the tunnels, such as those at Napeague Harbor, were in locations which would occasionally be covered by salt water during storms or exceptionally high tides. But I did not see *Scalopus* tunnels in the true intertidal zone of beaches, such as have been reported by McCully (1967) for the California mole (*Scapanus latimanus*).

Fresh swamps and meadows on the island are mostly without moles, since the semi-aquatic *Condylura* is extremely local here, and the present species generally avoids water. Occasionally though, tunnels of *Scalopus* penetrate a short distance into the damp soil of creek banks and wet woods. In the shrubby grassland of Shinnecock Hills, moles seemed scarce; tunnels were noted only in a few depressions among the hills. On the grassy, hilly Montauk Downs I did not find any evidence of mole activity.

Moles seemed to be uncommon in some cultivated areas, such as farmlands on the north fork. In this section moles were found primarily in the lighter soils of hilly, wooded areas, such as Browns Hills, where they are common. Roy Latham (personal communication) explains further: "*Scalopus* is restricted to the hills in Orient and dry soil on the north fork. I never saw it in the heavy farm land that is cultivated. It is uncommon in Greenport and Orient. Common in most sections of eastern Long Island." In Browns Hills, in June 1963, in a woodland of hickory, hackberry, and other deciduous trees, with an undergrowth of rank weeds, the loose, fertile soil teemed with earthworms, insects, and other invertebrates, and was riddled with mole tunnels (one *Scalopus* was collected).

Specimens were trapped in the different habitats mentioned above, such as various types of deciduous woods, pine barrens, fields, suburban yards, and sand dunes. Most specimens were caught with ordinary mouse snap traps placed crossways in the tunnels, level with the lower

surface, and the opening above covered over with cardboard, although they are harder to catch this way than *Parascalops* or *Condylura*. Some were collected in each of the four seasons; in cold, midwinter weather, trapping was possible in tunnels where the ground was not frozen, such as those under deep pine-needle litter. Moles remained active in winter in tunnels near the surface as long as the ground was not deeply frozen.

Also at this season (December, January) I occasionally noted in yards and gardens, large, conspicuous "mole hills," larger and more numerous than usually made by this species. These mounds probably consisted of earth brought up from deep burrows undergoing excavation. The ground often had a lumpy appearance in such areas, apparently the result of irregular up-and-down tunneling or shifting of earth, instead of the usual horizontal digging. In the warmer months a surge of increased activity near the surface was common when it rained following a dry period, especially in sandy areas.

Short-tailed shrews and pine mice were found to travel through the mole tunnels frequently and to make holes opening up on the surface. Other species such as masked shrews, meadow mice, and white-footed mice also used the tunnels in some localities.

Food habits. Eighteen stomachs were examined (five spring, four summer, six fall, three winter). Insects are foremost in the diet in much of the area judging from this small sample, being found in all the stomachs checked and comprising 68.8 percent of the total volume. Earthworms have been reported as the primary food of this mole in many regions, but I found them in only two stomachs (6.7 percent of volume). A mole from a north shore locality where earthworms were numerous, however, had been feeding almost entirely on these animals (June).

In most other Suffolk County localities where moles were collected, such as Riverhead, Hampton Bays, etc., earthworms are not so common, and insects were first in the diet. Most important in this category were "white grubs," the large larvae of June beetles (Scarabaeidae: *Phyllophaga*), 26.1 percent of total volume and present in 10 stomachs; and ants (Formicidae), 21.2 percent of total volume and in 11 stomachs. Over 100 ants were counted in one stomach (March). Other insects eaten included other Coleoptera (adults and larvae) and larvae of Lepidoptera and Diptera. Other invertebrates, which were present in only small numbers were slugs, sow-bugs (Isopoda), spiders, and centipedes.

The only vertebrates detected as food were two red-backed salamanders, (*Plethodon cinereus*, lead-back color phase), in the stomach of a mole collected at Flanders

on March 9. The eastern mole feeds to a limited extent on plant material. Vegetation was found in eight stomachs (8.9 percent of total volume); this was chiefly pieces of an unidentified slender root.

Reproduction. The eastern mole breeds early in spring, producing one litter a year. Two males collected in the first week in March were in apparent reproductive condition, with much enlarged testes and accessory structures. These males showed pronounced orange-brown glandular stains on the chin, snout, wrists, and along the ventral midline of the body. Males from May to January all appeared to be nonbreeding. A female on May 3 showed four distinct placental scars and evidence of having very recently given birth. Another female on June 6 also showed four placental scars and was lactating.

Hamilton (1943) found a nest containing four young in mid-April on Long Island.

Remarks. Two adults which showed distinct evidence of molting were taken on June 6 and 13, 1963. These individuals had extensive areas of new, shorter fur coming in dorsally and ventrally, contrasting with patches of old faded fur. These animals were probably molting from winter to summer pelage (spring molt).

A pure white albino mole of this species was plowed out at Calverton on July 4, 1952 (Roy Latham, personal communication).

Measurements. Ten adult males from Suffolk County average: weight, 64.3 grams (56.5-74.8); total length, 163.3 mm. (155-172); tail, 28.6 mm. (24-32); hind foot, 19.7 mm. (19-21). Nine adult females from Suffolk County average: weight, 49.9 grams (38.4-58.4); total length, 154.6 mm. (140-159); tail, 26.9 mm. (23-30); hind foot, 18.9 mm. (18-19.5). The smallest mole collected was an adult female in mid-January which weighed only 38.4 grams, and measured 140 mm. in total length.

Individuals taken. 22

Star-nosed Mole

Condylura cristata cristata (Linnaeus)

Distribution and habitat. The star-nosed mole is very scarce and local on Long Island, where it seems to have escaped detection by many of the active field naturalists and collectors. Helme (1902) searched various parts of the island without finding any evidence of its presence. The only record he had was one he found lying dead in the street at Miller Place on the north shore, about 4 miles east of Port Jefferson; Helme thought perhaps the ani-

mal had been dropped by a hawk which had carried it over from the Connecticut mainland. Jackson (1915) listed other New York, but no Long Island localities for this species, and he did not include Long Island in his map showing the geographic range of *Condylura*.

Three specimens, all males, collected on western Long Island after Helme's publication are in the American Museum of Natural History. Two are from Baldwin in Nassau County—September 1, 1907 (A.H.H.), No. 35155, and September 28, 1908 (D. Franklin), No. 73626; the third specimen was taken north of Jamaica in Queens, May 17, 1913 (H. Boyle), No. 37271. Apparently these specimens did not come to the attention of Jackson and others. Suitable habitat probably no longer exists in those localities. There are also some published references attesting to the presence of this species on Long Island. Audubon and Bachman (1851) stated they had received specimens from a collector on Long Island. Nichols (1907) on April 18 received a star-nosed mole (caught by a cat), from Great Neck, north side of Nassau County. Turrell (1939) termed the star-nosed mole as "fairly abundant" in the Smithtown region but gave no additional details. Probably he found the species present in this area without realizing its general scarcity on the island. The star-nosed mole is present on Staten Island, where some have been found in barred owl (*Strix varia*) nests and pellets (Chapin, 1908; Davis, 1908).

On our survey, a very few reports were received of animals seen (or found dead) which were recognized as this species by the observer, or consisted of a convincing description of it. Reports represented both north and south shores of western Long Island—Nassau County and into Suffolk County as far east as the Connetquot River. Because *Condylura* is so distinctive in appearance, such reports are considered reliable. Gilbert S. Raynor and Richard Van Gelder (verbal communications) also have received a few sight reports of this species on Long Island.

In and near Belmont Lake State Park, at Babylon, I collected six star-nosed moles and found numerous signs of this species. Whenever visiting meadows, wooded swamps, or streamside areas on the island which looked suitable for *Condylura* I examined the ground closely, but never found definite signs of its presence other than in this one locality. Favorable-looking but apparently uninhabited spots were examined at Carmans River, Eastport, East Hampton, East Quogue, Flanders, Forge River, Hauppauge, Middle Island, Nissequogue River, North Hills, Peconic River, and Westhampton Beach. On Great Hog Neck, on the north fork of eastern Long Island, mole tunnels were present in wet, black, swamp soil where there were many earthworms, tunnels which may have

been the work of this species. This seems somewhat questionable, however, since no specimens were taken and tunnelings of the eastern mole were abundant in dry soil nearby.

Thus it appears that the star-nosed mole is, or was, most common towards the western end of the island; however, in this section probably most of its habitat has been destroyed by the expanding metropolitan area. Evidently its range extends eastward in a spotty manner along both the north and south shores of the island. If it occurs in eastern Suffolk County, it must be very local, since we did much field work there without finding the species. Possibly the widespread boggy, acid conditions in the wet areas, with an accompanying scarcity of earthworms or other food, is unfavorable. However, Christopher McKeever has shown me an unpublished list of Long Island mammals by William T. Helmuth (consisting of marginal notes written in a copy of Hamilton, 1943) which records East Hampton as a locality for *Condylura*. This is far to the east of other specimens and reports, although I have not learned of any star-nosed moles actually collected at East Hampton.

The Babylon habitat was situated along a small stream, tributary to Carls River (figures 13, 14). The moles were found inhabiting the ground at least one-fifth of a mile along the stream, in the vicinity of the west boundary of Belmont Lake State Park (on both sides of the boundary line). Most of the mole activity was found within a few yards of the creek, which was shallow, sluggish, and about 2 to 3 feet wide. The ground was wet, mucky, and black and contained many earthworms. The site was rather heavily wooded with red maple and tupelo, and many shrubs and vines such as highbush blueberry, arrow-wood, common elderberry, *Smilax*, etc. Skunk cabbage and cinnamon fern also were plentiful.

No evidence of mole activity was detected in this area at first glance. The colony was located by probing the ground by hand until some rather deep tunnels were located. No surface ridges of pushed up soil were present. Eventually, small, inconspicuous "mole hills" were noticed—mounds of mucky soil pushed up from tunnels below and partly covered by fallen leaves. The larger mounds were about 2 inches high and 6 inches in diameter. These mounds apparently were made in the fall; by spring they had almost entirely disappeared, although the moles were still numerous in the area. Also, shallow tunnels of *Condylura* were noticed when setting traps—these were typically along the sides of logs and were merely furrows covered by leaves and other debris. From some of the tunnels vertical shafts led down to the water level a short distance below.

Two individuals were trapped on December 1, 1961, and four were caught on April 24, 1963. All were taken using standard wood pedal mouse traps set down in the tunnels in spaces excavated with a knife. Other small mammals present were *Blarina*, *Peromyscus*, and *Microtus*; *Blarina* and *Microtus* frequently used the *Condylura* tunnels. Other wildlife along the creek included woodcock, raccoon, opossum, cottontail, and gray squirrel. I have since learned that this creek area has been scheduled for drainage and other "improvements," which probably means the end of the colony of star-nosed moles.

Food habits. Earthworms ranked first in the stomach contents of the six moles examined, comprising 55 percent of the total volume and occurring in five stomachs. Insect larvae, including numerous craneflies (Tipulidae), were second at 26 percent of volume, present in five stomachs. Other foods included beetles, spiders, and plant material.

Reproduction. All three males taken on April 24 were in apparent breeding condition, with much enlarged reproductive structures (testes 20-21 mm.).

Measurements. Three April adult males average: weight, 49.4 grams (48.8-50.0); total length, 185.7 mm. (185-186); tail, 68.0 mm. (64-71); hind foot, 26.8 mm. (26-27.5). An adult female, in April, without embryos, measured: weight, 58.5 grams; total length, 185 mm.; tail, 67 mm.; hind foot, 27 mm.

Individuals taken. 6

Little Brown Myotis

Myotis lucifugus lucifugus (Le Conte)

Distribution and habitat. At the present time the little brown appears to be the most numerous summer bat over most of Long Island. Evidently it has increased considerably in numbers since the early part of the century. Helme (1902) does not mention this species, except for stating, under a brief account of the big brown bat, that a smaller unidentified brown species is of occasional but rare occurrence on Long Island. Murphy and Nichols (1913) stated that *Myotis lucifugus* was scarce at that time, that it rarely frequented houses or towns on the island, and that the species was not collected here until 1900, when three were shot from a flock of a dozen or more at Cold Spring Harbor.

The little brown myotis was known to be common in many mainland regions of New York State before 1900—such as the Adirondacks, Catskills, and Oneida

Lake region, and to form large colonies in buildings, at least locally, as summarized by Miller (1899). DeKay (1842) in his account of the little brown bat, which probably refers to *Myotis* in general, but this species primarily, stated that it was "very numerous . . . in the southern counties" (of New York). However, neither author mentions Long Island in his account of this species.

Today, summer colonies are well established at scattered localities over most of Long Island. During the survey, small bats observed hunting over ponds or clearings in most sections of the island usually appeared to be this species. Some accounts for the 1930's indicate it was common then: Nichols and Nichols (1934) found this species the most plentiful bat in summer evenings near Mastic on the south shore in 1934; Turrell (1939) had little to say about bats but remarked that this species was familiar in the Smithtown region near the north shore of the island. Roy Latham, in a personal communication, writes that the little brown species is common on Shelter Island.

Reports and complaints of colonies of brownish bats in houses (especially attics), churches, and other buildings during the summer were frequent. Such cases are generally referable to either this species or the big brown bat, but I did not visit very many of the sites. Most observing and collecting of this species was done at a readily accessible summer maternity colony discovered in the attic of an old abandoned house near Manorville, in central Suffolk County. However, one other summer colony was visited, situated in a large, old, uninhabited house north of Southampton. Also, reports of colonies which were probably *Myotis lucifugus*, or were identified as this species by the observers, were received from localities representing the central, north shore, and south shore sections of Suffolk County. I did not learn of any really large summer colonies, consisting of many hundreds or even thousands of individuals, such as have been reported for some regions.

In evening observations we never discovered large concentrations of hunting little brown myotis such as are frequently encountered in many areas of mainland New York State. Observations, mainly at certain ponds and clearings in eastern and central Suffolk County, only occasionally produced as many as three or four individuals in a group. At some localities none at all were seen, at others only a single one, even when weather and insect conditions seemed very favorable. This may indicate a relatively small population, in spite of the known colonies present, or the better hunting grounds may have been overlooked. More little browns were seen in August and September than in June and July, probably reflect-

ing increase in the population and dispersal after raising of young. Habitats where bats identified as this species were seen hunting included large ponds in both wooded and residential areas, small pond hidden in dense maple swamp, clearing in pine barrens, field near pond and house, vicinity of a dump, and once or twice at a street light.

Myotis lucifugus is also present on Staten Island; in fact all the species of bats which occur on Long Island have also been collected or reported on Staten Island, except perhaps *Myotis keenii*, for which I have been unable to locate any Staten Island records.

The little brown myotis hibernates chiefly in caves and mines, situations lacking on Long Island. Judging from what is known of seasonal movements of *Myotis lucifugus* in New England and elsewhere, most of the Long Island population probably migrates north or west to mainland cave regions for the winter. There is very little evidence of hibernation in situations other than caves and mines in the Northeast, although this possibility has not been fully investigated. Of interest in this connection is a personal communication from Roy Latham; he reports finding little brown bats (*Myotis*), thought to be this species (or possibly *M. keenii*?), in winter in the cellar of an old house near a swamp on Shelter Island, and some flying activity on mild days in February.

Reproduction (maternity colony). Occasional observations were made in 1962 and 1963 at a maternity colony, where, as is the custom of these bats, females gather in summer to give birth and raise their young. The colony was discovered May 23, 1962, in a low attic of an old abandoned farmhouse (figure 10) near Manorville. About two dozen bats of different ages were collected here and in outlying buildings during the two seasons. The attic had a broken window at each end, and was about 6 feet high at the center; the bats commonly clustered just under the peak of the roof on top of the ridgeboard. They were readily visible through a narrow space on either side, between the roof and ridgeboard.

The colony was not large; usually 30 to 50 little browns were visible. A maximum number of 51 adult females was counted on June 26; I believe this was most of them, and allowing for a few probably missed, the colony of adult females probably numbered about 60 in both years. Later in the season, the number was increased somewhat by the addition of young. Numbers remained high into the first week of August in 1962 but by August 9 there was a definite decline in the population as the bats dispersed. Some bats were present at least until September 25, when six remained. Visits in

October (9th and 18th) revealed no little browns, indicating the site had been deserted for the season. In 1963 no bats were found in mid-April (visits on the 12th and 13th), but the next visit, on May 15, revealed some of the bats had arrived, with about a dozen or more on hand, suggesting that the colony had begun to form at the end of April or in early May.

It appeared that most young probably were born in June. Nine females, each bearing a single embryo, were examined between May 15 and June 26. Embryos ranged from 5 to 20 mm. in size; the largest (20 mm.) were examined on June 2 and 26. The first small young, two which were probably a few days old, were seen June 26. These were nursing, were partly furred, and could crawl but not fly (weight of one: 3.7 grams, total length, 62 mm.). One large young close to early flight stage (weight 6.4 grams, total length 78 mm.) and probably 2-3 weeks old, was collected June 29; it could flap its wings strongly but was still nursing and had not yet begun to feed on insects. By August 1, active, approximately fully grown young bats at least a month old were noted in the colony.

A few bats occupied a large shed 50 yards away from the house. Most of the time only one or two males plus an occasional *Eptesicus* were to be seen. But on June 2 an adult female carrying an embryo was found tucked away in a crack, well removed from the main colony. Also from late August to late September some females and many of the active young were present, and had presumably moved over from the main building.

In the fall of 1962 the chimney of the house collapsed, leaving a gaping hole in the roof, which admitted much more light and air into the attic. This change in the environment did not seem to adversely affect the bats, and their production of young the following year, although observations were terminated July 2, 1963; on this date over 40 adult females and several crawling young were seen.

On the evening of June 8, 1962, (weather warm and calm) I watched from outside for bats to emerge, but saw only 20 fly out of the house, fewer than were actually present. Some may have been missed, since the bats came out of several openings beside one of the windows. After 9:15, when it was completely dark, I went inside and found several flying about within the house and at least nine still inactive in the roost. The bats were carrying embryos at this time, and may have been less active for that reason. On August 29, 1962, after two nights with much wind and rain associated with a tropical storm ("Alma"), three bats collected had virtually empty digestive tracts.

Measurements. Fifteen adult females in summer (May 23 to September 25) average: weight, 10.0 grams

(7.7-12.0); total length, 94.2 mm. (90-101); tail, 40.2 mm. (37-44); hind foot, 9.5 mm. (9.0-10.0); ear from notch, 15.1 mm. (14-16); tragus, 6.9 mm. (6.5-7.0); forearm, 38.8 mm. (36.5-40); wingspread, 264.1 mm. (250-275). Eight of the May and June females carried embryos; some of the August and September bats were quite fat—the heaviest individual (12.0 grams) was one of those collected on September 12. An adult male on June 26, 1962: weight, 8.5 grams; total length, 87 mm.; wingspread, 252 mm.; forearm, 37.5 mm.

Individuals taken. 34

Keen's Myotis

Myotis keenii septentrionalis (Trouessart)

Distribution and habitat. Very little is known about this species on Long Island, and few specimens have been collected here previously as far as I know. The first published occurrence was of an individual found in a house at Mastic, Suffolk County, on August 18, 1933 (Nichols and Nichols, 1934). Two other specimens from Long Island, collected in August 1886 (R. Waldo) and at Mt. Sinai, July 1940 (E. A. Williams, Jr.) are in the American Museum of Natural History. Roy Latham collected one at Mattituck, September 19, 1931 (skin and skull in his collection). The mapped range for *Myotis keenii* in Hall and Kelson (1959) seems misleading in that it does not include Long Island; the island is small on the range maps, which are designed to show much of the continent, but the other bats occurring here are correctly indicated.

This long-eared, northern myotis is not considered a rare species but it never seems to be abundant either, and it has been studied only casually. Most Keen's bats have been encountered in caves and mines in winter and during the late summer swarming period; relatively few have been observed on the summer range away from such retreats. Thus a large concentration of this species discovered on a Long Island feeding ground seems noteworthy and is described here in some detail.

All of our specimens were collected at Fresh Pond, Hither Hills State Park, on the south fork near the east end of the island (figure 22). Here Keen's myotis was found hunting in the evenings throughout the summer and early fall season and appeared to be the most numerous bat. Using Japanese mist nets, 11 (three males, eight females) were taken on June 26, 1963; two (one male, one female) on August 22, 1963; and nine (four males, 5 females) between October 2 and 18, 1962. During these operations about 15 other myotis were netted and re-

leased, and all of them were Keen's; no other species of myotis was taken. Besides those netted, additional scores of small bats were seen flying about in a similar manner; probably many or all of these also were *M. keenii*. Such information suggests that Keen's may be the commonest summer bat in sections of extreme eastern Long Island, replacing the little brown and big brown bats of farther west. Recent reports received of small brown bats in summer on Gardiners Island just a few miles north of Hither Hills may possibly indicate the presence of this species there.

Fresh Pond, about one-half mile long and two-tenths of a mile wide, is completely surrounded by woods, chiefly oaks (especially black oak, white oak) with a fairly dense shrub layer. The area is rather hilly. There are some fields and meadows within half a mile of the pond, where an occasional small bat (Keen's?) was seen. The peninsula is a little more than a mile wide here, with the bat collecting site situated about three-tenths of a mile from its north coast. Keen's bats are known to live in summer in such retreats as cottages, barns, and beneath the bark of trees. No buildings were noted in the immediate vicinity of the pond, and I did not find any bats in a hurried check of a few park buildings in the general region, although small colonies could easily be overlooked. The Keen's bats at the pond may represent a gathering from small colonies scattered in trees in the surrounding woods, or they may spend the day in buildings farther away, outside the park.

This species was first encountered in October 1962, when mist-netting was tried out at Fresh Pond after some red bats were seen. Much of the pond was bordered by impenetrable bushes and small trees, but netting was possible at a tiny shallow cove with a sandy beach. The nets (about 40 feet long, $\frac{3}{4}$ inch mesh) were set at right angles, approximately, to the shoreline. Usually one pole was placed on shore a few feet back from the water's edge, the other pole out in the shallow water; the net was attached between the poles, the lower edge of it a few inches above the water, the upper edge about 8 feet high. One to three nets were set up on netting nights; they were up by early twilight and taken down before midnight. Netting was restricted by the weather—often the evenings were windy here, rendering the nets ineffective.

On most evenings Keen's myotis did not appear before dark. On October 11, for example, none was seen during twilight in more or less continuous observation; yet four were netted after it was thoroughly dark (8:00, 8:30, 10:00, and 10:15 p.m., E.D.T.). After becoming active, these bats often hunted very low over the water close to shore, sometimes flying in tight circles in the

cove and frequently touching the water. Also they were seen at times closely following the shoreline, and flying above the bushy foliage at the water's edge. Individuals were caught above both water and land, from several inches above the surface to 4 feet high. Often these bats were seen to avoid the nets repeatedly, while at other times they flew directly into the nets. On one occasion a Keen's bat was observed chasing another one, and thus off-guard both plunged headlong into a net.

Bats were not sought here after October 13, although conditions remained warm and favorable for another week. Late in the month the weather turned much colder, with strong winds, light snow, and frosty nights. This species, like *Myotis lucifugus*, generally hibernates in caves during the winter, and all or most of the Long Island individuals presumably cross to the mainland for this purpose.

In the following year Fresh Pond was first visited on June 26, a warm and calm evening with many insects visible in the air. Many Keen's bats were about, but I was unable to detect any other species. Eleven *keenii* were collected using two mist nets placed near the wooded shore, in the usual manner, between 9 and 11 p.m., E.D.T. Scores of the bats were seen; many bounced off the nets, others were caught and released. All females collected carried well-developed embryos.

The pond was next visited on August 22, and again Keen's myotis, but no other species, was recorded. No bats at all were seen until late, darkening twilight (8:30 p.m., E.D.T.), when suddenly two were flying about close by, often to within a foot or two of my head and shoulders as I stood in shallow water. Soon more appeared. Three were caught in a mist net. The bats on this date hunted about 2 to 6 feet above the water and shore. Also they sometimes entered the woods by flying very low along paths leading away from the shore. It was not determined how far into the woods they went, but under the canopy of the trees seemed to be part of their "beat," at least on this evening.

The flight of feeding Keen's myotis showed a fairly steady course (in straightaway or when circling), with occasional sudden veering to one side; it would not be termed a fluttering flight. Regarding voice, these bats usually seemed silent in flight except for an infrequent short high-pitched squeak. When alarmed or excited, as when caught in a net or being handled, they gave a squeaking chatter very reminiscent of *Myotis lucifugus*.

In partial summary of the above observations on their foraging habits at Hither Hills, Keen's myotis are active in the area at least from June to October, appear late in the evening when it is quite dark, are numerous and associate together when feeding, and have a direct

manner of flight; both summer and fall they hunt low over the water (often 1 to 6 feet); and they also fly low over the shore, close to foliage, and low under the canopy of woodland trees. In this locality *keenii* seemed to be the commonest bat and was the only *Myotis* taken. Stomach contents, containing the remains of many insects have been saved, but not as yet examined closely to determine the identity of the insects.

Reproduction. Apparently small nursery (maternity) colonies are formed, but essentially nothing is known of reproduction in this species (Barbour and Davis, 1969). Reproductive females netted at Fresh Pond in late June indicated the presence of such colonial roosts in the area, but we did not locate them. Each of the eight females taken on June 26 contained a single, fairly large embryo, suggesting birth of young mainly in July (embryo crown to rump measurements, in millimeters, were 8, 13, 13, 14, 14, 15, 15, 16). The date seems a little later than with most of our local bats, and agrees with Hamilton's (1943) information for elsewhere in New York (he mentioned 3 females with single large embryo taken in late June and early July, indicating parturition in July).

Measurements. Eight adult females in June with embryos average: weight, 8.3 grams (6.4-9.2); total length, 91.6 mm. (86-96); tail, 38.1 mm. (36-40); hind foot, 9.6 mm. (9.0-10.5); ear from notch, 17.6 mm. (17.0-19.0); tragus, 9.1 mm. (8.5-9.5); forearm, 36.0 mm. (34.5-37.5); wingspread, 249.8 mm. (241-253). Three adult males in June average: weight, 6.0 grams (5.5-6.4); total length, 85.7 mm. (83-88); tail, 39.0 mm. (38-40); hind foot, 9.2 mm. (8.5-9.5); ear from notch, 17.3 mm. (16.5-18.0); tragus 9.0 mm. (all about 9.0); forearm, 34.7 mm. (34.0-35.0); wingspread, 243.3 mm. (232-237). Weights of nine specimens of both sexes in October average: 7.2 grams (5.9-9.7). All of the above bats had food in their stomachs. The October specimens had accumulated considerable body fat.

Individuals taken. 22

Silver-haired Bat

Lasionycteris noctivagans (Le Conte)

DeKay (1842) termed the silver-haired bat as common on Long Island (season not stated). Since then, various writers (Helme, 1902; Murphy and Nichols, 1913; Nichols and Nichols, 1934) have shown that this northern bat is rare on Long Island in spring and early summer, is occasionally plentiful in late summer and early autumn (period of southbound migration), and

that, singly or in groups, a few remain to hibernate during the winter in hollow trees, in ships, and in buildings of every description. It has been reported from Staten Island, New York Harbor, and Brooklyn east to Orient Point, Montauk Point, and over the ocean.

Nichols and Nichols (1934) collected five specimens between June 17 and July 10, 1933, at Mastic, establishing the first definite information on the presence of *Lasionycteris* through the summer. The authors, experienced in collecting bats on Long Island, were surprised to encounter this species in June, outside the period of southward migration; two of the June ones were females carrying well-developed embryos.

As with the red bat, the highly migratory silver-haired bat has been encountered migrating south along our beaches (both north and south shores) and even out over the ocean. Migrating individuals may linger to hunt over woods, clearings, and bodies of fresh water; on the coast quite a few have been found resting on vessels at anchor. Helme (1902) stated that in some years during migration this species even outnumbered the red bat, but that in other years very few are seen. Large numbers have been seen gathering in late summer in Prospect Park, Brooklyn, and flying over the lake there (Murphy and Nichols, 1913). We did not collect or positively identify this species on the survey; some of the bats seen in the Hither Hills area in October 1962, may have been silver-hairs—if so, they were apparently outnumbered by Keen's bats and red bats. Roy Latham has in his collection several *Lasionycteris* secured during the month of September on the north fork of eastern Long Island and on Shelter Island; two specimens from Shelter Island were found drowned in a pail of water on September 3, 1929, by W. W. Worthington. Latham's latest fall record is October 10 (1939).

Robert Cushman Murphy has made many observations on the migration of this species along our coast. Early in the morning of September 6, 1907, while in a boat 4 or 5 miles off Sandy Hook, New Jersey, in blustery weather, he saw several individuals struggling towards the Staten Island shore (Murphy and Nichols, 1913). A specimen in the American Museum of Natural History was collected by Murphy while 3 miles at sea off Long Beach, Nassau County, on September 7, 1918. Murphy and Nichols also wrote that silver-haired bats have been seen in September evenings flying above the beaches of Long Island Sound and circling high over Mt. Sinai Harbor and other salt water inlets. A far-offshore record is one collected on August 19, 1953, after it circled about and landed on the rigging of a vessel in 39°36' N, 71°03' W, about 95 miles SSE of Montauk Point, the nearest land (Mackiewicz and Backus, 1956).

Long Island seems to be near the northern limit of the winter range of this species. Regarding winter habits in our area, Murphy and Nichols (1913) wrote: "Silver-hairs . . . are not infrequently found in hollow trees cut in winter for firewood, and they also have been discovered hibernating in sky-scrapers, churches, wharf-houses, and the hulls of ships in New York City and Brooklyn, during the months between December and March." The authors also referred to over 20 "black bats" found in January in Port Jefferson Harbor aboard a yacht, and then thrown overboard by the captain, as probably belonging to this species. Roy Latham (personal communication) has one winter record for Orient, a lone individual found in a building on January 23, 1946. Another winter record is a female *Lasionycteris* in the American Museum of Natural History which was collected at Mastic in February 1937, by David G. Nichols.

Eastern Pipistrelle

Pipistrellus subflavus subflavus (F. Cuvier)

The little pipistrelle is apparently uncommon on Long Island. Helme (1902), Murphy and Nichols (1913), and Nichols and Nichols (1934) did not mention this species. But Hamilton (1949) wrote that one summer evening he nearly succeeded in capturing one with an insect net. Roy Latham collected a male pipistrelle at Montauk on August 25, 1931; preserved as skin and skull in his collection, this is the only Long Island specimen I have examined.

During our survey, a bat identified as a pipistrelle was observed on the night of October 10, 1962, at Belows Pond near Hampton Bays. At 8:00 p.m., E.D.T., in bright silvery moonlight, I watched a tiny bat with an erratic and moth-like fluttering flight hunting back and forth above the tops of tall bushes near the pond. It appeared smaller and had a different manner of flight than the little brown, Keen's and other bats that were observed on the island.

Known hibernation sites of the pipistrelle are chiefly caves and mines, and the deficiency of such sites on Long Island may account for the scarcity of this species. Not much is known about distances traveled by this small bat to and from its winter quarters.

On Staten Island, pipistrelles have been found in barns and other buildings during the summer. Several which have been collected there are in the American Museum of Natural History.

Big Brown Bat

Eptesicus fuscus fuscus (Palisot de Beauvois)

Distribution and habitat. This large bat may be seen anywhere on the island, and since it is hardy and often hibernates in buildings it may also be encountered during any month. *Eptesicus fuscus* is a rather sedentary species, as stated by Barbour and Davis (1969), and it seems likely that most of the population remains on Long Island throughout the year. Maternity colonies as well as hibernating sites appear to be most frequent in the western part of the island, and this bat is not uncommon in the urban areas of Brooklyn and Queens. Murphy and Nichols (1913) wrote that *Eptesicus* frequents large parks and cemeteries in Brooklyn, and hibernates abundantly in city buildings of the area. Several old publications indicate that the big brown was also common on Long Island during the last century, and DeKay (1842) obtained this species in Kings County (Brooklyn). *Eptesicus* also raises young (at least locally) and hibernates in Suffolk County, but becomes less common towards the east end of the island.

Complaints about bats in buildings frequently came from western Suffolk and eastern Nassau Counties. On investigating a few of these reports, some big brown bats were found. In a small village in eastern Nassau County, a maternity colony was located high in a house (where 20-30 bats were shot in the previous year in an unsuccessful attempt to eliminate them). The bats were not readily accessible, but big browns were seen peering out of holes near the roof on July 27. On the previous day, which was very hot, the bats had been reported hanging on the outside surface of the house with their young. Also, bats were heard squeaking during the day in woods near the house, possibly in hollow trees, although we were unable to locate them.

At another house nearby in the same village, during late May, 25 bats (*Eptesicus*?) were reported shot while flying out of the attic at dusk, after which no bats were seen there. In a nearby town up to 60 bats had been reported emerging at dusk in May from the attic of a large building. On entering the attic June 2, I found the floor littered with many droppings which seemed to be of this species, but the site appeared to be almost deserted, even though these bats had not been shot or molested as far as I know; only a solitary male *Eptesicus* was present. Big browns occasionally leave a nursery roost at least temporarily; one reason, as mentioned by Barbour and Davis (1969), is that this species is not as tolerant of high temperatures as *Myotis lucifugus*, and during a hot spell may move to a cooler part of the building or

abandon it altogether. Or possibly this was a recently-abandoned winter roost.

A maternity colony of big brown bats has occupied a large barn near Yaphank in central Suffolk County for some years (LeRoy Wilcox, verbal communication).

At the attic colony of little brown bats near Manorsville, one or two adult male *Eptesicus* were often found in small sheds near the main house, from May to October. Although maternity colonies of these two species do not occur together, individual male big brown bats were apparently attracted to the vicinity of the *Myotis* colony. In October, after the little browns had abandoned the location for the season, single big browns were occasionally seen hanging in the attic itself (where the smaller species had raised young).

The big brown bat was frequently detected in an area by seeing lone individuals, just before dark, flying rather high on a straight, steady course to their feeding grounds. Localities in eastern Suffolk County where *Eptesicus* was seen or collected, although maternity colonies were not found, include Amagansett, Calverton, Flanders and Squiretown. Near Amagansett, well out on the south fork, several were seen in late June hunting around street lights near the ocean. Solitary individuals were noted on two or three occasions flying before dark near buildings on the outer beach strip (between Shinnecock and Moriches inlets).

Summer maternity colonies and wintering individuals have been found on Staten Island.

Food habits. Only two stomachs were examined, and these were filled almost entirely with beetles (Coleoptera), including large June beetles of the family Scarabacidae; some remains of moths (*Lepidoptera*) were noted in one of the stomachs.

Individuals taken. 4

Red Bat

Lasiurus borealis borealis (Müller)

Distribution and habitat. Helme (1902) designated this species as the most abundant bat on Long Island. Likewise, Murphy and Nichols (1913) stated that "During most of the summer a bat seen anywhere on Long Island is, nine times out of ten, a red bat. The species is abundant from the busy streets of Brooklyn to Orient and Montauk . . ." As far as I have been able to determine, this no longer seems to be true on most of the island, although the red bat is not rare. In many areas the little brown myotis, which was found to be scarce

by Murphy and Nichols, is the bat most likely to be encountered. Locally, other species, namely Keen's and big brown bats, appear to be first in abundance. Also, in some apparently favorable situations, such as certain ponds and fields on still summer nights when insects were abundant, we failed to detect any bats at all.

There does not seem to be much information on the status of this bat during the early summer season (June, July), before the fall migration, except that it appears to be widely distributed but not abundant then. In 1933, four red bats were collected between July 3 and August 7 among more plentiful *Myotis lucifugus* at Mastic (Nichols and Nichols, 1934). Lanyon (1961) termed the red bat a regular but uncommon summer resident on the Kalbfleisch Field Research Station in the Dix Hills area of western Suffolk County, and mentioned a specimen collected on July 12, 1961.

Red bats have been collected on Long Island in every month from late May to late November; many specimens are in the American Museum of Natural History. Murphy and Nichols (1913) stated that the red bat appears on Long Island on the first warm spring days, and that there is a Staten Island record as late as December 5. Kimball and Nichols (1940) have recorded this species flying about at Mastic, Suffolk County, on mild days in December (as late as December 26, 1936, and December 25, 1937). I do not know of any winter records later than December. Most red bats move well to the south of Long Island for the winter; but the late December sight records suggest that a few individuals, hidden and dormant, may remain this far north all winter, emerging to fly only during unseasonably warm spells. The red bat does not hibernate in caves, and generally roosts in trees throughout the year.

The red bat is most frequently observed in this region during late summer and early fall. This species, like the silver-haired and hoary bats, is highly migratory, and southbound flights and concentrations are often noticed along the coast at this season. Red bats may be seen flying by day over the beach or ocean, or found roosting in unusual locations. Carter (1950) reported on a flight of 200 bats seen around a ship enroute to New York, about 65 miles offshore (40°10' N, 71°00' W) on September 29, 1949; three individuals collected were red bats. Several reports we received, from south shore localities in the fall, of bats hanging in trees and bushes during the day or found dead on the ground, seem to refer mainly to this species. LeRoy Wilcox and Walter Terry have informed me that they usually catch one to several red bats in mist nets each fall, while banding migratory birds on the outer barrier beach strip near

Quogue. These bats probably come across Long Island Sound, too, and during October many have been found hanging asleep on exposed roots under the overhang of the beach cliffs which fringe the north shore (Murphy and Nichols, 1913). The seven specimens I collected were taken between August 21 and October 18; also all of my field observations of this species were made during August, September, and October.

Field observations. Red bats were seen in August in the area of Shinnecock Bay and adjacent barrier beach. Individuals were occasionally seen flying over the bay in all directions at twilight, apparently dispersing to feed rather than migrating on these flights. Here, on the outer beach strip near Shinnecock Inlet, I watched one migrating by day on August 10, 1968, at 4:30 p.m., E.D.T., in bright sunlight. The bat flew over the marshy bay side of the strip, heading in a generally southwesterly direction, that is, following the coast. When "on course" it flew high with a steady flight, but also it occasionally interrupted its progress to dip down low, perhaps to feed. Once it flew low around a small salt marsh pond close by; the red color was striking in contrast to the green of the marsh grass. Numerous birds, including terns, shore birds, starlings, and swallows were present, but they showed no interest in the bat. After a few moments the bat resumed its trip. I followed its course with binoculars as it flew, occasionally dipping down again, before it was lost to sight. Also on this date there was a nearly continuous passing of barn swallows (*Hirundo rustica*), tree swallows (*Iridoprocne bicolor*), and monarch butterflies (*Danaus plexippus*), all migrating in the same direction as the bat.

During our survey, these bats were most regularly encountered on the eastern part of the south fork, hunting over ponds and clearings and around certain street lights during the early fall season. Here they seemed to gather and linger, and could be seen whenever the weather was not too bad. Rather intensive searching in these same areas in June, however, failed to indicate the presence of red bats.

Red bats were observed on mild October evenings at Fresh Pond (figure 22), the large pond at Hither Hills described in the account of Keen's myotis. Here they were seen flying high over the pond and adjacent woods, and also hunting close to dense vegetation along the shore or skimming over the water. Occasionally one was seen early, while it was still quite light, but normally red bats did not appear until late twilight or after dark, when they were caught in Japanese mist nets or spotted momentarily in the light of a strong flashlight. The presence of hunting red bats seemed to be determined in part by the

occasional large concentrations of moths along the shore of the pond. Bats of both sexes appeared to be common.

Migrating hawks of various species were occasionally noted in this area in the fall, and as many as seven pigeon hawks (*Falco columbarius*) were seen in one afternoon flying over or perching near the pond. One of the early flying red bats observed was apparently pursued by a pigeon hawk. As I watched a red bat circling above the pond late in the afternoon, on October 11, 1962, a pigeon hawk darted from its lookout perch on a tree on the opposite side of the pond and headed directly toward the bat. The bat turned toward the woods, the hawk followed, and both disappeared behind the trees without my learning the outcome of the brief episode. But it seems likely that this swift little falcon, a fairly common coastal migrant in early fall, may at times prey on migrating or other day-flying bats, as well as birds.

At Fresh Pond, red bats were taken in mist nets placed along the shoreline over the water and beach; net captures were made from just a few inches above the water to over 6 feet high. Sometimes these bats were observed to detect the nets as they hunted low over the water, veering off at the last possible moment time and again. Once one was seen to collide with a net, and then fall into the water; but it managed to fly up into the air after flapping its wings on the water for a few moments. These bats occasionally gave rather loud hissing screams when caught or handled.

Near some villages on the south fork red bats were seen hunting around bright street lights, often quite near the ocean. Usually they were seen repeatedly at certain lights to the exclusion of other similar lights nearby, probably indicating rather fixed hunting territories of individual bats. At the lights the bats made swift passes at the clustering insects, then disappeared into the dark for a while before returning.

Food habits. The stomachs of four red bats collected at Fresh Pond during October 1962, contained many moths. Many, perhaps most, of the moths belonged to the family Geometridae, and numerous moths of this family were also observed swarming over the water and near shore during warm evenings. Small beetles and other insects were also eaten.

Measurements. Four October specimens average: weight, 10.6 grams (9.2-11.8); total length, 102.3 mm. (96-106); tail, 44.5 mm. (42-48); hind foot, 8.6 mm. (8.0-9.0); forearm, 39.3 mm. (37.0-40.5); wingspread, 301.0 mm. (275-313).

Individuals taken. 7

Hoary Bat

Lasiurus cinereus cinereus (Palisot de Beauvois)

On Long Island this large, handsome bat is the rarest of the three highly migratory species, which (like birds) fly south in the fall and north in spring. As with the red and silver-haired, most occurrences are in late summer and autumn. Murphy and Nichols (1913) knew of records of hoary bats being collected on Long Island in August, September, and October, including one discovered under a driftwood plank on a north shore beach. Kimball and Nichols (1940) reported an individual hanging on the porch of a cottage facing the sea at Oak Island, south shore of Suffolk County, on December 2, 1939, apparently the first published record later than October. It was assumed by the authors that this individual was still migrating on this late date, not disturbed from hibernation.

This heavily furred species may be considered a rare possibility any time during the colder months. There are a few December, January, and February records for the general latitude of Long Island (Connecticut, New Jersey, and Pennsylvania). DeKay (1842), in his discussion of this bat in New York State, mentioned seeing two individuals actively flying about shortly before noon on December 12, 1841; he did not mention the locality, but I assume it was somewhere in the State, possibly even Queens, Long Island, then DeKay's place of residence. In the American Museum of Natural History there is a female hoary bat, preserved in alcohol, which was collected on January 16, 1969, at Far Rockaway, southern Queens, by John Bull; this is the only midwinter record for Long Island, as far as I know. Such records may indicate that a few individuals hibernate in this region, well to the north of most of their fellows. Hoary bats, like red bats, normally roost among the twigs and foliage of trees and generally do not frequent caves or buildings. Perhaps trees serve as winter retreats also, with the bats leaving them to fly after insects on warm days, although practically nothing is known for certain about the winter habits of this species.

There seems to be no information on spring migration of hoary bats in the Long Island area. Nor do I know of any records of these elusive bats during the period from about late May to early July when they give birth to young. They appear to be more common farther north at this season, but a few may occur here since Roy Latham has recorded this species as early as July 14, and specimens have been collected in nearby New Jersey and Pennsylvania during June.

Our only observation on the museum survey was of one flying low, near a street light after dark, at Hampton Bays on September 29, 1962. For Orient, Roy Latham (personal communication) has four records, dates ranging from July 14 (1963), as mentioned above, to October 29 (1919).

Eastern Cottontail

Sylvilagus floridanus mallurus (Thomas)

Distribution and habitat. Two cottontail rabbits, the New England cottontail (*Sylvilagus transitionalis*) and the eastern cottontail (*S. floridanus mallurus*) occur on Long Island, as indicated by Nelson (1909), Hamilton (1949), and others. Both kinds appear to be rather widely distributed on the island, based on specimen records. But the exact status of the two species—relative abundance and patterns of distribution, perhaps in the process of change—awaits clarification. Nelson (1909) and others have shown that *transitionalis* was probably the only native cottontail in an extensive area of the Northeast, including all of New York State and adjacent states to the north and south, and that *floridanus* has extended its range into this region rather recently. Possibly *floridanus* is in the process of replacing *transitionalis* on Long Island, as it has in some mainland areas of eastern New York and southern New England.

Also, cottontail rabbits of other subspecies of *S. floridanus* from certain midwestern states have been introduced on Long Island. Very likely some of these arrivals survived to interbreed with the local stock (*S. f. mallurus*), although presumably the native form tends to prevail in most areas of the island. Western cottontails became very numerous on Fishers Island following introduction (Joseph Dell, verbal communication).

Although fluctuating in abundance from year to year, cottontails are generally common from highly developed residential areas and parks in eastern Queens and even parts of Brooklyn to the very tip of Montauk Point, and near both the north and south shores. They are numerous on some outlying islands, including Shelter Island, Gardiners Island, and the full length of the outer barrier beach of the south shore, including Fire Island. Apparently *S. floridanus* is the common cottontail in most of these areas, judging from the many museum specimens of this species (American Museum of Natural History, U.S. National Museum, N.Y. State Museum, and elsewhere) from more than 30 localities throughout the island. The eastern cottontail is also common on Staten Island.

On the field survey, we collected 17 cottontail rabbits in the area south and southwest of Great Peconic Bay, that is, from Riverhead and Flanders south to Moriches, and outer beach near Quogue, Hampton Bays, and Mecox Bay. These animals all proved to be *floridanus* (based primarily on skull characters commonly used in separating this species from *transitionalis*). Additional eastern cottontails collected included specimens from Shelter Island and Hither Hills.

It seems amazing that these fairly sizable, defenseless animals manage to survive in many built-up areas where their habitat consists solely of the yards of suburban homeowners. Here they thrive in spite of the many dogs, cats, people, and automobiles. Although not often noticed during the day, a visit to such areas at night may reveal rabbits feeding in the open on grass, clover, and weeds, or sometimes on the more valuable plants of yard and garden.

In the less developed countryside cottontails are widespread, wherever suitable food is found, and they feed on a vast array of shrubby and herbaceous plants. We found rabbits present in all sorts of woods, from dry to swampy, as well as in fields, bogs, and various grassy and bushy areas. Cottontails are found throughout the pine barrens and dry oak woods, although presumably in fewer numbers than in areas endowed with a greater variety of food plants. Often they were seen in or along the edge of red maple swamps; here there was evidence of their browsing heavily in winter on young red maples and other plants, such as greenbrier (*Smilax*).

On the highly agricultural north fork of the island, cottontails were very numerous wherever there were trees or bushes, at least in 1963.

Cottontails do well in the maritime areas. A walk through the grass and low shrubs among the ocean-front dunes often results in one to several individuals being startled from their forms and hiding places. Their droppings often seem to be "nearly everywhere" on the sand. The rabbits are even found in the beachgrass on the very summits of the outer or primary dunes, one of the few mammals regularly found in this environment. They may be encountered here any time during the year, although they probably withdraw somewhat towards the better cover about the inner dunes and edge of salt marshes during winter. In many sections, the salt marsh edge, with its rather good variety of food and cover plants is home for numerous cottontails. They also venture out into these marshes to a limited extent. On Fire Island we saw cottontails (and abundant signs of their presence) among the dunes, including the vicinity of the Sunken Forest.

Measurements. Four winter adults average: weight, 1,167.5 grams (984-1,279); total length, 407.8 mm. (398-421); tail, 43.5 mm. (40-45); hind foot, 93.5 mm. (91-96); ear from notch, 62.0 mm. (59-67).

Individuals taken. 20

New England Cottontail

Sylvilagus transitionalis (Bangs)

The New England cottontail is a small rabbit which is very similar in external appearance to the eastern cottontail, the two differing only slightly in pelage and form. But the two cottontails are distinct and separate species, even though closely related, and apparently they rarely hybridize in the wild. The New England cottontail does not presently appear to be as common on Long Island as the eastern cottontail. Nevertheless, in various museums there are specimens of *transitionalis* which have been collected at localities in Nassau County and east through Suffolk County (including some north shore and south shore localities) to Shelter Island and Montauk Point. During the 1930's about 20 were collected at Mastic by David G. Nichols and John G. Nichols (specimens in American Museum of Natural History). This species has also been collected on Staten Island.

The various locality records indicate that the two species of cottontail may be found in the same general area on Long Island. But I have no information on habitat differences, if any, although it has been shown that on the mainland *transitionalis* tends to prefer wooded and brushy areas, as opposed to more open areas often favored by *floridanus*.

Nelson (1909) observed that specimens of *S. floridanus mallurus* from New Jersey and southeastern New York, including Long Island, are especially close to *S. transitionalis* in size, and often in color. Benton and Atkinson (1964) add that identification of the two species is virtually impossible in the field and is difficult in the hand. This situation is frustrating to the active naturalists of the island who observe and study the local fauna. During the survey, we occasionally observed rabbits at very close range, encouraging tentative species identification based on several external characters such as apparent length and shape of ear (shorter and more rounded in *transitionalis*). Individuals thought to be *transitionalis* were observed at several south shore localities from Babylon to Montauk Point, and also on the north fork of eastern Long Island. However, one such individual was collected and it proved to be *floridanus* instead, thus

our field identifications cannot be relied on, although perhaps some of them were correct.

A close examination of key skull characters, which are consistently different in the two species, is the dependable way to distinguish the cottontails; Hamilton (1943) and Fay and Chandler (1955) are helpful references for identifying specimens. Recently, Hinderstein (1969) made a comparative study of skull characters of the eastern and New England cottontails in the region of northern New Jersey to Connecticut, including Long Island; she also studied geographical variation between Long Island and mainland specimens of each species.

Woodchuck

Marmota monax rufescens A. H. Howell

Woodchucks are only locally common, being distributed in a spotty manner over an extensive portion of central Long Island. I saw very few woodchucks during the survey, these primarily in fields and scrubby woods in the Peconic River region of Suffolk County. However, woodchucks occur westward about as far as central Nassau County, and are still common enough to cause complaints from gardeners in some areas of that county. They are also seen regularly along the Northern State Parkway north of Hicksville. Lanyon (1961) terms this species as regular and fairly common on the Kalbfleisch Field Research Station, in the Dix Hills area near Huntington, with daily observations (including den sites and juveniles) from mid-April to late November. Several writers have mentioned various habitats frequented by woodchucks on Long Island, including fields, meadows, wooded fence rows, brush, scrub oak woods, oak-hickory woods, hillsides, and highway and railroad embankments.

Woodchucks are found near the north and south shores in places, but today are rare towards the eastern end of Long Island as well as in the built-up areas of the western part of the island. Evidently the species was formerly much more numerous, but has declined in numbers; the reasons for this are not entirely clear. Helme (1902) maintained that woodchucks, although still common at the turn of the century, had become greatly reduced in numbers in many localities after several towns began paying bounties for their destruction. Also the rather barren, sandy pine and oak areas with their abandoned fields, although wild enough, may be capable of supporting only a low population of chucks.

According to Roy Latham (personal communication) years ago woodchucks were very abundant and widespread on the east end of Long Island, including Shelter

Island; there were many in the agricultural Orient region before 1910, but Latham recorded his last one there in 1915. He reports that they are still present in the Sound Avenue section north of Riverhead and are found eastward from there, in small numbers, as far as Great Peconic Bay. Latham's earliest seasonal record of this hibernator on the north fork was one caught near Orient on February 1, 1902.

Long Island specimens (skins and skulls) are preserved in the American Museum of Natural History, in the U.S. National Museum, and in the collection of Roy Latham. Although uncommon now, woodchucks have been on the island for a long time, and their remains have been found in Indian archaeological sites dating back many centuries before the white men arrived.

Eastern Chipmunk

Tamias striatus fisheri A. H. Howell

Distribution and habitat. Chipmunks are moderately common to conspicuously abundant in most wooded areas of Long Island. We saw them in and near parks in Queens and in residential areas on the north shore of Nassau County, eastward to Hither Hills State Park well out on the south fork. Also, chipmunks are reported as still present in Prospect Park, Brooklyn [where they are less common than formerly] and to occur as far east as Montauk (Anon., 1968a). Roy Latham collected one at Montauk in June 1927 (in his collection). Possibly this species is relatively new in the Montauk area, since Dutcher and Dutcher (1893) stated that there were no chipmunks in the woods of Montauk. *Tamias* is also present on Staten Island.

Chipmunk distribution appears to be "spotty" compared with many mainland regions, however, since we were unable to find it in several seemingly suitable areas near both the north and south shores. Also, *Tamias* shuns the immediate vicinity of the ocean beaches here, and is absent from most if not all of the small outlying islands off the east end and south shore of Long Island.

The majority of the specimens were collected in central Suffolk County south of Riverhead and Manorville, in pine barrens, and in oak woods and other deciduous growth. They are quite common in the pine barrens, especially near the ponds and streams found in parts of this region; pitch pine, bear oak, and blueberry comprised the principal woody cover in many of the pine-region localities. Chipmunks were noted as common in oak woodlands, also locally in various scrubby woods and residential areas near bays along the south shore.

Chipmunks were numerous throughout the period of this survey on the south fork of eastern Long Island in woods composed primarily of various species of oaks (white, black, scarlet). In contrast, this species seemed to be very rare on the north fork, at least during the summer of 1963 when observations were made in a number of wooded areas, including Browns Hills and Great Hog Neck (none seen, although probable burrow noted on Great Hog Neck). Gray squirrels, however, were recorded as being very numerous in the same north fork areas. Roy Latham (personal communication) writes that there are no chipmunks in Orient, and he has never seen them in Greenport, although he reports that a few chipmunks are found between those localities, at East Marion. From this it appears that *Tamias striatus* is quite scarce and local in this northeast section of the island.

Shelter Island appears to lack chipmunks altogether. In a week of active field work in June 1963, no chipmunks were found. Roy Latham adds that as far as he knows there are no Shelter Island records.

Food habits. Chipmunks feed on many kinds of nuts, seeds, fruit, and other plant material, and also on invertebrates and small vertebrates. Our observations were few and casual. Chipmunks were noted as consuming acorns and hickory nuts, the former probably an important staple here. In the pine barrens they feed on the seeds of pitch pine, as do gray squirrels and flying squirrels. During August I saw chipmunks climb wild black cherry trees (*Prunus serotina*) to feed on the fruit. In September some were seen joining robins and catbirds to feed on the fruit of tupelo (*Nyssa sylvatica*). Wild grapes and blueberries also were eaten in season.

Remarks. Little information was gathered relating to reproduction. A few females were collected in June and September with three to six placental scars, probably indicating spring and summer litters (there are two breeding periods in the eastern chipmunk).

Chipmunks sleep underground through the winter, although occasionally individuals are active above ground at this season. We did not see any chipmunks between November 22 and April 5, and most of our records were from May to October.

We received two or three reports of all-white chipmunks on Long Island. However, albino chipmunks are rare and were not seen by us.

One day during June, a red-tailed hawk (*Buteo jaamaicensis*) was observed to catch a chipmunk in low, scrubby pine plains habitat just inland from Napeague Beach, an area, incidentally, where I had not previously suspected the presence of chipmunks. The hawk watched from the top of a telephone pole for several minutes,

then it dove down, disappearing briefly among some bushy pitch pines, before emerging with a chipmunk in its talons. It flew off with its prey, pursued by a pair of noisy sparrow hawks (*Falco sparverius*) which apparently had their headquarters nearby.

Measurements. Eight adult males (Suffolk County; April to September) average: weight, 88.8 grams (79.0-105.3); total length, 237.7 mm. (230-251); tail, 87.3 mm. (85-90); hind foot, 34.0 mm. (31.5-36). Eight non-pregnant adult females (Suffolk County; June to September) average: weight, 82.5 grams (75.5-86.6); total length, 233.3 mm. (228-238); tail, 86.7 mm. (83-97); hind foot, 34.0 mm. (31-38).

Individuals taken. 26

Gray Squirrel

Sciurus carolinensis pennsylvanicus Ord

Distribution and habitat. This large squirrel is the conspicuous diurnal tree squirrel of Long Island; the red squirrel (*Tamiasciurus*) does not occur. We observed gray squirrels in all types of woodland: coniferous pitch pine barrens and small stands of southern white cedar as well as deciduous types such as oak, mixed deciduous, and swampy woods of red maple and tupelo. An adaptable species, it is found in city parks and crowded suburbs as well as in predominately open agricultural land, provided there are scattered trees, groves, or small woodlots. Occasionally individuals were encountered traveling on the ground at considerable distances from trees in both suburban and farm areas.

As one would expect, general observations indicate that gray squirrels are more numerous in the richer and more diversified leafy woods such as occur on the north shore, than in the pine barrens region. The former provides a more plentiful and dependable food supply. The species was noted as very numerous—at least in 1963—on eastern Long Island's north fork, where it was seen or heard almost every place where there was woody vegetation. For example, in Browns Hills, which extend to within 3 miles of the tip of Orient Point, it was noted as very numerous in June of that year, in scrubby areas as well as among tall trees. There is a great variety of trees here, including much hickory.

On the south fork in the same year, gray squirrels seemed much less numerous, although they were observed in various areas east to Montauk Point State Park. These squirrels were also recorded on Shelter Island and on outlying Gardiners Island. In the pine barrens of Suffolk County gray squirrels are fairly common; they are found

throughout the region wherever the trees are of appreciable size and they are often seen near streams or other bodies of water. Occasionally gray squirrels were noted in bushy pine plains habitat, probably foraging for food or passing through rather than residing in such areas. These squirrels are probably hard pressed to find food in the pine barrens during years of failure in pine cone or oak acorn production.

Gray squirrels are found near the ocean towards both ends of the island, but they become very rare and local on the barrier beach strip where it is widely separated from the mainland by Great South Bay and other bays.

Gray squirrels were noted to inhabit cavities in trees and also to build conspicuous outside leaf nests (often of oak leaves), as is the custom of this species. Reports were received of gray squirrels causing rather severe damage inside buildings, by chewing holes through walls in the attics of houses, and in summer camp and gun club buildings in the woods.

Food habits. Casual observations indicated gray squirrels feed on such items as nuts of hickory and black walnut, acorns of various oaks (including white oak, black oak), and seeds of pitch pine. Many of the feeding signs seen under pitch pines—little piles or scattered litter of scales and stripped cores of cones—were probably the work of gray squirrels. Nichols (1927, 1958) made interesting observations on the food habits of gray squirrels in a suburban area of western Long Island.

Color. Gray squirrels in the black color phase are uncommon here, but are occasionally observed. Several individuals essentially black throughout, although often with a noticeable brownish tinge to the pelage, were noted in Queens, Nassau, and Suffolk Counties. Apparently the black form is especially scarce on eastern Long Island, but I saw one at Hampton Bays in October 1961; Hatt (1930) reported on a melanistic gray squirrel from East Hampton (in the collection of Roy Latham). No white (albinistic) gray squirrels were seen, but reports were received of partially and completely white squirrels in certain areas, including Shelter Island and central Suffolk County; Roy Latham reports two white ones observed on Shelter Island in the winter of 1951.

Measurements. Seven adult males from Suffolk County average: weight, 609.7 grams (528.5-661.0); total length, 491.5 mm. (488-496); tail, 215.7 mm. (208-230); hind foot, 69.7 mm. (68-74).

Individuals taken. 11

Southern Flying Squirrel

Glaucomys volans volans (Linnaeus)

Distribution and habitat. This nocturnal species is still common in the more heavily wooded sections of central Long Island. There we found flying squirrels in woods with assorted oaks or other deciduous trees, pitch pine, mixed pitch pine and oaks, and southern white cedar. *Glaucomys* is present also on the north side of the island, near the Sound, and on the south side, near the bays, wherever there are suitable woods.

Eastward, however, the flying squirrel apparently extends only as far as Riverhead and Hampton Bays. It seems to be absent from woods on both the north and south forks and on the neighboring islands, such as Shelter Island and Gardiners Island; at least I have not heard of any records for these areas. Roy Latham (personal communication) has never encountered this species in years of field work on the north fork. In the present survey, many hours of evening observations and rodent trapping in the extensive oak woods of Hither Hills failed to indicate the presence of flying squirrels, although gray squirrels and chipmunks were common enough; the last two are evidently much more accomplished in crossing treeless ground and necks of land to reach such areas.

To the west, *Glaucomys* is restricted mainly by the expanding metropolitan area. Flying squirrels are present on the Kalbfleisch Field Research Station, in the Dix Hills area of western Suffolk County (Lanyon, 1961). In Nassau County a few are still present locally, and they also occur, or formerly occurred, within the limits of New York City, including Queens and Staten Island.

Flying squirrels were observed (a few collected), and seemed to be fairly common, well out in the extensive sandy pine barrens of Suffolk County south of the Peconic River (figure 3). They were not noted in the low, shrubby so-called "pine plains," but frequented areas where the pine trees were of fairly good size. But there was rarely much variety in the flora in these localities—mainly just the rather well-spaced pitch pine (*Pinus rigida*), some low understory oak, usually bear or scrub oak (*Quercus ilicifolia*), with the prostrate shrub, bearberry (*Arctostaphylos uva-ursi*) covering much of the ground. There was evidence of flying squirrels feeding on the seeds of pitch pine, and it may be that in this sparse habitat much of the diet consists of pine seeds, acorns, and perhaps fungi and insects or other animal food. Evening parties of flying squirrels were observed in stands of southern white cedar (*Chamaecyparis thyoides*)

in this region, especially along the edge of a large (for Long Island) cedar swamp near Riverhead (figure 7).

Remarks. Flying squirrels live in hollows of trees and stubs and also may build outside nests. One January day in a pitch pine and oak woodland near Hampton Bays I briefly shook a tall pine stub which had a conspicuous hole about 11 feet above the ground. A flying squirrel immediately came out of the hole and scurried to the top of the stub, after which a second one appeared at the entrance and gazed down at me, without emerging. After I backed off a short distance, they both settled back down in the cavity. Woodcutters reported up to a dozen or so flying squirrels found together in one large hollow tree or stub, and also we heard that they occasionally take up residence in buildings near woods, habits characteristic of this species.

At another locality, near Flanders, two females were caught during April at the base of an old pine stub (which had numerous holes). This area was of interest in that the stub was on a dry slope just above a small white cedar swamp, and in some of the cedars were outside nests somewhat resembling in general appearance the work of red squirrels (which do not occur on Long Island). The nests, most of which were fairly high up and on branches near the trunk, were globular, compact, and constructed mainly of shredded cedar bark with some cedar twigs and leaves included. These nests may have been constructed by flying squirrels rather than gray squirrels, at least the nests differed considerably from the usual leaf nests built by gray squirrels.

Measurements. The following figures are for specimens taken in Suffolk County during winter and spring. Four adult males average: weight, 72.3 grams (65.8-76.1); total length, 231.5 mm. (221-237); tail, 99.5 mm. (96-101); hind foot, 31.5 mm. (30.5-34). Three adult females without embryos average: weight, 67.9 grams (63.1-73.3); total length, 234.3 mm. (230-238); tail, 100.0 mm. (97-105); hind foot, 31.7 mm. (30.5-33.5).

Individuals taken. 10

White-footed Mouse

Peromyscus leucopus noveboracensis (Fischer)

Distribution and habitat. The white-footed mouse probably is the most widespread or generally distributed mammal on Long Island, although perhaps not the most numerous. This species was taken on more traplines than any other small mammal; very often only one or two

Peromyscus were caught in a given area, but this was enough to indicate its presence. It seems to be rivaled only by the masked shrew in its adaptability to the various environments here.

Woods of every general type trapped were occupied by *Peromyscus*, including oak woods, mixed deciduous woods, maple swamps, pine barrens, and cedar swamps; dry, damp, mature, and second-growth woods were all inhabited. *Peromyscus* was numerous in the dry, sandy pine and oak woods of Suffolk County, and was definitely the most abundant mammal in the drier barrens, under pitch pine and low bear oak (figure 3). Also this is the common mouse of the cedar swamps, generally avoided by the other mice. Other moist areas inhabited included sphagnum bogs near woods, and bushy zones around ponds and along streams in wooded areas.

Open, treeless areas of various sorts were also occupied, and accounted for approximately one-fourth of the total catch. These areas were predominately grassy and often included low shrubs. The areas were primarily in two categories—abandoned inland fields and various coastal habitats.

In the coastal areas, trees were often far away and of no apparent significance to *Peromyscus*. Here the ground was usually dry and sandy, rarely marshy (fresh to salt), where these mice were collected. Little valleys and depressions among the sand dunes, such as are found at Hither Hills and at East Hampton Beach (figure 17), were found to harbor many white-footed mice. Fewer were found on the harsh outer dunes, a habitat of sand and beachgrass. Also *Peromyscus* was present in extensive, level, open areas at Napeague Meadows, on Shelter Island, etc.; beachgrass and other grasses, plus low shrubs (bayberry, beach plum, etc.), formed low cover in these areas. On the outer strip, *Peromyscus* was found in grassy and grassy-shrubby areas far from any trees; areas included Fire Island and the strip east of Moriches Inlet.

Peromyscus was common in various types of vegetation at the very end of Montauk Point, including the vicinity of the old lighthouse. Dutcher and Dutcher (1893, in their survey at Montauk, found this species present in woods, wet and dry meadows, and even under logs and rocks just above the tidal zone, in fact everywhere except on the open uplands.

Three white-footed mice were taken well out in salt marshes, one on the north shore (Mt. Sinai) and two in the Moriches Inlet area, but probably the mice had wandered out from drier, sandy areas. Salt marsh appeared to be the least preferred by *Peromyscus* of all the major habitats on the island.

Peromyscus has been collected on various smaller islands in this region besides Fire Island and Shelter Island. This species is present on Plum Island off Orient Point, and one collected by A. H. Howell in 1898 is in the U.S. National Museum. It is common on Fishers Island, and three collected by G. G. Goodwin in 1924 are in the American Museum of Natural History. For Gardiners Island, Richard Van Gelder (verbal communication) found *Peromyscus* abundant in woods there during a brief period of trapping. White-foots are common on Staten Island, where I have found individuals living in roofed-over bird nests.

Remarks. This species, in common with many other rodents, fluctuates in abundance, being much more numerous some years than others. This may be why our trapping indicated white-footed mice to be rare or apparently absent in many seemingly favorable woodland areas. In the winter and spring of 1962, especially, these mice were notably scarce in woods throughout much of eastern Long Island. Roy Latham (personal communication) reports a marked low at Orient during 1968. Usually, many white-footed mice come into Orient houses during the winter. But they were so scarce in the winter of 1967-68 that not one came into Latham's house, and he did not see any of these mice during 1968; *Peromyscus* seemed to be virtually extinct locally. By the spring of 1969, however, Latham found *Peromyscus* to be on the increase again, becoming common in 1970.

White-footed mice were usually trapped on the surface of the ground, but a few (mainly in winter) were caught underground in tunnels of the eastern mole; also catches were made several feet above ground on the trunks of leaning trees. A few individuals from tunnels were dirty white or grayish beneath, presumably a stain from contact with the soil. This species is found in many houses and other buildings in the more rural areas, but is not as much of a nuisance as the house mouse.

An amusing instance of the wide variety of nest sites utilized was noted near Great Peconic Bay in late September 1960. I found an old wooden kitchen table standing on bare ground under some oak trees, evidently the abandoned remnant of a summer campsite. When the drawer was pulled out, four more or less fully grown white-foots looked up from a cozy nest within. One scurried out of a hole in the back of the drawer and then down to the ground, but the others remained in place in the nest as I shut the drawer. Helme (1902) on two different occasions on Long Island found as many as 16 individuals of this species in one nest.

Reproduction. The reproductive season extended at least from March to October (female with embryos on

March 29, 1961, lactating individuals in mid-October, 1960). First young juveniles out of the nest were trapped April 24 (1961). Average litter size based on 12 embryo counts (March 29 to August 23) is 4.3, with a range of three to six. Thirty females showed placental scars; individual counts ranged from three to 10, some of the higher counts apparently representing two litters. Males in evident breeding condition were collected from late March through most of September.

Measurements. Seventy adult males from all seasons (fall, 1960 to summer, 1963) average: weight, 22.0 grams (16.8-27.8); total length, 175.3 mm. (155-197); tail 81.2 mm. (67-93); hind foot, 20.8 mm. (19.5-22); ear from notch, 16.9 mm. (15.5-18.5). Thirty-eight non-pregnant adult females in the same period average: weight, 21.2 grams (16.3-29.5); total length, 175.0 mm. (156-197); tail, 81.0 mm. (71-92); hind foot, 20.6 mm. (19-22); ear from notch, 16.8 mm. (15.5-18). Localities range from western Nassau County to Montauk Point.

Individuals taken. 219

Meadow Mouse

Microtus pennsylvanicus pennsylvanicus (Ord)

Distribution and habitat. The meadow mouse, also commonly known as field mouse or meadow vole, is abundant in many grassy areas, from the outer dunes and salt marshes to inland fields and bogs. This is one of the most numerous mammals of Long Island, but it is not found in as many different habitats, and thus probably does not equal in total numbers such species as the masked shrew, short-tailed shrew, and white-footed mouse. As far as is known, all meadow mice in the Long Island region today are the same as those on the mainland (*M.p. pennsylvanicus*); the recently exterminated subspecies on tiny Great Gull Island, *M.p. nesophilus*, is discussed at the end of this account. A surviving insular form just outside this region is *M. pennsylvanicus procvectus*, confined to Block Island, Rhode Island, about 15 miles east of Montauk Point.

Microtus is especially numerous (and far outnumbered other mammals) in the extensive salt marshes which fringe the south shore bays and which also dot the edge of Peconic Bay (figure 6) and the north shore. In these marshes, areas of low grass, such as *Spartina patens*, are highly favored by the mice. Surface runways, cuttings, and nests of meadow mice are usually the only signs of mammals in the mole-shrew-mouse size range to be seen in the Long Island salt marshes. Occasionally we caught a few masked shrews or individuals of other species in the meadow mouse runways, but often *Microtus* appeared

to be the only small mammal present. As a general indication of meadow mouse abundance in this habitat, 25 single-catch live traps which were set in a small area of salt marsh near Moriches Inlet (figure 16) for two nights and the intervening day in August 1962, and checked three times during this period, caught a total of 49 different individuals.

Dry, sandy, coastal areas, with assorted grasses and shrubs, also produce many meadow mice. They are common on the tops of the outer dunes which border south shore beaches (figure 17). Here there is little vegetation save beachgrass (*Ammophila breviligulata*), but it grows in fairly dense stands where the ground is reasonably level along the summits of the dunes. To judge from the abundant cuttings and other signs, *Microtus* feeds on the leaves, stems, and seeds of beachgrass; but generally no distinct runways are to be found in this habitat, just the grass cuttings littering the bare sand where meadow mice are present. Signs of *Microtus* were found even on the summits of the steep moving or "walking" dunes in Hither Hills State Park near Napeague Harbor (figure 19). These dunes are much higher than the ocean beach dunes, and yet the mice were present, at least periodically, wherever there were stands of beachgrass growing on the tops of these otherwise bare peaks of sand.

Microtus was common in fields island, especially where the grass was thick and luxuriant. It was often present in the same sandy field with *Pitymys*, but *Microtus* generally favored the denser stands of *Andropogon* or other grasses, while the more fossorial pine mouse was less restricted, and was apt to occur in the more open, sparsely covered field areas, and in adjoining woods as well.

Fresh-water habitats included moist places adjacent to ponds and streams, cattail marshes, meadows, and sphagnum bogs; usually sedges or grasses were present. In the bogs, covered with shrubs, sedges, and the like, *Microtus* was locally abundant (figure 9); here it tunnels through and under the sphagnum moss. In central and eastern Long Island the shrubby, sedgy bogs strikingly resemble those on the New Jersey coastal plain, where *Synaptomys* and *Clethrionomys* live, but on the island *Microtus* seems to be the only microtine present in such areas.

This species was rare in wooded areas in general, and apparently nonexistent in the dry oak and pine woods covering much of the region. Only six were collected in areas that were classified as woods—three in a red maple swamp, three in grass under a stand of black locust trees.

We collected specimens of *Microtus* on Fire Island and Shelter Island, and found abundant signs of these

mice on Gardiners Island, but we did not work farther offshore. Frank M. Chapman collected this species on Gardiners Island in 1902 (specimens in American Museum of Natural History). Eight specimens collected on Plum Island by A. H. Howell in 1898 are in the U.S. National Museum. This form also occurs on Fishers Island. Meadow mice are common on Staten Island, although landfill operations in salt marshes have destroyed much of their habitat. In Roy Latham's collection there is an all-white meadow mouse from moist woods on Shelter Island.

Food habits. Many kinds of plants are eaten by meadow mice. Food habits were not studied, except that we could hardly avoid noticing signs of feeding, such as the many cuttings of grass or sedges where these mice were present. Frequently noted examples of this included cuttings of cord-grass (*Spartina alterniflora*, *S. patens*) and bulrush (*Scirpus* sp.) in salt marshes, beachgrass (*Ammophila breviligulata*) on the ocean dunes, and broomsedge (*Andropogon virginicus*) in sandy fields. In a few salt marsh areas many cuttings were found of the odd succulent plant, glasswort (*Salicornia* sp.). Also we observed extensive diggings by meadow mice in stands of reed (*Phragmites communis*) on the barrier beaches, suggesting feeding on the rhizomes of this large plant.

Meadow mice of the genus *Microtus* are noted for storing quantities of food, especially underground parts of plants belonging to the buckwheat, pulse, morning-glory, and composite families. In North America this habit is especially developed in certain northern and western areas. In March 1961, on Long Island, I found rather striking accumulations of the tuberous enlargements from rootstocks of the groundnut or wild bean (*Apios americana*); apparently these had been gathered by meadow mice, rather than pine mice, which also store plant roots. The tubers, about an inch long when dry, resembled tiny sweet potatoes in general shape and color (figure 24). Groundnut grows in moist ground and thickets, often in or near areas frequented by *Microtus*, although it is not an abundant plant. Most of the stores were found east of Hauppauge in an area of ponds, and moist meadows near the northeast branch of the Nissequogue River. Piles of the tubers were found on the surface of the ground in grass, and associated with *Microtus* runways. Two piles were examined closely: one contained over 100, the other about 175 tubers. One of the piles was next to a well-used *Microtus* runway, the other was at the end of a short spur connecting with a main runway.

Remarks. Meadow mice are destroyed by a host of vertebrate predators. We found their remains in pellets

of several species of hawks and owls. Short-eared owl pellets were noted as especially numerous in salt marshes and fields along the south shore in the winter and early spring of 1961, and they contained many meadow mice. On one occasion a short-eared owl was observed to catch and eat a meadow mouse during the day on snow-covered dunes at Tiana Beach. There was also much evidence of red foxes preying on meadow mice in different areas of the island.

Occasional hurricanes and other severe storms undoubtedly drowned many meadow mice in the shore areas, although the reduction in the numbers of these mice is only local and temporary. A prolonged and devastating east-northeast storm which reached its peak on March 6, 1962, washed over or broke through the outer barrier beach in several places between Moriches Inlet and Shinnecock Inlet. A week later along this same strip I noticed several dead meadow mice that had apparently drowned or died of exposure. Also some beachgrass and salt marsh areas were buried under a deep layer of sand probably carried by storm waves from the beach and outer dunes. One depression back of the dunes, formerly grassy and with a population of meadow mice, when revisited after the storm was found to be covered with 2 to 4 feet of new sand resembling a vast snow-drift. However, in the summer and fall of 1962 meadow mice were generally numerous along this strip of barrier beach. The experienced Long Island observer, Dr. William T. Helmuth (1954) wrote that meadow mice were still plentiful on eastern Long Island near the shore after the destructive 1938 hurricane, even though many storm-killed mice were noted.

Reproduction. Average number of young based on 57 spring, summer, and fall embryo counts (Suffolk County) is 4.3, with a range of one to seven; three to five was usual (four the most frequent number). These figures are somewhat smaller than usually reported for this prolific species. Size of embryos ranged from small swellings 3 mm. in diameter to large embryos near birth about 30 mm. in length (crown to rump).

A long breeding season was indicated, with some individuals probably breeding in winter. Embryo dates ranged from April 16 to December 15. Also, females which had already given birth (lactating, placental scars) were collected on the south fork in mid-April. Males in breeding condition were trapped primarily in the period March 22 to December 19, but two such males were also collected in central Suffolk County on February 7 and 8, 1962.

Measurements. The following refers to specimens taken at various Suffolk County localities during all sea-

sons of the year. One hundred and twenty-five adult males average: weight, 44.5 grams (28.4-75.7). Eighty adult males average: total length, 171.3 mm. (151-211); tail, 50.9 mm. (38-67); hind foot, 21.7 mm. (20-24). Fifty-eight adult females average: weight, 39.5 grams (28.3-65.4). Seventy-two adult females average: total length, 167.6 mm. (150-197); tail, 48.3 mm. (42-59); hind foot, 21.3 mm. (19-23).

Individuals taken. 396

Gull Island Mouse. The Gull Island subspecies (*Microtus pennsylvanicus nesophilus* V. Bailey) apparently became extinct 9 or 10 years after its discovery. Formerly it was considered a separate species, but it appeared to differ only in minor skull and pelage characters (skull shorter and wider, color of pelage darker) from the common meadow mouse of Long Island and the mainland. This form was evidently confined to Great Gull Island. This island, and nearby Little Gull Island are located at the entrance to Long Island Sound between Plum Island and Fishers Island. Great Gull is long and narrow, slightly over one-half mile long, and is about 2 miles east of much larger Plum Island, which in turn is about 1½ miles off the end of Orient Point across Plum Gut. Plum Island mice, however, resemble the mainland form rather than *nesophilus* (Miller, 1899).

Dutcher (1889) collected the first known specimen of *nesophilus* on August 6, 1888, and he described the birdlife, habitats, and dimensions of the two Gull Islands. Great Gull, 14 or 15 acres in extent, was composed of sand, with a shoreline and outlying reef of rocks; it was hilly (probably 25 feet high at highest point), covered with coarse grass and some clumps of bushes, and had a small fresh-water marsh. Dutcher stated that Great Gull Island was purchased by the Government to serve as a garden for the keepers of Little Gull Lighthouse, but it was so overrun with the mice that it was useless for that purpose. Little Gull Island was only about 100 by 50 yards in size, and consisted mainly of gravel and boulders, with a lighthouse.

Dutcher also wrote that in the summer of 1888 common terns (*Sterna hirundo*) were nesting in abundance on Great Gull Island, and that song sparrows (*Melospiza melodia*) were quite common, especially in and near the marsh on Great Gull. Marsh hawks (*Circus cyaneus*) visited the island and apparently preyed on the mice. Dutcher secured one of these hawks on Great Gull Island on August 12 and the stomach contents included the remains of a mouse (I presume *nesophilus*); he also stated that the marsh hawk was known as "mouse hawk" to the keepers of Little Gull Light.

More of these mice were collected on Great Gull Island in the years immediately following Dutcher's 1888 visit. Frank M. Chapman collected seven in July 1889 (skins and skulls in American Museum of Natural History) and Basil Hicks Dutcher returned to collect more specimens in 1890 (deposited along with type specimen in U.S. National Museum). Bailey (1898, 1900), who examined 15 specimens, published a description of the new mouse. During 1897, fortifications were erected on the island and in conjunction with this the entire surface of the island was disturbed, wiping out the original habitat. Reed (1898) described the rapidly changing environment, and its effect on the tern colony, on Great Gull Island during the summer of 1897. On August 8, 1898, Arthur H. Helme and Arthur H. Howell visited Great Gull Island, searched every part of the island, noted the nearly complete destruction of the vegetation, and found no trace of the voles; they concluded that the Gull Island mouse was probably extinct (from Miller, 1899, who quoted notes furnished by Howell). At the present time the introduced house mouse is the only mouse on Great Gull Island as far as I know.

Pine Mouse

Pitymys pinetorum scalopsoides (Aud. and Bachman)

Distribution and habitat. The pine mouse, or pine vole, spends much of its life underground, is highly adaptable, and is one of the common mammals of Long Island. Perhaps it is exceeded in numbers only by the masked shrew, short-tailed shrew, white-footed mouse, and meadow mouse. The pine mouse has long been known to occur on Long Island, the type locality of *scalopsoides*; Audubon and Bachman (1841) obtained many Long Island specimens, on which they based their original description of this form, naming it *Arvicola scalopsoides*.

Pitymys is found in most of New York State, but becomes progressively less common northward, where it is confined mainly to the humus of the forest. In southern mainland New York (such as lower Hudson Valley, Delaware River drainage), and on Long Island and Staten Island it is quite common, even abundant in places. On Long Island this mouse is widely distributed in the light sandy soils of fields and woods.

Eastward on the island we found it common as far as Hither Hills on the south fork and Great Hog Neck on the north fork, and it is known to occur all the way to Montauk Point, where William Dutcher collected this species in 1893 (specimen in American Museum of Natural History). I was unable to find the pine mouse in several days spent collecting on Shelter Island. It is possible

that it was overlooked on this large island, although Roy Latham, in a personal communication, writes that he has no record of *Pitymys* on Shelter Island either. He also writes that this species has not been recorded on the north fork east of Southold. *Pitymys* also appears to be absent from Gardiners Island and Plum Island, judging from the lack of records.

Pine mice and meadow mice may occur together in the same field on Long Island (figure 11), but there are so many differences in habitat preference that more frequently only one is found in an area. The pine mouse is scarce in the immediate vicinity of the ocean front along the south shore. This fossorial species avoids the salt marshes (where *Microtus* abounds), although it is locally common at the dry edge of this habitat. Also *Pitymys* was not found in grassy dunes and hollows behind the ocean beaches of eastern Long Island, even though *Sorex*, *Blarina*, *Scalopus*, *Peromyscus*, *Microtus*, *Mus*, and *Zapus* were found in such areas. We were unable to find *Pitymys* on the outer barrier beaches, where our collecting localities included Moriches Inlet, Tiana Beach, and Fire Island opposite Smith Point.

Inland in Suffolk County, however, *Pitymys* finds more territory suitable to it than *Microtus* does. The pine vole tunnels under the leaf litter of oak and pine-oak woods; also it finds satisfactory the dry sandy ground of pine barrens, and old sandy fields where ground vegetation is too sparse for *Microtus*. The latter often does predominate where the grass is thick, and invariably does so where the ground is wet, as along streams and in marshes and bogs.

Around some of the bays, pine mice may be found living right up to the edge of tidewater. We found this to be especially true in the vicinity of Great Peconic Bay, which penetrates far inland (figure 6). Here *Pitymys* was associated with *Microtus* in a dry sandy zone (often 30-40 feet wide) along the very border of the salt marsh under beachgrass (*Ammophila breviflora*), a tall unidentified grass growing in tussocks, groundsel-tree (*Baccharis halimifolia*), bayberry, and the like. The pine mice were found occupying subterranean burrows, and also surface runways in the grass. Windrows of old storm debris from the bay were conspicuous in this zone. This edge zone was a clear-cut area of overlap for the two microtines: *Microtus* alone occurred out in the wet tidal marsh, while inland, under pines and oaks, only *Pitymys* was found.

This species is sometimes said to be poorly named and rarely found under pines. Probably it would be more accurate to say that *Pitymys* does not appear to be restricted to pines in any region, and it is also found in regions where there are no pines. In the Long Island pitch-

pine region *Pitymys* is actually rather common; in fact, it is only microtine present in this environment (figure 3). Here it is found even in rather barren areas, with few green plants besides pitch pine, an undergrowth of bear oak, and for ground cover, bearberry and some scattered sedge. Pine mice were also taken in tunnels under fallen leaves in deciduous woods. At Hither Hills it was trapped under black oaks and white oaks (figure 21), many stunted and bent by the wind, near the shore of Block Island Sound.

In old sandy fields, formerly cultivated and now covered with broomsedge (*Andropogon virginicus*), composites, and other herbs, and sometimes scattered young pitch pine, wild black cherry, etc., pine mice are often abundant, and easily trapped because the holes leading to their tunnels are numerous and readily seen. Occasionally we found *Pitymys* in parts of a field where the ground was nearly bare, with only a scanty growth of grass, while the less fossorial *Microtus* and *Sorex* were rather closely confined to dense grass cover. The burrows appeared to be smaller than those of meadow mice, and in fields were more apt to be seen in bare, open ground, as mentioned above. In one small field surrounded by woods, where no meadow mice were taken, pine mice frequented surface runways in dense broomsedge. I had mistaken the runways for those of *Microtus* before trapping, but they did seem to be narrower than those of *Microtus*.

Blarina appeared to be the most regular mammal associate of *Pitymys*, both showing a somewhat similar habitat distribution, and often found in the same tunnels. The eastern mole was also quite characteristic of the same areas, pine mice often using the larger mole tunnels. Because of a more subterranean existence than *Microtus*, probably relatively fewer pine mice are destroyed by predators, although various birds, mammals, and snakes eat them. We did see remains of pine mice apparently killed and eaten by red foxes and other wild predators, and at Hampton Bays our pet cat occasionally caught them.

Food Habits. This omnivorous and rather voracious vole is of economic importance, although its mainstay may be said to be succulent roots and other underground parts of wild plants, with seasonal variation. At times this species causes considerable damage in orchards and nurseries on Long Island and elsewhere by eating the bark and cambium of tree roots, girdling them. Some damage to potatoes and other root crops of farm and garden may occasionally be caused by *Pitymys*. Roy Latham, an experienced potato farmer, writes (personal communication) that on Long Island pine mice nibble on potatoes, carrots, rutabagas, and other roots in weedy fields but

apparently do no notable damage. Moles, which make more conspicuous tunnels, are frequently blamed for the depredations of underground pine mice.

Some green foliage is consumed, although the cuttings are generally not as numerous and conspicuous as those of meadow mice. In a number of abandoned fields visited there was evidence of pine mice feeding on various herbaceous plants. For example, goldenrod (*Solidago* sp.) was being eaten during May in some fields in central Suffolk County; many tender shoots and small plants a few inches high were cut off and carried into the burrows. Also, daisy fleabane (*Erigeron* sp.) was similarly used, and cuttings were found in the burrows. In June in the same region it was noted that a cinquefoil (*Potentilla* sp.) had apparently been added to the diet, with fresh cuttings in burrows frequented by *Pitymys*.

Some individuals, especially in spring, gave off strong odors from feeding on pungent herbs, including wild onion (*Allium* sp.). Seventy stomachs were saved but most have not been examined at the time of this writing. A few that were examined contained only plant material—the roots and green parts of grasses and other vegetation. These mice are also inclined to eat animal food; quite a few specimens were destroyed in the traps, many presumably eaten by their own kind.

Reproduction. Litters are small in *Pitymys*, and this was borne out in our Suffolk County information based on 14 embryo and placental scar counts. The average was 2.4, with a range of two to four. The season of reproduction extended at least from early April (female with embryos on April 17, another nursing on April 18) to September (one recently nursing on September 27, several with placental scars in October). Although litters are small, Raynor (1960) found three litters and a pregnant female in a single nest at Manorville, Long Island, in April; it was assumed that at least one of the nest litters belonged to another female.

Color. The only noticeable color variants collected were two adult females near Flanders in October 1960, which tended to melanism, showing a dark grayish-brown (nearly blackish) hue on the upper parts, rather than the bright chestnut-brown characteristic of this species. Buffy specimens have been found at Mattituck and nearby Cutchogue, as described by Hatt (1930) from a skin in Roy Latham's collection.

Measurements. The following pertains to specimens collected in central and eastern Suffolk County at all seasons of the year. Thirty adult males average: weight, 25.2 grams (21.2-30.7); total length, 123.9 mm. (120-129); tail, 23.1 mm. (19.5-26); hind foot, 16.5 mm. (15-

17.5). Thirty adult females without embryos average: weight, 25.5 grams (20.1-32.0); total length, 126.3 mm. (117-131); tail, 23.4 mm. (20-27); hind foot, 16.6 mm. (14.5-18).

Individuals taken. 85

Muskrat

Ondatra zibethicus zibethicus (Linnaeus)

Muskrats are common throughout the Long Island area wherever their modest aquatic requirements are met. All the earlier references dealing with the mammals of the island, going back to early Colonial days, mention this valuable rodent, and it was known to the Indians even earlier. Through the years, many thousands have been trapped for their fur. At the time of DeKay (1842) the skins sold for 25¢ apiece and were extensively used in the manufacture of hats. Musk rats are still present in Brooklyn (Jamaica Bay) and Queens, and on Staten Island; eastward they extend to Montauk Point, Orient Point, Shelter Island, and Gardiners Island (we saw several on Gardiners Island in 1962).

Their most extensive habitats, and where they flourish, are the great salt and brackish tidal marshes which encircle the bays along the south shore (including Fire Island). The similar but more scattered marshes around the Peconic bays and on the north shore also harbor many muskrats. Inland, muskrats live in almost all fresh-water localities, especially in marshy areas along the major streams (figure 5), but also in the many ponds in the pine barrens (figure 4) and elsewhere, and in bushy sphagnum bogs, old cranberry bogs, and wooded maple swamps.

The overall muskrat population is much smaller than in the past, because of the many acres of aquatic environment which have been drained or otherwise lost. Thus Hamilton (1949) remarked that in the winter of 1919, when the rats brought up to \$4.25 a pelt, over a thousand dollars worth of the furs were harvested from the salt marshes and creeks (Flushing Meadows area in Queens) that later became the site of the 1939 World's Fair. Roy Latham (personal communication) used to be able to trap about 80 muskrats in a season on the agricultural north fork at Orient, an area where they are now scarce.

Hatt (1935) described an unusually dark muskrat (black phase) collected by Roy Latham at Orient on December 28, 1929. Formerly, Latham (personal communication) saw or obtained about two individuals in the black phase each trapping season at Orient.

There seem to be relatively few muskrat houses, or lodges, compared with the many muskrats obviously present in the various areas. Many must make their homes in burrows dug into banks. We did see some houses in marshes, both tidal and inland, also on ponds, and in overgrown bogs.

House Mouse

Mus musculus Linnaeus

Distribution and habitat. This familiar species, introduced from the Old World about two centuries ago, is numerous in and around buildings in cities and towns and on farms, where it lives in association with man. Since little field work was done in such situations, we did not collect many house mice. This species is sometimes found in fields and less often in woods in this region; also it lives along the seashore and on outlying islands in various parts of its worldwide range, including the Long Island area.

In winter, at least in 1960-61, feral or wild-living house mice seemed to be rather numerous and widespread on the outer ocean dunes along the south fork of eastern Long Island. At East Hampton Beach, in December, several were trapped on the outer dunes (figure 17) just back of the beach in nearly pure stands of beachgrass (*Ammophila breviligulata*) with some scattered herbs, chiefly composites. This was during severe weather, a period of low temperatures followed by unusually heavy falls of snow. I do not know how dependent this hardy colony was on the presence of buildings; the nearest inhabited houses were about one-half mile inland, although several summer cottages were somewhat closer.

The beach individuals were probably feeding on seeds (and perhaps green parts) of beachgrass; several were trapped on the sand next to little piles of the seed heads. *Microtus* was the only other small mammal collected on the outer dunes at East Hampton Beach; the two species appeared to be living closely together on the same ground. Some of these outdoor house mice were breeding during the winter, and a female on December 8 contained five small embryos.

House mice also were found living on the barrier beach strip near Moriches Inlet in rather wild, deserted dunes country far removed from any buildings. Here they were considerably outnumbered by *Microtus* and *Peromyscus*. One January day in this area we saw a sparrow hawk (*Falco sparverius*) feeding on a freshly caught house mouse. House mice are present on remote Great Gull Island (specimens in American Museum of Natural

History), the island formerly inhabited by the Gull Island vole (*Microtus pennsylvanicus nesophilus*).

Most trapping in natural habitats inland, away from buildings, farms, and the like, gave only negative results for this species. One was collected in a sphagnum bog bordering a cold stream, along with a large number of meadow mice.

Individuals taken. 14

Norway Rat

Rattus norvegicus (Berkenhout)

Distribution and habitat. The Norway rat, also known as brown rat, house rat, barn rat, and even water rat in some localities, is probably our most destructive and hated mammal. It is usually associated with man and is often extremely abundant in and around barns and other buildings. Hundreds of rats were seen at a time at certain Suffolk County dumps visited after dark, and rat burrows were noticed on duck farms and even in the better residential areas. Rats were encountered near water, both salt and fresh, often at a considerable distance from human habitations. On Long Island this species is distributed from the Brooklyn waterfront to the rocky tip of Montauk Point.

Signs of rats are frequently noted near inlets and at rock jetties on the ocean front. At the jetty which hugs the west side of Shinnecock Inlet (figure 12) rats make their home among the rocks, and I have observed them boldly active on the nearby open beach during daylight hours. When pressed too closely, they take cover among the rocks. Rats appeared to be present throughout the year here, and they were abundant even in January (noted in 1963). Their numerous footprints formed beaten trails in the sand next to the jetty and among nearby sand dunes. On the bay side of the inlet there are fishing stations and assorted buildings which probably shelter many other rats of the area, and where the jetty rats may take refuge during storm tides and whenever necessary.

Rats are also found at Montauk Point in a somewhat similar situation. They live among the rocks and boulders at the base of the cliff at the very end of the point, and judging from the many tracks, are present here even in the bitter, windy midwinter season. Turrell (1939) mentions that rats are occasionally seen in broad daylight foraging on the beaches of the Smihtown Bay region on the north shore.

A few individuals were trapped in the Great Peconic Bay region in salt and brackish marshes and in adjacent

dry grassy areas (figure 6). Norway rats are said to be a problem in some Peconic localities (and probably elsewhere) when exceptionally high tides or storms drive them out of the marshes, at which times they appear in abundance in and around houses. Rats are also present in fresh-water areas, and individuals were seen foraging along the shores of ponds in the evening, tracks were seen along streams in red maple swamps, tracks were numerous around waterways in certain parks, and the like. A few even frequent small streams in the dry pine-oak woods. Norway rats inhabit muskrat burrows in some of the marsh and pond areas.

Norway rats are present on most of the eastern islands, including Shelter, Gardiners, Plum, and Fishers, and, reportedly, even Great Gull Island.

Food habits. Rats eat all sorts of animal and vegetable food, including carrion, garbage, and food stored by man. In the shore and marsh areas of Long Island, rats probably feed extensively on certain readily available forms of animal life (both living and dead). Rats living among rocks at the ocean, such as inlet jetties and boulders at Montauk, may subsist mainly on dead birds, fish, and other marine life washed ashore, and probably also eat the remains of bait and fish discarded by fishermen. One January morning I saw a Norway rat feeding on the carcass of a herring gull on the beach beside the Shinnecock Inlet jetty. Audubon and Bachman (1851) told of Norway rats along the East River which were reported to dig up and feed on a small ($\frac{3}{4}$ -inch long), thin-shelled species of clam which was then abundant in sandy places below high-water mark.

Individuals taken. 8

Black Rat

Rattus rattus Linnaeus

The black rat (also called ship rat or roof rat), like the Norway rat, lives in human habitations and was accidentally introduced from the Old World. However, the black rat arrived much earlier than the Norway, probably with the first colonists. The latter species is said to have been introduced to the seaboard states during or about the time of the Revolutionary War; it spread rapidly in the Northeast, replacing the black rat, which seemed to disappear entirely from most areas where it had been numerous.

The two species of *Rattus* cannot be distinguished by color alone, regardless of common names; melanic (black) Norway rats are not rare, and also *R. rattus* has

different color phases or variants, some closely resembling typical Norways in color. Such features as the longer tail, larger ears, and smaller body size of *R. rattus* are more reliable.

The present status of the black rat in the Northeast is not clear; perhaps it may be described as either very rare or very local. This species may have been abundant on Long Island at one time, as it seems to have been in some other areas of New York and neighboring states, but practically nothing is known of its history here. It has certainly long since disappeared from most of the island. Very likely the black rat in this region has continued to exist in city waterfront areas (e.g. Brooklyn), where its numbers are maintained by new arrivals brought in by ships. Naturalists rarely visit or collect in such areas.

Helme (1902) wrote that "many years ago" some specimens of *Rattus rattus* were caught in a stable in Brooklyn. The only existing Long Island specimen I know of was collected at Douglaston on the north shore of Queens near the Nassau County line, March 13, 1921 (Dr. Fisher). It is a male in the black color phase, preserved as skin and skull at the American Museum of Natural History, No. 42978. Kieran (1959) stated that this species is far behind the house mouse and Norway rat in abundance in all five boroughs of New York City, but that recent collecting by professional exterminators has revealed that sizable numbers of *Rattus rattus* are present. I do not know if any specimens collected in this manner have been preserved.

Meadow Jumping Mouse

Zapus hudsonius americanus (Barton)

Distribution and habitat. The meadow jumping mouse is rather rare and local on Long Island; it seems to be more numerous on the adjacent mainland. This species has been collected from Brooklyn and Queens east to Montauk Point, and is still found thinly spread throughout the full length of Suffolk County, but at the present time appears to be common only near the eastern end of the island. There jumping mice are found in very dry, as well as moist, open areas with grasses and other low vegetation. They thrive in sandy areas near salt water marshes and bays, and in the grassy hollows just back of the ocean dunes. But even though we found these mice in places along the very edge of salt marshes, they rarely venture out into this habitat.

Fourteen individuals were collected in dry, sandy areas east of Amagansett, in the region of Napeague

Meadows and Hither Hills (figure 18). The vegetation consisted of a variety of grasses, including much beachgrass (*Ammophila breviligulata*), and also many shrubs and vines, especially bayberry (*Myrica pensylvanica*), poison ivy (*Rhus radicans*), and wild rose (*Rosa carolina*). One was collected on Shelter Island in similar habitat, adjacent to a salt marsh (figure 25). Such areas of excessively drained ground (nearly pure sand), often remote from any standing fresh water, appeared to be the most productive habitat for *Zapus* on eastern Long Island judging from our trapping results.

The remaining four jumping mice were collected in moist, somewhat boggy situations with grasses and sedges. *Sorex cinereus* and *Microtus pensylvanicus* were common in all of the *Zapus* collecting areas, but other small mammals were scarce. In the pine barrens of Suffolk County, jumping mice are found in some of the more luxuriant areas near water, and we saw one or two among shrubs and grass on the edge of a pond near Flanders.

Dutcher and Dutcher (1893) reported *Zapus* to be the "least numerous" species of mouse at Montauk, but they found it widespread there, present in swamps and wet and dry meadows, and also on the Montauk Downs. Eight meadow jumping mice (and other mammals) collected by the Dutchers at Montauk are in the U.S. National Museum. Although found at Montauk and on Shelter Island, *Zapus* has not been recorded from the more outlying eastern islands, such as Gardiners Island and Plum Island, as far as I know; nor do I know of any records for Fire Island, although there appear to be extensive areas of suitable habitat there. This species is a resident of Staten Island, where it has been collected in several localities.

Reproduction. Several breeding females were collected in June: one with six tiny embryos on June 8, one lactating and with four placental scars on June 22, and two lactating and with placental scars on June 27.

Measurements. The following refers to specimens taken on the southern fork of eastern Long Island and on Shelter Island. Nine adult males without hibernation fat (May and June specimens) average: weight, 15.0 grams (11.6-17.3); total length, 201.3 mm. (194-205); tail, 116.3 mm. (101-128); hind foot, 27.9 mm. (26-29). Five nonpregnant adult females without hibernation fat (June and August) average: weight 17.4 grams (14.7-19.3); total length, 208.4 mm. (193-227); tail, 122.2 mm. (112-134); hind foot, 27.8 mm. (26-30). The heaviest individual, weighing 24.9 grams, was a nonbreeding female with much fat on October 19.

Individuals taken. 18

Common Dolphin

Delphinus delphis Linnaeus

This graceful and beautifully marked dolphin, which reaches a maximum length of about 8½ feet, frequents New York waters on occasion, and is fairly common well offshore. Schevill and Watkins (1962), who point out that *Delphinus delphis* is known as the saddleback porpoise by fishermen (because of the shape of the dark dorsal area), encountered a group of 20 individuals and made sound recordings in August of unstated year some 60 miles south of Martha's Vineyard, Massachusetts; in relation to Long Island, this general location is the open sea several score miles southeast of Montauk Point. Edwards and Livingstone (1960) observed two in mid-winter 1959, feeding on fish escaping from an otter trawl net, depth of water 200 feet, lat. 39°48' N, long. 72°28' W (about 65 miles off the south shore of Long Island).

The New York coastal records (sightings and strandings) now available are more numerous than when Stoner (1938) documented a remarkable movement of common dolphins far up the Hudson River in October 1936. Roy Latham has numerous records of this species in the waters about the east end of Long Island; he writes (personal communication) that it is recorded every year and is more frequent than *Tursiops*. Some of his locality records are as follows: East Marion, January 24, 1947; Orient, Gardiners Bay, May 26, 1947; Robins Island, Great Peconic Bay, September 11, 1947; Plum Island, July 14, 1951. Latham also has records for Shelter Island and Gardiners Island. Specimens in Latham's collection include one from Orient, Gardiners Bay, April 1928, and one from Cutchogue, Peconic Bay, 1923.

On December 6, 1960, an individual 7 feet 2 inches long stranded alive on the eastern shore of Staten Island and was transported to the New York Aquarium, where it lived 4 days (Ray, 1961).

Long Island specimens (skulls and skeletal material) of the common dolphin, presumably strandings, in the American Museum of Natural History include the following: Montauk Point, September 9, 1931; Jones Beach, August 1938 (H. C. Raven); Fire Island Beach, November 1, 1908 (skull found on beach) (H. C. Raven). Also in the collection are the Staten Island individual mentioned above and specimens from the Hudson River, 1911 and 1936. Another record for Montauk (Dead Mans Cove) is a skull in the Cornell University collection dated January 2, 1951 (M. Gordon). True (1889) listed common dolphins taken in the last century near both ends of Long Island, including New York Harbor and off Block

Island, Rhode Island (specimens in U.S. National Museum).

This species, common enough in the North Atlantic, is a particularly conspicuous inhabitant of many warm-temperate regions, such as the Mediterranean Sea, where it is regularly seen playing about ships and leaping high out of the water. This is the dolphin most frequently depicted and written about in the ancient art and literature of the Old World; the ancients of the Mediterranean area also knew the next species, *S. coeruleoalbus*, judging from surviving portrayals of it on vases and other works of art.

Striped Dolphin

Stenella coeruleoalbus Meyen

This little-known pelagic species, which is about the same size as the common dolphin, but with a different color pattern and heavier beak, has not often been reported on the east coast of North America. The striped (or Gray's or eufrosyne) dolphin infrequently comes near shore or strands, but it is not really rare. A group of about 200 was noted passing by in deep water over the lower Hudson Canyon about 140 miles out from New York (south of Long Island) in August of unstated year, when sound recordings were made (Schevill and Watkins, 1962).

At least two striped dolphins have been found on Long Island. A male weighing about 85 lbs. was found alive on the beach at the foot of the Throgs Neck Bridge on May 6, 1967, and was transported to the New York Aquarium, but it had a broken neck-vertebra and died on May 9, 1967 (Robert A. Morris, personal communication). This locality is on the north shore of Queens, where the East River meets Long Island Sound. The skeleton is preserved at the American Museum of Natural History. Another one (skull at the same museum) was found at Bellport, on the south side of Suffolk County, in May of 1929 (P. White). A previously published locality record which is close to eastern Long Island—some 30 miles northeast of Montauk Point—is Narragansett Town Beach, Rhode Island, where a male 7 feet 9 inches in length stranded on December 5, 1966 (Cronan and Brooks, 1968).

The taxonomy of *Stenella*, a large genus of dolphins, is poorly known; it is being studied by F. C. Fraser of the British Museum according to Rice and Scheffer (1968). Striped dolphins of northern oceans, including our Atlantic coast, have been called *Stenella eufrosyne* (= *S. styx*), but apparently just one worldwide species of striped dolphin exists. There are two strongly marked

ances, however; thus local specimens may be designated *S. c. euphrosyne*.

Another member of this genus, the spotted dolphin (*Stenella plagiodon*, also known as *S. pernettyi* or *S. dubia*) is a southern species which has not been recorded in the Long Island area. The island is perhaps too far north to be visited by this species, but it has been reported as far north as southern New Jersey. Voice recordings were made from a group of two or three dozen spotted dolphins 60 miles off Cape May, New Jersey, in August of unstated year (Schevill and Watkins, 1962); this location is roughly 110 miles south of Long Island.

Bottle-nosed Dolphin

Tursiops truncatus (Montagu)

The bottle-nosed dolphin, a large grayish species which may attain a length of 12 feet, is a common coastal species of the Atlantic, and is especially abundant along the shores of our southern and mid-Atlantic states. It is migratory along the coast and visits the Long Island area, including Long Island Sound and various bays, in the warmer months.

Roy Latham (personal communication) writes that this species is recorded every year at various stations along the eastern Long Island coast from May 28 (year?), Greenport, Long Island Sound, to November 17 (1937), Bay View, Peconic Bay, and also in 1932 a single one was present as late as December 2, at Southold, Peconic Bay. He has records of *Tursiops*, as well as *Delphinus*, at Shelter Island and Gardiners Island. Latham (1954) reported on an adult female *Tursiops truncatus* 9 feet long, and bearing an unborn young 43 inches in length, which stranded and died on the Sound beach at Orient, June 11, 1953. Specimens (chiefly skulls) in his collection include the above female and young, and also one from Mattituck, Peconic Bay, May 1928, and another from Shelter Island, Gardiners Bay, 1921.

Helme (1902) wrote that dolphins in general, either this species or *Delphinus*, may be seen as early as April and as late as December, and are plentiful in Long Island Sound from June to late October. Some of the reports we received in the 1960's of "dolphins" or "porpoises" observed in Gardiners Bay, Peconic Bay, and lower New York Bay may refer to the present species. On October 17, 1960, we found a bottle-nosed dolphin, which was about 8 feet long and had been dead for several days, on Tiana Beach, ocean side of Suffolk County.

A highly unusual account by Stone (1964) tells how the author, during many July and August days in 1945 and 1946 when she was a girl of 13 and 14, played with

a group of about six dolphins in Long Island Sound near a boat 2 or 3 miles off the north shore of Suffolk County. By the end of the second summer the play developed to the point where on several occasions she grasped a fin of a dolphin and was actually towed around on the surface. Late in the day the boat was sometimes taken into Port Jefferson Harbor, and the dolphins would follow far into the harbor. These animals were apparently small (young) *Tursiops truncatus*.

Two specimens collected near western Long Island are in the American Museum of Natural History: one (skeleton preserved) from Pelham Bay, New York, mainland side of extreme western Long Island Sound, August 16, 1906, (W. Dolan), and another (skull only) from Navesink River, New Jersey, May 25, 1960. A group of five to eight *Tursiops* was observed in the tidal Shrewsbury River, New Jersey, in an area 3½ miles from the mouth of the river at Sandy Hook Bay, from April 17 to June 16, 1965, (Clark, 1965). The Shrewsbury River, its tributary the Navesink, and Sandy Hook Bay are not indicated on the map but are just south of Lower New York Bay on the west side of Sandy Hook. A few have over-wintered in the Navesink River (Ulmer, 1961).

Dolphins, especially those of the genus *Tursiops*, are called "porpoises" in America by many cetologists as well as by most mariners and landsmen. The word "dolphin," although an old name for small beaked cetaceans, is confusing in that it is also used for two species of fast, colorful, warm-water ocean fishes (genus *Coryphaena*); the species *C. hippurus* grows to about 5 or 6 feet in length and is popular with offshore sport fishermen as far north as our region. *Tursiops truncatus* is the species of dolphin or porpoise which has become especially familiar in recent years as a performer in public oceanariums and as a much written-about experimental subject in studies of echolocation, intelligence, etc. Dolphins and porpoises feed largely on fishes, squids and other marine animals.

The Atlantic white-sided dolphin (*Lagenorhynchus acutus*) is a northern species found at times in schools as far south as the ocean waters off Cape Cod. Apparently it is unknown in the Long Island area, although it would be possible to find a dead or stranded one on this coast. The nearest record I know of is a dead one found in the Town of Naragansett, Rhode Island, on July 22, 1967, (Cronan and Brooks, 1968).

Killer Whale

Orcinus orca Linnaeus

The killer whale is a large (males up to 30 feet long) relative of the dolphins which is noted for its attacks on

other marine mammals. Prey includes seals and porpoises, many of the larger cetaceans ranging in size up to the huge but defenseless whalebone whales, and also schooling fishes, squids, and seabirds. It has a strikingly tall dorsal fin, up to 6 feet high in the large adult males. Grampus, finner, and killer are among the various common names that have been applied to this species. The range of the killer whale is essentially worldwide, but it is most numerous towards the Arctic and Antarctic regions where large warm-blooded prey is plentiful.

Few killer whales have been captured or stranded along the Atlantic coast of the United States, although they are sighted offshore fairly regularly at least as far south as New Jersey, where two stranded specimens have also been found. A small number have been found beached in recent years on the southern coasts of nearby Rhode Island and Massachusetts. For Long Island, Roy Latham (personal communication) reports that a killer 24 feet in length stranded alive on a clam flat in Orient Harbor, January 11, 1944, and then died. Cook and Wisner (1963), in an exaggerated but profusely illustrated account of the killer whale, reported on one which followed a 23-foot fishing boat one July day in 1953, from 35 miles off Montauk Point towards land to about 15 miles off the point; included in the book are several photographs of this individual, apparently a large male. *Orcinus* was probably more abundant in earlier days when various other cetaceans and seals abounded. DeKay (1842) mentioned seeing killer whales off the coast of Long Island on several occasions, but asserted that they were formerly more numerous here, at a time when right whales were also abundant.

Gray Grampus

Grampus griseus G. cuvier

The gray grampus, white-headed grampus, or Risso's dolphin, is about the size of the bottle-nosed dolphin, but is beakless, with a blunt rounded snout, and a rather high, recurved dorsal fin. This species is widely distributed in the oceans of the world, but is not very well known. It appears to be a deep-diving form which feeds on cephalopods (squids and relatives). In the western North Atlantic this small whale has been recorded, though rarely, from Massachusetts to the coast of New Jersey. Schevill (1954) made observations suggesting greater abundance than previously suspected off our coast; on August 20, 1952, a group of over 60 grampus was watched from a ship near Lat. 40°00' N, Long. 71°31' W. The animals consorted in small bunches of four to six within the larger grouping, and they were quite playful, often leap-

ing out of the water. The position indicated is roughly 75 statute miles out to sea in a southeasterly direction from Southampton, Long Island.

Blackfish

Globicephala melaena Traill

Blackfish, or pilot whales, which are related to dolphins and killer whales, are almost entirely black, have a high, bulging forehead, and frequently travel in large migratory schools. Maximum length is about 28 feet. Squids, cuttlefish, and various fishes are eaten by pilot whales. This is one of the more numerous cetaceans, and it is common offshore in this region, especially during the warmer months. Helme (1902) and other observers have mentioned frequent sightings of blackfish off the coast of eastern Long Island. There are also records for western Long Island and Long Island Sound. Strandings of pilot whales are frequently reported, and occasional mass live strandings of many individuals at one time are known to occur, although in this area, at least, usually only single individuals come ashore.

On May 13, 1960, a live pilot whale, a female 12 feet 9 inches long, was found stranded alive on Brighton Beach, Coney Island, Brooklyn, about half a mile from the New York Aquarium; it was retrieved and lived at the aquarium for 29 days (Ray, 1961). At Atlantic Beach (west end of Long Beach strip), Nassau County, a male 13 to 14 feet long came ashore on April 15, 1966, and died later the same day (Robert A. Morris, personal communication). An immature female was collected near Massapequa, south shore of Nassau County, on April 28, 1960, (skeleton preserved in American Museum of Natural History). That blackfish penetrate extreme western Long Island Sound and even the East River is indicated by one which stranded in Flushing Creek, Queens, off the upper East River, June 13, 1944, (Anon., 1956) and others which have grounded on the Sound shore of the Bronx.

The name "blackfish" is also used by fishermen for a popular salt-water fish less than 3 feet long, the tautog (*Tautoga onitis*).

The Short-finned blackfish (*Globicephala macrorhyncha*) may visit; difficult to distinguish from the common blackfish, it ranges north at least as far as New Jersey.

Harbor Porpoise

Phocoena phocoena Linnaeus

The harbor porpoise is smaller than the dolphins, reaching a maximum size of 6 feet. It seldom leaps clear

of the water, and the head is blunt and rounded, lacking the beak characteristic of the dolphins. *Phocoena frequens* coastal waters and enters inlets, bays, and even rivers; New York is near its southern limit of abundance on the coast. Miller (1899) termed this species the commonest cetacean in New York tidal waters. Perhaps this is still true today, although for a long time now the porpoise has been gradually declining in numbers in our area. Apparently the harbor porpoise no longer forms large schools here of up to 100 or even "hundreds" of individuals such as were occasionally reported late in the last century.

There are numerous published reports of harbor porpoises in Long Island Sound. Rowley (1902), for example, stated that *Phocoena* was then very common in summer in this body of water, and that schools could be seen on almost any clear day, while Goodwin (1935) also mentioned the presence of this species in the Sound. Turrell (1939) wrote that harbor porpoises enter Smithtown Bay on the north shore of Suffolk County in large schools in summer. We received verbal reports for the 1950's and 1960's of sightings of porpoises in summer in Long Island Sound and also Great Peconic and Little Peconic Bays, although some of these reports may refer to dolphins (also called "porpoises") rather than *Phocoena*.

For the Orient region, Roy Latham (personal communication) writes that *Phocoena* is recorded every year at all stations, but that the big schools which were recorded yearly up to 1920 are no longer seen. The last sizable group recorded in this area, in Long Island Sound near Orient, was 25 individuals on December 7, 1921. Latham also reports that one came ashore, chilled, in the Sound at Orient on January 12, 1943; two specimens from the Orient region are in Latham's collection. Gilbert S. Raynor informs me that a harbor porpoise was found dead on the beach near Orient Point (Gardiners Bay side) about 1960.

Harbor porpoises may still be seen on occasion in Lower New York Bay and in Raritan Bay (waters bounded by Long Island, Staten Island and New Jersey). I have seen small groups in the summer months (during the 1940's) in this area. Porpoises also ascend rivers in this general region (New Jersey, Connecticut, and Hudson River), although I have no definite reports of this for the small rivers of Long Island. On the south shore of the island stranded individuals have been collected during various months of the year from Brooklyn to Montauk Point (specimens from Montauk Point in American Museum of Natural History and N.Y. State Museum). Anthony S. Taormina (personal communication) has

many Long Island records, including photographs, of both the harbor porpoise and the harbor seal.

Of interest is DeKay's (1842) account of this species. He related that, although still common in his day, the harbor porpoise was formerly so abundant on the shores of Long Island that it was avidly pursued for its oil (from the blubber), and also for its durable leather (from the hide). He described in detail the procedure used in seining schools of harbor porpoises at the east end of Long Island based on a paper published in 1792 by E. L'Hommedieu. At the time of DeKay's publication harbor porpoises were evidently being killed in Long Island Sound, on the Connecticut coast at Stratford (opposite Port Jefferson), according to Linsley (1842), who wrote: "Numbers of the common (harbor) porpoises are taken in this town for the sake of the oil, which is usually from three to seven gallons."

White Whale

Delphinapterus leucas (Pallas)

The white whale, or beluga, a small whale usually 11-14 and rarely up to 18 feet in length, and which (after early life) is completely milk-white in color, inhabits arctic and subarctic seas including the northern North Atlantic. It occurs regularly in the Gulf of St. Lawrence and adjacent bays and rivers. But southwards this species is rare, occurring as a straggler only as far as Cape Cod, Massachusetts, according to Miller and Kellogg (1955) and other recent authorities. There are two century-old records for that area—outer Cape Cod—but no recent records (Waters and Rivard, 1962).

Although never collected on Long Island as far as I know, *Delphinapterus* has probably visited the area at least once judging from the following sight report. A small whale, white in color, which was believed to be this species was observed in Long Island Sound off the north fork for 4 days in June 1942 (Roy Latham, personal communication). Latham first observed the whale off Orient, noted that it was moving west, and estimated the animal to be 10-12 feet long. He immediately alerted a friend in Mattituck who observed a white whale there the following day, presumably the same individual, 25 miles west of Latham's first sighting; this second observer reported the whale moving east.

In earlier years Roy Latham had heard of fishermen seeing white whales in the Sound, but he was unable to establish a record for one prior to 1942. Latham has considered the possibility of albinos of other species of whales being responsible for at least some of the

sightings. Albinism in whales is rare but has been reported in a number of species ranging in size from the huge sperm whale (*Physeter catodon*) to the little harbor porpoise (*Phocoena phocoena*); Tomilin (1967) wrote that rare instances of partial to complete albinism (one specimen out of tens of thousands) occur in the harbor porpoise. Also, increasing whiteness comes with age in some species, and old individuals of the bottle-nosed whale (*Hyperoodon ampullatus*) may be encountered which are yellowish-white in color. For Latham's sight record, however, his original field identification, the estimated size of the animal, and his familiarity with the common small cetaceans (dolphins, porpoises) as well as the white coloration, all strongly indicate *Delphinapterus leucas*. The bottle-nosed dolphin (*Tursiops*), although rarely over 10 feet long here, overlaps *Delphinapterus* in size, but the latter is shaped differently and lacks the conspicuous dorsal fin of *Tursiops*.

Sperm Whale

Physeter catodon Linnaeus

This species is the largest of the toothed whales, the males, which are much larger than the females, attaining a length of about 60 feet. The massive squarish head and relatively small lower jaw are distinctive. Food of this deep-diving whale is primarily squids, also sharks, skates, and fishes. This is essentially a whale of tropical and warm temperate seas, but it is migratory, and some of the males go far to the north in summer.

According to DeKay (1842) and some other accounts sperm whales were formerly abundant "along" or "on" our coast. Also, some sperm whales were taken in Long Island waters during the early days of American whaling (Murphy, 1918). But unlike finback whales and right whales, probably the sperm whales only occasionally came close enough to be sighted from shore, even in the early days of whale abundance. Sperm whales generally avoid shallow waters of sandy coasts, although they may approach shore closely where the water is deep, such as near the Azores.

Today, sperm whales are very rare near the shores of Long Island, and are uncommon offshore although occasionally reported from ships out at sea. Some in-shore records are as follows. On March 13, 1928, a young male 18 feet 3½ inches long strayed into New York Harbor (Upper New York Bay), where it was captured alive, but it died soon after being towed to Gowanus Canal, Brooklyn (Raven and Gregory, 1933). A female 39 feet long became stranded on Great South

Beach (Fire Island) opposite Bellport on February 28, 1918 (Murphy, 1918); this individual came ashore alive during the night but died before daylight as the tide receded. On December 9, 1894, a sperm whale 40 feet long was captured in Fishers Island Sound, between Fishers Island and the Connecticut coast. No very recent Long Island records have come to my attention, but according to Cronan and Brooks (1968) the only authentic record for Rhode Island is a 14 foot 5 inch individual which washed ashore in Charleston, Quonochontaug Beach, February 20, 1967; this locality is in the southwestern corner of Rhode Island, near eastern Long Island (about 12 miles east of Fishers Island).

New England whalers, seeking the sperm whale primarily, ushered in a famous era of American whaling. They extended the fishery from coastal waters, where the right whale had been pursued, out on to the open sea, eventually leading to lengthy voyages to other oceans. Sag Harbor on Long Island also became one of the leading deep-sea whaling ports during this period, along with New Bedford and Nantucket, Massachusetts, and New London, Connecticut. This enterprise began early in the eighteenth century, and finally declined after the middle of the nineteenth century. This period was for the most part still one of harpoons thrown by hand from open boats which were carried to sea by a mother ship, before modern methods used in pursuit of the fast blue and fin whales were put to use.

Sag Harbor was established as a whaling port before the Revolutionary War and its peak whaling years came in the late 1830's and in the 1840's (biggest year—1847); a rapid decline followed the peak years, and it is said the last whaling ship set sail from this port in 1871. It was not until 1785 that the first successful trips were made from Sag Harbor by ships fully equipped for long (South Atlantic) whaling voyages (Willey, 1949). Before this time the ships made short voyages lasting no more than a few weeks, often near shore, then returned to Sag Harbor to process the blubber for oil. According to Howell (1941) in this period the ships ventured out only two or three hundred miles from port, usually to the southeast of Montauk. Although I am uncertain which species of whale comprised the bulk of the catch on these early offshore trips, such a voyage in summer would have taken whalers into an area of sperm whale abundance, as described below.

Although the sperm whale is almost cosmopolitan, there were favored feeding areas or "grounds" known to the whalers. Townsend (1935) studied whale distribution based on whalers' logbook records dating from 1761 to 1920; the logs indicate positions and dates of whales

taken by seagoing whaling vessels from New England and Long Island, enabling Townsend to plot on maps the location of the take by month. An extensive sperm whaling ground centered roughly southeast of Long Island and northwest of Bermuda (approximately 33°–40°N, 60°–75°W), where sperm whales may still be observed, was known as the "Southern Ground." The western edge of this ground coincided approximately with the edge of the continental shelf; and like other North Atlantic grounds it was influenced by the Gulf Stream. This was a summer whaling ground, sperm whales being taken here primarily from May to September (especially May to July at the northern limit of this ground, near the latitude of Long Island). Few were taken in winter here; at that season attention was directed chiefly to waters below 25°N latitude.

Pigmy Sperm Whale

Kogia breviceps Blainville

Although related to the great sperm whale, *Kogia* is very small (maximum length 13 feet), and in outward appearance somewhat resembles a porpoise. Also the protruding snout and underslung lower jaw with sharp teeth are suggestive of a shark, for which it is sometimes mistaken by fishermen. The rather sluggish pigmy sperm whale is rarely observed and is little known, although it appears to be rather widely distributed in the tropical and temperate waters of the world. Evidently *Kogia* was never common in historic times; however, it has stranded fairly frequently along the east coast of the United States, where more than 50 records are now known (Handley, 1966).

Since 1914, at least eight specimens of *Kogia* have become stranded on the New York coast or captured a short distance offshore, and information is available on several. A large female with an unborn young (male fetus) stranded at Long Beach, on the south shore of Nassau County, Long Island, on February 28, 1914 (Schulte, 1917; Schulte and Smith, 1918; Allen, 1941). A pigmy sperm whale 9 feet long and weighing 700 pounds was captured off South Beach, Staten Island, on March 2, 1920 (Davis, 1920); this individual was reported as a porpoise in the local newspapers. Another one, a female, was captured 10 miles south of Shinnecock Inlet, near Hampton Bays, Long Island, in July 1941 (J. Carter). A specimen has also been collected at West-

hampton Beach, Long Island (H. Raven). All of the above specimens (skulls and/or other skeletal material) are in the American Museum of Natural History.

In August 1942, Roy Latham collected the skull and some other bones of a *Kogia breviceps* about 9 feet long. This animal had become caught 10 days earlier in the leader of a fish trap at Major Bank, Orient Harbor, and then washed ashore dead. Latham also recalls another *Kogia* taken near shore at Hampton Bays about 1930.

James W. Romansky, Jr. (personal communication) reported on a pigmy sperm whale he found on the south shore of Captree Island, approximately 200 feet east of Fire Island Inlet Bridge, on the morning of November 24, 1968. Total length of the animal, measured 32 hours after it was found, was 157.5 cm. (less than 6 feet); it was an immature male. The cause of the death was an apparent gunshot wound just behind the left pectoral fin. It is believed the wound was inflicted by commercial fishermen, since the skin had parallel marks as if caused by rubbing against metal trawling rigs or offshore poundnets. Careful measurements and notes were taken, and an articulated skeleton and internal organs in formalin are being kept at the Bay Shore High School. This individual was identified by Romansky as *K. breviceps* (identification confirmed at Smithsonian Institution and American Museum of Natural History).

It is possible that some of the smaller New York specimens of *Kogia* are referable to the closely related dwarf sperm whale, *K. simus* Owens. As shown by Handley (1966), *simus* is a strongly differentiated species of *Kogia*, which, like *breviceps*, commonly strands along the coasts of eastern United States. Considerable taxonomic confusion has existed regarding members of this genus, and *simus* has been overlooked and not distinguished from *breviceps* by most authors and collectors. Long Island may fall within the geographical range of *simus* as well as of *breviceps*, but I do not know if the former has been collected here. *Kogia simus* is even smaller than *breviceps*, adults under 9 feet in total length, while the latter commonly ranges from 9 feet to 11 feet when adult. Size and skull differences and other distinguishing characteristics are tabulated by Handley (1966). I have closely examined only one Long Island specimen of *Kogia*, the Orient Harbor skull collected by Roy Latham in 1942 (now at the N.Y. State Museum), and identified it as *breviceps*. Besides this one and Romansky's *breviceps*, probably the Long Beach and Staten Island specimens cited above are also *breviceps*, judging from available measurements and illustrations.

Dense-beaked Whale

Mesoplodon densirostris Blainville

This species is frequently called the Atlantic beaked whale or Blainville beaked whale. Members of the genus *Mesoplodon* are small, mostly rare whales, the life histories of which are very little known; food is chiefly squids and fishes. Some species are known only by a small number of stranded specimens. Moore (1966) discusses distinguishing skull characters and apparent distributions of species of *Mesoplodon* which strand in North America. On May 12, 1925, a young female *densirostris* was found stranded on eastern Long Island at Southampton (Raven, 1942). A few other individuals of this species have come ashore to the north and south of our area, including Massachusetts and New Jersey.

Antillean Beaked Whale

Mesoplodon europaeus Gervais

The Antillean beaked whale is also known in the literature as Gervais' beaked whale or Gulf Stream beaked whale. This rare whale, of which a total of 14 verifiable records of occurrence are known, is principally southwestern North Atlantic in distribution (Moore, 1966). An adult female 15 feet 4 inches in length became stranded on the south shore of Long Island at Rockaway Beach, Queens County, on December 22, 1933 (Raven, 1934, 1937). This is the northernmost record for the western North Atlantic, although another one came ashore in 1905 on the nearby northern New Jersey coast at North Long Branch.

True's Beaked Whale

Mesoplodon mirus True

The principal range of True's beaked whale appears to be the North Atlantic, from which about a dozen stranded specimens are known. Raven (1934, 1937) reported on an adult female *mirus* about 16 feet long stranded at Edgemere, Rockaway Beach, on January 14, 1934, less than a month following the discovery of the specimen of *europaeus*, also at Rockaway Beach. Another adult female (15 feet, 6 inches long) stranded alive and died on Mason Island, off Mystic, Connecticut, on No-

vember 19, 1937 (Thorpe, 1938); this locality is near the entrance to Long Island Sound and about 3 miles north of Fishers Island, New York.

As mentioned by Moore (1966), the North Sea beaked whale (*Mesoplodon bidens*) is even rarer on this side of the Atlantic (two strandings known) than the three other members of the genus discussed above. *M. bidens* is unrecorded on Long Island; the nearest record is a stranded male found on Nantucket, Massachusetts, in 1867.

Cuvier's Beaked Whale

Ziphius cavirostris G. Cuvier

This whale, also known as the goose-beaked whale, is somewhat larger than the species of *Mesoplodon*, adults generally ranging from 18 to 28 feet in length. Cuvier's beaked whale is nearly worldwide in distribution, but is rather scarce and little known. Two, a female 17 feet 6 inches in length, and a recently born young measuring 8 feet 3 inches, came ashore alive and then died at Long Beach, on the south shore of Nassau County, on August 15, 1914 (Rockwell, 1914; Ulmer, 1941). A third individual reportedly ran ashore briefly, but escaped capture by lifeguards who secured the other two as soon as they beached. Skeletons of the two Long Beach specimens of *Ziphius* as well as the New York individuals of *Mesoplodon* mentioned above, are in the American Museum of Natural History. A goose-beaked whale 18 feet 11 inches long beached to the northeast of Long Island at Newport, Rhode Island, on March 14, 1961 (Cronan and Brooks, 1968).

The North Atlantic bottle-nosed whale (*Hyperoodon ampullatus*), another member of the family of beaked whales, is a far northern species which has not, apparently, been recorded this far south on the western side of the Atlantic. According to Miller and Kellogg (1955), Hershkovitz (1966), and others, the bottle-nosed whale is unknown south of Rhode Island, where it is an extremely rare visitor. However, it is worth noting that this species is often mentioned in the literature as having occurred in the Long Island region, locations cited including Lower New York Bay, the south shore of Long Island, and also the nearby Connecticut coast of Long Island Sound; but, for one reason or another, all such published reports are incorrect as far as I know. Of course, there is always the possibility of a straggler being found here.

Little Piked Whale

Balaenoptera acutorostrata Lacépède

Least rorqual and minke whale are among the many vernacular names for this species. The little piked whale is the smallest of the rorquals or fin whales of the genus *Balaenoptera*; rarely does it exceed 30 feet in length. A broad white band on the outer side of the front flippers is a distinctive identifying mark. As with many other whales, the minke whale is widely distributed in the oceans of the world, and is most frequently encountered in colder waters. It is generally considered to be rare south of the latitude of Long Island. There are quite a few records for the Cape Cod-Nantucket-Rhode Island area to the east and north. Southward the story is different. For many years a single record for New Jersey (Long Beach, fall 1866) was the southernmost known occurrence; however, it is now known to occur occasionally as far south as Florida. The first recorded instance of the little piked whale in the Long Island area appears to be an individual captured in 1822 in the Lower Bay of New York. DeKay (1842), under the name beaked rorqual (*Rorqualus rostratus*) gives a detailed description of this specimen, indicating a fin whale 18 feet long with "swimming paws white in the middle." At the other end of the island, Helmuth (1931) examined a specimen about 25 feet long which was killed off Montauk Point and towed to shore on August 16, 1931.

Finback Whale

Balaenoptera physalus Linnaeus

The various species of *Balaenoptera* are known collectively as fin, finner, or finback whales or rorquals. They are streamlined and mostly very large whales, with a small dorsal fin in contrast to the right whales which lack this fin. The spout, or blow, of rorquals is single and vertical (if not deflected by the wind); sperm whales have a single spout directed forward at an angle, while right whales have a double V-shaped spout. *B. physalus*, the commonest rorqual, is huge (commonly 60-70 feet long), and exceptionally fast. This species feeds on planktonic crustaceans, also herring, mackerel, and other fishes.

The finback whale appears to be migratory, as are the other rorquals. In the North Atlantic this species moves northward in spring to feed at the higher latitudes during the summer, and southward in autumn to warmer waters, although its movements are imperfectly

known. Finback whales were rarely taken by whalers in the early period when right whales were sought, the former being faster and more difficult to handle, with a lower yield of oil and whalebone. Finbacks were caught in large numbers following the development of faster ships and more efficient equipment; there was an active fishery in the New England area from 1850 to 1896, as described by Allen (1916).

The finback whale has been greatly reduced in numbers by whaling, but is still generally the most numerous of the large whales off the coast of northeastern United States, including the latitude of Long Island, and also is the one most commonly stranded. Although probably not as common here as in the vicinity of Cape Cod, which extends farther out to sea, finbacks are occasionally seen near the Long Island shore. They are reported fairly frequently from fishing boats off Montauk Point. Finbacks are most frequent in summer, although they may be encountered in any month. Whales this large only rarely penetrate Long Island Sound beyond its eastern end, however.

Finback whales were frequently sighted, but rarely tackled, by eastern Long Island shore whalers who pursued right whales in small open boats launched from the shore as recently as the early 1900's. Edwards and Rattray (1932), who stated that finback whales often approach the Long Island shore closely in pursuit of small fish, related an instance of a crew fastening a harpoon to a finback off Amagansett; they were reportedly towed 3 miles away from shore in a fast and frightening "sleighride" until the whale broke free of the iron. Murphy (1918) wrote that finback whales regularly feed offshore in the Long Island area in summer, and reported that six finbacks came inside the inlet to Jamaica Bay in July 1916; one of these, 50 feet long, perished after becoming stranded on a bar. Other strandings include one at Huntington Harbor (inside Huntington Bay, western Long Island Sound) on October 22, 1946, and another at Sheepshead Bay, south shore of Brooklyn, on November 14, 1936, (Anon., 1956).

Sei Whale

Balaenoptera borealis Lesson

This species resembles in general appearance the finback whale (*Balaenoptera physalus*), but is somewhat smaller, attaining a maximum length of 50 or 60 feet. The word sei, correctly pronounced "say," is from the Norwegian, and refers to a kind of fish with which this whale often associates, both feeding together on the same crustaceans. The sei whale is widespread throughout the

oceans of the world, and is numerous at times along the Norwegian coast and also off Newfoundland. Generally, though, it is considered to be rare in the western North Atlantic.

I have no records for the sei whale on the Long Island coast, but probably it is a rare visitant; it has been recorded from Labrador south to Florida and Mexico, and has stranded on the Massachusetts coast at least twice in this century. Also, although *borealis* is smaller and darker than the more numerous *physalus*, it is so similar to the latter that it is difficult to identify at sea. Thus it is possible that undetected schools of sei whales are present at times offshore. This species is migratory but is more irregular in its occurrence than the other rorquals.

Blue Whale

Balaenoptera musculus Linnaeus

This species, also known as the sulphur-bottom, is the largest of all mammals. Total length of fully grown adults in the Northern Hemisphere is about 75-95 feet (females somewhat larger than males); blue whales grow even larger in the Antarctic, where specimens over 100 feet long have been recorded. Very large individuals are now rare, however. Food is almost entirely shrimp-like crustaceans less than 3 inches long which swarm in the cooler oceans of the world. The blue whale is pelagic and highly migratory, those in the Northern Hemisphere moving to far northern waters in spring or early summer to feed, and then southward in autumn for the winter breeding season. The breeding grounds have not been pinpointed, and most blues may spend this period far out in the central or southern North Atlantic; apparently only a few occasionally migrate as far as the tropics.

In the North Atlantic this species has been so over-exploited that probably only a very few hundred remain, and it is the most endangered of all the large whales. The blue whale is rare everywhere along the east coast of the United States, although it has been found off Newfoundland at times, and there is a sparse scattering of records of individuals which have stranded, or beached, as far south as Ocean City, New Jersey. I know of only one record of a blue whale on the Long Island coast. An individual came ashore at Sagaponack several decades ago (date unknown to me). This stranding is mentioned by Edwards and Rattray (1932), who also provide a photograph of the dead whale lying on the ocean beach.

Humpback Whale

Megaptera novaeangliae Borowski

This species is closely related to the rorquals but has a stout body and long pectoral fins; adults are about 40 to 50 feet in length. It occurs in all oceans and is highly migratory along often rather well-defined routes, spending the winter in tropical and subtropical waters and migrating to high latitudes for the summer. In spring, northbound humpbacks pass our region, and large herds have been seen in April moving north some 200 miles east of the North American coast. Kellogg (1929) provides a distribution map with probable migration routes. Humpback whales may be seen in spring near the coasts of the northeastern states, and a few may also be encountered in summer and fall, but the fall migration south appears to be farther offshore. Also, the larger schools are usually fairly well offshore at all times according to Allen (1916). Formerly common, *Megaptera* has been badly depleted and is now considered to be rare in the North Atlantic, although increasing slightly in recent years and more numerous on the western side (Kenyon, et al., 1965; Simon, 1966).

In the Long Island area, probably a few humpbacks were taken by early shore whalers pursuing right whales, with more attention being directed to this species from boats cruising offshore following the decline of the right whale. According to Allen (1916) a favorite whaling ground for humpbacks was on the Nantucket Shoals, which are about 100 miles due east of Montauk Point. They were killed here, and also on the Georges Banks farther east, during the eighteenth and nineteenth centuries. Everett J. Edwards, who participated in 15 late period shore whaling expeditions for right whales off the Long Island beaches, and whose father, Captain Josh Edwards, led the Amagansett whaleboats for nearly 50 years, until 1915, recalled only one humpback sighted locally. According to the younger Edwards (in Edwards and Rattray, 1932) about 1913 his father headed a boat which fastened a harpoon to a humpback which had been sighted from the Amagansett beach. But the bomb failed to go off, and the whale towed the boat at high speed until the line parted.

Humpback whales rarely become stranded and I do not have any such records for Long Island, although undoubtedly this has happened. One stranded at nearby Matunuck, Rhode Island, June 1957 (Cronan and Brooks, 1968).

Black Right Whale

Balaena glacialis Müller

Right whales, like the rorquals, are huge whalebone whales which lack teeth but have horny plates of whalebone or baleen, which are frayed on the inner side and serve to strain small food organisms from the water. Right whales lack both a dorsal fin and grooves on the throat characteristic of the fin whales, but have a relatively larger head and chunkier appearance; adults may be 45 to 55 feet long. This species was the main object of pursuit by the early North Atlantic shore whale fishery, in the day of small boats and hand-held harpoons, because of its slowness, buoyancy when dead, and high yield of oil and whalebone.

The coastal area from Massachusetts to Long Island, where this whale was numerous in season, was one of several important centers of the right whale fishery in the North Atlantic. One after the other these various areas of abundance became depleted, until the right whale verged on extinction. The species survived, is now protected by international law, and appears to be slowly increasing; but in all the North Atlantic perhaps only a few hundred right whales exist (Anon., 1968b).

Shore whaling, using open boats launched from the shore, became established on Long Island during the 1640's and 1650's, and was particularly active along the southern coast of the east end of the island, although right whales were taken as far west as Brooklyn. Also larger boats were used to hunt right whales a short distance from shore. In the early decades of whale abundance scores were caught in some years, and also the many "drift whales," those which had been cast up on shore, were utilized; probably many of these had been disabled by harpoons, others may have been driven ashore by storms or illness. Native Long Island Indians were skillful whalers willing to work for low wages, and thus were frequently employed in manning the whaleboats. After the early part of the eighteenth century, intensive shore whaling rapidly declined here (1707 peak year for amount of oil sold).

A few right whales continued to appear along this coast, and sporadic shore whaling continued through the eighteenth and nineteenth centuries, even though the major whaling effort was then far at sea in larger vessels. Especially in the region of Amagansett, East Hampton, and Southampton, where Long Island shore whaling began, whales were still pursued whenever sighted from shore. At times this amounted to only one or a few taken at intervals of several years. DeKay (1842) wrote: "The right whale was formerly captured in great numbers

from sloops and whaleboats, along our whole coast, chiefly from February to May, although they appeared occasionally at all seasons of the year. Along the southern coast of Long Island, whaleboats are still kept in readiness; and upon the appearance of a whale, the people in the vicinity quickly assemble, and soon are in pursuit of the animal."

Four which were harpooned on January 30, 1885, near Southampton attracted collectors attempting to salvage skeletal material, including Frederick W. True from the U.S. National Museum (True, 1885). The skeletons of a few other right whales killed off eastern Long Island in the late 1800's found their ways to various museums. Some were still being killed along this same coast early in the twentieth century; one of these, an adult female 54 feet long (from tip of snout to notch of flukes) captured off Amagansett on February 22, 1907, and the skeleton collected for the American Museum of Natural History, was one of the largest American specimens ever recorded (Andrews, 1908, 1916). A young whale 38 feet long believed to be the calf of the large one, was captured nearby. Andrews (1909) also studied another small specimen captured by shore whalers off Amagansett on December 10, 1908.

A lively firsthand account of this late period (1830's-1918) of shore whaling from open whaleboats in the Amagansett region is included in the book by Edwards and Rattray (1932). According to the authors the year 1918 was the last in which a right whale was caught and tried out for oil (30 barrels, but never sold); two were sighted off the East Hampton shore early one summer morning and the larger of the two was pursued to Napeague and killed. According to Sleight (1931) right(?) whales were sighted off Southampton and elsewhere in 1923, but the era was definitely over, and no boats were launched. Still to be seen on some old houses in the same region is the "scuttle," a trapdoor in the roof where a person could look out over the ocean and watch for whales.

True (1904) and Allen (1916) compiled reports of right whales captured off the Long Island shore, gleaned from state and local histories and records, and newspapers such as the *Nantucket Inquirer*, which kept its readers well posted on whaling matters. Years covered range from 1669 to 1908, with most data from the 1800's. Such reports often indicate date of capture, number of whales seen or killed, approximate location along the coast, number of barrels of oil produced or expected, and occasionally length of animal and if calves seen. Dates given indicate that right whales through the years have been most numerous from about late February to late May, with a few appearing earlier (November, De-

ember, January). According to Allen (1916) right whales are, or were, more numerous in April than during any other month of the year in the Long Island region. Cows with calves have been noted in March, April, and May.

That occasionally a right whale caused at least accidental damage to its pursuers after being wounded also is recorded in the documents; for example, a whale was struck on April 23, 1854, off Southampton, and though mortally wounded it demolished the whaleboat, injuring several men. Edwards and Rattray (1932) tell of right whales off Amagansett overturning whaleboats, even as recently as 1911, and in some instances cutting boats in half with their flukes. Human fatalities were infrequent, however.

This species generally avoids shallow waters and rarely strands, but there are old records (late 1800's) of individuals entering Upper New York Bay and Raritan Bay (near Staten Island), and in 1850 one was captured in Shelter Island Sound near Greenport. According to Edwards and Rattray (1932) right whales seldom came over the shallow sandbar said (by the authors) to lie about a quarter of a mile off the Long Island south shore beaches, whereas the more slender finbacks reportedly came over it frequently in pursuit of small fish.

Right whales continue to appear off the southeast coast of Long Island, and I assume mainly at the same time of the year as in the past, but reports are few, in part probably because the whales are no longer watched for at the proper season by many well-trained eyes on shore. In recent years right whales have reappeared in numbers in the Cape Cod area, with up to 40 or 50 present in Cape Cod Bay during May, and occasional occurrences as late as June (reported by Waters and Rivard, 1962, and others). A recent record for Long Island is that of a right whale observed on June 8, 1960, in the ocean off Shinnecock by Stanley E. Poole (William E. Schevill, personal communication). The East Hampton Town Marine Museum at Amagansett has a right whale skull found on the beach there in the summer of 1965.

Although frequenting temperate rather than tropical or arctic seas, in the western Atlantic these whales summer well to the north of Long Island, and many of them winter some distance to the south. In fall, most southbound ones pass by well out to sea. As Allen (1916) points out, in spring right whales apparently migrate fairly close to the coast and are turned abruptly eastward by the projecting coasts of Long Island and Cape Cod. Thus they converge on the south and east shores of Long Island and Massachusetts to round Cape Cod.

Vulpes vulpes fulva (Desmarest)

The red fox is surprisingly common at the present time in most parts of Suffolk County, and it is frequent also in the less developed areas of Nassau. Writing well over a century ago, DeKay (1842) mentioned a large male red fox killed in Queens, and evidently this species was common enough then, as it had been at least as far back as the late 1700's, although DeKay did not comment on the relative abundance of the red fox to the then very numerous gray fox. Later, at the turn of the century, Helme (1902) briefly noted that the red fox was very common throughout Suffolk and portions of Nassau counties. Through the years red foxes have been popular in furnishing sport for hunters, and also many have been killed for their pelts, which were formerly in demand and brought good prices.

The gray fox was more numerous on Long Island in prehistoric times than the red fox, judging from finds at Indian archaeological sites. I do not know of any published information confirming the presence of the latter on Long Island during Indian times. Waters (1967), who discussed archaeological finds of *Vulpes* and *Urocyon* on Martha's Vineyard, knew of no records of *Vulpes* from archaeological sites on Long Island or farther south. Thus the fact that *Vulpes* is represented in Roy Latham's archaeological collection from eastern Long Island is of interest. He writes (personal communication) that although more gray foxes were found in his excavations, both species were recorded from sites at Three Mile Harbor, Southold, and Shelter Island.

European red foxes, representing a different geographical race of *V. vulpes*, are said to have been released on Long Island for hunting purposes during the 1700's. Apparently such introductions, here as elsewhere, did not take hold, or at least had little effect on the natural increase and spread of the native American form, *fulva*, which extended its range southward into the middle Atlantic and southern states during Colonial times. Assuming the red fox was present on Long Island when the European settlers arrived, the changing environment which followed may have favored the increase of this species (or if it disappeared during late Indian or early Colonial times it could have reinvaded the island during the spread southward).

During the survey, we saw red foxes or signs of their presence in a great variety of habitats. Red foxes cover most of the wilder open country on the island in their

search for such food as cottontail rabbits, meadow mice, birds, carrion, insects, and other varied items. They are very common on the outer beach strip, such as Fire Island and the section between Moriches and Shinnecock inlets; here they patrol the dunes, thickets, and salt marshes, and even forage along the water's edge on the ocean beach. Inland, red foxes are present in woods, near streams, and around large fields.

Eastward on the island they seem especially common, and are very much at home at Montauk, Hither Hills, Shinnecock Hills, Napeague meadows and dunes, and on Shelter Island, and elsewhere. Apparently eastern Long Island is one of many regions where this species has shown a general increase in recent decades. According to Roy Latham (personal communication) red foxes were encountered only occasionally in the Orient region during four decades or more prior to 1930, but have become very common since then. During the late 1800's the wilder Montauk region was noted for its red foxes, and it attracted hunting parties from farther west on the island. Naturally, the fox has not fared so well on western Long Island, but it still thrives in some built-up areas near New York City. It was common in now densely settled eastern Queens at least as late as the 1920's and still is plentiful as far west on the south shore as Jones Beach (Anon., 1968a).

Dens, some actively in use, were found in various situations: on shrubby, grassy hillsides in the Shinnecock Hills (figure 15), in a dike crossing an old, abandoned cranberry bog, in sandy pitch pine barrens, and in the sand of the more sheltered inner dunes on the barrier beaches. In the Long Island sand dunes red foxes are reported to favor the concave face of a wind-carved and overhanging dune as a burrow site (Anon., 1968a). In an area of woods and estates on the north shore of Nassau County, in June, we were shown where red foxes had apparently raised four or more young in a long drainpipe under a paved drive; remains of cottontail, rabbits and other prey were present when we visited the site.

Latham (1954) wrote: "Probably the food of the red fox is more varied than that of any other wild mammal on Long Island, and no other is so clever in the methods of obtaining it." In the same article he wrote about two different occasions at Montauk when he observed red foxes catch a weasel and a muskrat. Hamilton (1935, 1949), drawing partly on information supplied by Roy Latham and others, mentioned some of the diverse foods of red foxes on the island, such as various kinds of frogs, birds, and mammals, and also discarded marine fish, snapping turtle eggs, blueberries, and other tidbits. Audubon and Bachman (1851) wrote an interesting ac-

count of the abundance of red foxes, and their food habits, on the New Jersey outer beaches, an environment similar to the south shore of Long Island; rabbits, waterfowl, wading birds, and crabs and fish thrown up by the surf were reportedly eaten.

Near the entrances to red fox burrows in the Shinnecock Hills, in the spring of 1963, I noted conspicuous remains of various food species, including eastern cottontail, meadow mouse, pine mouse, muskrat, pheasant, and meadowlark. A nursing red fox, examined after being shot by a hunter in central Suffolk County, was found to be carrying three adult meadow mice in its mouth. In unusually deep snow present in January and February 1961, we found a number of cottontails which had been cached by red foxes, several near small streams in the pine barrens. Scats (droppings) are a good indication of what foxes actually eat; only a small number were examined, and they contained cottontail and meadow mouse remains. Of course, the diet of red foxes on Long Island does not differ basically from those living elsewhere in the State, except for their propensity to feed on available marine organisms and sea birds.

Gray Fox

Urocyon cinereoargenteus cinereoargenteus (Schreber)

Originally the common native fox of Long Island, the gray fox became greatly reduced in numbers during the past century and it has remained rare and local since then. DeKay (1842) stated that the gray fox was then very abundant on Long Island, where it was often called the "plain fox" or "grass fox." Helme (1927) wrote that although formerly common, this species had become extinct on the island, and that few if any grays were to be found later than 1880; he thought that any instances of their occurrence in the present century must be attributed to introduction or escape from captivity.

However, the status of the gray fox remained in doubt, with a scattering of sightings reported since 1927, while perhaps a majority of the interested field naturalists believed the species had disappeared. I do not know of any specimens actually collected and preserved in recent years, and at least some reports of gray foxes killed have turned out to be red foxes. A few gray foxes have been included in the reported take of foxes by hunters and trappers on Long Island, as were mapped for the year 1940 by Seagears (1944). Even assuming that all of the reported grays were correctly identified, these records indicate that this species comprises only a very small percentage of the total number of foxes killed here.

Hamilton (1949) maintained that the gray fox is generally distributed (or at least was then) in the scrub oak and pine of the central portion of Long Island. Also, this fox apparently still exists in the Montauk-Hither Hills area according to Sam Yeaton (Anthony Taormina, personal communication). In recent years, gray foxes and their trails have been reported in dense thicket country at Montauk (Anon., 1968a). During our field survey we glimpsed single individuals believed to be this species on two occasions, although both of the sightings were disappointingly fleeting; localities were wooded areas near Hampton Bays and Montauk Point.

From the scanty evidence, it seems likely that the gray fox declined drastically in numbers without entirely disappearing from the island. It apparently survives today in the wilder sections of central and eastern Long Island, especially in the pine barrens region and the eastern part of the south fork. However, so little seems to be on record regarding this species here that any additional information, if made known, would be of considerable interest. It should be noted that the gray fox tends to be more nocturnal and secretive than the red, and less inclined to frequent the open country and beaches.

Raccoon

Procyon lotor lotor (Linnaeus)

The familiar raccoon, like the red fox, is a sizable member of the Carnivora which is more than holding its own on much of Long Island. It is common in various parts of the heavily settled western portion, including certain areas in eastern Queens, and ranges eastward to Montauk Point, Orient Point, and Shelter Island. While it has fluctuated in abundance through the years, probably according to the degree of persecution (many have been killed for sport and for their pelts) and in response to a rapidly changing environment, the raccoon has persisted; evidently it has been well served by its intelligence, adaptability, and highly omnivorous food habits.

The raccoon has been more or less widespread on Long Island throughout a long period of man's existence here. Helme (1902) stated that it was common in most parts of the island. For the Montauk region, Dutcher and Dutcher (1893) found raccoons common, especially around the various ponds there. On the north shore, Turrell (1939) reported raccoons numerous in the swamps of the Smithtown region, and also along the Nissequogue River and various brooks. DeKay (1842) did not mention Long Island specifically, but stated that the species was well known and found in every part of the State.

Going back three centuries, Denton (1670), in his account of Long Island, listed the raccoon as a member of the fauna, and also stated that it was eaten by the Indians. Also, bones have been found at prehistoric Indian sites of different periods.

In recent decades raccoons have been on the upswing in the area, becoming very common and spreading into new or reoccupying old neighborhoods. For example, Roy Latham (personal communication) writes that for at least 40 years, from about 1888 to 1930, there were no raccoons in the Orient region, but that they have become very common since 1930. Latham states further that they have become exceptionally numerous and locally troublesome to the farmer in the past 20 years. They eat potatoes by digging into the hills, and destroy corn, fruit, and other crops, and even damage buildings by pulling shingles off roofs to get inside. Other writers and observers also tell of a general increase of raccoons elsewhere on Long Island, especially since about 1940.

We saw tracks and other signs of "coons," and sometimes the animals themselves, in a variety of situations. These included margins of streams and ponds throughout the island, swampy maple woods, bogs, pine and oak barrens near water, small patches of deciduous woods in suburban areas, woods near brackish and salt marshes, grassland at Montauk and Napeague, and even the bare sand of the "walking dunes" (although near trees and marshes) at Napeague Harbor. Although frequenting the edge of protected salt water areas, such as Long Island Sound, and the Peconics and other bays, the raccoon does not seem to be as common on the ocean barrier beaches (with their dunes and salt marshes) as the red fox; this may be because of the lack of trees or other denning sites in many of these areas. Raccoons are on Fire Island, however. Inland, raccoons often survive in a patch of woodland trees, especially if a stream or pond is present, after it has been largely transformed into a suburban area or a developed park; their characteristic footprints are still to be seen long after most of the larger forms of wildlife have disappeared.

Long-tailed Weasel

Mustela frenata noveboracensis (Emmons)

Distribution and habitat. This is the common weasel found more or less throughout Long Island, except in the heavily built-up areas. Helme (1902) recounted his experiences with weasels on the island—family of young found under a pile of wood, one shot from a squirrel's nest about 20 feet above ground in a cedar tree, etc. In Queens this species was formerly common and probably

still occurs locally; Hamilton (1949) once observed a nest with young at Bayside in Queens. Quite a few Long Island specimens are in other museums and private collections, localities recorded including Flushing in Queens, various north shore and south shore points, and east to Orient and Shelter Island.

In eastern Suffolk County we occasionally observed long-tailed weasels, trapped a few, and found others killed on the highway; localities were Flanders, Hampton Bays, Montauk Point, Quogue, Riverhead, Sagaponack, Southampton, Squiretown, Tiana Beach, Wainscott, and Water Mill. Several of our specimens were caught at two trap sites near Flanders, one located at the base of a fallen tree in a densely wooded, bushy area by a fresh stream, the other in the base of a hollow stub in woods bordering a salt marsh.

It is not unusual to encounter this species near the ocean shore and on the outer barrier beaches. At Tiana Beach near Shinnecock Inlet a long-tailed weasel was observed in a salt marsh and another was found dead on Dune Road; this area is chiefly salt marsh, sand dunes, and flats. Tracks judged to be of this species were noted in the sand on Fire Island (opposite Smith Point and near the Sunken Forest), and on the east side of Moriches Inlet in salt marsh and sand. One January day in grassy ocean dunes near Wainscott, Christopher McKeever and I found a large adult male weasel which had been killed just a short while previously, apparently by a marsh hawk (*Circus cyaneus*). The weasel, decapitated and partially eaten, was found lying on the ground near a summer cottage, after we had startled a marsh hawk into flight from the spot. Next to the weasel were several pellets probably cast by the hawk, three of which contained the remains of weasel, others the remains of meadow mice.

Tracks and other signs of weasels (probably *frenata*) were also noted in the following habitats: large field near Manorville with many meadow mice and pine mice present, bog near Speonk with many meadow mice, pine barrens near Flanders, and red maple swamp at East Hampton. Two were found dead on roads next to duck farms—the weasels may very well have been seeking Norway rats often abundant in such areas.

Mustela frenata is the species of weasel usually found on Staten Island, too, although it no longer seems to be very common. Some years ago (1941) I saw one hunting far out in a salt marsh there, near New Springville.

My impression, in limited trapping for this species, was that it is much less common on Long Island than in many "upstate" (mainland) New York areas. Roy Latham, in a personal communication, writes that weasels were common and widespread up to about 1950, but he

believes they have become very scarce, at least on eastern Long Island, during the last two decades.

Remarks. All the winter individuals collected or observed were in brown pelage. Although most long-tailed weasels in northern and central New York turn white in winter, virtually all of them remain brown on Long Island. Helme (1902) and Hamilton (1949), both familiar with this species on Long Island, never recorded any in white winter pelage. During the survey, we received a few sight reports of white weasels in winter in Suffolk County. This could indicate that a small proportion of the population assumes a white winter coat, or that the observations refer to *Mustela erminea* (which turns white throughout its eastern range). Based on what is already known, the latter seems more likely, although *erminea* is rare on Long Island.

Most of the stomachs examined were empty, but one held the partial remains of a gray squirrel. Some of the prey species on record as having been caught by weasels on Long Island are *Sorex cinereus* (Nichols and Nichols, 1935); moles, *Scalopus Aquaticus* (Helme, 1902); cottontail rabbits; chipmunks; meadow mice; white-footed mice; and Norway rats.

A female on April 17, 1961 (Flanders, Suffolk County) contained six embryos, the swellings 8 to 9 mm. in diameter.

Measurements. Data for the female with embryos mentioned above are: weight, 109.5 grams; total length, 298 mm.; tail, 90 mm.; hind foot, 34 mm. An adult male on the same date: weight, 205.4 grams; total length, 397 mm.; tail, 138 mm.; hind foot, 45.5 mm.

Individuals taken. 9

Short-tailed Weasel

Mustela erminea cicognanii Bonaparte

The short-tailed weasel, or ermine, a smaller and more northern species than the long-tailed weasel, is very rare in the coastal plain portion of New York State. An individual in white winter pelage has been taken at Babylon, Suffolk County, and was the only Long Island record known to Hamilton (1949), who obtained a photograph of the specimen. Some nineteenth century publications refer to possible but not well substantiated early records of this species on Long Island (summarized by Helme, 1902). *Mustela erminea* is also rare on Staten Island, where it has been collected by Crowe (1939). There are a few sight reports by biologists of *erminea* on both Long Island and Staten Island. This region is not

included in the range of *erminea* as described by Hall and Kelson (1959); for the east coast they state only that this species occurs south to Rhode Island, although they also note an inland Maryland record.

We did not obtain any firsthand information regarding short-tailed weasels on this survey, although reports received from Suffolk County residents of "very small" weasels and white winter weasels may refer to this species. It is said that one or two least weasels (*Mustela nivalis*) have been collected on Long Island and the skins mounted or otherwise preserved, but I have been unable to locate the whereabouts of any such specimens. Weasels so labeled and actually from Long Island may be *Mustela erminea*, since this rather small weasel has, in the past, been called "least weasel," as it was in Crowe's paper cited above; the range of the true least weasel, *nivalis*, is not known to extend this far east.

Mink

Mustela vison mink Peale and Palisot de Beauvois

Although the mink is not often seen and is much less common than formerly, it is not really rare and in fact has a rather wide distribution in the region. This species may be encountered near water, mainly in the less populated areas, for almost the full length of Long Island and on both the north and south shores. Like the muskrat, the mink is at home in the coastal salt marshes as well as fresh water areas inland.

Quite a few mink live on the open stretches of the outer barrier beaches, especially Jones Beach, Fire Island, and the strip between Moriches Inlet and Shinnecock Inlet. In these areas I noted their footprints quite frequently in mud, sand, and snow, and also occasionally found troughs in the snow made by traveling mink when coasting for short distances. In the salt marshes on the bay side of the outer beaches (figure 16) the mink appear to spend much time following the main creeks and ditches, judging from the tracks. In these marshes are many muskrats, meadow mice, birds, fishes, and aquatic invertebrates, while cottontail rabbits abound in the adjacent areas, all potential food for hunting mink.

Regarding eastern Long Island, Roy Latham (personal communication) writes that mink are still on Montauk Point, at Three Mile Harbor, and on Shelter Island (12 taken in winter of 1952) and are not uncommon around the Peconic River. At Orient, mink were formerly common, but Latham's last record in that area was one collected on November 28, 1910; before 1910 he averaged about two per winter on his traplines. In Hither Hills State Park, I saw a mink skirting the shore of Fresh

Pond one October evening in 1962 (figure 22). As an indication of former abundance, Dutcher and Dutcher (1893) remarked that mink were very common on Montauk Point, with some trappers securing as many as 50 skins apiece in the winter of 1892-93.

The status of this species on Gardiners Island was not determined. Chapman (1908), in a chapter devoted to Gardiners Island, referred to a lack of minks, weasels, and other mammalian carnivores. However, Roy Latham was informed by an earlier caretaker there that mink were present before 1900. On a 1-day visit on July 22, 1961, we found partial remains of what appeared to be a mink on the south point of Gardiners Island, but this material was lost on the return boat trip before being definitely identified.

For the New York metropolitan area, Hamilton (1949) mentioned trapping mink as a boy near Douglaston, north side of Queens, as well as nearby in western Nassau County. A few mink survive on Staten Island, although much of their habitat has been destroyed in recent years.

Study skins and skulls from Long Island are represented in various collections, including the U.S. National Museum, the American Museum of Natural History, Cornell University, and the collection of Roy Latham.

Striped Skunk

Mephitis mephitis nigra (Peale and Palisot de Beauvois)

The skunk, like the woodchuck, is a medium-sized mammal which has decreased markedly on Long Island in this century and is generally much less common here than in the mainland portions of New York State. Formerly common the length of the island, apparently the skunk has declined in numbers over a long period. At the time of Helme (1902) it was still numerous, although less so than formerly. Helme suggested that perhaps the Paris green poison used to control the Colorado potato beetle ("potato bug"), which arrived in the 1890's, was reducing its numbers; it was thought that the skunks ate the poisoned beetles and suffered a rather abrupt decline at about this time. Murphy (1964) and some other veteran observers agree, although there is not unanimity of opinion on this point. Skunks seemed to remain common much longer in certain wilder, nonagricultural sections, such as Montauk and in pine-oak barrens but have gradually become scarce there too. This animal is a frequent victim of automobile traffic, and the dense network of roads and ever-increasing traffic on the island has possibly been one cause of continued reduction in more recent years.

River Otter

Lutra canadensis (Schreber)

Hamilton (1949) mentioned that 20 years earlier skunks were common, even in sections of western Long Island. Roy Latham informs me that when he was a boy, skunks used to make burrows in potato fields at Orient; his last record for that area was in the year 1911, but he noted skunks as still common in some other Long Island areas where potatoes are commonly grown, many years after they were gone from Orient. Several residents of eastern Long Island, from Hampton Bays to Montauk, told us (in the early 1960's) they believed skunks were much more numerous 15 to 20 years earlier. Skunks were formerly abundant on Shelter Island, and specimens collected there are at the U.S. National Museum and in the collection of Roy Latham. In the 1920's Roy Latham occasionally saw albino or white skunks at Montauk, including two observed together on June 14, 1928, in the daytime. On Staten Island, a few skunks were present at least as late as 1940, but evidently they have become extirpated or very rare (I have no recent information).

It is possible that the skunk is holding its own or even increasing slightly in a few of the less developed areas of eastern and central Long Island. The only specimen we obtained was one killed by a car, but in good condition when found, near Sag Harbor in October 1961. No other road kills were seen, although some were reported to us from the Montauk area. I noted signs of skunks including a den, odor, tracks, and droppings, in an area of fields and pine-oak barrens near Manorville in 1962 and 1963. The den, a burrow occupied by skunks in the winter of 1962, was in level, sandy ground under scrubby oak trees, near the edge of a large field. Tracks were seen in the smooth sand of the moving dunes in Hither Hills State Park (figure 20) in 1962. Skunks are reported to be common in the Hither Hills section where they sometimes raid the garbage cans at the beach camping grounds (Anon., 1968a). Various observers reported seeing skunks in the following localities in the early 1960's: Montauk, Calverton, and Yaphank in Suffolk County, and North Hills in Nassau County.

Three hundred years ago, Denton (1670) listed the skunk as one of the wild animals of Long Island. He also mentioned this species as an article of food of the local Indians. In his account of the Indians, by then considerably reduced in numbers, Denton wrote: "The meat they live most upon is Fish, Fowl, and Venison; they eat likewise Polecats, Skunks, Raccoon, Possum, Turtles, and the like." Roy Latham (personal communication) writes that the skunk was one of the more common mammals discovered in his Indian archaeological excavations on eastern Long Island, found at most sites, as were muskrat, raccoon, deer, beaver, and wolf.

The time is long past since the otter was common on Long Island. Denton (1670) included the otter in his brief listing of Long Island land mammals, but 172 years later DeKay (1842) wrote that this species, although formerly numerous throughout the State, had become extirpated on Long Island and Staten Island. Nevertheless, during the past 100 years or so, a few otters have been observed at various localities on Long Island and some have been killed. Possibly the otter was never completely extirpated here, but it has certainly been very rare, at least, for a long time nearly everywhere on the island. Most of the locally active field naturalists have never seen it.

According to Helme (1902) at least four otters were killed, then mounted by taxidermists, between 1875 and 1901, as follows: Yaphank, about 1875; Carmans River, 1898; Peconic River near Calverton, winter of 1900-01, also other individuals seen; Patchogue, 1901. Roy Latham (personal communication) states that one trapped at Three Mile Harbor in 1881 may have been the last one taken at that south fork locality. Another record is an otter shot in Great South Bay near Smith Point in 1902.

In Roy Latham's collection is the skin of an otter trapped on March 5, 1929, at Oyster Pond on Montauk Point; it was a male weighing 20 pounds and had been skinned for the fur market before Latham acquired it. Latham writes that otters were present on Montauk for years before this one was trapped, and he saw them there on several occasions in the 1920's when this was still wild country. He first saw them in 1925 at Oyster Pond and Great Pond (Lake Montauk or Montauk Harbor on recent maps) before the latter was opened to the sea; he also saw them at Big Reed Pond, a smaller body of water in the same area. In the fall of 1928 he saw two otters at Great Pond and the slide they were using. Otters still persist in this general area; in a recent communication Roy Latham writes that in February 1969, an adult female otter was caught in a fishtrap at a Montauk Point locality.

Otters were on Shelter Island in the late 1920's, and one was seen several times by a reliable observer during the winter of 1940-41, according to Latham. Also, Latham writes that otters were sighted in the Peconic River near Calverton in the 1920's and 1930's. No otters were encountered during the museum survey, but several reports were received from reliable persons of single otters seen during the 1950's: Shelter Island (about 1955), locality

near north shore of Nassau County (about 1957), Peconic River, and two south shore localities near Great South Bay.

Many otter reports, especially certain recent ones and those from western Long Island, can perhaps best be explained as individuals which have come across the Sound from Connecticut, where the species has been increasing in numbers. On the other hand, Roy Latham has shown that the otter has had a long history at Montauk, and the frequency of reports from certain other areas suggests additional centers where this species may have become at least temporarily established from time to time.

Harbor Seal

Phoca vitulina Linnaeus

This is the only seal which regularly visits the area and, as its name implies, it frequents harbors, bays, and inlets, and also even enters rivers on occasion. *Phoca vitulina* is a small (up to 6 feet), densely spotted species. Here, in the southern part of its range, where it is a migratory visitor, it is most numerous during winter and early spring, is occasionally observed during the fall, and is rare in summer. This species may be seen swimming along with its head out of the water, when it appears somewhat dog-like, or intermittently diving beneath the surface; also the harbor seal may be found hauled out on the more deserted beaches, islands, rocks, marshy banks, and points of land.

Harbor seals in New York State are most numerous about the east end of Long Island, where even in recent years up to half a dozen or more together on shore have been reported. Roy Latham (personal communication) writes that seals, (usually singles, sometimes three to five in a group) are recorded every winter in Long Island Sound, Gardiners Bay (from Orient west to Cutchogue), and from all the islands of the east end region, including Gardiners Island and Shelter Island. His dates are from November 30 (1929) to May 5 (1932), the latter record at Orient Harbor. Also, 50 seals were counted on a single sailing trip around Plum Island on February 2, 1933. Christopher McKeever informs me that reports he has received indicate fairly large numbers of harbor seals still inhabit the bight on the south side of Plum Island every winter. Dutcher and Dutcher (1893) reported harbor seals as present every winter on rocks that lie off Montauk Point, usually arriving in the area in late November or early December and remaining until spring.

Robert A. Morris, Curator at the New York Aquarium, has been keeping records in recent years of reported sightings of harbor seals in the Long Island area. He

writes (personal communication) that over the past 2 years—1968 and 1969—the first reports of seals have come early in January. These reports continue until the end of April. Only one report was received of a harbor seal in August, one at Montauk Point on August 12, 1968.

Harbor seals may be seen just about anywhere along the entire Long Island coast, and small groups are occasionally noted in western Long Island Sound and along the south shore (ocean and bays). It is more usual to see lone individuals (as mentioned by Latham) and I have seen singles in winter swimming in Shinnecock Bay and in Lower New York Bay. During periods in the winters of 1960-61 and 1962-63 coast guard observers at the Shinnecock Inlet station reported seeing a seal, probably this species, swimming every morning in the inlet (figure 12). We also received reports of seals in winter in Moriches Inlet and Great South Bay. The tendency for harbor seals to enter rivers and fresh waters is well known, which explains sightings in the Hudson River.

In the collection of the American Museum of Natural History are several specimens (skins, skulls, skeletons) taken between 1928 and 1959, mainly during winter, also one in late October, at both ends of Long Island. Localities include New York Harbor and Rockaway Beach on the west and Montauk Point on the east; a few are from Long Island Sound. Richard Van Gelder informs me that harbor seals still occur regularly in the vicinity of Montauk Point, and that quite a few have been shot there in recent years. Many are short for sport. Some fishermen are prejudiced against seals, which do little harm, but eat the common and more available fishes, mollusks, and crustaceans, and also occasionally damage nets. But, as Van Gelder and others have urged, it would be desirable to pass a law protecting all seals on Long Island, while this interesting species is still present, for the benefit of the vast numbers of people who enjoy seeing seals.

For many years the harbor seal has been scarce compared with its former abundance in days before the heavy settlement of the coast, its history paralleling many of the cetaceans in this respect. Thus DeKay (1842) mentions the comparative scarcity of harbor seals in his time compared with their former great abundance, while much earlier Denton (1670) wrote of the "innumerable multitude of seals" present all winter on the marshes, beaches, and sandbars of the south shore of Long Island.

Harbor seals in the western North Atlantic are usually designated *P.v. concolor*. The type locality of this form is Long Island Sound, near Sands Point, Nassau County, New York. However, the seals frequenting our coastline are very similar to those of the eastern North Atlantic and Europe, which are designated a different subspecies, *P.v. vitulina*.

Harp Seal

Pagophilus groenlandicus (Erleben)

There seem to be few records for the Long Island area of seals other than the harbor seal. The harp seal, gray seal, and hooded seal undoubtedly visit these shores on occasion; a few stray individuals of all three have been recorded along the New Jersey coast south of Long Island. These seals have centers of abundance in the region of Newfoundland and the Gulf of St. Lawrence. Harp seals and hooded seals migrate to that region from farther north each winter. Gray seals and the now much depleted hooded seals number a few thousand each, while the harp seals are more numerous but even they are declining. Long Island is situated south of the regular range of these northern seals and only an occasional wanderer can be expected.

According to Linsley (1842) the harp seal was very rare on the Connecticut coast and was seen only at Stonington a few times on the rocks; he was told of an unsuccessful attempt to take a seal there, which from the description he believed to be this species, during the winter of 1841-42. This area is less than 3 miles from Fishers Island, New York, near the entrance to Long Island Sound. Kieran (1959) briefly mentions that the harp seal has been seen offshore at Coney Island in winter; I do not have additional information on this report. Stragglers have occurred as far south as Virginia. The gray seal and hooded seal are large spotted species (larger than the harbor seal), while the harp, which is about the size of the harbor seal, is pale grayish or yellowish, usually distinctively marked when adult with a large irregular, dark band on the back.

Gray Seal

Halichoerus grypus (Fabricius)

An interesting find, confirmed in 1958, was that of a small southern outpost colony of gray seals located in the vicinity of the west end of Nantucket (Andrews and Mott, 1967). The gray seals, or "horseheads" as they are known locally, are present year round there. The Nantucket locality is some 80 miles east-northeast of Montauk Point. Southward, a gray seal appeared at Atlantic City, New Jersey, after a severe northeast storm in March 1931 (Goodwin, 1933).

I know of no definite reports of this species on Long Island, but it should be looked for around the east end of the island. The relatively deserted coasts and subsidiary

islands favored by harbor seals in this area may very likely shelter an occasional wandering gray seal from the Nantucket colony or elsewhere. Young gray seals are known to disperse widely. This species may be distinguished from the harbor seal by its larger size, heavier head, and longer, more pointed snout, and by its slower, more deliberate manner; the color is variable, but usually it is a shade of gray, marked with spots or blotches.

Archaeological finds indicate Indians killed gray seals in prehistoric times as far south as Block Island, about 15 miles from Montauk Point, and also on the Connecticut coast (Waters, 1967). Harp seal remains have also been found on Block Island, but as far as I know, the harbor seal (*Phoca vitulina*) is the only seal which has been reported from material collected at Long Island archaeological sites.

Hooded Seal

Cystophora cristata (Erleben)

At least two hooded seals have been found near western Long Island. According to DeKay (1824, 1842), an adult male over 7 feet long was killed at Eastchester and then put on exhibition in New York City. DeKay (1824) wrote: "It was taken in a small creek emptying into Long Island Sound at Eastchester, about 14 miles from this city. The animal made considerable resistance, but exhibited no symptoms of fear. The captor succeeded in diverting his attention by means of a dog, and was thus enabled to destroy him by repeated discharges of his musket." This fearless, even pugnacious, behavior in face of attack is characteristic of male *Cystophora*. Eastchester, which is not shown on the map, is located on the New York mainland side of the Sound, a few miles across from western Nassau County. Also, within just the last few years a hooded seal was found in a tributary of New York Harbor, according to unpublished information, but I have been unable to locate specific details on this recent record.

White-tailed Deer

Odocoileus virginianus Zimmerman

The white-tailed or Virginia deer has had a long and varied history on Long Island. Archaeological finds and early Colonial records show that for centuries this was the principal big game species hunted by Long Island Indians and was one of their important sources of food. Van der Donk (1656) in referring to New York

in general (Colony of New Netherlands), wrote: "The deer are incredibly numerous in the country. Although the Indians throughout the year and every year (but mostly in the fall) kill many thousands, and the wolves, after the fawns are cast, and while they are still young, also destroy many, still the land abounds with them everywhere, and their numbers appear to remain undiminished." On Long Island, the number of deer declined with the spread of white settlers throughout the area; this was followed by enactment of various laws designed to conserve the deer herd.

DeKay (1842) claimed that, in New York State, attacks of men and wolves were daily decreasing the number of deer, but then went on to say: "In some insulated districts, as on Long Island, where the wolf has been extirpated and the deer are placed under the protection of the laws during the breeding season, although more than a hundred are annually killed by sportsmen, yet it is believed that their number is actually on the increase." Audubon and Bachman (1851) likewise remarked that on Long Island, where the game laws were strictly enforced, deer seemed to be increasing.

The deer population continued to decline later in the 1800's, however. According to Helme (1902) the deer had by then become restricted to a small area (6 x 4 or 5 miles) near the south shore of Suffolk County in the townships of Islip and Brookhaven. Protection afforded by game preserves and private estates enabled the deer to survive in this area. White-tailed deer were also introduced from the mainland. In recent decades deer have increased again, and have spread widely over much of the island, although the expanding metropolitan area restricts their numbers in the western portion.

At the present time deer are numerous on the eastern half of Long Island wherever there is suitable cover, in fact they have become a nuisance in some areas. Hamilton (1949) wrote that the Suffolk County deer herd, then numbering between 1,500 and 2,000 animals and increasing, causes considerable damage to vegetables, principally potatoes, and to nursery stock, such as the growing sprouts of young apples and other fruits. Hamilton predicted that in a few years radical measures would have to be considered to control the number of deer. Mild winters, abundance of food, no large predators except dogs, and the general absence of hunting have favored deer abundance in the more thinly settled areas of Long Island. Many are killed by dogs

and automobiles, but the deer have continued to increase and now number several thousand individuals.

In January 1969, a special deer hunt was held on Long Island, the first deer hunt since 1928; with permits carefully regulated by the State Conservation Department, 162 deer were taken by hunters using shotguns during two 5-day periods (Jackson and Miller, 1969).

We saw deer or their tracks at most of our trapline localities in Suffolk County. Deer were encountered in all sorts of woods, including the inland pine barrens, where they are numerous, and around fields, ponds, and bogs. Occasionally they were seen in woods on the very edge of large residential areas. Deer are abundant all through the Montauk area. Here they are easily observed and often appear quite tame in the extensive open and shrubby areas such as the Montauk Downs; we noted groups of up to 16 or more here in the evening. Signs of deer were even found on the ocean shore at the very end of Montauk Point.

At Hither Hills, deer are common in oak woods and other habitats. In Peconic Bay, deer were met with on Jessup Neck, and I understand they are present on Robins Island. On the north shore they are present locally in deciduous woods overlooking Long Island Sound, east to the vicinity of Orient. Roy Latham, in a recent personal communication, writes: "Orient is overrun with white-tailed deer. We counted 28 in a field east of us early in the spring (1970) and I had a herd of nine in my little garden; they have done much damage to plants and small trees." In western Suffolk County, deer are regular but uncommon in the vicinity of the Kalbfleisch Research Station, Dix Hills near Huntington (Lanyon, 1961) and are said to be numerous in Heckscher State Park on Great South Bay.

Deer were seen on visits to Gardiners Island, Shelter Island, and Fire Island (including the Sunken Forest). Controlled marketing is practiced on Gardiners Island, where deer are very abundant (Anon., 1968a). Gardiners Island, incidentally, has had a uniquely long record of one-family ownership, and the deer were carefully protected in the days when they had disappeared elsewhere on eastern Long Island. I am not familiar with the history of this deer herd, but Dutcher and Dutcher (1893) in their account of the mammals of Montauk wrote, "Deer sometimes swim across from the Gardiners Island game preserve some three miles away, causing tremendous excitement and great loss of breath among all the native inhabitants of Montauk."

OTHER MAMMALS

Vanished Recent Mammals

A number of modern-day species of mammals which evidence indicates lived (or probably lived) on Long Island, have become extirpated. Several members of the original mammalian fauna which coexisted with the Indians, including all of the larger carnivores, disappeared early in the settlement of Long Island by the Dutch and English. Little is known about these formerly important species, which include the gray wolf (*Canis lupus*), bobcat (*Lynx rufus*), black bear (*Ursus americanus*), and beaver (*Castor canadensis*). Because this area is coastal and insular, and was heavily settled early in Colonial times, most of the large wild animals were rather quickly exterminated. A few mountain lions, or panthers (*Felis concolor*), may have been present then, too, but there seems to be no information about them on Long Island; if a few of these large cats roamed the island originally, they probably disappeared very early in the Colonial period, which is apparently what happened in various other areas along the East Coast. The white-tailed deer is the one large land mammal which managed to survive to the present, although severely restricted at one time to one or two small protected areas of Suffolk County, and the present stock is much diluted by animals introduced from the mainland.

Denton (1670) mentioned the presence of deer, bears, and wolves on Long Island, besides various small furbearers. A number of early documents and accounts refer to the great abundance of wolves and bobcats, upon which the settlers made war for many years. In the 1600's and beginning of the 1700's bounty payments for wolves killed were made by towns throughout Long Island from Brooklyn to East Hampton (Thompson, 1839, and other sources). Often it was required that the heads of the wolves be displayed in public, such as having them nailed to the door of the constabulary. Large pits and guns set overnight were among the methods used in effecting their capture. As for the bobcat, DeKay (1842) related that it was believed to be extirpated on Long Island then, but that it was so numerous 130 years earlier that the General Assembly passed an act [regarding bounty payments] to encourage the destruction of wildcats in Suffolk County, and that this act was renewed in 1745. Very little is on record concerning bear and beaver here, except that apparently they did occur in

early historic times. Thompson (1839) recounts that beavers were reportedly common at a well-known body of water called Beaver Pond near an Indian settlement not far from present-day Jamaica in Queens, during the time of first settlement of the area. Murphy (1964) has been unable to find anything in the literature about beaver trapping on Long Island, but has found the term "beaver dam" in written records. Latham (1940) lists beaver, bear, wolf, and bobcat as recorded for the Town of Southold during the Colonial period, but with dates of latest captures uncertain.

Van der Donk (1656) described in much greater detail than Denton the abundance and habits of animals in early Colonial days. Van der Donk, however, wrote not about Long Island or of any one area in particular, but of the entire New Netherlands colony, the area now consisting of southern and eastern New York State and parts of adjacent states. But his words help give some idea of the abundance of certain species in the general region in the early and mid-1600's, including the following mammals then present on Long Island as well as on the mainland: beavers—"numerous," wolves—"numerous," and preying on deer, calves, sheep, etc.; and bears—"many." Mountain lions, however, were evidently very scarce or absent near the settled areas and coast according to Van der Donk, although known to the Dutch settlers from skins brought in by the Indians to sell.

Scanty remains of some large game mammals have been found at Indian archaeological sites on the island, species which did not exist on the island in colonial times, but which are still found today on the North American mainland. These include wapiti or elk (*Cervus canadensis*), moose (*Alces alces*), and apparently bison (*Bison bison*). These species, as well as some others which survived to early Colonial days, are in Latham's archaeological collection from eastern Long Island. He writes (personal communication), in response to a request for information on vanished species, as follows: "I have teeth from the black bear from Indian village sites on Shelter Island, Three Mile Harbor, and Southold. I have a section of an antler from a wapiti from a pit on an Indian site in Noyack near Sag Harbor and a section of a moose antler from an Indian site in Acquebogue. These antlers were determined by [Robert T.] Hatt. I have the leg bone of a bison from Noyack. This member was identified at the U.S. National Museum as 'either a bison

or a domesticated cow.' It could not have been a cow as it was in the bottom of a 4-foot deep pit in ground not disturbed since the Indian occupation in the prehistoric period. Remains of beaver have been found in all Indian sites from Montauk to Riverhead. None of the Indian sites excavated have been contact sites. We found wolf remains, but we know that they were common in early settler times. We must take into consideration that antlers and even bear teeth could have been brought to Long Island in trade." In a later letter Latham adds that the Shelter Island bear has been dated at about 1,000 B.C.; also he recorded a bobcat from a Shelter Island site. Latham feels that the wapiti, moose, and bison remains, being of late prehistoric times (200-300 years before white settlement), were probably brought over from the mainland by the Indians.

Moose remains have been found on Fishers Island; Goodwin (1935) mentioned a fragment of an antler found in an Indian shell heap there, and Robert Cushman Murphy (personal communication) recalls that the late Harry Ferguson uncovered moose teeth on Fishers Island and had them identified by a qualified authority. Remains of Indian dogs have also been reported from Long Island archaeological sites.

The Dutch settlers of New Netherlands in the early 1600's had knowledge of living wapiti, moose, and bison, but not in the immediate vicinity of their coast. For example, it is well known that Van der Donk (1656) was familiar with bison. At the beginning of a rather long passage on this species, he wrote: "Buffaloes are also tolerably plenty. These animals mostly keep towards the southwest where few people go."

A well documented example of a small mammal (subspecies) which became extinct quite recently (late 1800's) in the Long Island area because of the complete destruction of its habitat by man is the Gull Island mouse (*Microtus pennsylvanicus nesophilus*), which is discussed in the species account. Other small, inconspicuous mammals may have disappeared without notice in the years following European settlement of Long Island. Fox squirrels vanished during the last century from the Northeast; the subspecies known as the northern fox squirrel (*Sciurus niger vulpinus*) once ranged north to Connecticut and New York. But Bangs (1896) wrote that this shy form could not withstand persecution, and clearing and settlement of the land. For Long Island, there seems to be little information available concerning *vulpinus*, and also much confusion existed in the past regarding the various races and color forms of fox and gray squirrels. But Audubon and Bachman (1849) apparently had this subspecies primarily in mind when they wrote that the

"cat squirrel" (*Sciurus cinereus*), which they explain is the fox squirrel of New York, Pennsylvania, and New Jersey, and intermediate in size between the gray squirrel and the fox squirrel of the southern states, "is rather a rare species—and is met with on Long Island and some other portions of the state of New York."

Introduced Mammals

The Norway rat and house mouse are familiar associates of man which came over from the Old World. So did the black rat, which is now rare. At least one and probably more native American species also made their way to Long Island by one method or another during the historic period. This is fairly well documented in the ease of the opossum. Other species, such as the eastern cottontail, and possibly the little brown bat, also may have invaded the island and prospered in response to changing ecological conditions since the coming of the white man. All of these well-established mammals are discussed in the species accounts.

But in addition to these, Long Island has played host to an unusually large number of deliberately imported and escaped exotic mammals, some of which have become temporarily established locally. The many wealthy landowners and sportsmen, with their private estates and game preserves, and numerous travelers returning from other lands have contributed to this situation. Also certain outlying islands have proved to be havens for some of the newcomers. None of the species has become widely distributed, as far as I know, and lacking details on the history and status of most of them, they will be discussed only briefly. But the possibility of encountering such animals is something to be kept in mind by the student or observer afield in this area.

Various hares and rabbits have been introduced, besides western races of *Sylvilagus floridanus*, and some of these may be found locally in small numbers. These include—European rabbit (*Oryctolagus cuniculus*), said to be on Great Gull Island and possibly one or two areas on Long Island proper; black-tailed jackrabbit (*Lepus californicus*), reported in some limited areas of western and central Long Island in recent years; European hare (*Lepus europeus*), a few reportedly in Nassau County, possibly also central Suffolk County; and varying hare (*Lepus americanus*), introduced in several localities years ago. Some varying hares introduced into Orient in 1915 lasted about 4 years (Roy Latham, personal communication). Among the hares (*Lepus*), authentic recent records (within the past 2-3 years) are known only for the black-tailed jack, of which two skins have been examined

(Joseph Dell, Anthony Taormina, personal communications).

As far as I know, the varying hare was not a native resident of Long Island during historic times. The citing of Locust Grove, Nassau County, as a peripheral locality record for this species by Hall and Kelson (1959) appears to be an error. After tracing this record back to Nelson (1909), who did not include Long Island in the range of this species, I believe the probable location for this record is the very small village of Locust Grove in Lewis County (northwestern New York), where C. Hart Merriam collected many specimens in the late 1800's, rather than the much larger town of the same name on Long Island.

For deer, there are black-tailed deer (*Odocoileus hemionus*) on Shelter Island and sika deer (*Sika nippon*) near the Carmans River. The former, which are well known to the local residents, were introduced in 1910 and still survive in an undeveloped area of Shelter Island; I noted several black-tailed and white-tailed deer associating together and feeding in an open field there in June 1963. The sika deer were introduced at Suffolk Lodge (the Hard property on the Carmans River, now a county park) many years ago; the small herd remains in a wild state, but is largely confined to the park (Anthony Taormina, personal communication).

Beavers (*Castor canadensis*) have been reintroduced and established locally and temporarily, but I have no knowledge of any presently-existing colonies. Other oddities include escaped hedgehogs (*Erinaceus europaeus*) in central Long Island, and thirteen-lined ground squirrels (*Citellus tridecemlineatus*) on Fishers Island; I have not heard of any recent reports of these species. The hedgehogs are said to have escaped from greenhouses where they were kept to control insects (as is done in Europe).

Even escaped California sea lions (*Zalophus californianus*) have been encountered. In July 1965, about 15 escaped from a marineland at Ocean City, Maryland, and although most of them eventually headed south, two of them were recovered as far north as the Long Island area (Robert A. Morris, personal communication).

Missing Land Mammals

Long Island lacks several kinds of small mammals presently found on the nearby mainland or in similar terrain along the New Jersey coastal plain. For some of

the species this seems surprising, but probably the situation is about what one might expect for a large island near the mainland—the island fauna is mostly similar, but has somewhat fewer species. Certain forms apparently did not make the short jump from the mainland at the western end of the island, or if they occurred earlier, conditions may have become unsuitable for them in the limited Long Island area. With the paved metropolis now blocking this approach, Long Island seems more effectively isolated than previously to natural invasion by four-footed land mammals (although not to accidental or intentional introduction by man).

The red squirrel (*Tamiasciurus hudsonicus*) is missing, without any evidence that it ever occurred here as far as I know, although it is found in southern New England and also abundantly southwards on the New Jersey coastal plain in pitch pine—oak woods resembling those growing on Long Island. The red squirrel formerly occurred as close as Bronx and Manhattan on the other side of the East River. The red-backed mouse (*Clethrionomys grapperi*) has never been found either, although it is present in southern New England and southern New York and also south of Long Island in the coast white cedar swamps and sphagnum bogs of New Jersey; if it existed on Long Island one would expect it in these same habitats and possibly also in red maple swamps.

The bog lemming (*Synaptomys cooperi*) has apparently escaped all search for it on Long Island. This species is often local and uncommon where it occurs and there is the possibility of it having been overlooked, but it seems unlikely that *Synaptomys* remains undiscovered in such a heavily settled area as Long Island. The scattered sphagnum bogs of the pine region would be the most likely habitat. There are no records of the least shrew (*Cryptotis parva*), to my knowledge, although there is still some chance it may be found here. More than most small mammals it is apt to go unnoticed, and it appears to be rare and local this far north. *Cryptotis* has been found twice on the Connecticut coast, at Darien and Westbrook (see Jarrell, 1965) and several have been collected on Staten Island (Chapin, 1908).

Two small bats, the Indiana myotis (*Myotis sodalis*) and the small-footed myotis (*Myotis leibii*) have not been found on Long Island as far as I know. Both are rare in the Northeast and known primarily from winter hibernating sites in caves. If a few individuals occasionally visit Long Island or even spend the summer here they would be difficult to detect.



Figure 1. Woods of large beech, tuliptree, oaks, etc., surviving near North Hills, western Nassau County, but encircled by the expanding metropolitan area. March, 1961. Short-tailed shrew, eastern mole, cottontail, chipmunk, gray squirrel, white-footed mouse, pine mouse, and raccoon recorded.

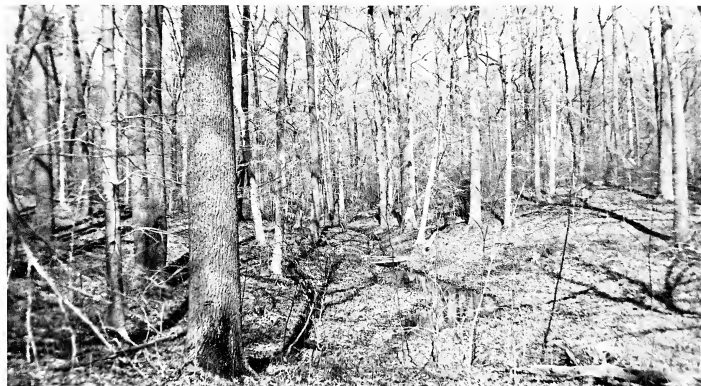


Figure 2. Same woodland area as figure 1, with small stream.



Figure 3. Pine barrens near Flanders. November 1962. Opossum, masked shrew, short-tailed shrew, eastern mole, eastern cottontail, chipmunk, gray squirrel, southern flying squirrel, white-footed mouse, pine mouse, red fox, long-tailed weasel, and white-tailed deer present.



Figure 4. Pond in pine barrens near Flanders. October 1962. Muskrat common, mink occasional. Also all species as in figure 3, with some kinds more numerous in the vicinity of the pond.



Figure 5. Peconic River, near Calverton, July 1963. Masked shrew, meadow mouse, and muskrat numerous in cattails and other marsh vegetation. Otters have been reported in this general area of the river.



Figure 6. Looking towards Great Peconic Bay marshes from pine land east of Flanders, November 1962. Eastern mole, chipmunk, and pine mouse common under the pines, but not venturing out into salt marsh (the home of many meadow mice). Also masked shrew, eastern cottontail, Norway rat, white-footed mouse, raccoon, long-tailed weasel, and white-tailed deer found in the general area.



Figure 7. Edge of southern white cedar swamp (pine-oak woods to right), near River-head, November 1962. Flying squirrels observed in the cedars; masked shrew, short-tailed shrew, eastern cottontail, gray squirrel, and white-footed mouse collected under the cedars. Eastern mole tunnels in dry ground near edge. Also chipmunk, woodchuck, red fox, and white-tailed deer recorded in the general area.



Figure 8. Within cedar swamp shown in figure 7. Masked shrews numerous in cavities at the base of cedar trees and mounds.



Figure 9. Small sphagnum bog with southern white cedar, leatherleaf, and a large sedge, near Flanders, October 1962. Masked shrew and meadow mouse numerous. Also eastern cottontail, southern flying squirrel, white-footed mouse, muskrat, raccoon, long-tailed weasel, and white-tailed deer recorded.



Figure 10. Abandoned farmhouse near Manorville, November 1962. Summer maternity colony of little brown bats in attic, just under peak of roof; bats flew in and out of upper window. Also a few big brown bats present in fall.



Figure 11. Weedy, sandy field with black oak and young pitch pines, Hampton Bays. November 1962. Short-tailed shrew and pine mouse abundant, meadow mouse uncommon. Also eastern mole tunnels throughout the area.



Figure 12. Shinnecock Inlet, from base of jetty on west side. Harbor seals in inlet and vicinity during winter, bottle-nosed dolphin found stranded nearby. Also records of pigmy sperm whale, finback whale, and Atlantic right whale off the inlet in recent years. Norway rats live among the jetty rocks.



Figure 13. Red maple swamp with small stream, cinnamon fern, skunk cabbage, vines, etc., near Babylon. April 1963. Several star-nosed moles (very local on Long Island) collected in area shown, in tunnels near the stream. Short-tailed shrew and meadow mouse used the mole tunnels. Also opossum, cottontail, gray squirrel, white-footed mouse, and raccoon listed.



Figure 14. Star-nosed mole above deep tunnel where caught (in area shown in figure 13). April 1963.



Figure 15. Grassland with clumps of shrubs and scattered trees, in Shinnecock Hills. November 1962. Masked shrew, short-tailed shrew, and meadow mouse numerous; eastern mole in some depressions. Red foxes observed and dens found in area shown. Opossum and white-tailed deer common.



Figure 16. Salt marsh on outer strip about 1 mile east of Moriches Inlet. November 1962. Meadow mouse abundant, masked shrew present. Also muskrat, long-tailed weasel, and mink recorded in this marsh, with opossum, eastern cottontail, and red fox common in general area.



Figure 17. View from outer dunes (with beachgrass) across interdune valley to inner dunes, East Hampton Beach. November 1962. Meadow mouse, house mouse, and cottontail rabbit frequented the outer dunes. More mammals were found in the interdune valley, including the above species and also masked shrew, short-tailed shrew, eastern mole, and white-footed mouse. Opossum, red fox, and long-tailed weasel in the area.



Figure 18. Sandy, tall-grass area near the moving dunes (background) at Hither Hills. Meadow jumping mouse, as well as meadow mouse and masked shrew, very common in the tall grass here.



Figure 19. View across extensive marshes and Napeague Harbor (left) from summit of high moving dune in Hither Hills State Park, November 1962. Meadow mice everywhere here, even in clumps of beachgrass on the high dunes. Red fox common.



Figure 20. Moving dunes, showing active edge of a dune encroaching on a patch of woods, Hither Hills State Park, November 1962. Tracks of cottontail, red fox, raccoon, striped skunk, and white-tailed deer frequent on the smooth sand.



Figure 21. Woods of white oak and black oak with bayberry undergrowth, in Hither Hills near shore of Block Island Sound. October 1962. Our easternmost locality for the eastern mole. Also chipmunk and pine mouse present, local this far east. Both shrews, gray squirrel, white-footed mouse, and white-tailed deer common.



Figure 22. Fresh Pond, Hither Hills State Park. October 1962. Keen's bats abundant and active over the pond and vicinity at least from June to October. Red bats common in late summer and fall. Both species mist-netted over water and shoreline on left. Red fox and mink observed along the shore.



Figure 23. Typical scene under a pitch pine in the pine barrens—husked cones and litter left by squirrels feeding on the pine seeds.



Figure 24. Tubers of groundnut or wild bean, from a large pile accumulated by meadow mice, near Hauppauge. Collected in March 1961. Individual tubers about 1 inch long.



Figure 25. Sandy area with beachgrass, bayberry, etc., in foreground, near salt water bay on Shelter Island. June 1963. Meadow jumping mouse present, also short-tailed shrew, white-footed mouse, meadow mouse, and raccoon listed. (osprey nest on dead tree in distance).



Figure 26. Field on Shelter Island. June 1963. Black-tailed deer (introduced) and white-tailed deer observed feeding here. Red fox sat on rock under lone tree in center distance. Short-tailed shrew, meadow mouse, and eastern cottontail common.

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APPENDIX

Allen H. Benton, Danny L. Kelly, State University College, Fredonia, New York 14063

Siphonaptera From Long Island, New York

During the study of Long Island mammals, Paul Connor collected 421 fleas which form the material for this study. We are grateful to Mr. Connor and the New York State Museum and Science Service for the opportunity to study this interesting collection.

The 421 specimens include only 11 species, a remarkably small number. In comparison, a study of material collected by Connor in Lewis County (Benton, 1966) produced 118 individuals of 13 species, while a study of Connor's Schoharie County material (Kuczek, unpub.) produced 606 specimens of 19 species. It appears that the flea fauna of Long Island is impoverished. In part, this is due to the absence of a number of northern forms associated with such mammal species as *Clethrionomys gapperi* and *Tamiasciurus hudsonicus*. In other cases, the host species may have been present but not collected or collected in such small numbers that a representative sample of the fleas was not obtained. For example, both *Tamias striatus* and *Glaucomys volans* were collected in small numbers, but such flea species as *Megabothris acerbus* and *Tamiophila grandis* from the chipmunk, and *Epitedia faceta*, *Conorhinopsylla stanfordi*, and *Opisodasys pseudarctomys* from the flying squirrel were not taken. Geary (1959) lists three additional mammal fleas from Long Island localities: *Oropsylla arctomys*, the common flea of woodchucks; *Megabothris asio*, usually found on *Microtus*, and *Odontopsyllus multispinosus*, a parasite of rabbits. Possibly, the relatively small number of species reflects the very limited altitudinal and ecological variability on the island. Certainly, one might expect more than one-third of New York's flea fauna to be found on such a large land area. Selective collecting from species poorly represented in the State Museum collection might add several species of fleas to the list of species which follows:

FAMILY PULICIDAE

Cediopsylla simplex (Baker)

Fourteen specimens of this rabbit flea were collected from two specimens of *Sylvilagus floridanus*. This is a common flea on Leporids, particularly cottontails, throughout the east except in high areas where cottontails do not exist. (2 males, 12 females)

FAMILY HYSTRICOPSYLLIDAE

Athyphloceras bishopi (Jordan)

Three specimens were taken from *Microtus pennsylvanicus* at Shinnecock Hills, December 15, 1961. This is primarily a winter flea, usually taken in larger numbers from nests of the field mouse. It is known from only a few localities in New York, but probably occurs throughout the State. (3 females)

Stenoponia americana (Baker)

Forty specimens of this species were taken, with 35 of them (87.5 percent) having been taken in the months of September-March. Six hosts were represented, with the largest numbers being found on *Peromyscus leucopus* (35 percent), and *Microtus pennsylvanicus* (20 percent). In New York, this species has been found only on Long Island and up the Hudson Valley as far north as Albany. (15 males, 25 females)

Epitedia wenmanni testor (Rothschild)

Seven specimens were taken from November-March, four from *Peromyscus leucopus*, three from *Microtus pennsylvanicus*. The distribution of this southern subspecies in New York is similar to that of *Stenoponia americana*. (2 males, 5 females)

Ctenophthalmus pseudagyrtus pseudagyrtus (Baker)

By far the commonest flea species collected, this flea made up 30 percent of the fleas collected, with 128 specimens from 10 host species. It was taken throughout the year, with 80 percent occurring in the September-March collections. (76 males, 52 females)

Doratomyella blarinae (C. Fox)

Forty specimens of this species were taken, 39 of them from *Blarina brevicauda*. This species is thus the most host-specific flea taken during this study. The specimens were quite evenly distributed throughout the year, except for a surprising gap during the months of July-October. Possibly this gap was caused by a low population of the host species, or by limited collections during this time period, since it has been taken commonly during these months in other parts of New York. (18 males, 22 females)

Nearctopsylla genalis genalis (Baker)

Eleven specimens were taken, six from *Blarina brevicauda*, five from *Scalopus aquaticus*. All were taken between December and March. (5 males, 6 females)

FAMILY CERATOPHYLLIDAE

Orchopeas howardii howardii (Baker)

This common squirrel flea is represented by 113 specimens, seven from *Glaucomys volans*, the rest from *Sciurus carolinensis*. No specimens were taken from September to February (37 males, 76 females)

Orchopeas leucopus (Baker)

The 54 specimens of this species were well distributed throughout the year, with peaks in November-December. Forty-eight (88 percent) were taken from *Peromyscus leucopus*. (22 males, 32 females)

Nosopsyllus fasciatus (Bosc)

The common rat flea was taken only once, a single specimen from *Didelphis marsupialis*. This was undoubtedly due to an accidental transfer to the opossum from a barn or outbuilding where rats were present. (1 female)

FAMILY LEPTOPSYLLIDAE

Peromyscopsylla scotti (I. Fox)

Ten specimens of this species were taken from October-December, substantiating previous reports that this is an autumn flea. All except one were from *Peromyscus leucopus*. (4 males, 6 females)

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Uppermost Clinton
(Middle Silurian)
Stratigraphy and Petrology
East-Central New York

Donald H. Zenger
Temporary Geologist
Geological Survey
New York State Museum and
Science Service



BULLETIN NUMBER 417

NEW YORK STATE MUSEUM AND
SCIENCE SERVICE

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Uppermost Clinton (Middle Silurian) Stratigraphy and Petrology East-Central New York¹ by Donald H. Zenger²

ABSTRACT

THE UPPERMOST CLINTON UNITS in the type area in east-central New York include the thin 0-1.2 meters (0-4 feet) Kirkland Dolostone, a hematitic, fossil fragmental dolostone, overlain by the Herkimer Formation 0-30.5 meters; (0-100 feet); these units pinch out eastward but disconformities are less significant than was previously believed. The Herkimer is divided into western and eastern facies. The western facies (Joslin Hill Member) consists of fossiliferous, quartzose dolostone and dolomitic sandstone, dolomitic siltstone, shale, ferruginous sandstone, dolostone, and orthoquartzite. Shale-sandstone ratios increase to the west. Ripple marks, cross-bedding, bioclasts, and shale clasts are common. The eastern facies (Jordanville Member) is a well rounded and sorted, medium-grained orthoquartzite including conglomeratic and cross-laminated beds, shales being practically absent. An eastern source of terrigenous material is indicated by the distribution of lithologies and paleocurrent directional indicators. The discovery of the ostracode *Drepanellina clarki* above *Paraechmina spinosa* permits direct correlation with the Appalachians farther south and supports the contention that the upper Clinton in east-central New York is younger than the same horizon in western New York.

The nonshaly beds of the Herkimer are divided into six microfacies: (1) orthoquartzite, (2) dolomitic, fossil-fragmental sandstone to quartzose biodolarenite, (3) dolomitic siltstone, (4) intraclast- and fossil-

¹ Submitted for publication, July 2, 1970.

² Department of Geology, Pomona College, Claremont, California.

bearing dolostone, (5) slightly impure sandstone, and (6) partially dolomitized, hematitic biosparite. Ferroan dolomite, determined by staining and by electron probe microanalysis, is the major carbonate. Iron-rich chlorite and illite are the predominant clay minerals in the shales. A statistically significant negative correlation exists between density and insoluble content; no correlation is indicated between dolomite and insoluble content. Fossil preservation suggests that dolomitization was mainly early diagenetic. Many of the postdepositional changes were early diagenetic. The basic paragenetic sequence is calcite-hematite-dolomite-chlorite-secondary silica-pyrite.

The Jordanville most probably represents a beach environment. The sandstones and dolostones of the Joslin Hill accumulated above wave base in a shallow-water, near-shore zone. Shales and siltstones formed under conditions of less energy.

Acknowledgments

Considerable field work was supported by a grant from the Geological Society of America. Acknowledgment is also made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of this research. Timothy Tackett performed some of the analyses under NSF-URP GE-1038. I thank D. W. Fisher and A. O. Woodford for their critical reading of the manuscript. Helpful advice or suggestions were given by A. J. Boucot, H. S. Muskatt, and Robert Schoen. I am especially grateful to R. G. C. Bathurst for discussions regarding some of the problems associated with the carbonate fabrics. Drilling information was provided by G. C. Borland, S. S. Galpin, and A. M. Van Tyne. J. W. Teeter kindly permitted the examination of a specimen of *Drepanellina* from the Lockport Formation at Hamilton, Ontario.

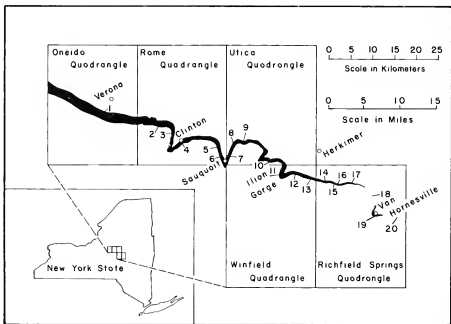


FIGURE 1.—Index and outcrop map of the Herkimer Formation in east-central New York.

Introduction

PURPOSE

While studying the stratigraphy of the Lockport Formation (Middle Silurian) in New York, the writer discovered an apparent facies relationship between the uppermost Clinton Herkimer Formation and the overlying Lockport (Zenger, 1965, p. 131-132) instead of the long accepted disconformity between these major units (Swartz, and others, 1942; Fisher, 1960). Because New York provides the standard Silurian section for the United States and because most of the evidence for the above-mentioned facies relationships occurs in the area of the type Clinton, a further consideration seemed important. It was decided to focus on the uppermost Clinton, particularly the Herkimer "Sandstone." This paper summarizes the stratigraphic and paleontologic relations within the uppermost Clinton in the type area and discusses the petrology of the Herkimer. It is hoped that this will provide the beginning of a long-overdue petrologic analysis of the entire Clinton.

GENERAL SETTING

Clinton section.— Figure 1 shows the outcrop map of the Herkimer Formation in east-central New York. Upper Clinton units, their ranges in thickness, and corresponding ostracode zones are presented in table 1. All units pinch out eastward within the area shown (fig. 1) or a short distance to the east.

Previous work.— An exhaustive review of earlier work is not attempted. Chadwick (1918, p. 351) named the "Herkimer Sandstone," the name being based on outcrops in southern Herkimer County, and the "Kirkland Iron Ore" (1918, p. 349) for exposures in the Town of Kirkland in which Clinton lies (fig. 1). Zenger (1966,

TABLE 1. — UPPER CLINTON UNITS IN AREA OF TYPE CLINTON, INCLUDING OSTRACODE ZONES OF GILLETTE (MODIFIED FROM GILLETTE, 1947)

	Rock Units	Ostracode Zones
Lockport Formation	Ilion Member 0-21.3 meters (0-70')	
Upper Clinton	Herkimer Formation 0-30.5 meters (0-100')	<i>Paracchmina spinosa</i>
	Kirkland Dolostone 0-1.5 meters (0-5')	
	Willowvale Shale 0-7.6 meters (0-25')	<i>Mastigobolbina typus</i>
	Westmoreland Hematite 0-0.9 meters (0-3')	

Note: The Dawes Sandstone, a restricted unit 0-3 meters (0-10 feet) thick found only in the western part of the outcrop belt, lies between the Willowvale and the Kirkland.

p. 1159-1161) has presented a summary of work on the Herkimer. Gillette (1947) provided the most thorough stratigraphic treatment of the Clinton Group in New York, but the emphasis was on western and central New York. Fisher compiled Silurian correlations in New York (1960). He showed disconformities between the Willowvale Shale and overlying Kirkland and between the Herkimer and overlying Ilion Shale of the Lockport. A portion of Fisher's chart is presented in figure 2. As Gillette had concluded (1947, p. 23, 112), Fisher showed the Herkimer as the time equivalent of the Rochester Shale of western New York.

METHODS OF STUDY

Approximately 2 months were devoted to the field study of the uppermost Clinton stratigraphy across the outcrop belt shown in figure 1. The 20 localities studied are marked in figure 1 and are briefly described in the appendix. Directional features were measured in the field and oriented specimens were collected.

Quantitative insoluble residue determinations were based on solution with 25 percent HCl. The precision of the method is good; based on analyses of 16 splits of a calcareous sandstone, the standard deviation is 0.46 percent. The relative standard deviation (standard deviation expressed as a percent of the mean) is 0.70 percent.

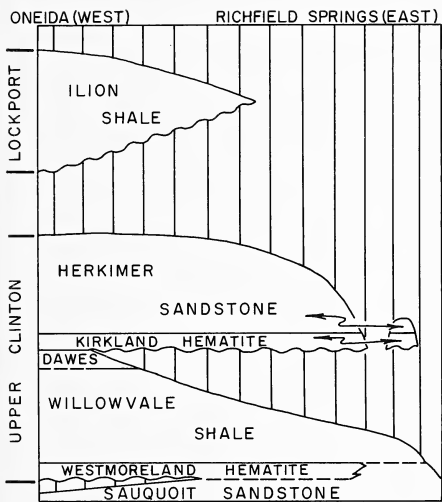


FIGURE 2. — Relations between Upper Clinton units in east-central New York as considered by Fisher (1960). Vertical ruling signifies disconformity; wavy line indicates physical evidence of a disconformity.

Densities of rock powders were determined using a Beckman Air Comparison Pycnometer (#930). This instrument and its geologic application was described by McIntyre, and others (1965), and by Zenger (1968). The precision of density determinations is high; 18 replicate measurements gave a standard deviation of 0.0027 units.

X-ray diffraction (Philips X-ray Diffractometer) scans were run on all samples over a 2θ range of 5° to 60° . Quantitative calcite and dolomite compositions were determined using a ratio of peak heights (fixed counts) of these minerals (at about $2\theta = 29.4^\circ$ and 30.9° , respectively). These ratios were referred to a calibration curve of calcite-dolomite ratios vs. dolomite percent similar to those presented by Bromberger and Hayes (1966, p. 360). Whereas the instrumental precision is good (relative deviation = 1.1 percent), the analytical, or within specimen variability is considerably higher (relative deviation = 4.0 percent) owing mainly to variation through sample preparation. Calcite-dolomite determinations are best considered semi-quantitative.

The electron probe microanalyzer (Philips Electronic Instruments AMR/3) was used to determine the distribution of iron in the iron-rich carbonates of the Herkimer. A description of the operating conditions of the probe was presented by Baird and Zenger (1966).

All samples were studied in thin section. Acidic solutions of Alizarin Red S (calcite positive) and potassium ferricyanide (ferrous iron positive) were used as stains (Sabins, 1962, p. 1184; Warne, 1962, p. 37).

Stratigraphy and Paleontology

KIRKLAND DOLOSTONE

Figure 3 comprises columnar sections and figure 4 is a restored section showing the stratigraphic relations across the outcrop belt. "Kirkland Dolostone" is used for the unit commonly called "Kirkland Hematite" and "Kirkland Iron Ore" because the dominant lithology is dolostone. Fisher (1960) showed the Kirkland extending across the entire outcrop belt but it is the contention of this writer that as a continuous lithologic unit it does not extend eastward beyond Iliion Gorge (loc. 11); thin hematite beds in that interval east of Iliion Gorge are best considered as part of the uppermost Willowvale Shale (figs. 3 and 4). From the Oneida quadrangle to Iliion Gorge, the Kirkland ranges from 0.45–1.2 meters (1.5 to 4 feet) in thickness. The unit is grayish-red to moderate red, mottled, thin- to medium-bedded (commonly weathering more massive), coarse-grained to conglomeratic, fossil-fragmental, calcareous, slightly sandy, very hematitic dolostone. Shaly zones and seams of medium-gray, less hematitic dolostone are commonest in the lower and upper parts. Pyrite is relatively common in some beds and shale clasts are present. The lower contact with the Willowvale is generally sharp, although at some localities there is a very small-scale interfingering of Kirkland and dolomitic laminations of the Willowvale. The contact is considered to be conformable. In the vicinity of Clinton, the Kirkland overlies the Dawes Sandstone, a very restricted, irregularly bedded unit which this writer considers the equivalent of the upper Willowvale farther east. The presence of a marine fauna including *Atrypa*, *Coolinia* [*Fardenia*], *Leptaena*, *Calymene*, *Trimerus*, and *Cornellites* indicates that Gillette's consideration of a continental origin (1947, p. 100) for the Dawes was in error. In all cases, the uppermost Kirkland grades into the Herkimer through at least a few inches of transition.

The unit is fossiliferous, the dominant elements being brachiopods, bryozoans, and pelmatozoan (probably crinoids) fragments. Abrasion

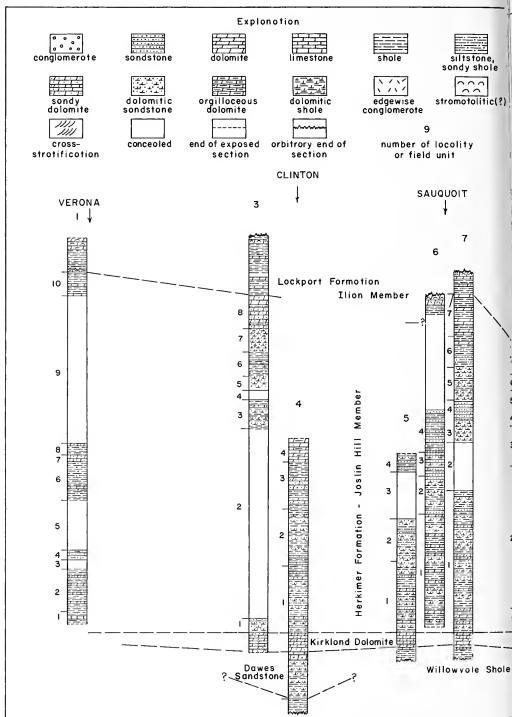
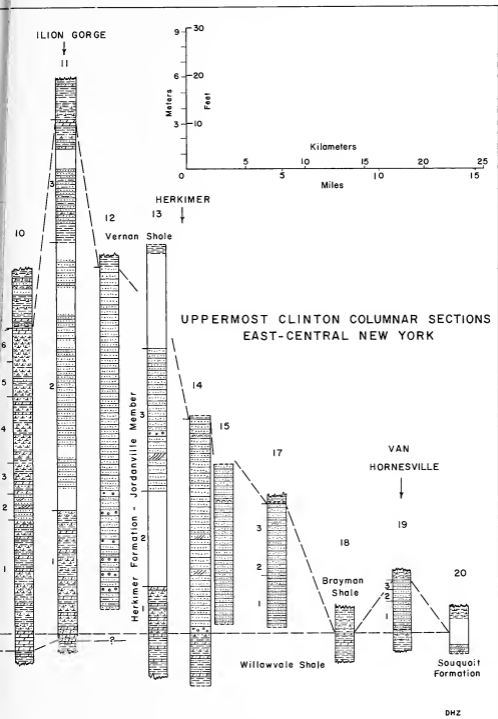


FIGURE 3.— Columnar sections of uppermost Clinton units, east-central New York



Numbers at top of sections refer to localities ; numbers within sections are field units.

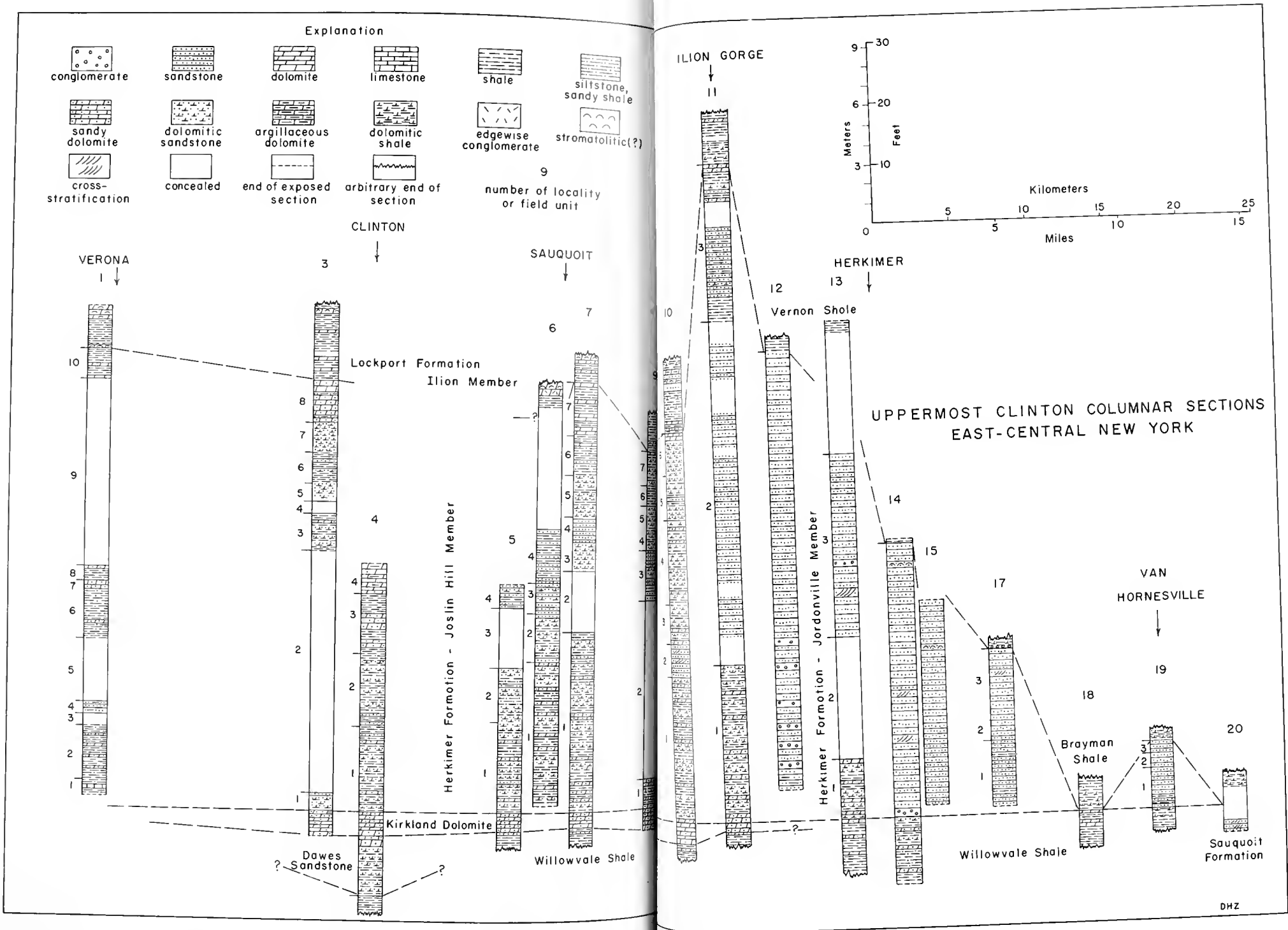


FIGURE 3. — Columnar sections of uppermost Clinton units, east-central New York.

Numbers at top of sections refer to localities; numbers within sections are field units.

and subsequent hematitization have affected the preservation. Following is a list of the forms collected by the writer:

	<i>Locality Number</i>
Brachiopods	
<i>Coolinia</i> [<i>Fardenia</i>] <i>subplana</i> (Conrad)	3,9,10
<i>C.</i> [<i>F.</i>] sp.	5,6*,7
<i>Leptaena</i> " <i>rhomboidalis</i> " (Wilckens)	5,6*
<i>Protomegastrophia profunda</i> (Hall)	6*
<i>Amphistrophia striata</i> (Hall)	6*,9
<i>Stegerhynchus neglectus</i> (Hall)	7,9
Bryozoans	
<i>Diploclema sparsum</i> (Hall)	11
<i>Eridotrypa striata</i> (Hall)	4
<i>E. solida?</i> (Hall)	10
<i>Fenestrellina elegans</i> (Hall)	4
Trilobites	
<i>Trimerus</i> (<i>Trimerus</i>) <i>delphinocephalus</i> Green	3,5,10,11
<i>Liocalymene clintoni</i> (Vanuxem)	7,11
Others	
<i>Dawsonoceras americanum</i> Foord	6*
<i>Mastigobolbina?</i> sp.	6*
<i>Murchisonia</i> (<i>Hormotoma</i>) sp.	3,11

* collected from loose block of Kirkland

The stratigraphic position of the Kirkland is equivocal. This writer acknowledges the close lithologic relationship with the Herkimer but is impressed by the lack of a distinct break between the Willowvale and Kirkland. Consequently, the Kirkland is treated as a unit separable from the Herkimer.

HERKIMER FORMATION

Introduction. — Zenger (1966) considered the "Herkimer Sandstone" of Chadwick (1918, p. 351) as a formation with western and eastern lithofacies, each of which was designated as a member. "Joslin Hill Member" was applied to the western facies (Oneida, Rome, and Utica quadrangles; fig. 1) and "Jordanville Member" to the eastern facies (Winfield and Richfield Springs quadrangle). The abrupt lateral change between these facies occurs in the vicinity of Ilion Gorge (figs. 3 and 4).

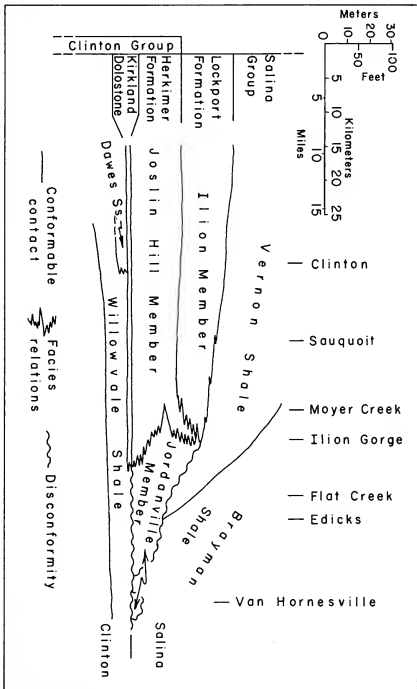


FIGURE 4.—Restored section of Herkimer and Kirkland and adjacent units.



FIGURE 5. — Interbedded shale, dolostone, and sandstone of Joslin Hill Member at Dawes Quarry Creek.

Joslin Hill Member. — The type section is along the south branch of Moyer Creek in the western part of the Utica quadrangle (loc. 10; figs. 1 and 3; Zenger, 1966, p. 1163–1164) where 19.8 meters (65 feet) of Herkimer are exposed above the Kirkland. From its westernmost outcrop (loc. 1) to Moyer Creek the thickness is consistent, ranging from 18.3–22.8 meters (60 to 75 feet). The lower contact with the Kirkland is gradational. Although Gillette (1947, p. 113) and Fisher (1960; fig. 2) postulated a disconformity between the Herkimer and overlying Ilion Member of the Lockport, this writer found a gradational to interfingering relationship (Zenger, 1965, p. 101–103). The exact contact is difficult to determine at many localities. At South Moyer Creek, a greenish sandstone bed of Herki-

mer affinity occurs 2.1 meters (7 feet) above the base of the Iliou.

Shale occurs throughout but becomes more important westward (figs. 3 and 5). Shale-sandstone+dolomite ratios range from 1:1 in the west to 1:3 at Moyer Creek. The shales range from dark gray, smooth, and fissile or paper thin varieties to more thickly laminated and silty types. Though generally unfossiliferous, some shales contain a well preserved fauna.

Nonshaly lithologies are dominated by gray to brownish-gray, very fine- to commonly medium-grained dolomitic sandstone followed in abundance by gray, fine-grained quartzose dolostone and dolomitic siltstone, light-gray to grayish-green sandstone, medium-gray to dark-gray dolostone, grayish-red hematitic sandstone to dolomitic sandstone, and at the westernmost outcrop some beds of dolomitic, very hematitic calcarenites (fig. 3). Bedding ranges from thin to medium and from irregular to flaggy. These beds are more resistant than the intercalated shales and form small waterfalls. Fossils, particularly fragments, are abundant. These bioclasts range from sand-size to pebble-size. Pelmatozoan fragments, probably crinoids, are ubiquitous. Preservation of fossils is usually poor owing to abrasion or loss of detail as a consequence of fossilization as molds in a relatively coarse matrix. In addition to the pelmatozoans, the dominant elements are brachiopods, pelecypods, and bryozoans. A complete list of Joslin Hill fossils is presented in table II. *Drepanellina clarki* and associated ostracodes have been found in the uppermost part of the member. Fucoids occur on the bottom of many beds and Hall (1852, p. 18) considered these to be the remains of marine plants. *Rusophycus bilobata* (fig. 6) is one of the more common types. Seilacher (1964, p. 298-299, 310) considered this form to represent the cast of a trilobite burrow, a likely suspect in this case being *Trimerus*.

TABLE II—LIST OF JOSLIN HILL FOSSILS

	1	2	3	4	5	6	7	8	9	10	11	12	13
Locality Numbers													
Brachiopods													
<i>Amphistrophia striata</i> (Hall)	2,6	x*			1	1				1			
<i>Atrypa reticularis</i> (Linnaeus)	1			1									
<i>Coelonia</i> [<i>Fardenia</i>] <i>subplana</i> (Conrad)	2		1,3	1	1	1	1			1	x		
<i>Coelonia</i> [<i>Fardenia</i>] sp.								1					
? <i>Coelonia</i> [<i>Fardenia</i>] <i>decewensis</i> (Williams)	1			1									
<i>Dalcyna</i> [<i>Rhipidomella</i>] <i>circulus</i> (Hall)	1												
<i>D.</i> [<i>Rhipidomella</i>] <i>hybrida</i> (Sowerby)	1												
<i>Dalcyna</i> [<i>Rhipidomella</i>] sp.	1									3			
<i>Hedcyna erispa</i> (Linnaeus)	1												
<i>Homocospira?</i> sp.	1,2			1	1		7			2	1,3		1
<i>Howellella?</i> sp.	1,6						7				3		
<i>Leptaena</i> "rhomboidalis" (Wilckens)	2,6		3	1,2	1	1							
<i>Lingula</i> sp.													
<i>McLearnites</i> [<i>Mesodonwillina</i>] sp.	2,6		3,5	1,2	1		7						
<i>Meristina?</i> sp.													
<i>Orbiculoides</i> sp. cf. <i>O. tenuilamellata</i> (Hall)			3		1					4	3		
<i>Orbiculoides</i> sp.										6			
<i>Parnorthis elegantula</i> (Dalman)	1			1			3						
" <i>Pentamerus</i> " <i>ovalis</i> Hall						1							1
<i>Plectodonta transversalis</i> (Sowerby)	1				1								
<i>Protomegastrophia profunda</i> (Hall)	1				1								
rhychonellid indet.					1,4		5		4,5	2	3		x
<i>Rhynchotreta americana</i> Hall	1												
" <i>Schuebertella</i> " sp.													
<i>Stegerhynchus acinus</i> (Hall)						1							

* fossil observed but not referred to particular unit

TABLE II — LIST OF JOSLIN HILL FOSSILS — continued

	1	2	3	4	5	6	7	8	9	10	11	12	13
Brachiopods (continued)													
<i>Stegorhynchus neglectus</i> (Hall)	1,2, 6	x	1,3, 5,8	1,2	1,2	1	1,2, 5			1,2			
<i>Struispirifer</i> [<i>Eospirifer</i>] <i>niagarensis</i> (Conrad)	1,2												
<i>Struispirifer</i> [<i>Eospirifer</i>] <i>radiatus</i> (Sowerby)	1,2 2			1									
<i>Strophonella</i> sp.	1												
<i>Trematospira camura</i> (Hall)	6			1,2		1	7	x		2			
<i>Ucinulus obtusiplicata</i> (Hall)	2						7			4			
<i>Ucinulus</i> sp.	1						7						
<i>Whitfieldella nitida</i> (Hall)	1			1									
<i>Whitfieldella</i> sp.	1												
Bryozoa													
bryozoa indet.	6		7			4	3,7 5	x	4	3,6	3		
<i>Chasmatopora asperatostrata</i> (Hall)													
<i>Chilotrypa ostiolata</i> (Hall)			1										
<i>Eridotrypa solida</i> (Hall)			1				7			2			
<i>Eridotrypa?</i> sp.				3			3						
<i>Fenestrellina?</i> <i>elegans</i> (Hall)							5						
<i>Hallopora elegantula</i> (Hall)			1				7						
? <i>Mesotrypa nummiformis</i> (Hall)							7			2			
Cephalopoda													
** <i>Dactyonoceras americanum</i> (Foord)													2
<i>Orthoceras</i> sp.													

** Found in quarry near Clinton exposing middle Joslin Hill

TABLE II — LIST OF JOSLIN HILL FOSSILS — continued

	1	2	3	4	5	6	7	8	9	10	11	12	13
Coelenterata													
<i>Conularia niagarensis</i> Hall	2												
<i>Cladopora?</i> sp.	6												
<i>Diplophyllum?</i> sp.								x					
<i>Paraconularia</i> sp.													
Gastropods													
<i>Murchisonia (Hormotoma)</i> sp.	1,7		8	1,4		1,4	1,3		7	1,6	1		
<i>Platyceras (Platyostoma)</i> sp.	1			1,4		1	7						
<i>Straporollus</i> sp.	1										1		
Ostracodes													
<i>Aechmina</i> sp.													
<i>Dizygopleura</i> sp. cf. <i>D. swartzii</i> Ulrich and Bassler										6			
<i>Drepanellina clarkei</i> Ulrich and Bassler			8				7		7	6			
<i>Drepanellina modesta</i> Ulrich and Bassler										6			
<i>Paracchmina abnormis</i> (Ulrich)	2									6			
<i>Paracchmina postica</i> Ulrich and Bassler	2									6			
<i>Paracchmina postica?</i> Ulrich and Bassler	2									6			
<i>Paracchmina spinosa</i> (Hall)	2									6			
<i>Vclibeyrcchia</i> sp.										6			
Pelecypods													
<i>Cornclites emaceratus</i> (Conrad)	2,6			1,2	1		1						2
<i>Ctenodonta curta</i> (Hall)			5										
<i>Ctenodonta? elliptica</i> (Hall)		x	5	1,2									
<i>Ctenodonta</i> sp. cf. <i>Ctenodonta machaeriformis</i> (Hall)	2												

TABLE II — LIST OF JOSLIN HILL FOSSILS — concluded

	1	2	3	4	5	6	7	8	9	10	11	12	13
Pelecypods (continued)													
<i>Ctenodonta</i> sp.			3		1								
<i>Cyrtodonta? alata</i> (Hall)				2			7						
" <i>Eoschizodus</i> "? sp.			5										
<i>Leptodesmia curta</i> Hall			6	1,2	1	1	1,7			1,2, 4	1		
<i>Modiolopsis ovata</i> Hall													
<i>Modiolopsis subcarinata</i> Hall													
<i>Modiolopsis</i> sp.	2		5	2	2	2,3, 4	3,5	x	3	2,4	3		
<i>Mytilarca mytiliformis</i> (Hall)							7				1		
<i>Nucula?</i> sp.				2									
<i>Pterinea</i> sp.				2									
<i>Pyrenomoeus cuneatus</i> Hall			5				7			6			
Trilobites													
<i>Calymene niagarensis</i> Hall	2			1			7						
<i>Calymene</i> sp.							1						
<i>Dalmanites limularus</i> (Green)	2											1	
<i>Trimerus (Trimerus) delphinocephalus</i> Green	1,2, 6	x	3	1	1	1	1,3, 4,7	x		2,4, 6			1
Miscellaneous													
<i>Bifungites</i> sp.	2												
<i>Butotrochis gracilis</i> (Hall)	2,6			2		4							
fucoids indet.	2			2	2	2,3, 4	3,5	x	3,4	4			
<i>Ichthyophycus tridactylus</i> Hall	6		5	2	2	4	1,7		4,7	1,6	1,3		
<i>Rusophycus bilobata</i> (Vanuxem)			8	1,2	2	1							
tentaculitid indet.	6												
<i>Spirorbis</i> sp.	2,6												



FIGURE 6. — External mold of *Rusophycus bilobata*, natural size.

Some bottom marks appear to be inorganic, resembling flute casts and striation and groove casts. Ripple marks are relatively common as is tabular cross-stratification. Para-ripples with wave lengths up to 3 feet are found in coarse-grained, fossil-fragmental dolostone layers (fig. 7), a situation similar in occurrence to those described by Bucher (1919, p. 258-268). Such ripple marks are symmetrical and there is no apparent difference in sorting between the troughs and the crests. Bucher attributed these structures to tidal currents.



FIGURE 7. — Para-ripples in coarse dolostone, Joslin Hill Member, Dawes Quarry Creek (loc. 4).

An attempt was made to determine paleocurrent directions using directional indicators including cross-stratification, ripple marks, and fossil lineations (e.g. tentaculitids and the conispiral *Murchisonia*). Forty-six determinations were made but the results are not unequivocal. Of 27 ripple mark measurements, only one lay within 20° of the east-west line and 78 percent lay within 50° of north-south, suggesting a shoreline oriented roughly along this line. The azimuths of cross-stratification were even less consistent. Hunter (1960, p. 181), however, on the basis of 21 readings for cross-beds in the "marine" Herkimer, recorded a deficiency of eastward directed orientations. He concluded that currents were to the west and northwest.

Some generalizations can be made despite the complex association of lithologies. The beds immediately beneath the contact with the Ilion, and representing the *Drepanellina clarki* Zone, are low-clastic dolostone containing the gastropod *Murchisonia* and tentaculitids, in addition to the ostracode assemblage. With the exception of ferruginous sandy dolostone just above the Kirkland at College Hill (loc. 3) west of Clinton, hematitic dolarenites and sandstones are only of importance in the middle or upper part of the Joslin Hill, above a consistently sandy zone containing *Mytilarca*, *Modiolopsis*, and other pelecypods. This zone is probably an extension of a westerly directed tongue of the Jordanville Member, and it becomes less impressive westward. At Sauquoit (loc. 7) and along South Moyer Creek, the lower third of the member consists of intercalated, fossiliferous, thin-bedded dolomitic siltstone to very fine-grained sandstone, fine-grained to coarser, crinoidal sandy and silty dolostone, and dark shale. Brachiopods, particularly *Coolinia* [*Fardenia*] and *Amphistrophia*, are the dominant faunal elements in this interval followed by gastropods (mainly *Murchisonia*), pelecypods (particularly *Modiolopsis* sp.), and tentaculitids. Restriction of fossils to certain intervals is generally not striking. The ostracodes associated with *Drepanellina clarki* (e.g. *Drepanellina modesta*, *Paraechmina postica*, *Aechmina* sp., *Dizygo-pleura* sp. cf. *D. swartzi*, and *Velibeyrichia* sp.) are limited to the uppermost few feet of Joslin Hill. Strophomenids such as *Amphistrophia*, *Coolinia* [*Fardenia*], and *Protomegastrophia* are most common in the lower part of the member.

Jordanville Member. — The Jordanville was named from outcrops along Flat Creek (loc. 14) and along the road south of Edicks (loc. 15), both exposures being near the town of Jordanville in the Richfield Springs quadrangle (Zenger, 1966, p. 1164–1165). Within the outcrop belt, the unit ranges from about 22.8 meters (75 feet) in

thickness at Spinnerville Gulf (loc. 12) to a feather edge to the east (fig. 4). The reduction of the Herkimer eastward is caused by a prominent disconformity which has eliminated all Clinton units 4 miles east of Van Hornesville (Fisher, 1960). The disconformity is so oriented that although the Jordanville is missing at Ohisa Creek (loc. 18), it reappears at Van Hornesville (loc. 19) before pinching out just east of that village (figs. 3 and 4). At all exposures of the lower contact, the Jordanville rests on the Willowvale Shale. Hematitic beds in the upper part of the Willowvale probably represent the eastern equivalents of the Kirkland but with the exception of a 0.3 meter (1-foot) bed at Ohisa Creek (loc. 18), the thin beds are not lithologically similar to that unit being less hematitic and more argillaceous. This contact is sharp and in places the basal Herkimer is conglomeratic. This situation is taken to represent a slight disconformity. The upper contact with the Salina units is also disconformable. The Lockport is absent east of Ilion Gorge. The top of the Jordanville, overlain by the Vernon Shale, at Spinnerville Gulf (loc. 12) and at Flat Creek (loc. 14), is weathered, friable, and limonitic. Farther east, south of Deck (loc. 17), the overlying Brayman Shale has a basal clayey zone containing rounded quartz grains presumably derived from the underlying Jordanville. At Ohisa Creek (loc. 18), the section is well exposed and hematitic beds of the upper Willowvale are overlain by the Brayman Shale. On Wiltse Hill (loc. 20) just east of Van Hornesville, the Sauquoit Formation is directly overlain by the Brayman, both the Willowvale and Herkimer having been removed by Silurian erosion.

The Jordanville is a consistent mass of light gray to light brownish-gray, medium to coarse-grained, mostly medium-bedded (fig. 8) mature sandstone or orthoquartzite. Thinner bedding is found in the lower part at Edicks (loc. 15) and at Deck (loc. 17). Conglomeratic layers are present throughout; the clasts are well rounded and reach pebble proportions. The unit forms high waterfalls as a consequence of its greater resistance than underlying and overlying shales. Within the Jordanville, shale is minor, occurring either as thin intercalations between quartzite intervals or as shaly partings on sandstone beds. Shale clasts are common. Greenish-gray quartzites are found at the two eastern exposures (locs. 17 and 19) and at Van Hornesville (loc. 19) there are grayish-red hematite stringers. Tabular cross-stratification occurs at various horizons but only a few exposures were suitable for the determination of their orientation. Four of five measurements showed southwest to northwest directed currents. All of Hunter's (1960, p. 181) 15 cross-bedding determina-



FIGURE 8. — Medium-bedded Jordanville Member south of Edicks.

tions from the "nonmarine" Herkimer are to the southwest or northwest.

Fossils are very rare in the unit, no definite organic remains having been reported before this study. At Van Hornesville, the writer has found the pelecypods *Modiolopsis*, *Mytilarca*, and a rhynchonellid in the upper unit (unit 3, loc. 19). These forms are typically sand dwellers. Arched bedding in the upper part of the member at Flat Creek (loc. 14) and south of Edicks (loc. 15; fig. 9) may represent stromatolites. Davis (1968) has recently reported, for the first time, stromatolites preserved in quartz sandstone.

Transitional zone. — Along Steele Creek in the Ilion Gorge (loc. 11), the Herkimer Formation reaches its maximum thickness of more than 30.5 meters (100 feet). This area includes the type section of the Herkimer as established by Chadwick (1918, p. 351) although it was neither precisely located nor described. Although a complete section is not exposed, the sequence as compiled shows an interfingering of Jordanville and Joslin Hill and also of the upper sandstones and overlying Ilion. The lower part of the section consists of 7.9 meters (26 feet) of fine-grained, dolomitic, silty sandstone and crinoidal dolostone containing *Murchisonia* and tentaculitids, and dark, fissile shale with *Modiolopsis* and *Stegerhynchus*; this unit is Joslin Hill in affinity. The middle, main mass of Herkimer is pale yellowish-brown, medium- to coarse-grained sandstone which in places is very pyritic. This portion is more than 15.2 meters (50 feet) thick and represents a westerly directed tongue of the Jordan-



FIGURE 9. — Stromatolitic (?) structures in the upper Jordanville Member, south of Edicks.

ville. The upper 9.1 meters (30 feet) is dominated by clastics and includes faunal elements that are Joslin Hill in aspect. Gray, argillaceous, locally dolomitic and hematitic sandstone with intercalated dark shales contain *Tentaculites*, *Murchisonia*, *Mytilarca*, *Ctenodonta*, *Coelospira* (?), and *Chasmatopora*. This transitional zone is very limited laterally owing to the abrupt change of facies within the Herkimer.

Stratigraphic Relations and Correlation

It is the opinion of the writer that the Kirkland should be considered a separate unit rather than a member of the Herkimer. Gillette (1947, p. 23; table I) included the Kirkland with the Herkimer as the *Paraechmina spinosa* Zone although he had no ostracode evidence for this. However, elements of the *Mastigobolbina typus* Zone (table 1) such as *Mastigobolbina* (?) and *Plethobolbina* have been found in the Kirkland or its equivalents east of Ilion Gorge. In addition, the presence of *Liocalymene clintoni* (locs. 7,11) suggests an association with the Willowvale. Farther south in the Appalachians, this trilobite does not occur above the *Mastigobolbina typus* Zone. The time relationship of the Dawes, Kirkland, and Herkimer is not clear, however. The Dawes at Lairdsville contains *Trimerus delphinocephalus*, which, so far as I know, has not been recorded below the Herkimer elsewhere in east-central New York. However, *Trimerus* has been observed in the Irondequoit limestone of western New York (Fisher, 1969, personal communication; Gillette, 1947, p. 152), this unit also representing the *Mastigobolbina typus* Zone. In addition, a form similar to *Trimerus delphinocephalus* was reported from the *M. typus* Zone near Hollidaysburg, Pennsylvania, by Ulrich and Bassler (1923, p. 362). If the ostracode occurrences and presence of *Liocalymene* properly place the eastern part of the Kirkland in the *M. typus* Zone, then either *Trimerus* in the Dawes at Lairdsville (loc. 2) is also in that zone or the Dawes and overlying Kirkland are younger in a westerly direction and would be the time equivalent of the lower Herkimer to the east. Both *Trimerus* and *Liocalymene* have been found in the Kirkland. It is felt that the restriction of *Liocalymene clintoni* to the *M. typus* Zone in this area is a more plausible hypothesis than the exclusion of *Trimerus* from it. On the accompanying correlation chart (fig. 10), the Kirkland-Joslin Hill contact is shown as essentially parallel with time lines although it is possible that the contact rises to the west with respect to time.

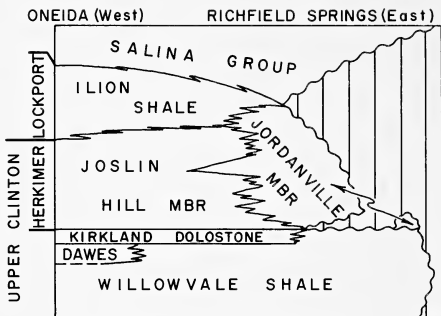


FIGURE 10.—Correlation chart for uppermost Clinton units, east-central New York. Wavy lines represent disconformities; vertical ruling represents hiatus.

Based on stratigraphic relations discussed, as well as the presence of *Mytilarca* and *Modiolopsis* in both units, the Joslin Hill and Jordanville are lateral equivalents. The interfingering of upper Herkimer and Iliion Shale indicates a partial lateral equivalence of the Clinton and Lockport Groups. Because of this relationship and because the Iliion is considered equivalent to the upper Lockport of western New York (Zenger, 1965, p. 128-132), it is possible that the upper Herkimer correlates with the lower Lockport of western New York instead of with the upper Rochester Shale as has been thought. The *Drepanellina clarki* Zone apparently overlies *Paraechmina spinosa* (Berdan and Zenger, 1965, p. 99) in the Herkimer; in the Rochester Shale, however, *Paraechmina* ranges practically to the top of the Rochester and *Drepanellina* is not known. Such relationships suggest that the uppermost Clinton in east-central New York is younger than the uppermost Clinton in western New York. Furthermore, although *Drepanellina* has not yet been found in the lower Lockport of western New York, J. W. Teeter (personal communication) has found the ostracode in the Eramosa Member of the Lockport at Hamilton, Ontario.

With regard to more southerly Appalachian sections, the Kirkland, and equivalent beds in the uppermost Willowvale, with *Liocalymene*, *Mastigobolbina* (?), and *Plethobolbina* would best correlate with the upper part of the *Mastigobolbina typus* Zone whereas the overlying Herkimer, based on Joslin Hill fossils, correlates directly with the *Drepanellina clarki* Zone of Maryland and Pennsylvania. Although lithologically similar to the Keefer Sandstone, the Herkimer appears to be, at least in part, younger than that unit.

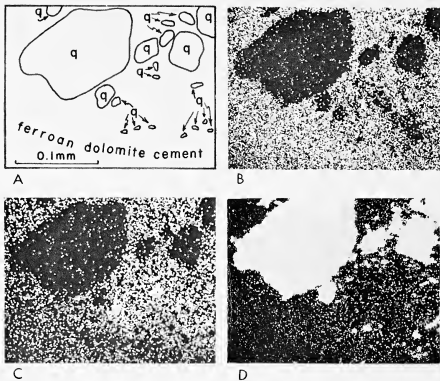


FIGURE 11. — Electron probe photomicrographs of ferroan quartzose dolomite; A, sketch of area of analysis; B, C, and D, X-ray beam scan images for MgK α , FeK α , and SiK α , respectively.

Petrology

GENERAL REMARKS

Considerable effort has been devoted to the petrology of the Kirkland by Dale (1953, p. 77-79), Hunter (1960, various pages), and others. The emphasis in this petrological study is on the Herkimer, particularly on the sandstones and dolostones.

Excluding shales, the range of quantitative insoluble residue determinations for the Joslin Hill Member is from 8 to 99 percent. The average terrigenous content of the Jordanville, however, is about 99 percent, quartz being the major constituent. Density determinations, using the air comparison pycnometer, range from 2.68 gm/cc to 2.95 gm/cc, with a mean of 2.84 for the Joslin Hill, whereas the Jordanville averages 2.70 gm/cc. The main end members of the Joslin Hill are quartz, dolomite, and much less chlorite. Calcite is minor. Typical dolomite averages about 2.86 gm/cc in density. The high density values in the Joslin Hill can be accounted for by the substitution of the ferrous iron ion primarily in dolomite and also in the chlorite (leptochlorite). Electron probe microanalysis (fig. 11) shows the coincident distribution of magnesium and iron in a quartzose dolostone. The distribution of potassium ferricyanide staining also indicates the presence of ferroan dolomite in the member.

As might be expected, a statistically significant negative correlation exists between insoluble content and density ($r = -0.8670$, $n = 72$), owing to the low density of quartz and the high density of soluble ferroan dolomite. That the ferroan dolomite has not reached the end member ankerite is indicated by the lack of any appreciable displacement of the major dolomite diffraction peak at 2.89Å.

Crushed samples of all specimens were scanned with the diffractometer; figure 12 shows X-ray diffractograms for some characteristic lithologies. Although it is difficult to distinguish between chlorite and kaolinite at normal scanning rates (Biscaye, 1964, p. 1281, 1283), peak positions at about 7.08Å ($2\theta = 12.5$) and at 3.53Å ($2\theta = 25.2$) strongly suggest chlorite. Biscaye 1964, p. 1281) has mentioned the

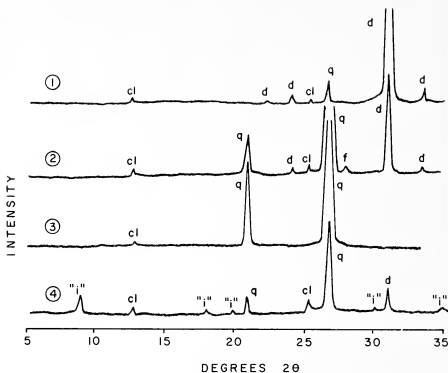


FIGURE 12. — X-ray diffractograms for (1) slightly quartzose dolostone, Joslin Hill, (2) "typical" dolomitic sandstone, Joslin Hill, (3) orthoquartzite, Jordanville, (4) shale, Joslin Hill. q = quartz, d = dolomite, cl = chlorite, "i" = "illite" Cu radiation, Ni filter; scanning rate 1°/minute

solubility of chlorite, but not kaolinite, in dilute HCl. Residues of the Herkimer, scanned after such acidization reveals the removal of these chlorite peaks. Optically, the light greenish color and low birefringence indicate chlorite. The chlorite is high in ferrous iron, as Schoen (1964, p. 859) has shown.

In figure 13, the shaded area of the triangular diagram represents the area in which the nonshaly lithologies in the Herkimer would fall with respect to quartz, ferroan dolomite, and chlorite. X-ray analysis of the shales shows the constituents to be mainly quartz, chlorite, and "illite" that may include some muscovite.

Calcite is very minor occurring in less than 25 percent of the specimens. There is a lack of a statistically significant correlation between insoluble content and calcite-dolomite ratios determined through X-ray diffraction.

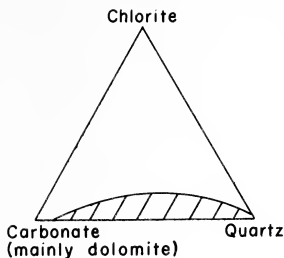


FIGURE 13. — Triangular diagram with end members of quartz, dolomite, and chlorite. Shaded area would include nonshale lithologies of the Herkimer.

THIN SECTION PETROLOGY

Friedman's (1965) terminology of crystallization textures and fabrics will be used with but slight modification. Friedman (1965, p. 648) proposed "xenotopic" for fabrics in which the majority of the constituent crystals are anhedral, "hypidiotopic" for fabrics in which the majority of crystals are subhedral, and "idiotopic" for those fabrics in which the majority are euhedral. As used by Friedman, the terms anhedral, subhedral, and euhedral refer to the degree of development of crystal faces. As Friedman pointed out (p. 653), however, a plane intercrystalline boundary between two crystals is either a crystal face of one or a compromise boundary between the two. To determine whether a plane intercrystalline boundary is a crystal face is impractical when analyzing large numbers of thin sections and a descriptive scheme to be used with a less rigorous visual inspection of crystal boundaries is valuable. Friedman's classification is modified so that the concept of "plane intercrystalline boundaries" is substituted for "crystal faces"; in this way, all straight boundaries are included, whether or not they are true crystal faces.

For purposes of environmental interpretation and discussion, it is practical to consider six microfacies. Although shales are vital when discussing environmental characteristics, they were not studied optically. The six microfacies are illustrated in figure 15 and are as follows:

(1) orthoquartzite (fig. 15a); (2) dolomitic, fossil-fragmental sandstone to quartzose biodolorudite or biodolarenite (fig. 15b); (3) dolomitic siltstone to very fine-grained sandstone (fig. 15c); (4) intraclast- and fossil-bearing dolostone (fig. 15d); (5) slightly impure sandstone (fig. 15e); and (6) partially dolomitized, hematitic biosparrudite to biosparite (fig. 15f). The first four microfacies are dominant and together with the shaly intervals comprise more than 95 percent of the Herkimer.

(1) *Orthoquartzite*.—This microfacies (fig. 15a) is represented primarily by the Jordanville Member although some orthoquartzite is found toward the middle of the Joslin Hill. Rounding and sorting of the original detrital quartz grains are excellent. Relic grains are distinguished by "dusty," microlitic cores or rims surrounded by clearer silica overgrowths. In practically all samples there is a mode between 0.12 and 0.35 mm, or in the fine or medium-grained range. This matrix also exists in conglomeratic samples which consequently have a bimodal grain-size distribution. Overgrowths result in an interlocking texture. Where the quartz grains are elongate, the long axis usually parallels the bedding. "Single" quartz grains dominate; extinction in these ranges from nonundulatory through slightly undulatory to very undulatory (Folk, 1961, p. 71). Polycrystalline grains are common and include those types mentioned by Blatt and Christie (1963, p. 561). These are: (1) grains composed of elongate elements with close optical orientation, (2) those in which each unit has nonundulatory extinction but a different extinction position from that of its neighbors, and (3) those with crystal units having strong undulatory extinction and with sutured contacts (fig. 16a). Blatt and Christie (1963) have presented strong evidence indicating that caution is necessary when using the nature of the extinction and crystallinity to imply a particular source. However, in this and other microfacies, distinctly foliated quartz grains (fig. 16b) indicate a contribution from a metamorphic source.

Minor chlorite cement occurs primarily as small (silt-sized) greenish blades. In places these corrode secondary silica whereas in others, secondary silica overgrowths include chloritic material. Hematite, after chlorite, may form rims around detrital cores and in turn

are surrounded by secondary silica. Minor dolomite having the geometric aspect of cement is present in some samples. Pyrite, muscovite, and biotite, and carbonaceous bodies are uncommon. Shale clasts are present in some sections. Zircon is the predominant heavy mineral. Porosity is highest in this microfacies and exists either as intergranular voids or along partings.

(2) *Dolomitic, fossil-fragmental sandstone to quartzose biodolomite or biodolarenite.*—This diverse microfacies (fig. 15b) is unquestionably the dominant one in the Joslin Hill Member and has no representation in the Jordanville. Terrigenous content ranges from 24 to 80 percent and there is a gradation across the 50 percent boundary used to separate detrital rocks from carbonates.

Transported constituents consist of terrigenous quartz grains plus various allochems (Folk, 1959), including bioclasts and less common intraclasts (few, if any, oolites and no pellets were observed in the Herkimer; oolites are present in the Kirkland). Quartz grains and allochems tend to lie with their long axes parallel with the bedding. Quartz is an important constituent of all samples; allochems vary from constituting a few percent up to 40 percent of a sample. The crystallinity and nature of extinction of quartz grains are similar to those properties in the orthoquartzite microfacies. A foliated, metamorphic grain is shown in fig. 16b. The size range of quartz grains is primarily from very fine sand through the sand-sized categories, into granule sized (see Folk, 1961, p. 24). Commonly, two modes exist in the grain-sized distribution permitting a separation of grains from matrix. In such samples there is a lower mode in either the very fine sand or coarse silt range and an accompanying mode in the medium or coarse sand range. Not uncommonly the two modes are represented by alternate laminations. The finer grained quartz is subangular in contrast with the better rounded, coarser grains. Corrosion of the quartz grains by dolomite or chlorite (fig. 16c) is severe in places.

Pelmatozoan fragments are the dominant bioclasts followed by fragmentary or intact bryozoa zoaria, many of which are out of growth position. Another common type is the gastropod *Murchisonia* preserved either as single whorls or as two or three connected whorls. Brachiopod and pelecypod remains are rare. The pelmatozoan fragments usually occur as pseudomorphic replacement (Lucia, 1962, p. 855) of calcite by dolomite. These bioclasts may be surrounded by optically continuous dolomite (fig. 16d). Bryozoan clasts commonly consist of sparry zooecial walls with micritic or chloritic material in the voids. Many specimens show laminations of bioclast-rich

layers alternating with finer, more quartzose, less fossiliferous ones. Bioclasts are most common in the medium and coarse sand sizes but occur also in the pebble range.

One kind of intraclast consists of chloritic material in which are embedded corroded quartz grains (fig. 16e) and pelmatozoan fragments. Another is the "clay gall" or shale clast consisting of argillaceous matter and silt-sized quartz grains. Other transported constituents are minor grains of plagioclase, mica, rare heavy minerals including zircon, tourmaline, and sphene, and carbonaceous flakes.

The major orthochem is ferroan dolomite, which constitutes from 10 to 60 percent of the rocks. As groundmass material, dolomite consists of a xenotopic to hypidiotopic fabric ranging from decimicron-size to centimicron-size. Very little dolomite is micritic but is predominantly spar. Decimicron-sized dolomite appears as anhedral grains with corroded edges; many of these may have undergone some transportation. Coarser dolospar has the geometry of cement. Quartz grains may float in the dolomite but more commonly are dominant where the dolomite has the appearance of cement. Coarse to very coarse spar also occurs in pockets, most of which are probably void fillings, and as optically continuous spar around pelmatozoan fragments.

Chlorite occurs either as small, silt-sized blades forming a corrosive selvage around quartz grains or as more homogeneous patches of cement. The mineral forms up to 10 percent of some specimens but is generally less abundant. In places dolomite grains are corroded by chlorite (fig. 16e).

Secondary quartz overgrowths are not so common as in the previous microfacies, but become most significant in the dolomitic sandstones where quartz grains are in contact rather than floating in the dolomitic matrix. There are a few instances in which dolomite grains have been "engulfed" by secondary quartz overgrowths, some of which have euhedral faces (fig. 16f).

Hematite is a minor but practically ubiquitous mineral. It occurs primarily as rims around zoecial openings of bryozoa, within the fenestrate structure of pelmatozoan fragments (fig. 16d), as replacement of fossils, and as rims around quartz grains in places followed by secondary quartz overgrowths.

Pyrite exists as euhedral grains, averaging 0.38 mm in size, replacing portions of pelmatozoans, bryozoans, or apparently even dolomitic matrix (fig. 17a). It occurs also as a replacement of irregularly shaped organic flakes. Calcite is very rare, existing as isolated grains of spar in only a few samples.

(3) *Dolomitic siltstone to very fine-grained sandstone.*— This microfacies is restricted to the Joslin Hill. Many of the characteristic features are shared with the microfacies just discussed.

Quartz grains are commonly angular to subangular and are corroded by both chlorite and dolomite. Polycrystalline grains are not abundant, probably as a consequence of the smaller grain size; most fall within the range 0.04–0.15 mm. The average quartz content is between 60 and 70 percent. Secondary silica is minor.

Bioclasts become more important as the quartz content decreases. Where present, they are aligned parallel with the bedding and occur in laminations separated by more quartzose, less fossiliferous layers. The dolomitic "groundmass" ranges from less than 10 percent to more than 40 percent. It occurs as subhedral grains which are somewhat coarser than the associated quartz or as coarser, interlocking crystals around the clastic grains. Both dolomite and quartz are corroded by argillaceous material, particularly chlorite, which is found most typically as small blades around quartz grains but also exists as homogeneous cement. Minor constituents include plagioclase, muscovite, carbonaceous bodies, zircon, and sphene.

(4) *Intraclast- and fossil-bearing dolostone.* — This microfacies (fig. 15d), restricted to the upper part of the Joslin Hill Member, is one of two represented primarily by carbonate textures. The terrigenous content ranges from 8 to 16 percent. Fossil fragments observed up to 4 mm in greatest dimension constitute between 35 and 50 percent of the samples; these are pelmatozoan fragments, whorls of *Murchisonia* (fig. 17b), pieces of bryozoa, fillings of shells, of tentaculitids, and ostracodes. Preservation of fossils ranges from good to poor. There is not such a noticeable tendency for fossils to be oriented with their long axes parallel with bedding. Argillaceous intraclasts are present and pockets of coarser dolomite mosaic, with vague boundaries, represent either clasts or "micro"-pseudobreccia (Bathurst, 1959, p. 371).

Dolomite is micritic only in the voids of fossil fragments (fig. 17b). Much of the dolomite is "dusty" and occasional grains show a rhomb-shaped area within surrounded by clear spar, similar to such features described by Murray (1964). Quartz is generally silt-sized or in the very fine sand range and usually constitutes less than 10 percent of each specimen. Authigenic chlorite is very rare. Hematite occurs in fossil voids and pyrite as disseminated flakes or replacing carbonate grains. Calcite, as isolated grains of spar, is minor.

(5) *Slightly impure sandstone*. — This microfacies includes a variety of minor sandstone types mostly in the Joslin Hill but with some representation from the Jordanville. It is very similar to the orthoquartzite microfacies so far as characteristics of the quartz grains is concerned, but differs from it in the presence of more appreciable amounts of dolomitic, calcareous, and strontianitic cement. Chlorite is ubiquitous as a minor constituent. Fossil fragments are practically lacking.

A type having most of the above characteristics is hematitic, dolomitic sandstone. The hematite occurs as rims around the original quartz grains, in turn followed by secondary silica (fig. 15e). The hematite replaces tiny chlorite blades, and, in places, dolomite in the matrix. Pyrite grains transect hematitic areas. Zircon, biotite, and dark carbonaceous chips are present but uncommon in these impure sandstones.

(6) *Dolomitic, hematitic biosparrudite to biosparitic*. — This microfacies (fig. 15f) occurs as thin beds at the westernmost locality in the Joslin Hill. It is characterized by the abundance of calcite and by the lack of terrigenous quartz. The common bioclasts are pelmatozoans, brachiopods, and *Murchisonia*.

Intraclasts are rare, and micrite is minor. Void-filling spar is common both within fossils and in the space beneath brachiopod shells where the growth is commonly as prismatic crystals. Most pelmatozoan fragments consist of a single calcite crystal surrounded by optically continuous calcite as rim cement. Much of the calcite is ferroan.

Quantitative X-ray diffraction analysis of two samples indicated a dolomite content of 16 and 32 percent. Dolomite occurs as rhomb-shaped crystals within the micritic filling of fossil voids, as subhedral to euhedral grains in the calcite matrix or cutting across shell walls (fig. 17d), and together with calcite as secondary deposits in voids.

Hematite is very common. It occurs within void spaces in pelmatozoans and gastropods, within orthid brachiopod shells as concentrations along the punctae, and along the edges and well into the interiors of fossil fragments. Hematite along the shell margins occurs in micron-sized carbonate that may represent micrite envelopes (Bathurst, 1966). Limonite occurs as a replacement of carbonate material.

All quartz is authigenic, consisting of euhedral crystals (fig. 15f) 0.08 to 0.50 mm in length within brachiopod shells. The base of the crystals, which contain calcite inclusions, is along the shell margin, the apices being directed inward.

DIAGENESIS

Most studies of Holocene (Recent) carbonate sediments involve low-terrigenous material. However, as Chave (1967, p. 200-201) pointed out, to "rock-type" geologists, a carbonate rock may contain up to 50 percent terrigenous matter. Such compositions, coupled with the nearly complete dolomitization of the Herkimer, make difficult any attempt to discuss diagenesis in the light of present-day processes. The determination of paragenesis is based primarily on textural relations.

With the exception of the predominantly calcitic microfacies 6, much of the earlier diagenesis is clouded or lost through neomorphism (Folk, 1965, p. 21) or replacement. Neomorphism includes all transformations between one mineral and itself or a polymorph, with particular emphasis on the common carbonate minerals. As is indicated by the dolomitized fossils, that dolomite is of definite replacement origin; it is probable that the matrix dolomite is also of a replacement variety although this cannot be proven. Microfacies 6, which is but partially dolomitized, reveals some significant paragenetic relations which may be extrapolated to other microfacies although this microfacies has such characteristics that it cannot be considered simply as a less dolomitized equivalent of another microfacies.

On the basis of relations seen in microfacies 6, pelmatozoan clasts were transported as calcite crystals and overgrowths later developed around them as rim cement. Some hematitization occurred very early in diagenesis, probably prior to rim cementation, as revealed by hematite within the fenestrate structure of pelmatozoan crystals (fig. 16d) which are surrounded by the clear rim cement. Dolomite rhombs transecting the hematitized margins of brachiopods indicate that this hematitization preceded dolomitization (fig. 17d).

For other evidence of the diagenetic sequence, one must turn to the dolomitic microfacies. Because in microfacies 6 pelmatozoan plates are followed by calcite overgrowths, it seems most logical to assume that pseudomorphic replacement by dolomite (Lucia, 1962, p. 861) of the plate, as well as of the rim cement, occurred after deposition of the bioclasts and after some hematitization. The occurrence, within the replaced fossil, of euhedral dolomite grains which extinguish at different positions than the main mass suggests later possible "degrading recrystallization" (Folk, 1965, p. 23) of the dolomite (fig. 17c). The common preservation of the original fene-

strate structure in dolomitized pelmatozoan plates (fig. 16d) suggests early dolomitization. Early dolomitization is further suggested by the excellent preservation of many bryozoa zooecia (fig. 17e) which have walls composed of sparry dolomite crystals that are restricted to the walls. However, in some instances, dolomite crystals cut across the walls indicating subsequent recrystallization and some bryozoa are more obliterated than others (fig. 17f), indicating a more intensive dolomitization. The origin of the dolomite of the "groundmass" presents more of a problem. It is very possible that the subhedral grains of dolomite are detrital. Amsbury (1962) described terrigenous dolomite grains in Cretaceous rocks of Texas and concluded (p. 14) that the small detrital grains of dolomite could not be distinguished from silt-sized authigenic dolomite. In the case of the Herkimer, it is improbable that the dolomite, or perhaps calcite grains prior to dolomitization, have a terrigenous origin; the source would more likely be intrabasinal. Much of the dolomite, however, has the geometric aspect of cement, that is, large crystals binding quartz grains or bioclasts. Especially where quartz grains are abundant and commonly in contact, the dolomite is in the form of cement and it seems likely that the dolomite represents replaced calcite cement. On the other hand, in some samples the packing of quartz grains and bioclasts is sufficiently "loose" that the original carbonate probably was fine-grained carbonate sediment deposited with the allochemical grains and acting as support for them. This would suggest later aggrading neomorphism (Folk, 1965, p. 22) resulting in coarser spar. It seems possible, however, that where clastic grains or allochems are slightly floating, the effect could be caused by the growth of cement forcing grains apart (Krinsley and Donahue, 1968, p. 861).

Chlorite, as blades or as homogeneous cement, is considered to be authigenic and relatively early diagenetic. Wherever chlorite is in contact with quartz it corrodes it severely (fig. 16c); in places it corrodes dolomite grains (fig. 16e) indicating that the chlorite postdates much of the early diagenetic dolomitization. As dolomite content increases, chlorite content tends to decrease. The spatial relationships suggest that chlorite was precipitated in voids not previously occupied by dolomite, or, in other words, after dolomitization. Chlorite rims in the quartzites and slightly impure sandstones are commonly followed by secondary quartz overgrowths (fig. 16c) suggesting that the secondary silica followed initial formation of the chlorite. Similar overgrowths commonly "trap" euhedral dolomite (fig. 16f) indicating that secondary silica postdates dolomitization.

Such chlorite rims, outlining the detrital quartz grains, are often partially to completely replaced by hematite (fig. 15e). This later stage hematitization also seems to be represented by the replacement of some dolomitic "groundmass" by hematite and more locally by the corrosion of dolomite grains by hematite. Later recrystallization of the chlorite has corroded secondary overgrowths. The last mineral to form in the paragenetic sequence is pyrite, euhedral crystals of which may be seen to transect dolomite, chlorite, and hematite (fig. 17a). Figure 14 is an estimation of the timing of the various diagenetic processes relative to one another.

A significant factor is the presence of intraclasts showing many diagenetic features similar to the rocks in which they are enclosed. For example, chloritic clasts containing corroded quartz and dolomite fragments (fig. 16e) probably represent Joslin Hill intraclasts. This possibly indicates that many diagenetic changes necessarily occurred while the sediment was at or near the sediment-water interface. On the other hand, some of the diagenesis may well have gone on after incorporation of the clast in the matrix. It is of interest to note that later diagenetic changes, such as secondary silicification and pyritization were not observed in the clasts.

Hunter (1960, p. 195-200) hypothesized that the iron for the Clinton iron ores was provided by thorough weathering of mainly crystalline rocks, of not unusually high iron content. He envisioned deposition as occurring when the acidic river waters reached the sea. Schoen (1965, p. 177) could not accept this theory mainly because the ironstones contain less terrigenous material than most other Clin-

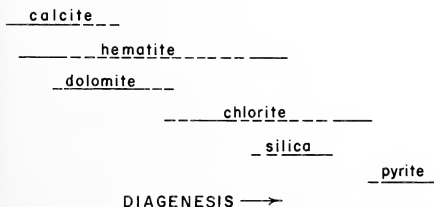


FIGURE 14. — Paragenetic sequence. Dashed line connects diagenetic stages for which there is textural evidence.

ton rocks, an unlikely situation near the mouths of rivers. He suggested that submarine discharge of iron-rich ground water could have been the medium.

Several writers (Murray, 1964; Murray and Lucia, 1967; Weyl, 1960) stressed the importance of "local source" dolomitization. Weyl (1960, p. 87) pointed out that since most ground waters contain little total carbonate, it could be supplied by local solution of carbonate with a mole-for-mole exchange of calcium by magnesium. In such instances, porosity would be produced in a dolomitized limestone owing to the fact that excess carbonate is necessary to account for the 12 percent volume decrease when calcite is converted to dolomite (Murray, 1964, p. 391). According to Murray and Lucia (1967, p. 29), if the sediment being dolomitized is the only source of carbonate (i.e., local source), porosity can be formed and maintained. If, however, the carbonate is brought in with the dolomitizing water (distant-source), porosity would be destroyed. Porosity certainly is minimal in the dolomitic rock of the Joslin Hill but it is believed that compaction, recrystallization of dolomite, and precipitation of chlorite and secondary silica could have destroyed any porosity present. Some evidence of compaction exists in the form of some stylolitic contacts between grains, and quartz grains penetrating fossil fragments and intraclasts. A local source of carbonate for dolomitization is considered feasible for the Herkimer.

Of late there has accumulated a considerable mass of literature on the recent occurrences of supratidal dolostone. In fact, Friedman and Sanders (p. 267) considered most dolostones to be evaporitic deposits. Hypersaline brines would act as the dolomitizing agent, either through capillary concentration, as in caliche formation, or through "seepage refluxion" (Adams and Rhodes, 1960). This later mechanism must be considered as a possibility for dolomitization of the Herkimer. The main dolomitization, in the Joslin Hill Member, is separated from the younger Salina hypersaline units by the thin Ilion Shale. Consequently, Mg-rich brines may have percolated downward from the Salina evaporites providing the possibility of dolomitization in the underlying sediments. There is little direct evidence for the passage of these fluids through the Joslin Hill. However, gypsum and celestite were reported by Vanuxem (1842, p. 81), from what is now the Jordanville Member, and Hunter (1960, p. 20) also reported celestite. It is possible that this occurrence resulted from percolating waters moving downward from the Salina Group above, but the Jordanville has little dolomite and, as mentioned above, there is no indication that the more prominent dolomitization of the Joslin Hill was accomplished

by such a means. Furthermore, the Ilion Shale, which separates the underlying Joslin Hill and overlying Salina, would have been a relatively impervious barrier to downward percolating brines.

There have been many recent attempts, perhaps overextended at times (Zenger, 1970), to find ancient analogs of recent supratidal dolostones. Joslin Hill carbonates did not accumulate in the supratidal zone. Not only do the abundant fossils and ripple marks bear out this contention, but there is a complete lack of typical supratidal features such as mud cracks, burrows, and stromatolites.

Lindholm (1969) recently proposed a possible terrigenous origin, combined with subsequent diagenetic overgrowths, for ancient dolostones that show evidence of subtidal accumulation. In many thin sections of Joslin Hill samples there is at least a rough correlation between the grain sizes of quartz and dolomite. This, coupled with the common occurrence of cross laminations and ripple marks, could constitute evidence in favor of Lindholm's hypothesis. However, it is more likely that these particular clastic textures and structures resulted from the movement above wave base of carbonate particles that formed within the basin.

It is well known that echinoderms contain high percentages of $MgCO_3$ in the calcite lattice (Chave, 1952; Chave, 1964). The abundant high-magnesian pelmatozoan fragments, and grains abraded from them, could act as "starters" (Fairbridge, 1957, p. 125), or nuclei, for further precipitation of $MgCO_3$ from alkaline interstitial waters and lead to the eventual development of the mineral dolomite. For example, Schlanger (1957) described the localization of dolomite crystals within segments of Eocene coralline algae of high-magnesian calcite.

Finally, it seems quite likely that his Mg/Ca ratios are essential for dolomitization, although perhaps not hypersalinity. In the Coorang of Australia, maximum dolomite formation occurs when salinity is about that of normal sea water (Skinner, 1963). In addition, Atwood and Bubb (1968) have reported that the salinity and chemistry of interstitial waters within Holocene supratidal dolomitic sediments at Sugarloaf Key, Florida, are essentially those of sea water. Gaines (1970, personal communication) has suggested that possibly in the ancient, very shallow epeiric seas characterized by high surface/volume ratios, the deposition of calcite, or aragonite, would be sufficient to raise the Mg/Ca ratio in the water to the point where dolomitization might become kinetically possible.

Economic Aspects

The interfingering of relatively porous quartzitic sandstone with more impervious dolostone, dolomitic sandstone, and shale would theoretically provide subsurface conditions suitable for oil or gas accumulation. Sandstone tongues are directed from the east with a minor dip away from the source. However, it would seem likely that local changes in dip in the subsurface could provide the appropriate attitude for natural gas entrapment along the contact between facies.

To date, however, little gas has been reported from the Herkimer (A. M. Van Tyne, personal communication). Of 22 wells in which the Herkimer was recognized, only eight reported some gas. Of these, only one has produced commercially (located near West Eaton south of the Oneida quadrangle; (fig. 1)). For a time, this well produced 1 million cubic feet/day (G. P. Borland, personal communication) and since 1961 has produced 475 million cubic feet of natural gas. It should be mentioned, however, that many wells bottom in the younger productive Oriskany, there being no information of the productivity of the underlying Herkimer.

Thin, even beds within the Joslin Hill Member could provide good flagstones (they have been used for this purpose locally around Clinton) and some thicker beds might be used as building stone of rather attractive quality. However, as evidenced by weathered rinds on many beds, the ferroan content of much of the dolomite eventually results in oxidation of the iron; the length of time that would be necessary for this reaction is not known.

The Joslin Hill probably should not be considered as a good prospect for aggregate in concrete or in bituminous mixes. Reaction between the alkalis in cement and silicate minerals may result in expansion, cracking, and decrease in strength of the concrete (Krynine and Judd, 1957, p. 330). Although the most susceptible silicate minerals are opal and chalcedony, quartz, if fractured, could be reactive. With but few exceptions, the Joslin Hill samples contain considerable quartz. The quartz does not appear to be fractured and might not be reactive with the alkalis released from the cement; this

point should be investigated more thoroughly before any attempt is made to use this rock as aggregate. It is known that rocks containing high percentages of silicate minerals, including quartz, are "hydrophilic" (Krynine and Judd, 1957, p. 338), that is, have a high water-sorption ability but a low bitumen sorption and are generally unsuitable for mixing with bitumens, such as asphalt.

Furthermore, in many sections of the Joslin Hill, the intercalated shale would have to be considered in any economic venture. Its removal could result in prohibitive costs.

As mentioned previously, the Jordanville Member consists predominantly of orthoquartzite. Such rock would not ordinarily provide an aggregate material for reasons mentioned above and because sandstones generally have a low wearing value (Krynine and Judd, 1957, p. 338). Consisting primarily of quartz and being quite uniform, the Jordanville offers some promise of utilization as a glass sand. The fine- to medium-grain size and the purity of the main, white Jordanville are important factors in this regard. Iron content is generally low with the exception of some pyritic beds in the zone transitional to the Joslin Hill and hematitic beds at Van Hornesville. The very minor shales and beds containing clay galls do not seem to pose a serious problem.

Conclusions

The Jordanville Member, represented primarily by the orthoquartzite microfaces, has been considered as terrestrial (fluvial) by Hunter (1960), although he considered the possibility of a transitional environment. The discovery of marine elements (a rhynchonellid brachiopod and two mytiloid pelecypods) in the member at Van Hornesville do not positively refute the concept of a nonmarine environment; such forms might have existed within or slightly below the intertidal zone and could easily have been washed up on a beach. Their presence certainly attests to a proximity of the shoreline. Although shells, both intact and broken, may be common on the surfaces of many sandy beaches, it seems to be a rule that fossils are extremely rare in ancient beaches now represented by quartzose sandstone (Dunbar and Rodgers, 1957, p. 68). Even in recent beach deposits with a litter of shell material on the surface, immediately beneath this surface there is a great reduction in such remains. The occurrence of hemispherical structures that may be stromatolites preserved in orthoquartzite (fig. 9) suggests an intertidal to supratidal environment for the Jordanville. It is here suggested that the Jordanville represents a beach (intertidal) environment with possible infranericitic or supratidal portions.

Evidence in the nonshale intervals of the Joslin Hill indicates a high-energy, near-shore, relatively shallow-water environment west of the Jordanville depositional site. Such evidence consists of elongate marine bioclasts lying with their long axes parallel with the bedding, the large size (up to pebble size) and good rounding of these fragments, the abundance of rounded quartz grains, and the general lack of carbonate mud. Most of these characteristics could be explained individually in ways other than by agitation in shallow water but collectively they seem to be unequivocal. Field evidence such as pararipples and cross-stratification further support this contention. Microfacies 3 (dolomitic siltstone to very fine-grained sandstone) as well as the shales probably reflect periods of less energy, although it is conceivable that they accumulated through the action of unpreserved

holdfasts. The complex association of the coarse-grained microfacies is taken to represent slight changes in the ratio of bioclasts to terrigenous grains, those being richer in bioclasts representing slightly more offshore positions. The Joslin Hill, then, reflects minor oscillations of the shoreline that lay just to the east for much of Herkimer time.

Although previous workers envisioned a disconformity between the western Herkimer, or Joslin Hill, and overlying Lockport, it has been demonstrated that the relations are those of a facies change (figs. 4, 10). Some interfingering also has been observed between the Ilion and the overlying Vernon Shale of the Salina. Consequently there was a much closer time and space relationship between Clinton, Lockport, and Salina units than was formerly believed.

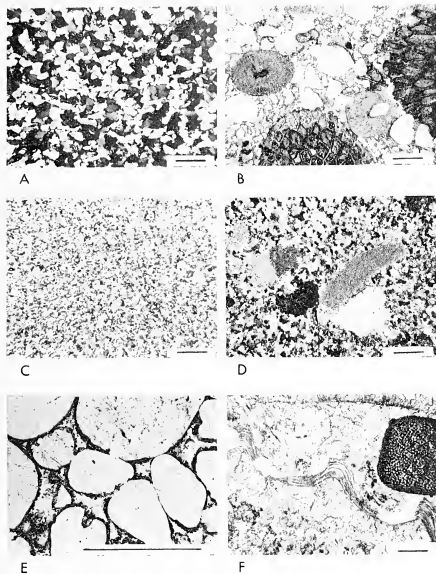


FIGURE 15. (length of line = 0.5 mm)

IA. Microfacies 1; orthoquartzite; crossed polarizers. IB. Microfacies 2; dolomitic, fossil fragmental sandstone; note crinoid and bryozoan fragments; ordinary light. IC. Microfacies 3; dolomitic siltstone; crossed polarizers. ID. Microfacies 4; crinoid-bearing dolostone; crossed polarizers. IE. Microfacies 5; hematitic sandstone; note hematite (after chlorite), outlining relict quartz grains, followed by secondary silica; plane polarized. IF. Microfacies 6; dolomitic limestone; note hematitized crinoid fragment and euhedral quartz crystals replacing brachiopod shells plane polarized.

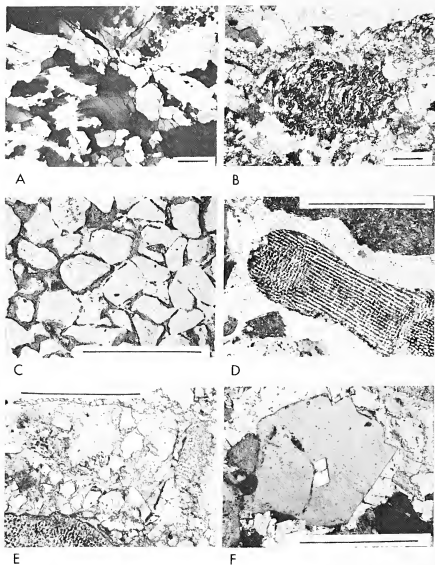


FIGURE 16 (length of line = 0.5 mm)

IA. Polycrystalline quartz (left center) in conglomeratic ortho-quartzite; crossed polarizers. IB. Foliated quartz clast in microfacies 2, Joslin Hill Member; crossed polarizers. IC. Corrosion of quartz by chlorite followed by secondary silica, Joslin Hill Member; plane polarized. ID. Hematitization within fenestrate structure of dolomitized pelmatozoan fragment; optically continuous rim cement surrounding clast; Joslin Hill Member, crossed polarizers. IE. Portion of clast with chlorite corroding quartz grains and larger dolomite grain at top of clast; Joslin Hill Member; plane polarized. IF. Euhedral dolomite grain surrounded by secondary silica with euhedral faces; Joslin Hill Member; crossed polarizers.

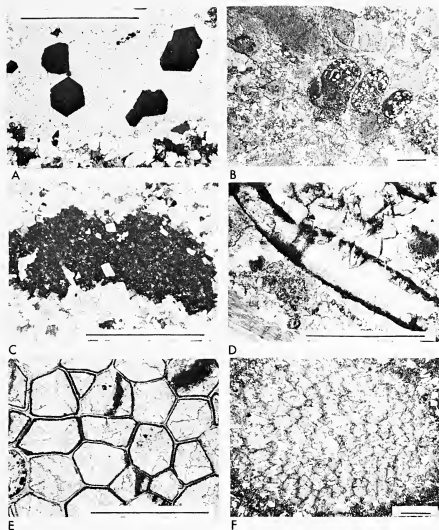


FIGURE 17 (length of line = 0.5 mm)

IA. Pyrite euhedra replacing dolomite of a crinoid fragment; note quartz corroded by dolomite along margin; Joslin Hill Member; crossed polarizers. IB. *Murchisonia* with whorls filled with finer dolomite than that outside shell; note abundance of quartz grains within shell; Joslin Hill Member; ordinary light. IC. Dolomite rhombs within pseudomorphically replaced (dolomite) crinoid fragment (dark, at extinction position); Joslin Hill Member; crossed polarizers. ID. Dolomite rhomb (right center) cutting across hematitized margin of fragment; Joslin Hill Member; plane polarized. IE. Well preserved, though dolomitized, bryozoan walls with sparry zoecial fillings; Joslin Hill Member; ordinary light. IF. Nearly obliterated bryozoan zoarium; Joslin Hill Member; plane polarized.

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Appendix

Locations of Sections of Uppermost Clinton and Adjacent Units.

1. Abandoned quarries and small exposures of Herkimer along Stony Creek beginning 91.4 meters (300 feet) north of east-west secondary road, and west of Route 365, extending to abandoned quarry just south of creek about 274.3 meters (900 feet) east of Route 365; from 3.2 to 4 kilometers (2 to 2.5 miles) SW of Verona; C 1/9 Oneida 15' quadrangle (NW 1/9 Vernon 7½' quadrangle); lowest exposure of Herkimer (Joslin Hill Member) at about 470 feet. Farther south, Herkimer-Ilion contact (at about 425 foot elevation) exposed in bank of Sconodoa Creek about 182.8–274.3 meters (600–900 feet) west of Route 365 about 1.6 kilometers (1 mile) east of Oneida, N 1/9 Oneida 15' quadrangle (NE 1/9 Oneida 7½' quadrangle).
2. Section, with considerable covered intervals, along stream flowing north to Lairdsville at which points it bends toward the east; about 5.6 kilometers (3.5 miles) NW of Clinton; SW 1/9 Rome 15' quadrangle (C 1/9 Clinton 7½' quadrangle); Willowvale, Dawes, Kirkland, Herkimer (Joslin Hill Member), and Ilion; base of Herkimer at about 660 feet.
3. East-flowing tributary of Oriskany Creek on north side of College Hill, 1.1 kilometers (0.7 mile) north of Route 412, just west of Clinton; S 1/9 Rome 15' quadrangle (E 1/9 Clinton 7½' quadrangle); Kirkland, Herkimer (Joslin Hill Member), Ilion; Herkimer-Ilion contact at about 740 feet.
4. Sherman Brook (known also as Dawes Quarry Creek) both east and west of bridge on north-south road (Dawes Ave.) which crosses creek 2.8 kilometers (1.8 miles) east of village square in Clinton; C 1/9 Rome 15' quadrangle (W 1/9 Utica West 7½' quadrangle); upper Willowvale, Dawes, Kirkland, lower and middle Herkimer (Joslin Hill Member); base of Dawes at about 685 feet.
5. Section along "The Glen," an east-flowing tributary of Sauquoit Creek at Chadwicks (formerly known as Willowvale), 3.2 kilometers

(2 miles) south of New Hartford; SE 1/9 Rome 15' quadrangle (SE 1/9 Utica West 7½' quadrangle); Willowvale, Kirkland, lower Herkimer (Joslin Hill Member); base of Herkimer at about 815 feet.

6. Northeast-flowing tributary of Sauquoit Creek parallel to and about 0.8 kilometer (0.5 mile) south of Grange Road in village of Chadwicks; SE 1/9 Rome 15' quadrangle (SE 1/9 Utica West 7½' quadrangle); Herkimer, Ilion; base of Herkimer (Joslin Hill Member) at about 790 feet.

7. West-flowing tributary of Sauquoit Creek, midway between and parallel to Roberts Road and Laughlin Road, about 1.6 kilometers (1 mile) NNE of Sauquoit; SE 1/9 Rome 15' quadrangle and SW 1/9 Utica 15' quadrangle (SE 1/9 Utica West 7½' quadrangle and SW 1/9 Utica East 7½' quadrangle, respectively); Willowvale, Kirkland, Herkimer (Joslin Hill Member), Ilion; base of Herkimer just below 840 feet.

8. Abandoned quarry in middle (?) Herkimer (Joslin Hill Member) just east of Tilden Road about 0.24 kilometer (0.15 mile) northeast of junction of Tilden and Higby Roads on hill overlooking Utica; SW 1/9 Utica 15' quadrangle (W 1/9 Utica East 7½' quadrangle); top of quarry at about 1130 feet; similar quarry just west of Tilden Road.

9. Section along Starch Factory Creek and west-flowing tributary from 1.2-1.6 kilometers (0.8 to 1.0 mile) NW of Stewart Corners; SW 1/9 Utica 15' quadrangle (C 1/9 Utica East 7½' quadrangle); Kirkland, Herkimer (Joslin Hill Member), and Ilion; base of Herkimer at about 1105 feet.

10. South branch of Moyer Creek about 2.1 kilometers (1.3 miles) ENE of Parker Corners; S 1/9 Utica 15' quadrangle (SE 1/9 Utica East 7½' quadrangle); Willowvale, Kirkland, Herkimer (Joslin Hill Member), Ilion; base of Herkimer at about 1000 feet.

11. Composite section along Steele Creek (Ilion Gorge), a northeast-flowing tributary of the Mohawk River, between 4.8-5.6 kilometers (3-3.5 miles) SW of Ilion; data taken from the following: SE-flowing tributary of Steele Creek immediately SW of Ilion Fish and Game club on Barringer Road, uppermost Herkimer at about 1090 feet; abandoned quarry immediately north of bend in Barringer Road 1.6 kilometers (1 mile) ESE of Kinne Corners, top of quarry at about 1080; banks of Steele Creek proper between 915 and 930 feet about one-half mile north of Beckus Gulf; also ledges on hills between

these localities, on northwest side of Steele Creek; upper Willowvale, Kirkland, Herkimer (Joslin Hill and Jordanville transitional), Ilion.

12. Section along and above 35-foot waterfall in Spinnerville Gulf, 1.1 kilometers (0.7 mile) NW of Spinnerville; NE 1/9 Winfield 15' quadrangle (N 1/9 Millers Mills 7½' quadrangle); Herkimer (Jordanville Member) and lower Vernon, top of Herkimer at about 1190 feet.

13. Discontinuous section along northeast-flowing tributary of Fulmer Creek southwest of Mason Road crossing; NE 1/9 Winfield quadrangle (NE 1/9 Millers Mills 7½' quadrangle); upper Willowvale, Kirkland (?), Herkimer (Jordanville Member); top of Herkimer (not exposed) at about 1240 feet.

14. Flat Creek just north of paved road 4 kilometers (2.5 miles) NNW of Jordanville; NW 1/9 Richfield Springs 15' quadrangle (W 1/9 Jordanville 7½' quadrangle); Willowvale, Herkimer (Jordanville Member), Vernon; top of Herkimer (Jordanville Member) capping falls at about 1250 feet.

15. Roadcut along sharp bend in paved road over Rock Hill 1.6 kilometers (1 mile) south of Edicks; NW 1/9 Richfield Springs 15' quadrangle (C 1/9 Jordanville 7½' quadrangle); Herkimer (Jordanville Member); top of exposure (top of Herkimer not exposed) at about 1350 feet.

16. Section along west fork of north-flowing creek at waterfall about 1.9 kilometers (1.2 miles) SSE of Edicks; NW 1/9 Richfield Springs 15' quadrangle (C 1/9 Jordanville 7½' quadrangle); upper Willowvale, lower Herkimer (Jordanville Member); Willowvale-Herkimer contact at about 1310 feet.

17. Section along waterfall 0.48 kilometer (0.3 mile) south of settlement of Deck; N 1/9 Richfield Springs 15' quadrangle (E 1/9 Jordanville 7½' quadrangle); Herkimer (Jordanville Member), Brayman; top of Herkimer at about 1400 feet.

18. Discontinuous section along Ohisa Creek from just east of road crossing 3.4 kilometers (2.1 miles) SW of Cramer Corners on downstream to about 1300-foot elevation; N 1/9 Richfield Springs 15' quadrangle (W 1/9 Van Hornesville 7½' quadrangle); Willowvale, Brayman.

19. Sharp bend in Route 80 on western margin of village of Van Hornesville, E 1/9 Richfield Springs 15' quadrangle (S 1/9 Van Hornesville 7½' quadrangle); Willowvale, Herkimer (Jordanville Member), Brayman; base of Herkimer at about 1215 feet.

20. Sporadic outcrops along west fork of northeast-flowing stream on Wiltse Hill just north of school No. 7 about 3.5 kilometers (2.2 miles) south of Starkville; E 1/9 Richfield Springs 15' quadrangle (SE 1/9 Van Hornesville 7½' quadrangle); Sauquoit, Brayman.

Printed by the University of the State of New York Press

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