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The Common Salt-Marsh Tabanidae of Long Island, New York

BY

HUGO JAMNBACK

Entomologist

New York State Museum and Science Service

AND

WILLIAM WALL

Suffolk County Mosquito Control Commission



NEW YORK STATE MUSEUM
AND SCIENCE SERVICE
BULLETIN NUMBER 375

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The State Education Department

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FOREWORD

This bulletin on the salt-marsh Tabanidae is one of a series of New York State Museum and Science Service publications dealing with the taxonomy, biology and control of the biting flies of New York State. Previous bulletins have treated the blackflies (Simuliidae), and work is under way preparatory to one on the sand flies or punkies (*Culicoides*, Heleidae).

This series represents a continuation of studies in a field that has been one of the principal concerns of this office for many years. The more recent investigations have been undertaken in the belief that with new and different insecticides, new mechanical equipment for insecticide application, and more precise knowledge of the taxonomy and biology of the groups involved, practical control measures can be developed.

DONALD L. COLLINS
State Entomologist

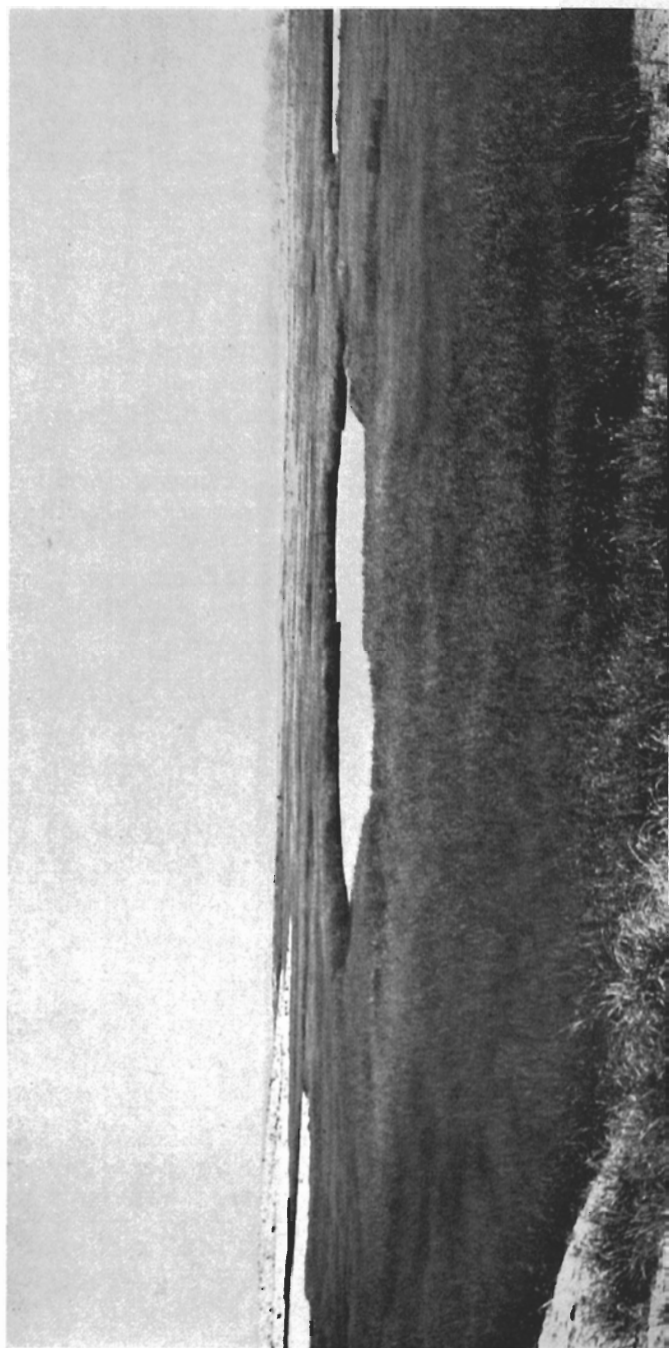


Figure 1. Towd Point, Long Island salt marsh

The Common Salt-Marsh Tabanidae of Long Island, New York

BY

H. JAMNBACK

Entomologist

State Museum and Science Service

AND

W. J. WALL¹

Suffolk County Mosquito Control Commission

INTRODUCTION AND GENERAL BIOLOGY

The coastal salt marshes and adjacent beaches of New York State provide suitable breeding habitats for several groups of biting flies that are pests of men and animals. The most abundant and annoying of these are the mosquitoes (Culicidae). The life histories of the different salt-marsh mosquitoes and methods by which they may be controlled have been studied extensively. Reasonably safe, economical, and effective methods of control have been developed. In Nassau and Suffolk Counties of New York, mosquito control is carried out on a routine annual basis.

Other biting flies that frequently are pests and that may breed along the coast in saline habitats are the stable flies (*Stomoxys calcitrans*, Muscidae), horse flies and deer flies (Tabanidae), and punkies or sand flies (*Culicoides*, Heleidae).

The stable fly breeds in many types of decaying vegetation, both along the coast and inland. In coastal areas it breeds, in large numbers, in windrows of decaying seaweed. The life history of these flies and methods by which they may be controlled have been studied by a number of workers. Effective control of this species in coastal areas has been reported by Hansens (1951) in New Jersey and Quarterman *et al.* (1951) in Florida.

The other two groups of biting flies that breed along the coast, the tabanids and punkies, are not so well known. The annoyance they cause may be severe but is generally localized because they do not migrate far from their breeding areas.

¹ Professor of Biology, Bridgewater State Teachers College, Bridgewater, Mass.

A study of the annoying horse flies, deer flies and punkies that breed in the Long Island salt marshes was undertaken in 1951 by the New York State Museum and Science Service with the active cooperation of the Suffolk County Mosquito Control Commission. The present report deals with the salt-marsh tabanids. The first part deals with the identification of the immature stages, the second with life history studies, the third with control experiments, and the last with the effects of control on some of the other salt-marsh fauna.

The tabanid species, which are annoying to man in coastal areas of Long Island, and their relative importance were determined by collecting flies that were actually biting or causing annoyance by buzzing around the head or landing on the face or body. Four species make up the vast majority of specimens collected on Long Island. These are *Tabanus nigrovittatus* Macq., *Tabanus lineola* Fab., *Chrysops atlantica* Pech., and *Chrysops fuliginosa* Wied.

Tabanus nigrovittatus, commonly known as the "salt-marsh green-head" along the eastern seaboard, is, by far, the most important of these species as a pest of man. It is abundant in midsummer when outdoor activities such as swimming, recreational fishing and picnicking are at a peak, and it readily attacks man. *C. fuliginosa* is, in some areas, even more abundant than *T. nigrovittatus* and also attacks man readily. However, it is present in numbers for only about a month (late May to late June) on Long Island. It has largely disappeared before there are many people in or near the salt marshes. *C. atlantica* attacks man readily and is present during the entire summer after mid-June, but it is not very abundant at any one time. *T. lineola* is moderately abundant during the summer but rarely attacks man.

Details of the life histories of a number of species of *Tabanus* and *Chrysops* have been given by various workers. There is substantial agreement on several points, suggesting that species have similar life history and behavior patterns. Most species lay their eggs on vegetation overhanging water or moist soil. The egg masses usually consist of one hundred to many hundred eggs laid in one to three or more overlapping tiers.

The location and shape of the egg mass are rather constant for a given species. During egg-laying the female faces head down on the plant. She deposits the eggs individually, by bending her abdomen down and at the same time extruding an egg. The tip of the egg sticks to the plant. When the abdomen is raised to its normal position the egg is gradually drawn out. This process is repeated until rows and tiers of eggs (depending on the species) are built up. The end result is a mass in which the eggs overlap one another and slope upward and in which the head of

the developing larva is at the upper end of the egg. The egg stage is relatively short, lasting approximately a week.

The larvae in a given mass all hatch at about the same time and the first moult occurs shortly thereafter. The larvae of *Tabanus* are predaceous and cannibalistic while those of *Chrysops* generally are not. They grow at an irregular rate; specimens hatching from the same mass often differ considerably in length after a few weeks. The larval stage is of long duration, usually lasting through one or two winters. Many species migrate to drier ground prior to pupation. The pupal stage generally lasts one to two weeks. The mating behavior of the adults often involves male hovering. The life histories of the salt-marsh tabanids, as far as has been observed, follow a similar pattern. These species are considered individually, beginning on page 25.

TAXONOMY

Association of the Immature Stages and Adults

Adult flies of the family Tabanidae have been extensively studied, and excellent keys and descriptions are available. Pechuman (1957) has published keys to species occurring in New York State and described the adults.

The immature stages are not so well known, partly because of the difficulty in finding and associating the immature stages with the adults and partly because of the lack of good, distinguishing characters. In many instances the larvae or pupae have been reared to adults to determine which species are breeding in a particular environment, but the immature stages have not been described.

Where taxonomic studies of the immature stages of this group have been made within a limited area, distinguishing specific characters have usually been found (see Hart, 1895; Hine, 1906; Neave, 1915; Malloch, 1917; Webb and Wells, 1924; Cameron, 1926; Stone, 1930; Philip, 1931; and others).

For the most part, in the Long Island studies, only large, nearly mature larvae were kept for rearing. A discussion of the various rearing methods used for tabanids was given by Philip (1928). The one described below is essentially similar to those employed by other workers where the larvae were kept in jars that contained the media in which they naturally occur. Larvae were placed in one-third-pint jelly glasses containing a small amount of salt-marsh sod moistened with ocean water. The water was changed three times a week, and the larvae were fed at those times. The food included dipterous larvae, snails and pieces of fish. The larvae of *Tabanus* species were observed feeding on many occasions, but those of

Chrysops were not. The rearing jars were kept covered to prevent escape of the larvae and to reduce evaporation and consequent changes in salinity.

Larvae of *T. nigrovittatus*, *T. lineola* and *C. fuliginosa* were reared to adults, but those of *C. atlantica* were not, although a special effort was made, in 1957, to collect and rear mature larvae of the latter species (see below).

Females were associated with egg masses and recently hatched larvae by capturing them in the act of oviposition, (*T. lineola*), or by obtaining eggs from confined females (*T. nigrovittatus* and *C. fuliginosa*). Immature stages of *C. atlantica* were associated with adults only by circumstantial evidence which we believe is reasonably conclusive. This may be summarized as follows:

1. Two morphologically distinct types of *Chrysops* larvae were regularly collected in salt marshes. One type possessed an exsertile stigmatal spine that the other lacked.

2. Adults of only two species of *Chrysops*, *C. atlantica* and *C. fuliginosa*, were common in the salt marshes.

3. One of these types of larvae was shown, by rearing larvae to adults and the hatching of an egg mass laid in captivity, to be *C. fuliginosa*. These larvae lacked an exsertile stigmatal spine.

4. In July and August, the only *Chrysops* adults commonly collected in the marshes were *C. atlantica*. *Chrysops* egg masses were found during this period in the salt marshes. The emerging larvae possessed a well-developed exsertile stigmatal spine.

From this evidence we have concluded that the larvae possessing an exsertile stigmatal spine and distinctive anal pattern (figure 21) are very probably *C. atlantica*, and we have considered them as such in this report.

Among the *Tabanus* species, the eggs, newly hatched larvae, mature larvae and pupae of *T. nigrovittatus* and *T. lineola* may be readily distinguished. Two other morphologically distinctive *Tabanus* larvae were collected in the salt marshes. Neither of these was reared. One is almost certainly *T. atratus*, which has been described by many workers and is distinctive in size and appearance. The other, which we have called *Tabanus* sp. A, is a large translucent white larva with a distinctive pattern of anal pubescence. It was found only in a very wet, muddy site (see page 22) with a sparse growth of tall *S. alterniflora*.

Since *T. nigrovittatus* breeds almost entirely in portions of salt marsh flooded by average high tides, larval collecting was largely confined to this section of the marsh. Although further collecting and rearing would undoubtedly add to the number of species known to breed in portions of the salt marshes subject to daily flooding, our studies suggest that their number is limited.

Samples taken along the margins of tidal streams above normal high tide limits and near brackish ponds on Long Island contained a number of morphologically distinct tabanid larvae unlike those found in the salt marsh proper. Since these were somewhat outside the scope of our study, only a few were kept for rearing. One, a *T. pumilus* Macq. larva, was collected from mud beside Phillip's Creek in Quogue. The site is in the fresh water zone but is occasionally flooded by unusually high tides. The larva was collected on April 8, 1957, and pupated on April 24. A female emerged on May 5. A *T. nigripes* Wied. larva was collected from mud beside East Branch Seatuck Creek on May 10, 1956, and pupated on June 30. A male emerged on July 14. This site was about a mile inland and was not flooded by even the highest tides. A *Tabanus hinei* Johnson larva was collected from mud beside Big Fresh Pond Outlet, North Sea. This site was above the normal high tide level but was occasionally flooded by unusually high tides. The larva was collected on April 30, 1957, and pupated on May 9. A male emerged on May 19.

The distribution records of some tabanids for which the immature stages are not known suggest that they may breed in tidal or brackish habitats. In New York, these include *T. daeckei* Hine, *T. sparus* Whitn., *T. sparus milleri* Whitn., *C. nigribimbo* Whitn., and *C. pudica* O.S. (see Pechuman 1957).

MacCreary (1940) reared *C. callida* O.S., *C. nigra* Macq., and *C. obsoleta* Wied. from brackish water areas. He reared *C. callida*, *C. obsoleta*, and *C. striata* O.S. adults from larvae taken from tideswept sandy soil, which supported a heavy growth of *Nymphaea*.

MacCreary (1940) also recorded *C. flavida* Wied. larvae from tidal areas. However, at least some of these specimens were *C. atlantica*, which Pechuman described in 1949. Pechuman (1957) noted that *C. sackeni* Hine larvae have been collected in organic material at the edge of salt marshes.

With the exceptions of *C. nigra*, *C. striata*, *C. sackeni*, and *C. nigribimbo*, we have collected adults of all the species mentioned in the preceding three paragraphs. However, none of these was at all common in the salt marshes on Long Island.

Obviously, much remains to be learned regarding the identification and biology of the immature stages of Tabanids in coastal regions. A point of particular interest is the range of habitats in which a given species may breed. Some are apparently restricted to tidal marshes, e.g., *T. nigrovittatus*, *C. fuliginosa*, *C. atlantica*. Others such as *T. lineola*, *C. callida*, *C. nigra* and *T. nigripes* can apparently breed in both saline and fresh water habitats.

Characters Used in Identification

EGGS

The eggs of most species of tabanids are laid in masses of about a hundred to many hundred eggs. The number for each species is variable, depending, in part, on whether or not the female is disturbed during egg-laying. Usually the eggs are shingled, i.e., they overlap one another for more than one-half their length and slope upward. Hart (1895) noted that the egg masses of *Tabanus* consist of two or more tiers while those of *Chrysops* consist of a single tier. This generic difference has proved to be reasonably constant although several exceptions have been noted (Isaac, 1926; Hine, 1903; Schwardt, 1936). An examination of figures of egg masses given in the literature and of those collected in the Long Island salt marshes indicate that, although there is some variation, there are specific differences in their structure, color and location as Schwardt (1932, 1936) noted for species found in Arkansas.

Individually the eggs are elongate cigar-shaped, about 2 mm. long, and taper to a blunt point at each end. They are circular in cross section and about 0.3 mm. in maximum width. The external surface is smooth. Internally there is a micropyle cone that surrounds the micropyle at the anterior end of the egg. The head of the developing larva possesses a well-developed, dark, anterodorsal hatching spine. This hatching spine appeared to be similar in all of the salt-marsh species, but the shape of the micropyle cone, although variable, showed specific differences. In some cases this was helpful in identification (figure 14).

The developing larva of *C. atlantica* is surrounded by a hatching membrane. This membrane possesses a darkened, sclerotized anterior point forming what appears to be an auxiliary hatching spine. The membrane remains in the eggshell after the larvae emerge. No trace of the hatching membrane egg burster could be found in mature eggs of *T. nigrovittatus*, *T. lineola*, *T. atratus*, or *C. fuliginosa*, or in eggshells of these species after the larvae emerged.

The egg masses usually were kept in vials until the larvae emerged; both were then preserved in alcohol. The newly hatched larvae provided further confirmation of the identity of the respective species.

LARVAE

The newly hatched larvae are about as long as the eggs from which they emerge. The patterns of the thoracic and abdominal segments are much less distinct and complete than are those of larger specimens. The mature larvae of *Chrysops* are generally about 15 mm. long while those

of *Tabanus* are 25 mm. or more in length (*T. atratus* is about 50 mm. long). The body is made up of a retractile, incompletely sclerotized head, three thoracic segments, eight abdominal segments, and an anal siphon. Detailed descriptions of the larvae are given by Böving (in Webb and Wells, 1924) and Stone (1930). Cook (1949) described the head structures in detail.

Tabanus larvae can be distinguished from those of *Chrysops* by the diameter of the tracheae, antennal segment lengths, and degree of striation on the thorax (see key, page 14). Specific differences may be found in the thoracic, abdominal, and anal patterns. There may be areas of dark pubescence on the anterior margins of the thoracic segments, the *thoracic* or *anterior rings*. The abdominal segments of some species have dark rings that can be divided into three portions for convenient reference. The most conspicuous of these are the *girdles*, which are located near the anterior margin of the segments and from which the pseudopods project. Anterior to these are the *intersegmental rings*. Anterior to the intersegmental rings are the *posterior rings* of the preceding segments (figures 15, 16). These rings can best be distinguished in ornate larvae such as *T. atratus*.

Other characters of taxonomic value are the presence or absence of a stigmal spine (see page 18), pigmentation of the head capsule and, in some cases, size. Freshly hatched larvae of salt-marsh species have either two or four capsules in Graber's organ. The number appears to be constant for a given species.

PUPAE

The pupae of most *Tabanus* species are about 15 mm. long while those of *Chrysops* are slightly shorter. Detailed descriptions of tabanid pupae are given by Webb (in Webb and Wells, 1924) and Stone (1930). *Tabanus* pupae can readily be distinguished from those of *Chrysops* by the pattern of spines, bristles, and combs (see key, page 15). In general, abdominal segments 2-7 in *Chrysops* species possess a single row of spines while *Tabanus* species have two irregular rows of spines on these segments. In some species, e.g., *T. punilus* Macq. and *T. cinctus* Fab., some of the dorsal abdominal spines are modified by thickening, lengthening, or shortening to form a distinctive pattern. The shape of the pupal aster, spiracles, and the frontal carina (a transverse ridge at the apex of the head), while variable, may also be helpful in specific identifications.

Preliminary Keys to the Immature Stages of Tabanids Found in Long Island Salt Marshes

EGGS

1. Egg mass made up of a single tier *Chrysops* 2
 Egg mass made up of two or more tiers *Tabanus* 3
2. Egg mass about 20 mm. long, 2-3 mm. wide, dark chocolate brown. Present in July and August. Hatching larvae with well-developed exsertile stigmal spine *C. atlantica*
 Eggs known only from an incomplete mass laid in vial by a confined female. Masses probably present in June. Eggs tawny brown, ends darker. Hatching larvae lack exsertile stigmal spine *C. fuliginosa*
3. Eggs about 2.5 mm. long. Hatching larvae with 4 capsules in Graber's organ *T. atratus*
 Eggs less than 2 mm. in length 4
4. Egg mass about 1 mm. wide, laid near tip of vegetation. Eggs 1.5 mm. long. Hatching larvae with 2 capsules in Graber's organ *T. lineola*
 Egg mass 3-4 mm. wide, not laid near tip of vegetation. Eggs 1.8 mm. long. Hatching larvae with 4 capsules in Graber's organ *T. nigrovittatus*

LARVAE

1. Length of second antennal segment subequal to first. Thoracic segments mostly striated dorsally and ventrally. Tracheal trunks not dilate, tracheae tapering to a point in siphon (lateral aspect) or extending free beyond end of siphon as exsertile stigmal spine *Chrysops* 2
 Length of second antennal segment $\frac{1}{2}$ that of first. Thoracic segments mostly smooth dorsally and ventrally. Tracheal trunks dilate for most of their length, tracheae blunt tipped (lateral aspect), stigmal spine lacking *Tabanus* 3
2. Exsertile stigmal spine absent, anal segment longer than high *C. fuliginosa*
 Exsertile stigmal spine present, anal segment length and height subequal *C. atlantica*
3. Thoracic pattern conspicuous. Anterior ring of prothorax with wide lateral projection extending back more than $\frac{1}{2}$ segment length. Mesothorax with well-developed lateral markings 4
 Thoracic pattern faint or absent, anterior ring of prothorax, at most, with faint lateral lines. Mesothorax, at most, with 4 faint lateral markings 5
4. Abdominal segments with conspicuous dorsomedian and dorsolateral markings extending back from girdle. Anal segment with extensive lateral markings that join anal ring and anal flap. Mature specimens 35 mm. or more in length *T. atratus*

Abdominal segments lacking dorsomedian and dorsolateral markings extending back from girdle. Anal segment with lateral markings on each side consisting of a ventrolateral dark area broadly joined to the anal flap and 2-3 discrete dorsolateral spots on each side. Mature specimens about 25 mm. long *T. lineola*

5. Anal segment with upper and lower lateral markings on each side broadly joined. These are joined to the anal flap. Mature specimens about 25 mm. long *T. nigrovittatus*

Anal segment with upper and lower lateral markings on each side separated. The lower ones are not joined to the anal flap. Mature specimens about 50 mm. long *T. sp. A.*

PUPAE

1. Bristles on frontal tubercles double; antenna about twice as long as basal width. Anal segment lacking dorsolateral and lateral combs *Chrysops* 2
- Bristles on frontal tubercles single; antenna less than twice as long as basal width. Anal segment with dorsolateral and/or lateral combs present *Tabanus* 3
2. Pupae present in June primarily *C. fuliginosa*
Pupae present in July and August primarily *C. atlantica**
3. About 30 mm. long. Abdominal spines annulated and tipped with black *T. atratus***
About 15 mm. long. Abdominal spines, at most, with an occasional dark spine, spines mostly light yellow brown 4
4. Dorsolateral combs absent on anal segment; pupal aster with tips of dorsal and dorsolateral arms in about straight line *T. lineola*
Dorsolateral combs present on anal segment; pupal aster with dorsal arms extending about $\frac{1}{2}$ length above straight line between tips of dorsolateral arms. *T. nigrovittatus*

* No consistent differences between the pupae of *C. fuliginosa* and *C. atlantica* were noted. Reared pupae of *C. atlantica* loaned by Prof. D. MacCreary, University of Delaware.

** Adapted from descriptions in the literature.

Reared Specimens¹ and Descriptions of the Immature Stages of Tabanid Species Found in Long Island Salt Marshes

The descriptions given here include characters that were selected after comparing the species with one another, with freshwater species in our collection, and with published descriptions of other species. In some instances, characters that are similar in the species described here but dissimilar in other species are included.

¹All specimens were collected and reared by the authors unless otherwise stated.

Tabanus nigrovittatus Macq.

Bailey (1948a) reported an instance in which an infertile egg mass of this species was laid by a female in captivity. He did not describe the mass but noted that the individual eggs were about 2 mm. long. He characterized the larvae of this species as being pale amber in color and ranging from 2-24 mm. in length. The morphology of the larval head of this species was described by Cook (1949). Otherwise, the immature stages have not been described.

Although egg masses were laid in confinement (see page 39), oviposition of this species has not been observed under field conditions.

REARED LARVAE AND PUPAE

1952. Larva collected July 25, pupated August 30, ♀ emerged September 11. (Collected by R. Nardy and R. Jefferson). Heckscher State Park salt marsh.

1954. Larva collected July 8, pupated July 14, ♀ emerged July 20. Dune Road salt marsh, Hampton Bays.

Pupa collected July 29, ♀ emerged (date not noted), Dune Road salt marsh, Hampton Bays.

Larva collected August 30, overwintered as larva, pupal pelt and dead ♀ found in September 1955, Towd Point salt marsh, North Sea.

1955. Larva collected June 28, pupated August 22, ♀ emerged September 6, Towd Point salt marsh, North Sea.

1956. Larva collected April 26, pupated July 7. ♀ died before emergence. Dune Road salt marsh, Hampton Bays.

Larva collected April 30, pupated June 23, ♀ emerged July 7. Cedar Island salt marsh, Babylon Township.

1957. Pupa collected June 19, ♀ emerged June 26. Cow Neck salt marsh, North Sea.

Pupa collected June 19, ♀ emerged June 25, Cow Neck salt marsh, North Sea.

Pupa collected June 28, ♀ emerged July 1. Cow Neck salt marsh, North Sea.

Pupa collected June 28, ♂ emerged July 1. Cow Neck salt marsh, North Sea.

DESCRIPTIONS (FIGURES 14c, 17, 22, 25)

EGGS

Egg masses 7-28 mm. long, usually about 15 mm.; maximum width 3-4 mm. Found on *Spartina alterniflora* about one foot above marsh sod where blade is 5-6 mm. wide. Masses taper to a point dorsally and are bluntly rounded ventrally. Dorsalmost 1-2 eggs with pronounced bend away from substrate. Masses made up of two tiers, lower diverging about 30 degrees from substrate, upper subparallel to substrate. Eggs in lower tier overlapping about two-thirds their length, those in upper tier barely overlap. General color of mass medium brown, portions of eggs protected from light and air translucent white. Individual eggs about 1.8 mm. long and 0.38 mm. wide at widest; micropyle cone 250-350 microns in length, measuring from outside of shell; basal fourth to half irregularly thickened, apical half tapering to a blunt conical point.

LARVAE

Developing larvae in eggs may have two capsules in Graber's organ before hatching, but four are present when the larvae emerge. Recently hatched larvae with no apparent thoracic or abdominal markings.

Mature larvae about 24 mm. long. General appearance pale amber with faint light brown rings on abdomen and dark pattern on anal segment. Head capsule varying from hyaline to light brown, mandibles medium brown. Prothorax with faint pattern consisting of narrow lines extending back from anterior ring dorsolaterally, ventrolaterally, and ventrally, usually very faint. Thoracic rings present on all three segments and extending back one-tenth to two-tenths distance to posterior margin of segments. Abdomen with rings and girdles faint; girdles lacking dorso-median backward extensions, joined irregularly with intersegmental rings except dorsally; posterior rings extend around segments 4-8, apparently lacking on preceding segments. Anal segment with lateral markings consisting of two broadly joined areas, the dorsolateral and ventrolateral (these may not be joined in smaller specimens), ventrolateral broadly joined to anal flap. Anal ring broad; stigmal spine absent.

PUPAE

Length 13-18 mm. Frontal carina elevated, separated by cleft at mid-line, shape variable. Thoracic spiracles only slightly elevated, rima elongate C-shaped. Spines on abdominal segments 2-7 consisting of two irregular rows; not conspicuously stouter on dorsum, yellowish brown as is rest of abdomen. Head and thorax darker brown. Caudal fringe of male with about 22 spines; female with about 9 on each side. Dorsolateral comb with 2-3 spines; lateral comb with 0-2 spines. Pupal aster with

dorsal arms about as broad as dorsolateral arms; dorsolateral arms directed dorsolaterally. If straight line were extended between tips of dorsolateral arms, about half of dorsal arms would extend above line.

Tabanus lineola Fab.

This species with its subspecies and closely related species form a difficult taxonomic group as evidenced by the studies of Philip (1942) and Fairchild (1942). The form that breeds commonly in the Long Island salt marshes keys out to *T. lineola sens str.* in their keys and was considered as such by Pechuman (1957), who noted that this form also breeds in inland sites.

Schwardt described (1931a, 1936) and illustrated (1936) eggs identified as *T. lineola*. Specimens reared from these eggs were later separated from *T. lineola* as *T. vittiger schwardti* by Philip (1942). These masses were laid lower down on the vegetation and are wider than the masses of *T. lineola* collected in salt marshes.

Specimens identified as *T. lineola* have been described and/or included in larval keys by Hart (1895), Malloch (1917), Stone (1930) and Philip (1931). Hart and Philip record the presence of a protrusile stigmatal spine, not mentioned by the other authors cited. The Long Island form lacks this stigmatal spine, which we here define as the modified posterior end of the paired tracheae in tabanids that are closely appressed and flattened along the midline, strongly sclerotized, taper to a distal point (in lateral aspect) and that, when exerted, extend well beyond the end of the siphon.

Pupae of fresh water forms identified as *T. lineola* have been illustrated, described, and/or included in keys by Hart (1895), Malloch (1917) and Philip (1931).

Females of the species were collected in the act of oviposition on five occasions (see page 43).

REARED LARVAE AND PUPAE OF *T. LINEOLA*

1954. Larva collected July 22, pupated on July 26; died. Parasitized by *Trichopria tabanivorus* Fouts (Hymenoptera: Diapriidae) (Determined by C. F. W. Muesebeck, U. S. National Museum). Cow Neck salt marsh.

1956. Larva collected April 17, pupated June 21. ? emerged July 3; Cow Neck salt marsh.

Larva collected May 9, pupated June 16, ♂ emerged June 26; Cow Neck salt marsh.

Larva collected June 15, pupated July 4. ♂ emerged July 11; Towd Point salt marsh.

Larva collected June 26, pupated July 17, ♂ emerged July 30; Cow Neck salt marsh.

Larva collected July 19, pupated August 3, ♀ emerged August 13; Cow Neck salt marsh.

1957. Pupa collected July 18. ♂ emerged July 20; Cow Neck salt marsh.

DESCRIPTIONS (FIGURES 13, 14d, 15, 16a, 23, 26a)

EGGS

Egg masses of salt-marsh breeding *T. lineola* are laid at tip of plants or within 15 mm. of it. Masses have been found on *Spartina alterniflora*, *Spartina patens*, *Distichlis spicata* and *Salicornia* sp. Masses 8-26 mm. long with no distinct mode; maximum width about 1 mm. Masses made up of two tiers, lower diverging about 20 degrees from substrate, overlapping about three-quarters their length; upper (second) tier often incomplete: traces of a third tier made up of a few scattered eggs laid flat on top of second tier may be present. General color of mass fulvous (creamy white when first laid); portions of eggs protected from light and air translucent white. Individual eggs about 1.5 mm. long and 0.28 mm. wide at widest; micropyle cone 130-180 microns in length, measuring from outside of shell; basal half irregularly thickened, apical half tapers to a blunt conical point.

LARVAE

Recently hatched larvae possess two capsules in Graber's organ. Most specimens have a fairly distinct dark pattern on the thoracic and abdominal segments and some indications of lateral markings on the anal segment.

Mature larvae about 24 mm. long. General appearance white with distinct dark rings on thoracic and abdominal segments; those on the thorax have lateral extensions. Head capsule hyaline to medium brown, mandibles medium brown. Prothorax with anterior ring extending back 0.1 segment length, with broad lateral markings on each side extending back 0.6 segment length and a narrow midventral marking. Anterior rings of mesothorax and metathorax long, extending about 0.3 segment length; that of mesothorax with 4 narrow lateral markings on each side extending back 0.7 segment length; metathorax also with 4 narrow lateral markings but these extend back only slightly further than anterior ring. Abdomen with broad brown intersegmental rings. Rings and girdles irregularly joined except dorsally; girdles lacking dorsomedian extensions; posterior rings complete on segments 4-8, present as a short transverse bar dorsolaterally on each side of preceding segments. Anal segment

with lateral markings consisting of a ventrolateral area that is broadly joined to anal flap and 2-3 small dorsolateral spots on each side. Anal ring broad; stigmal spine absent.

PUPAE

Length 13-18 mm. Frontal carina made up of two large transverse elevations separated by cleft on midline, variable in appearance. Thoracic spiracles only slightly elevated, rima elongate C-shaped, may be slightly hooked on anterior end. Spines on abdominal segments 2-7 made up of two irregular rows not conspicuously stouter on dorsum nor much dilated at base, yellowish brown as is rest of abdomen. Head and thorax darker brown. Caudal fringe of male with 16-20 spines; female with about 8 on each side. Dorsolateral comb absent; lateral comb with 4-10 spines. Pupal aster with dorsal arms narrower at base than dorsolateral arms; tips of dorsal and dorsolateral arms in about a straight line.

Tabanus atratus Fab.

Bailey (1948c) observed oviposition of *T. atratus nantuckensis* in Massachusetts salt marshes and described and illustrated the egg masses. These were unlike the masses of inland forms described and/or illustrated by Hart (1895), Hine (1906), Garman (1910), Schwardt (1932, 1936) and Rau (1935). Stone (1930) described the recently hatched larvae of an inland form. The eggs, mature larvae and pupae of this distinctive species have been described, illustrated and/or included by many workers (see Philip, 1947).

SPECIMENS COLLECTED ON LONG ISLAND

This species is widely distributed in the United States and Canada (Philip, 1947). Although Davis and Bequaert (1923) noted that *T. atratus* is common on Staten Island, it is apparently rare on eastern Long Island.

Only three adults were collected during our study. These were identified by L. L. Pechuman as follows:

T. atratus ♀. Cow Neck salt marsh, North Sea, July 22, 1957.

T. atratus fulvopilosus ♀. Cow Neck salt marsh, North Sea, July 24, 1957.

T. atratus nantuckensis ♂, Long Beach salt marsh. Noyack, July 25, 1956.

Two egg masses agreeing in detail with Bailey's (1948c) description of *T. atratus nantuckensis* egg masses were collected in the Cow Neck salt marsh on July 5 and 10, 1957. Both masses were kept until larvae emerged. A few larvae were kept for rearing; some survived for several

months and developed the characteristic markings of *T. atratus* before they died.

Larger larvae of this species were apparently rare in the salt marshes on the eastern end of Long Island, as were the adults. Two large larvae agreeing with the descriptions cited above for inland forms were collected; one at Heckscher Park and the other at Orient Point. Neither of these was reared.

DESCRIPTIONS (FIGURES 14e, 16b, 18)

EGGS

Two egg masses were collected on *Spartina alterniflora* about 1 foot above the marsh sod. One mass was 22 mm. long, the other about 20 mm. long. The masses were about 4 mm. wide and were made up of two overlapping tiers of eggs. General color of mass, medium brown, portions of eggs protected from light and air pale translucent brown. Individual eggs about 2.5 mm. long and 0.44 mm. wide at widest; micropyle cone short with broad base; in some eggs present only as a thickening in shell wall; longest observed was 150 microns, measuring from outside of shell; broad, blunt, cone-shaped.

LARVAE

Recently hatched larvae with distinct dark thoracic and abdominal rings but lack typical pattern of larger larvae. This typical pattern developed after several moults and about 4 weeks as has been noted for inland forms by Schwardt (1932, 1936). Recently hatched larvae with 4 capsules in Graber's organ. Stone (1930) reported that newly hatched larvae of an inland form had 2 capsules.

The larger of the two specimens collected as larvae on Long Island was 30 mm. long. Records for mature larvae in the literature range from 40-55 mm. or more.

General appearance, milky white with extensive dark brown markings. Head capsule brown, mandibles reddish brown. Anterior ring prothorax about 0.2 segment length, with broad markings on each side extending back almost to posterior margin of segment, also with narrow midventral dark line. Mesothorax with broad anterior ring extending back 0.3 segment length, widened laterally, extending irregularly almost to posterior margin. Metathorax with anterior ring about 0.2 segment length with 4 narrow lines on each side extending back to posterior ring. Abdominal segments with broad intersegmental rings, girdles and posterior rings present on all segments; posterior rings broader on last few segments; median dorsal, dorsolateral and smaller ventrolateral projections extending back from girdle; segment 7 with dorsolateral and ventrolateral

markings extending back to posterior ring. Anal segment with extensive areas of coarse dark brown pubescence around segment broadly joined to anal flaps and anal ring; stigmal spine absent.

PUPAE

Length 30-35 mm. Long spines of abdomen annulate and black tipped. Dorsolateral comb with 7-9 spines; lateral comb with 5-6 short spines. Caudal fringe of male with 18-22 long spines and several short ones. Pupal aster with broad median part and rather short sharp prongs; dorsal and dorsolateral arms close together and separated from ventral pair (adapted from Stone, 1930, and others).

Tabanus sp. A

Larvae of this species were found in Duck Island Harbor salt marsh at Asharoken in samples taken from clay and mud where it was covered by high tide to a depth of 3 feet or more and where *Spartina alterniflora* grew, sparse but tall. These larvae were never collected in other areas where the typical marsh had less clay and the vegetation was denser. Six large larvae of this type were kept for rearing in 1956 and 1957, but none pupated.

DESCRIPTION (FIGURE 19)

LARVAE

General appearance large and translucent white. Mature specimens about 50 mm. long. Thoracic and abdominal markings very faint, indistinct except on anal segment. Anal segment with ventrolateral spot and 2 small dorsolateral spots on each side; the former not joined with anal flap. Anal ring present; stigmal spine absent.

Chrysops fuliginosa Wied.

The immature stages of this species have apparently not been described previously.

Fertile eggs were obtained, in one instance, from a female captured while mating (see page 46).

REARED LARVAE AND PUPAE

1956. Larva collected May 1, pupated June 20, ♂ emerged June 25, North Sea Harbor salt marsh.

Larva collected May 11, pupated May 29, ♂ emerged June 8, North Sea Harbor salt marsh.

Larva collected May 18, pupated May 27, ♂ emerged June 5, North Sea Harbor salt marsh.

Larva collected May 18, pupated June 10, ♂ emerged June 18, North Sea Harbor salt marsh.

1957. Pupa collected June 4, ♀ emerged June 9, Cow Neck salt marsh.

Pupa collected June 5, ♂ emerged June 7, North Sea Harbor salt marsh.

DESCRIPTIONS (FIGURES 14a, 20, 24, 26b)

EGGS

The eggs were laid irregularly in a vial under laboratory conditions. Individual eggs tawny brown at either end, lighter brown in middle; length about 1.1 mm., width 0.3 mm. at widest; micropyle cone 300-340 microns long, narrow columnar shape.

LARVAE

Recently hatched larvae without apparent dark markings, exsertile stigmal spine lacking; two capsules in Graber's organ.

Mature larvae about 14 mm. long. General appearance white, without dark markings except on anal segment. Head capsule white, mandibles yellow brown. Thoracic and abdominal segments with only faint, very indistinct pattern. Anal ring brown extending anteriorly almost entire segment length; segment longer than high. Siphon long, lacking exsertile stigmal spine.

PUPAE

Length about 10 mm. Frontal carina elevated, moderately separated at midline, often divided again on each side by a low spot. Thoracic spiracles prominently elevated, rima elongate C-shaped, dark brown. One row of spines on abdominal segments 2-7; spines not conspicuously stouter on dorsum; some spines slightly darker brown than rest of abdomen. Caudal fringe of female with about 5 spines on each side, that of male with about 21 spines in all. Pupal aster with dorsal arms less robust than dorsolateral arms; dorsolateral arms directed laterally; a small accessory lobe between the ventral arms may or may not be evident.

Chrysops atlantica Peck.

The immature stages of this species have apparently not been described. We were unable to rear mature larvae. However, there is considerable circumstantial evidence associating eggs and larvae found in the salt marshes with adults of this species. D. MacCreary, University of Delaware, lent us reared adults from an earlier study in Delaware. These consisted of 5 females and 2 males with their associated pupal pelts.

DESCRIPTIONS (FIGURES 14b, 21)

EGGS

Masses 13-32 mm. long, usually about 20 mm.; maximum width about 2.1 mm. Laid on *Spartina alterniflora* about a foot above the sod. Masses consist of single tier, each egg overlapping next by about half its length; eggs subparallel to substrate. General color of masses dark chocolate brown; portions of eggs protected from light and air translucent light brown. Individual eggs 1.5 mm. long and 0.30 mm. wide at widest; with micropyle cone about 230 microns long, measuring from outside of shell, elongate, cone shaped.

LARVAE

Recently hatched larvae lack dark markings but have a well-developed exsertile stigmal spine. There are 2 capsules in Graber's organ.

Mature larvae about 1.4 mm. long. General appearance white with only anal segment possessing a dark pattern. Head capsule white, mandibles light brown. Pubescent pattern of thorax and abdomen faint, very indistinct except on anal segment. Length and height of anal segment subequal; dark pattern extends anteriorly from anal ring almost to anterior margin of segment, broadly joined to anal flaps. Stigmal spine distinct, brown, heavily sclerotized; when fully exserted more than half as long as anal segment.

PUPAE

The pupae of *C. atlantica* closely resemble those of *C. fuliginosa*. Since they are both quite variable, we were not able to find reliable structural characters to distinguish them. The pupal pelts of *C. atlantica* were paler, being whitish yellow instead of fulvous and the rima of the thoracic spiracle was medium rather than dark brown. This difference may be due to the greater age of the specimens of *C. atlantica*, which were collected in 1937 and 1938, while the *C. fuliginosa* specimens were collected in 1956 and 1957. The thoracic spiracles of *C. atlantica* appeared to be somewhat less prominently elevated than those of *C. fuliginosa*.

LIFE HISTORY STUDIES

Measuring Adult Populations

It is difficult to measure the seasonal changes in populations of adult tabanids. Often the apparent abundance, as indicated by the degree of annoyance, varies from hour to hour probably because of the sensitivity of the flies to changes in wind velocity, barometric pressure, temperature, relative humidity and similar factors. On cold windy days the flies remain clinging to the marsh grass near the ground and take flight only when disturbed. Biting rates, landing rates, sweeping, or car counts, i.e., the number of flies entering a parked automobile in a given length of time, or estimates of the degree of annoyance may be misleading unless some consideration is given to the factors mentioned.

ADULT TRAPS

Slow-drying adhesives smeared on stakes were tested by Roth and Lindquist (1948) as traps for *Chrysops discalis* Will. Large numbers of adults of this species were captured, and they concluded that this method of sampling might be useful in survey and incidence studies.

A modification of this technique, square panels smeared with a slow-drying adhesive "Deadline," was used by Hansens (1952) to sample salt-marsh tabanid populations in New Jersey. These traps have the advantage of capturing flies over a long period. This tends to "average out" short-term fluctuations in activity.

Similar traps were tested on Long Island in 1954 (figure 2). These were made up of two pieces of masonite, each a square foot in area, attached back-to-back on a wooden stake. The stake was set in the ground so that the bottom of the masonite was about one foot above the ground. The two panels of the trap were then smeared with tanglefoot. Flies captured on these traps were counted and removed once a week, and the traps were resmeared.

The highest weekly trap count, i.e., the largest number of *Tabanus* adults collected on a given trap over a one-week period during the "green-head season," was used as an index of adult greenhead populations at each trap site for a given year. Since adult greenhead populations increase rapidly to a high peak and then decrease rapidly, the highest weekly count would seem to reflect the degree of annoyance during the peak period of activity more closely than would the total number collected on a trap each season. In general, about one-fourth of the flies captured on a given trap during the whole season were captured during the week of maximum abundance.

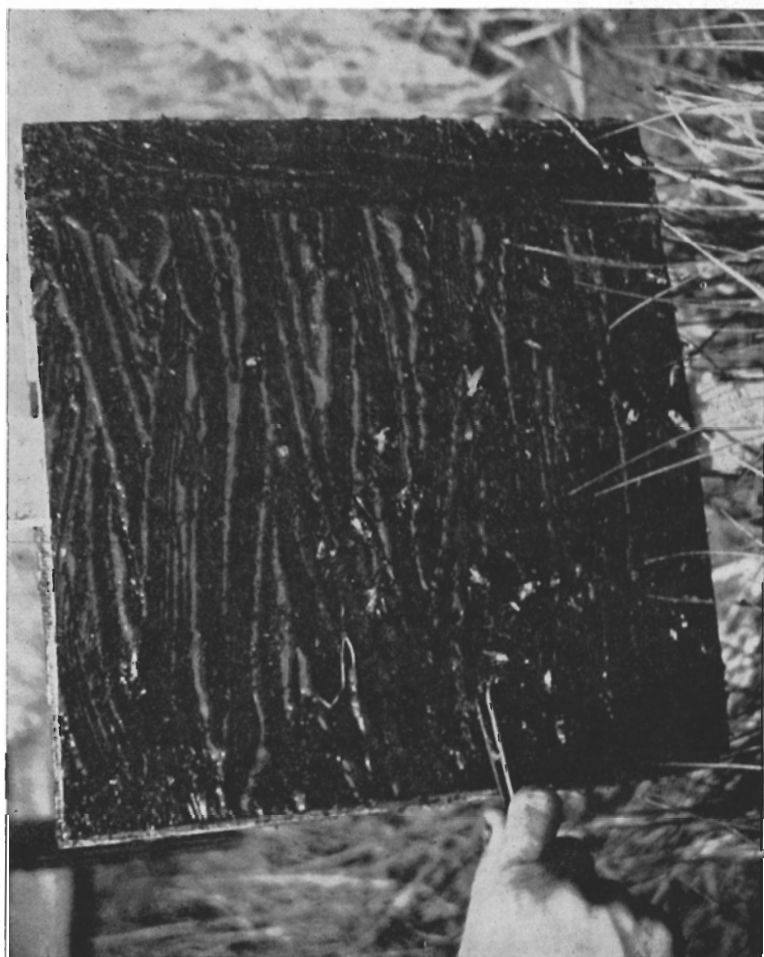


Figure 2. Tanglefoot traps used for collecting adult tabanids

BEST HEIGHT FOR ADULT TRAPS

In 1954 preliminary tests indicated that more adult greenheads were captured on traps set at the 1- to 2-foot level than at the 4- to 5-foot level. All of the traps set out for routine sampling were, therefore, set at the 1- to 2-foot level. In 1955 and 1956, more tests were made to determine the optimum trap height. Wooden boards 7 inches wide and extending 6 feet above the ground were set up in the salt marshes. The distribution of *Tabanus* adults captured at each level was tabulated. The results are given in table 1.

TABLE 1

Summary of *Tabanus* Adults Captured on 6-Foot-Tall Board Traps in 1955 and 1956

<i>Feet above ground</i>	<i>No. greenheads captured</i>
0-1.....	8
1-2.....	79
2-3.....	42
3-4.....	12
4-5.....	4
5-6.....	4
Total.....	149

The data in table 1 show that the highest counts were obtained at the 1- to 2-foot level just above the top of the salt-marsh grass.

TRAP AND SWEEPING COLLECTIONS COMPARED

Adult traps were ordinarily examined once each week. When this was done, the two common salt-marsh species of *Tabanus*, *T. lineola* and *T. nigrovittatus*, were not counted separately because of the difficulty in distinguishing large numbers of tanglefoot-smeared specimens, often in poor condition. In 1957, two traps located in the Cow Neck salt marsh were examined more frequently to determine the ratio of *T. lineola* to *T. nigrovittatus*. Fresh specimens could readily be distinguished by the eye markings, but these usually faded after a few days. Of 531 *Tabanus* specimens captured on two traps between July 1 and August 29, 92.6 percent were *T. nigrovittatus* and 7.4 percent *T. lineola*.

Sweep net collections were made at regular intervals during this period, and a total of 388 *Tabanus* captured. Of these, 86.3 percent were *T. nigrovittatus* and 13.7 percent *T. lineola*. The results obtained by the

two methods of collecting were quite similar insofar as the ratio of the two species captured is concerned. However, the ratio of females to males captured by the two methods was quite dissimilar, as can be seen from table 2.

TABLE 2

The Ratio of *Tabanus* Spp. Females to Males Captured in the Cow Neck Salt Marsh by Two Different Sampling Methods

Species	Adult traps		Sweep counts	
	% collected	No. collected	% collected	No. collected
	♀ ♀	♂ ♂	♀ ♀	♂ ♂
<i>T. nigrovittatus</i>	97.6	2.4	492	46.3 56.7 335
<i>T. lineola</i>	94.9	5.1	39	41.5 58.5 53
Total No. collected		531		388

These data indicate that proportionally fewer males than females of these two species are captured on adult traps and that approximately equal numbers of males and females of both species are captured by sweeping. Field observations suggest a reason for this difference, at least in the case of *T. nigrovittatus*. In the morning the males are quite active, hovering over open spots in the marsh or over water, and darting about the marsh, as has been described in some detail by Bailey (1948). Except for this relatively short period in the morning they remained quiescent on the grass. In contrast, the females are active for the entire day when the weather is favorable.

Hansens (1952) reported that about 20 percent of the flies captured by sweeping in New Jersey salt marshes were *T. lineola* and that most of these were males. The reason for the preponderance of males in his collections and the approximately even numbers of males and females of this species in our sweep collection is not known.

The seasonal abundance of *T. nigrovittatus* and *T. lineola* adults in the Cow Neck salt marsh, as indicated by trap counts, is shown in figure 3. From this it can be seen that the seasonal changes in abundance of these two species are similar although only about a tenth as many *T. lineola* as *T. nigrovittatus* were captured. This in itself is unusual because Berlese funnel samples indicated that larvae of these two species were present in approximately equal numbers in the Cow Neck salt marsh (table 3).

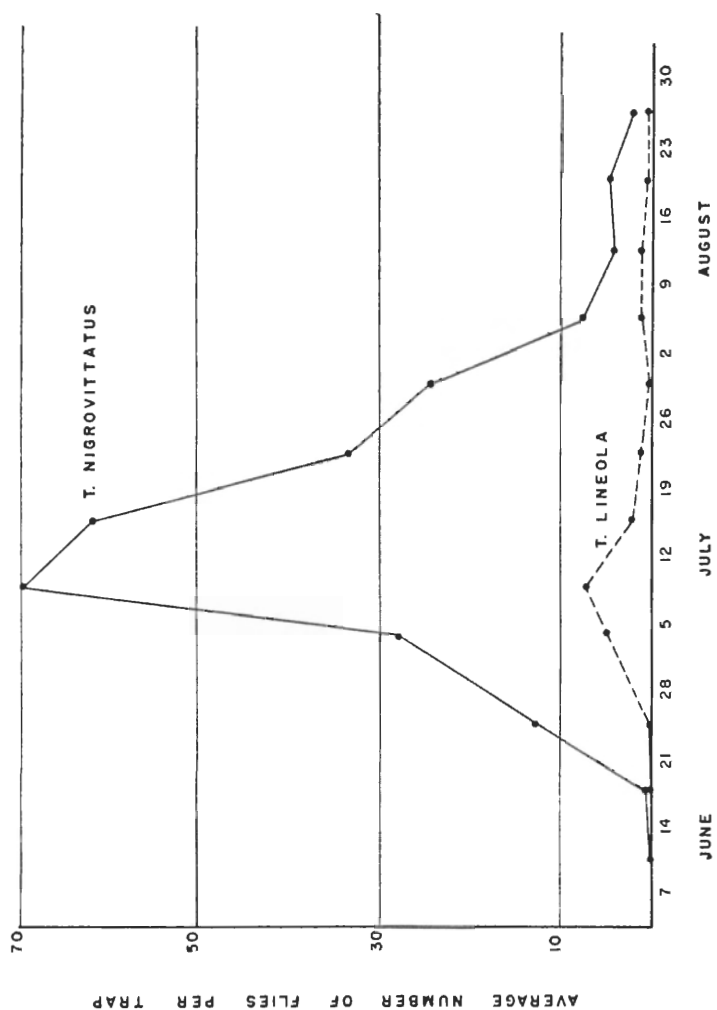


Figure 3. Adult populations of *T. nigrovittatus* and *T. lineola* in the Cow Neck salt marsh in 1957, as indicated by tanglefoot trap collections

TABLE 3

Relative Abundance of Larvae of the Different Species of Salt-Marsh Tabanids Collected in the Cow Neck Salt Marsh by Berlese Funnel Sampling in 1956 and 1957

Species	Percent of total	
	1956	1957
<i>C. fuliginosa</i>	9.8	8.6
<i>C. atlantica</i>	8.3	5.8
<i>T. nigrovittatus</i>	31.3	34.5
<i>T. lineola</i>	39.3	26.8
small unidentified <i>Tabanus</i> *	11.3	24.3
Total number collected	265	325

* Although newly hatched larvae of *T. nigrovittatus* and *T. lineola* can be distinguished by the number of capsules in Graber's organ and mature larvae can be distinguished by their distinctive markings, intermediate stages with an irregular number of capsules and faint, incomplete markings sometimes cannot be identified with certainty.

T. lineola adults were less abundant along the barrier beach bordering the south shore bays than in marshes bordered by woods. In 1957, all but one of 138 recently captured *Tabanus* on traps in that area were *T. nigrovittatus*. Larval collections (Wall and Jamnback, 1957) also indicated that there were few *T. lineola* along the barrier beach. For all practical purposes, therefore, the seasonal abundance of salt-marsh *Tabanus* adults, as indicated by trap counts, was considered to be an index of the seasonal abundance of *T. nigrovittatus*.

Sampling the Immature Stages

The sampling methods used in estimating larval populations of salt-marsh tabanids have been discussed elsewhere (Wall and Jamnback, 1957). The New Jersey larvicide sampling method involves clearing the vegetation from a plot in the salt marsh, spraying on a dilute emulsion of New Jersey larvicide (figure 4) and collecting the larvae as they come to the surface. The Berlese funnel sampling method involves removing pieces of salt-marsh sod, bringing them into the laboratory, and collecting the larvae that emerge as the sod dries (figure 5). In summary, it was found that both the New Jersey larvicide and the Berlese funnel sampling methods have advantages and disadvantages, as follows:

New Jersey larvicide square-yard samples. Advantages: Less variation between samples taken close together; sampling can be completed in about an hour. Disadvantages: Ineffective in cold weather; *Chrysops* larvae not collected; larvae suffer considerable mortality when kept for rearing; cannot be used when there is free water on marsh.



Figure 4. Spraying a cleared plot of salt marsh with New Jersey larvicide to sample *Tabanus* larval populations

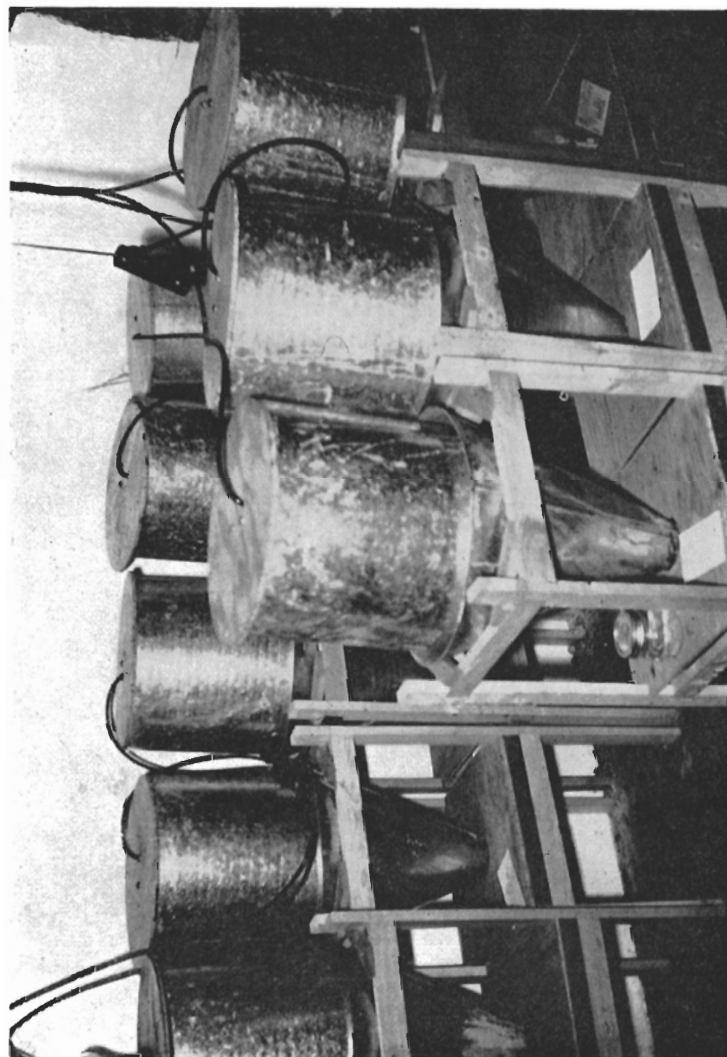


Figure 5. Berlese funnels used in sampling tabanid larval populations and other salt-marsh fauna

Berlese funnel square-foot samples. Advantages: Can be used in cold weather; both *Tabanus* and *Chrysops* larvae collected; larvae can be kept for rearing with less mortality; can be used when there is free water on marsh. Disadvantages: Considerable variation between samples taken close together; requires about one week and repeated examinations to collect all the larvae.

The collection of egg masses was primarily qualitative. Since they are often difficult to find, only a general impression of their changes in relative abundance during the egg-laying period can be given. Similarly, pupae or cast skins of pupae were occasionally found in the marsh but were not collected on a systematic basis.

Life Histories of the Common Species

Tabanus nigrovittatus Macq.

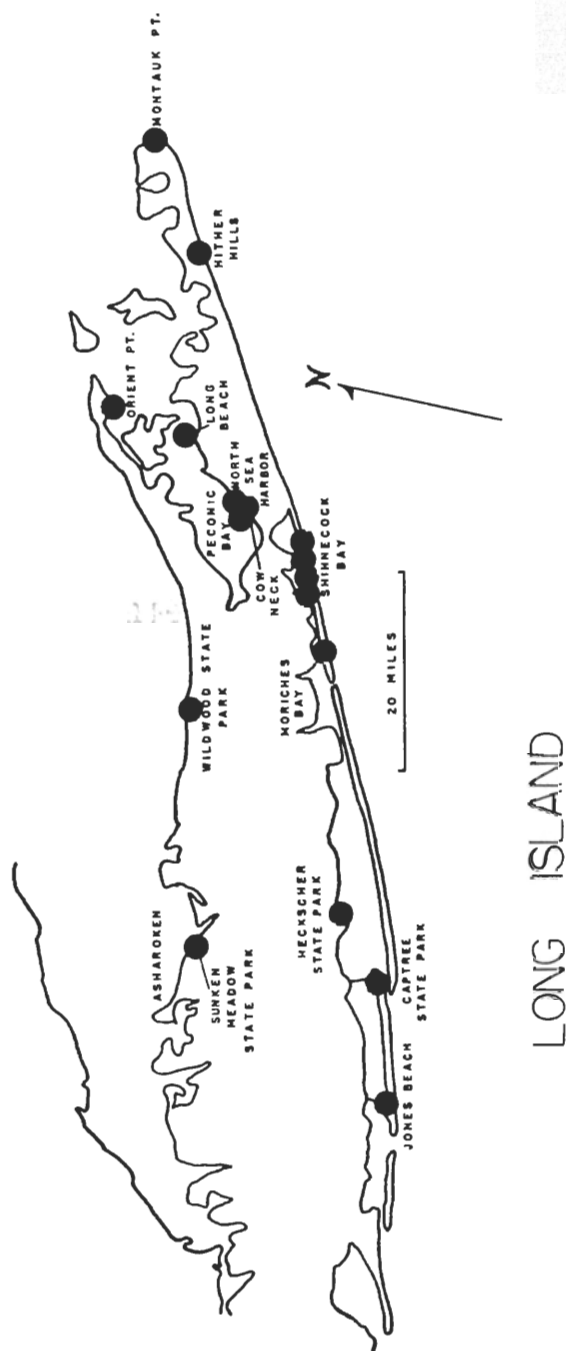
(The salt-marsh greenhead)

SEASONAL CHANGES IN ADULT ABUNDANCE

This species is found along the eastern seaboard from Nova Scotia to Texas and in the Antilles (Philip, 1947). It appears earlier and disappears later in the southern portion of its range. Stone (1938) gives the extreme dates of capture for adults as April 21 and November 23, both records from Florida. MacCreary (1940) gives June 2 and September 13 as the extreme dates of capture in Delaware. Our earliest and latest collections for *T. nigrovittatus* adults on Long Island are June 14 and September 8-14 (adult trap).

The seasonal changes in abundance in the northeastern United States seem to follow a fairly consistent pattern (Hansens, 1952, for New Jersey; Fairchild, 1950, for Connecticut; Gerry, 1949, for Massachusetts; Blicke, 1954, for New Hampshire; and Tuttle, 1948, for Maine). The first few are found in mid-June. Their numbers increase rapidly in late June and July, reaching a peak usually during the last half of July. The population then decreases rapidly during late July and August. There is sometimes a slight apparent increase in numbers in August and early September.

Adult traps were set out in a number of salt marshes on Long Island (figure 6). Those located in State parks were tended by park personnel through cooperation of the Long Island Park Commission. At most of these sites the traps were set out in pairs, one at right angles to the other. The average number of *Tabanus* collected each week on traps in untreated marshes in 1955, 1956 and 1957 are shown in figure 7. Supplementary data are given in table 4.



LONG ISLAND

Figure 6. A map of Long Island showing the areas where adult tabanid traps were located (indicated by black dots)

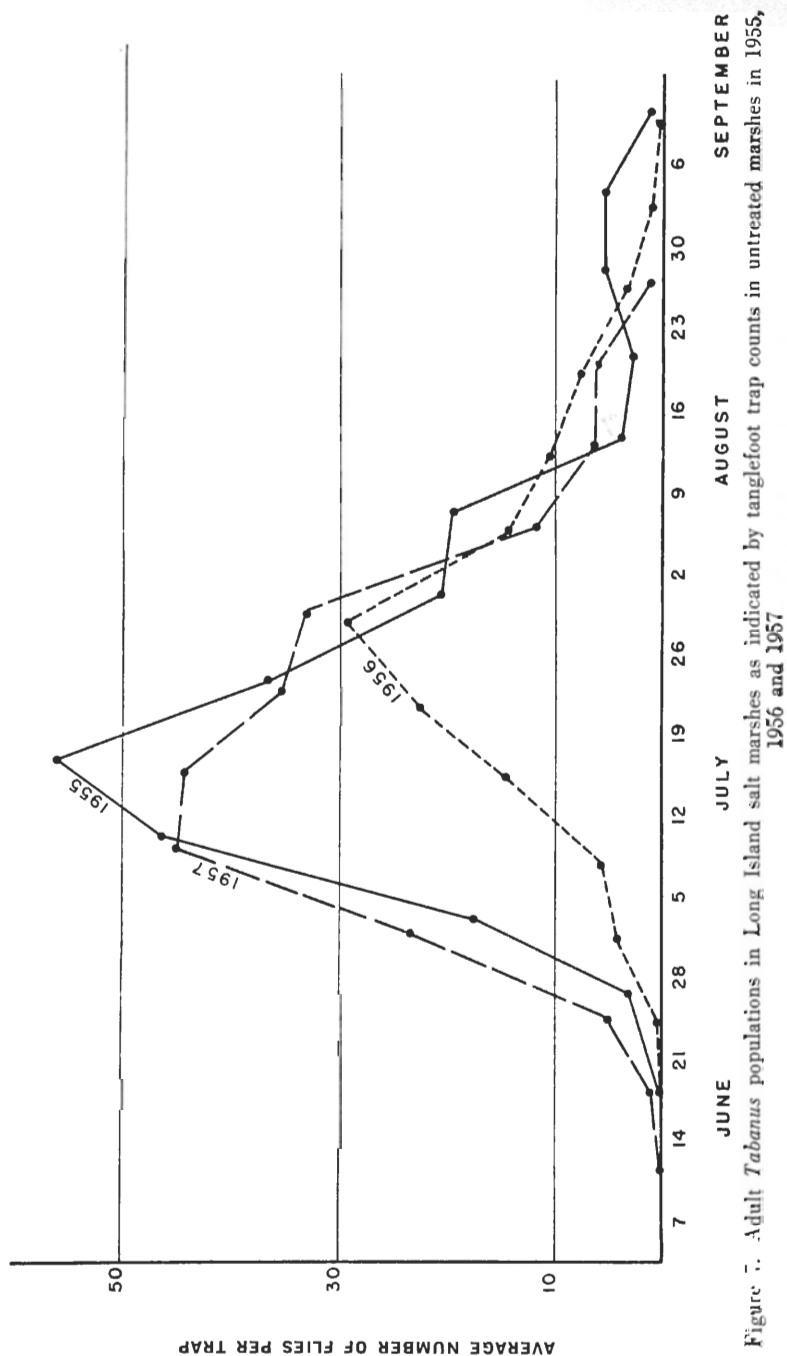


Figure 7. Adult *Tabanus* populations in Long Island salt marshes as indicated by tanglefoot trap counts in untreated marshes in 1955, 1956 and 1957

TABLE 4

Percentages of the Total Numbers* of *Tabanus* Adults Captured on Traps during Periods of Maximum Abundance in Different Years

Collection period	1955	1956	1957
	Percent of total		
6 weeks maximum abundance	92.9	88.1	90.6
3 weeks maximum abundance	65.7	59.0	58.8
1 week maximum abundance	26.6	26.9	21.2
Average No. flies per trap during entire season..	212.4	109.4	211.3

* From first appearance of flies each year to August 31.

These data indicate that adult populations have a similar pattern of fluctuation each year. The lower population in 1956 and later peak, as indicated by trap counts, agree well with other observations that year. Adult populations reached a peak about two weeks later in 1956 than during the preceding or following years. This was correlated with the lower soil temperatures prevailing prior to pupation and emergence of adults in 1956 (figure 3).

The soil temperatures were recorded on a thermograph located at a weather station in the Cow Neck salt marsh. The temperature-sensitive element was located a few feet to the south of the shelter, just beneath the sod surface below a dense growth of *Spartina alterniflora*. This was a typical *T. nigrovittatus* breeding area. The temperatures shown in figure 8 were obtained by averaging the daily high and low temperatures and using these data to calculate the weekly average mean temperatures.

FLIGHT HABITS

There are few published data dealing with the flight habits of *T. nigrovittatus* adults. MacCreary (1940) captured an adult in a light trap 8.4 miles from the mainland and 10 specimens 5.5 miles from the mainland. It seems possible that these specimens may have been carried part of this distance in boats, since they are attracted to them and are often annoying to bay fishermen a mile or more from shore. He noted that this species is generally limited to the salt marsh and areas immediately adjacent. Gerry (1950) and Hansens (1952) concur in this belief. Our observations agree with those cited above, as the examples given below indicate.

Two traps were set up in Wildwood State Park on the North Shore of Long Island bordering Long Island Sound. This park is not located near a salt marsh, the nearest one being slightly more than a mile away. No flies were collected on these traps during the entire season in 1955 and park employees stated that few greenheads were ever seen there.

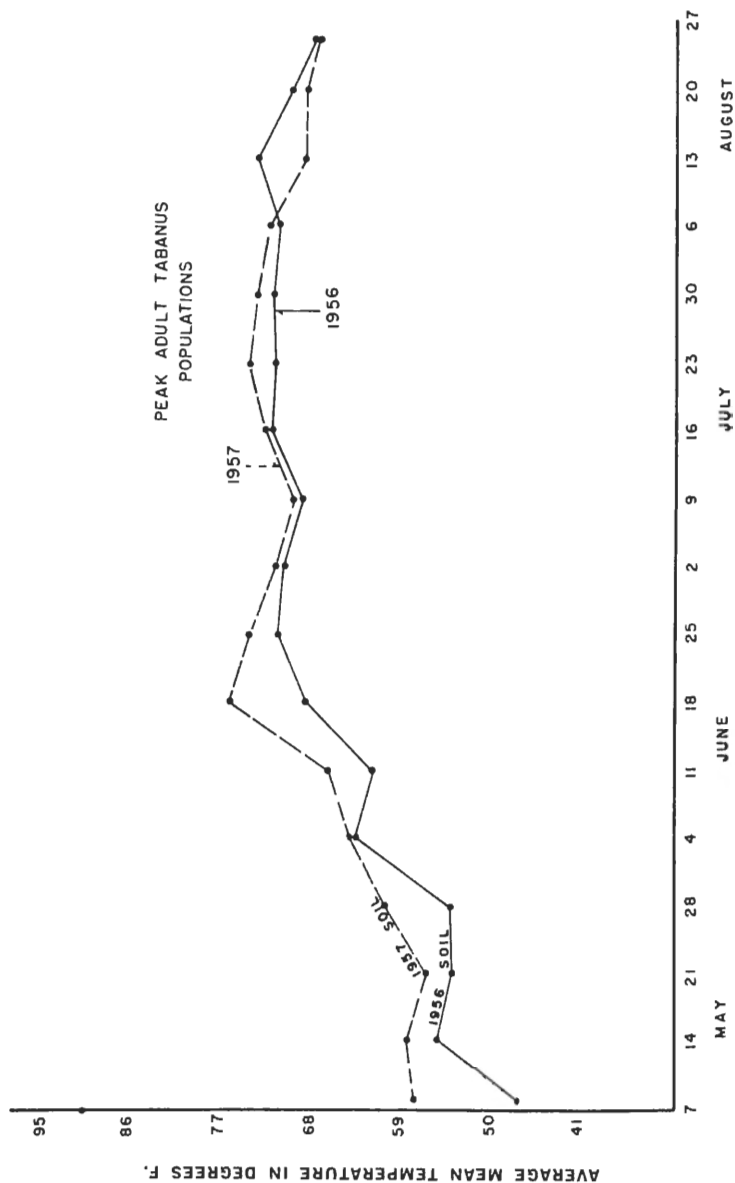


Figure 8. Soil temperatures in the Cow Neck salt marsh in 1956 and 1957

One of the authors lived for a summer (1955) in a cottage about 0.1 mile from the edge of North Sea Harbor and 0.3 mile from a salt marsh that produced a large number of *T. nigrovittatus* adults. These were rarely seen around the cottage although they were very annoying 0.3 mile away on a beach beside the salt marsh.

One trap was set up about 0.2 mile from the edge of a good breeding area at the North Sea Community House. The trap was surrounded by grass, shrubs and a few trees. No *T. nigrovittatus* adults were collected here during the entire 1955 season.

In 1955, in another inland area 0.5 mile from a salt marsh and separated from it by woods, no adults of this species were seen or trapped, although a few *T. lineola* were observed.

In 1956, two traps were set in a small "island" of woods surrounded by salt marsh at Cow Neck. The counts from these two traps are compared with those from adjacent open marsh in table 5. These data agree with our general observations indicating that this species is seldom found in woods, even close to the salt marsh.

One exception to this general condition occurred at Big Fresh Pond, North Sea. This pond is separated from the Cow Neck salt marsh by about 0.3 mile of woods. It is connected to the North Sea salt marsh by a fresh-water stream. *T. nigrovittatus* and, earlier in the season, *C. fuliginosa* adults were present here in numbers large enough to be annoying. This suggests that the adults may be attracted to fresh water.

TABLE 5

Total Number of *Tabanus* Collected in the Cow Neck Salt Marsh on Adult Traps in 1956

<i>Location of traps</i>	<i>No. of specimens</i>
Open salt marsh	
facing east-west	155
facing north-south	73
In woods—35 feet	8
At edge woods	6

Additional information regarding flight habits was obtained in larval control tests (see control section). In one instance (North Sea Harbor), an entire, relatively isolated marsh was treated and larval populations considerably reduced; this reduction was reflected in lower adult populations. In another case (Tiana Beach), a strip of barrier beach salt marsh about 3 miles long was treated and larval populations were reduced, but there appeared to be no significant change in adult populations. This strip was adjacent to similar untreated salt marsh. The following year an

additional 2.2 miles of the barrier beach were treated as well as the salt marsh bordering the opposite shore of the bay (figure 12). In this case there appeared to be a distinct reduction in adult populations toward the center of the treated area.

From these observations we have concluded that adults of this species may fly relatively long distances within marshes or over water adjoining marshes, but they rarely fly far from them. Since they are strong fliers, they are probably restricted to salt marshes by preference rather than necessity or by flight habits rather than by a limited flight range.

MATING

The mating behavior of *T. nigrovittatus* has been described by Bailey (1947a, 1948b) in some detail. On Long Island, mating was observed on two occasions: the first occurred on August 10, 1955, at about 2 p.m. on a warm overcast day, while a slight wind was blowing. The flies mated while resting on a blade of *S. alterniflora*. The second mating was observed on July 8, 1957, at about 6:45 a.m. (temp. 60° F.). At this time there were numerous males on the wing, hovering over open spots at a height of about 2 feet. When a female came near, the male darted after her, flying faster than the eye could follow. More often than not he did not make contact and returned to his hovering position. When contact was made, there was usually an audible thud. Hagmann *et al.* (1948) noted a similar phenomenon for *T. giganteus*. In both cases, where mating was observed, the male and female were facing in opposite directions with the tips of the abdomens in contact, that of the male just above that of the female. These observations agree, in general, with those of Bailey (1948b).

OVIPOSITION AND EGGS

Ernest Bay, of Cornell University, obtained a viable egg mass from a female *T. nigrovittatus* captured by sweeping on July 27, 1953, Dune Road, Westhampton Beach, Long Island. This female was placed in a 4-dram vial with a 2 by 1/4 inch piece of index card. The vial was covered with a piece of linen held in place by elastic. An egg mass was deposited between 4 and 11 p.m. three days later. When first observed the eggs were light brown. Most of the eggs hatched between 6 and 11 p.m., four days after they were laid.

Five masses of *T. nigrovittatus* eggs were deposited in an emergence cage in which six females had been placed on July 26, 1956, following a blood meal. The eggs were first noted on August 1, attached to the underside of wooden corner brace at the top of the cage. One mass hatched on August 8; the rest were preserved before hatching.

In 1956, 22 similar egg masses were collected in the field between July 11 and August 20 with peak numbers about August 20. In 1957, 28 egg masses were collected, mostly about July 25. These field-collected masses hatched in 0.7 days with an average of about 3 days. One mass deposited in the laboratory hatched in 4 days. A mass, deposited in the emergence cage, hatched 7 days after it was found.

Egg masses of this species were more difficult to locate in the marshes than were those of *T. lineola* because they were deposited lower down on the grass. They have been found only on the adaxial (inner) surface of *Spartina alterniflora* leaves, usually about a foot above the sod where the grass is about 6 mm. wide. They appeared to be laid at random throughout the marsh without reference to open water or the upper margins of the marsh. They were often located so that the mass was covered by average high tides. When taken into the laboratory and examined under a dissecting microscope, the larvae could often be seen moving about within eggs of nearly mature masses. In several instances, the larvae began emerging while the mass was being examined. In these cases most of the larvae emerged at about the same time. The newly hatched larvae moulted shortly after emergence as other workers have noted for many species of tabanids.

DISTRIBUTION OF LARVAE

In the initial stages of the study, a survey was made to determine whether or not salt-marsh *Tabanus* larvae were limited to a particular portion of the marshes. Their distribution in relation to plant cover, tides, distance from open water, pools, or mosquito ditches was studied by intensive sampling of limited sectors of marsh and more extensive random sampling in a number of different marshes.

The marshes bordering Moriches, Shinnecock and Peconic Bays on Long Island are low and quite level. The tides are restricted from entering many of these marshes by narrow inlets so that the tidal range is limited to one or two feet. In spite of this limited tidal range, these marshes are covered by average daily high tides. *Tabanus* larvae are rather uniformly distributed in these marshes, as is indicated by the example shown in figure 9.

In 1955, when these samples were taken, larvae of the two common species of *Tabanus*, *T. nigrovittatus* and *T. lineola*, were not distinguished. Later, in 1956 and 1957, sampling showed that the larvae of both species, when present, were both widely distributed in the marshes.

In one area bordering Long Island Sound, Duck Island Harbor salt marsh in Asharoken, the tidal range is much greater and the marsh slopes steeply. In this marsh, larvae of *T. nigrovittatus* appeared to be concen-

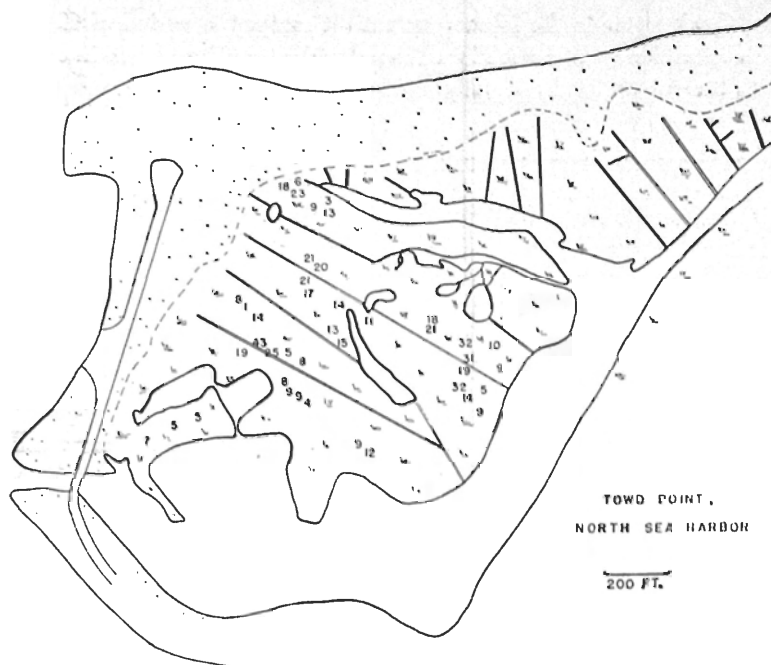


Figure 9. The number of *Tabanus* larvae collected in different portions of an untreated salt marsh by the New Jersey larvicide sampling method in 1955

trated in a narrow band as has been described by Gerry (1950) for some of the Massachusetts marshes.

In general, larvae of *T. nigrovittatus* were most abundant in areas where *Spartina alterniflora* was the dominant vegetation and where large areas of the salt marsh are covered, for relatively short periods, by all except the neap tides. Larvae were equally abundant beneath *Spartina patens*, where it occurs in patches surrounded by *S. alterniflora*, but were less abundant where there are large stands of *S. patens*. The number of larvae seemed to decrease slightly in areas of marsh less frequently covered by tides, usually indicated by the presence of *Distichlis spicata* or *Juncus gerardi*.

However, *T. nigrovittatus* larvae have also been found under *Phragmites communis*, *Scirpus* spp., *Salicornia* spp., and under thatch piles. We have not found them in portions of salt marsh where there is no plant or thatch cover. During unusually high tides a few large larvae have been found floating on the water surface. Larvae can survive for long periods in water. In one instance, a large larva of this species was kept in a

jar of salt water in the laboratory until it escaped, a period of 69 days. This specimen spent most of the time with the tip of its siphon in contact with the surface. fed normally and moulted once in the jar.

DURATION OF THE LARVAL STAGE

Although small *T. nigrovittatus* and *T. lineola* larvae became quite abundant in late August, several weeks after egg masses were found, it was not possible to determine the duration of the larval stage by measuring larvae collected at different times of the year. This was because small, medium, and large larvae could be collected any time during the year. The variation in size may be due, in part, to variations in the growth rate. The larvae from a single egg mass may differ considerably in size a few weeks after hatching (King, 1910; Stone, 1930; Tashiro and Schwardt, 1953b; and others).

The length of the larval stage of a tabanid species may be quite variable, as Stone (1930) and others have noted. It seems likely that *T. nigrovittatus* larvae may pupate after either one or two winters as suggested by Gerry (1948).

PUPAE

MacCreary (1940) reared six adults of *T. nigrovittatus* from larvae. The pupal period of one observed specimen was 8 days. On Long Island, pupae were collected in the field or obtained from reared larvae between June 23 and August 30. The pupal periods of four specimens reared from larvae were 6, 12, 14 and 15 days respectively. Pupae were found in the same location in which the larvae occurred at the surface of the sod. There was no indication that the larvae migrate to drier ground to pupate as is common for most species of *Tabanus* and as Bailey (1948a) reported for *T. nigrovittatus*. In many sections of salt marsh on Long Island such migration would involve lateral movement of several hundred feet or more because of the uniformity of the marsh level.

Tabanus lineola Fab.

(Striped horse fly)

ADULTS

As has been noted earlier (page 18), *T. lineola*, and its related species and subspecies, form a difficult taxonomic group. Lewis and Jones (1955) noted that the larvae of this group are highly adaptable and occur in a variety of habitats. Therefore, we have restricted the discussion to the salt-marsh breeding form as it occurs on Long Island.

The prevalence of adults of this species in tidal marshes is discussed beginning on page 27. The earliest and latest dates on which adults were collected during this study were June 17 and August 24. The adults are less abundant in the marshes than are those of *T. nigrovittatus*, although in some marshes larvae of the two species are about equally abundant (cf. table 3 and figure 3). *T. lineola* adults are commonly found inland, away from the salt marshes, while those of *T. nigrovittatus* are not. In almost every instance where "greenheads" have been reported from areas away from beaches or salt marshes they were actually *T. lineola*. This species rarely attacks man. In only one instance was it captured while biting man in Long Island marshes. This is in contrast to numerous records for *T. nigrovittatus*.

OVIPOSITION AND EGGS

T. lineola females lay egg masses near the tips of salt-marsh plants including *Spartina alterniflora*, *Spartina patens*, *Distichlis spicata*, and *Salicornia* spp. Females were captured in the act of laying eggs on five separate occasions. All occurred on warm clear days between 11:30 a.m. and 4:30 p.m. Three of these masses hatched in 4, 4 and 5 days respectively. In 1956 masses were collected in the salt marshes from July 18 to August 27 and were most abundant between July 29 and August 1. In 1957 masses were collected from June 24 to August 8, and were most abundant between July 11 and 31. During these two years 61 masses were collected and a great many more examined but not collected.

LARVAE AND PUPAE

The larvae of this species are more abundant in salt marshes bordered by woods than in the barrier beach marsh. They are found in the same general environment as *T. nigrovittatus* larvae, but seem to be proportionately more abundant in the drier marshes.

T. lineola pupae were collected from the same locations as the larvae. The pupal periods for five specimens reared from larvae were 7, 10, 10, 10 and 13 days respectively. MacCreary (1940) recorded a pupal period of 8 to 9 days for this species in Delaware.

Chrysops fuliginosa Wied.

ADULTS

This species is the first of the salt-marsh tabanids to appear in the spring on Long Island. Our earliest and latest collection records are May 29 and June 29 in this area. Pechuman (1957) recorded that it has been collected in New York from May to September, although it is present

in numbers only in June. He also showed that it is widely distributed on Long Island.

This species occurs along the eastern seaboard from Nova Scotia to Florida (Philip, 1947). It appears progressively earlier in its southern range but is present for only about a month in any one area (see records given by Brennan, 1935, for East Coast; and later by MacCreary, 1940, for Delaware; Fairchild, 1950, for Connecticut; Knutson *et al.*, 1954, for New England). This is in contrast to *T. nigrovittatus*, which appears earlier and disappears later in its southern range. The seasonal distribution of *C. fuliginosa* as indicated by adult trap collections in 1956 and 1957 is shown in figure 10. These data indicate that the adults were more abundant in 1956 than in 1957. This may be correlated with air temperatures since the adults disappeared suddenly after a period of high temperatures in both years. The air temperatures shown in figure 10 were obtained from a thermograph set out in a weather station in the Cow Neck salt marsh. The maximum temperature for each day was used to calculate the weekly average maximum temperatures.

The adults and larvae of this species are not uniformly abundant in all the Long Island salt marshes. They were collected almost exclusively in salt marshes with adjoining woods and only rarely (adults) along the south shore barrier beach. As an example, table 6 compares adult trap counts from the Cow Neck salt marsh, bordered by woods, with those along the nonwooded south shore barrier beach in 1956 and 1957.

TABLE 6

Weekly Counts of *C. fuliginosa* on Adult Traps in Salt Marshes Bordered by Woods Compared to Counts from Areas Not Bordered by Woods

Collection period	Average No. per trap*	
	Wooded margins (2 traps)	Not wooded (6 traps)
1956		
June 1-6	3	0
7-13	36.5	0.2
14-20	174.5	0.2
21-27	228.5	0.7
28-July 5	0	0.7
July 6-11	0	0
1957		
May 21-June 4	16	-
June 5-7	19	0
8-14	48.5	0
15-21	32	1.5
22-28	0	0
29-July 5	0	0

* Only traps in untreated areas are included.

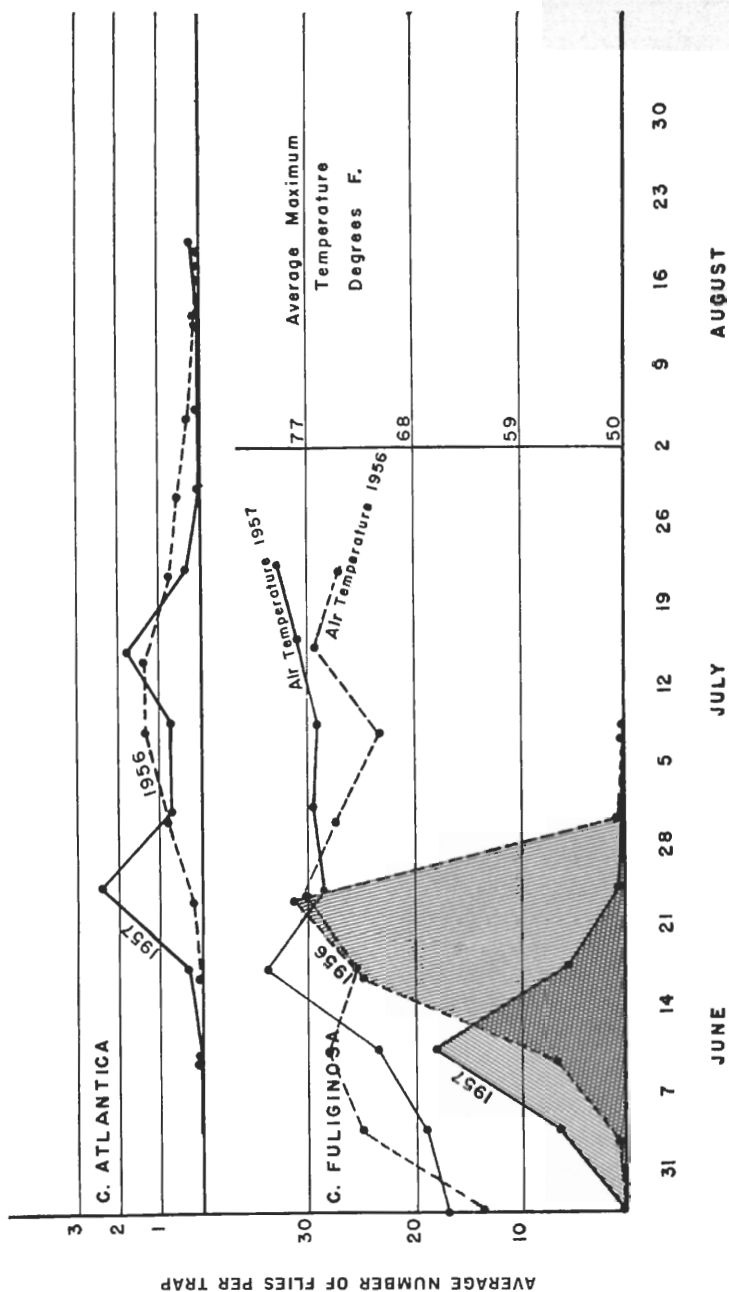


Figure 10. Adult populations of *C. atlantica* and *C. fuliginosa*, as indicated by adult trap counts in untreated salt marshes, and the average maximum air temperatures during their peak periods of abundance

OVIPOSITION AND EGGS

One mating pair of this species was collected at about 9 a.m. on June 10, 1957, on a cool morning; air temperature 62°F., relative humidity 55 percent. The pair was located in the shade of a weather station set out in the marsh. They were resting on a leaf of *Spartina alterniflora* and facing in opposite directions with the tips of the abdomens in contact, as has been observed for *T. nigrovittatus*. They were captured by netting after once eluding the net by flying away while remaining joined. The pair remained joined in the net for about 40 minutes and separated only when they were placed in a 4-dram vial. A moistened piece of raisin and a strip of filecard were also placed in the vial, which was then covered with cheesecloth.

The vial was examined daily, and ninety irregularly scattered eggs were found 5 days later. These eggs hatched in another 5 days and the larvae moulted within a day following hatching.

MacCreary (1940) observed mating of this species in Delaware on two occasions, on June 9 of one year and on June 10 of another year, in both cases between 9 and 10 a.m.

LARVAE AND PUPAE

Larvae of *C. fuliginosa* have been collected from March through August and in November. The New Jersey larvicide sampling technique was ineffective for this species and for *C. atlantica*. However, both species can be collected readily by drying sod samples in a Berlese funnel. No very small larvae were collected. Those found ranged from 8-15 mm. in length. They were of assorted sizes with no apparent seasonal changes in average length. The pupal periods of four specimens reared from larvae were 5, 8, 9 and 10 days respectively.

Chrysops atlantica Pech.

ADULTS

This species was originally recorded from Massachusetts to Virginia by Pechuman, who distinguished it from the closely related *C. flavida* in 1949. It has since been collected as far north as New Hampshire by Knutson *et al.* (1954). It is widely distributed in the coastal region of New York (see Pechuman, 1957). He recorded April 17 and October 6 as the extreme dates of collection in this area. Our earliest and latest records for this species on Long Island are June 17 and August 24. This species is less abundant than *C. fuliginosa* at any one time but is present over a longer period (figure 10).

OVIPOSITION AND EGGS

Chrysops egg masses, presumably of this species (see page 10) were collected in salt marshes during the period when this species was the only adult *Chrysops* collected there, with rare exceptions. In 1956, 9 masses were collected between July 13 and August 2. In 1957, 12 masses were collected between June 24 and July 30. These masses hatched in 2 to 7 days with an average of 4 days. As far as could be determined with these limited numbers, there seemed to be no site preference in relation to open water or the edge of the marsh. They were widespread in the marsh and were laid on the adaxial (inner) surface of *Spartina alterniflora* leaves about a foot above the marsh sod, as was the case with *T. nigrovittatus*.

LARVAE AND PUPAE

About half as many larvae of *C. atlantica* as *C. fuliginosa* were collected during our survey. In 1956 and 1957 a total of 61 *C. atlantica* were collected from Berlese funnel samples in comparison with 134 *C. fuliginosa* larvae. Neither species was collected from samples taken along the south shore barrier beach although they were regularly collected in marshes bordered by woods. Larvae of *C. atlantica* were collected from May through August in assorted sizes from 3 mm. to 14 mm., with no noticeable trend toward larger sizes late in the summer.

We were unsuccessful in obtaining pupae from larvae in the laboratory although about 30 large larvae of this type were kept for rearing.

CONTROL

There have been few attempts to control tabanids although a number of possible methods of control have been suggested. These include drainage, destruction of oviposition sites, collection of egg masses, sudden fluctuations in water level, and oiling pools of water to trap adults.

Parman (1928), in an experimental attempt to control *Tabanus hyalipennis* Hine (now *T. dorsifer* Walker) with parasites, collected thousands of egg masses of this species parasitized by *Phanurus* (now *Telenomus*) *emersoni* Girault (Hymenoptera: Scelionidae). The egg masses were placed in containers that allowed the parasites, but not the larval hosts, to escape. These were distributed in parts of southwest Texas where the parasite was scarce or absent. According to Parman, reductions of 50 percent or more in viable tabanid eggs were brought about under favorable conditions by the parasites. Since then, there seems to have been little work on biological control of tabanids, although a number of para-

sites have been recorded from different species. Many of these records are included in a review by Miller (1951). Additional ones for New York are given by Tashiro and Schwardt (1953a).

Adult Control with Insecticides

Insecticides have been tested for adult tabanid control with varying results. Howell *et al.* (1949) reported that solutions of methoxychlor, DDT, toxaphene and chlordane produced no appreciable control of adult tabanids when applied at the rate of 2 pounds² per acre in woodlands.

Brown and Morrison (1955) tested lindane and dieldrin emulsions and DDT solution, applied by aircraft to 1-mile-square plots for adult tabanid control at Goose Bay, Labrador. They reported that application of lindane at 0.5 pound per acre temporarily (2 days) reduced tabanids in open, but not dense, forest. DDT at 0.25 to 2 pounds per acre gave temporary but unsatisfactory reductions. Dieldrin at 0.5 pound per acre gave negligible reduction and at 1 pound per acre temporary reduction.

Gerry (1948, 1949) reported that *T. nigrovittatus* adults were successfully controlled in Massachusetts salt marshes with DDT solution applied as a spray at rates of 1 to 1.7 pounds DDT per acre. The addition of one percent aluminium stearate, as a spreader, prolonged residual effectiveness. The insecticide was applied by aircraft to the inner margins of marshes. Studies indicated that 94 percent of the larvae in a given marsh are found within 200 feet of the upper margin of the marsh. In 1949, 1,500 acres of salt marsh, comprising one-third of the total marsh, were treated twice, with treatments spaced 10 days apart. Marsh sweep counts and car counts taken before and after treatment indicated a reduction of about 95 percent in adult greenhead populations.

Larval Control with Insecticides

There are large expanses of relatively level salt marshes covered by average high tides along the south shore of Long Island and bordering Peconic Bay. *Tabanus* larvae are widely distributed in these marshes. Under these conditions, it seemed likely that barrier strips of residual insecticide for adult control would prove less effective than in situations where larval breeding was confined to a relatively narrow strip that could be covered by the insecticides. The use of barrier strip residual sprays for adult control may prove useful in some localities on Long Island, but larval control appeared to offer substantial advantages and was, therefore, the method studied.

² All dosages cited refer to the amount of technical insecticide.

In 1945, Gjullin and Mote noted that, in the laboratory, *Chrysops discalis* larvae may be killed with low dosages of DDT. The first large plot tests of larvicides under field conditions appear to be those of Hansens in New Jersey. He reported (1956) on tests of DDT, aldrin, and dieldrin granules (tobacco stem) for control of salt-marsh tabanids in plots ranging from 40 acres to 0.25 acre. Dieldrin was the best of these insecticides. It markedly reduced larval populations at dosages of 0.1, 0.2 and 0.5 pounds per acre.

CONTROL TESTS ON LONG ISLAND

REVIEW OF TESTS MADE IN 1955-56

The insecticides tested against *Tabanus* spp. larvae in small plot screening experiments in 1955 and 1956 included dieldrin, aldrin, chlordane, heptachlor and DDT (Jamnback and Wall, 1957).

All test materials were in granulated form (Attaclay or Diluex), because granules readily penetrate the dense salt-marsh vegetation and reach the sod below. In these tests, the granules were applied by hand sowing to square plots of salt marsh 60 feet on a side. Formulations containing 21½ percent or 5 percent of toxicant were used where possible. At the lower dosages it proved difficult to obtain an even distribution with these concentrations, since only a few handfuls of granules comprised the total dosage. In these cases, untreated granules were mixed with the formulation so that at least one quart of granules was used to treat each plot.

Heptachlor, chlordane and aldrin, in ascending order, were more effective than DDT but less effective than dieldrin.

Because of the superiority of dieldrin in the screening tests, it was chosen for the larger scale, practical control tests, in which a helicopter was used. Two plots of 105 and 232 acres, respectively, were treated with 2.5 percent dieldrin in a granulated formulation with 5 percent urea included as a stabilizer (Attaclay 30/40 R.V.M. granules; Velsicol AR-60 was the dieldrin solvent).

A Hiller helicopter equipped for dusting was adapted by the East Coast Aviation Corp., Bedford, Mass., for distribution of the granules (figure 11). A pair of dust hoppers (one on each side of the helicopter), each with a funnel-shaped base, were used to carry the granules. A manually controlled gate valve, used to start and stop the flow of insecticide, was located at the base of each hopper.

A 12-inch diameter disk was attached horizontally about an inch beneath the outlet to each hopper. There were eight vertical vanes, each ½ inch high, on the upper surface of each disk. The vanes were bent over slightly along the top margin in the direction of rotation to reduce

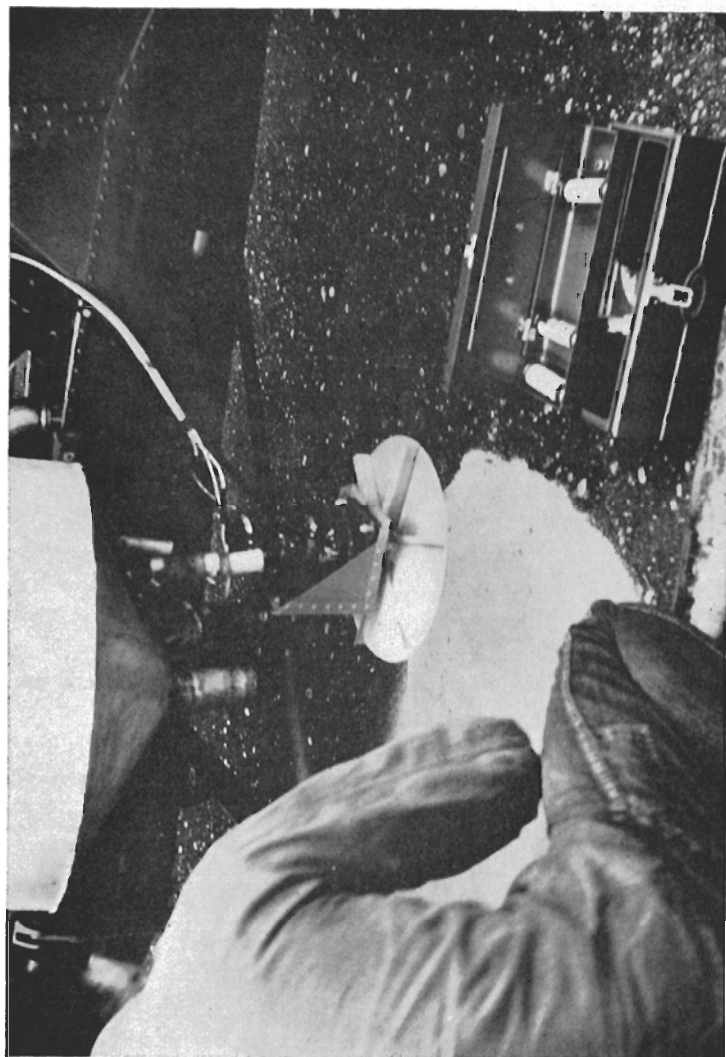


Figure 11. The apparatus used to distribute dieldrin granules from a helicopter

the amount of granulated material bouncing off the disk rather than being thrown off by the rotating vanes. The disk was rotated by an electric motor operating at about 1,500 r.p.m. The rotating disk broke up the stream of granules flowing out of the hopper and threw them out, away from the helicopter, where the wind aided in further dispersal.

The helicopter flew about 30 m.p.h. at an altitude of about 20 feet over open marsh and at 60 feet or more in areas where there were trees bordering the marsh. At an altitude of 20 feet with a wind of about 10 m.p.h., most of the granules landed in a swath about 35 feet wide. Approximately 8 minutes were required to disperse 200 pounds of granules with this equipment.

Larval *Tabanus* populations were greatly reduced in both plots (table 7). In the smaller plot, which consisted of an entire isolated salt marsh, this reduction was reflected in reduced adult populations. In the larger plot, which was contiguous with untreated marsh, adult *Tabanus* populations remained high.

TABLE 7

Numbers of Salt-Marsh *Tabanus* Larvae Collected by the New Jersey Larvicide Sampling Method in Plots Treated by Helicopter with Granulated Dieldrin in 1956 and 1957

Location	Average No. larvae per square yard		
	1954-1955	1956	1957
Tiana Beach Section of Shinnecock Bay			
treated 1956		0.2(22)	0(36)
	8.4(38)		
treated 1957		5.3(4)	0.1(28)
North Sea Harbor	15.5(39)	0.9(22)	0.3(36)
Cow Neck, untreated	13.6(15)	12.2(18)	10.4(24)

Samples all taken in July and August. The numbers of samples averaged are given in parentheses. Averages of samples taken before treatment or in untreated marsh are in boldface.

OBSERVATIONS AND RESULTS IN 1957

In 1957 further observations were made in these large plots. Samples taken in the early spring of 1957 using the Berlese funnel sampling method (the New Jersey larvicide method is ineffective in cold weather) indicated that there had been little if any *Tabanus* larval repopulation in plots treated the previous year (table 8). These portions of marsh were, therefore, not retreated in 1957 (with the exception of some marginal areas of the North Sea marsh where poor coverage had been obtained the previous year).

In the Shinnecock Bay area, where a 3-mile strip of the Dune Road salt marsh had been treated in 1956, an additional 483 acres bordering the bay were treated on May 22 and 28, 1957. The same helicopter that had been used in 1956 was used to disseminate the granules, which were 24/48 mesh instead of the 30/40 mesh material used in 1956. The area treated included all the salt marsh bordering the bay between the Quogue and Ponquogue Bridges (figure 12). New Jersey larvicide samples taken in July and August 1957, following treatment, indicated that larval *Tabanus* populations had been greatly reduced and also supported the Berlese funnel data taken in the early spring, which indicated that there had been little, if any, *Tabanus* larval repopulation of plots treated in May 1956 (cf. tables 7 and 8).

The west end of Shinnecock Bay narrows to a channel that is bordered by a small amount of salt marsh. This channel joins Quantuck Bay about a mile away where there is more salt marsh. To the east, the treated area is contiguous with similar, but untreated salt marsh. The irregular contours of the marsh, the prevailing winds, and normal variation in adult trap counts complicate interpretation of data collected from traps placed inside and outside the treated area. The highest weekly counts (see page 25) for traps in various locations in the marshes bordering Shinnecock Bay are shown in figure 12.

TABLE 8

Numbers of Salt-Marsh *Tabanus* Larvae Collected from Berlese Funnel Samples in Two Plots Treated by Helicopter with Granulated Dieldrin in 1956

	Average No. larvae per square foot		
	1956	1956	1957
	Mar.-May	July-Aug.	Mar.-May
Tiana Beach section of Shinnecock Bay..	3.5(29)	0.2(22)	0(11)
North Sea Harbor*	4.3(13)	0.9(13)	0.1(19)

The numbers of samples averaged are given in parentheses. Averages of samples taken before treatment are in boldface.

* Excludes samples taken near wooded margins of marsh where poor coverage was obtained in 1956.

Since adult greenhead populations vary in numbers from year to year, it is desirable to take these differences into account when evaluating the effectiveness of a control program. For example, in 1956 the average highest weekly count from all traps in untreated salt marsh on Long Island was 29.4 greenheads; in 1957 it was 44.8 greenheads. This difference was taken into account by calculating the *highest expected weekly*

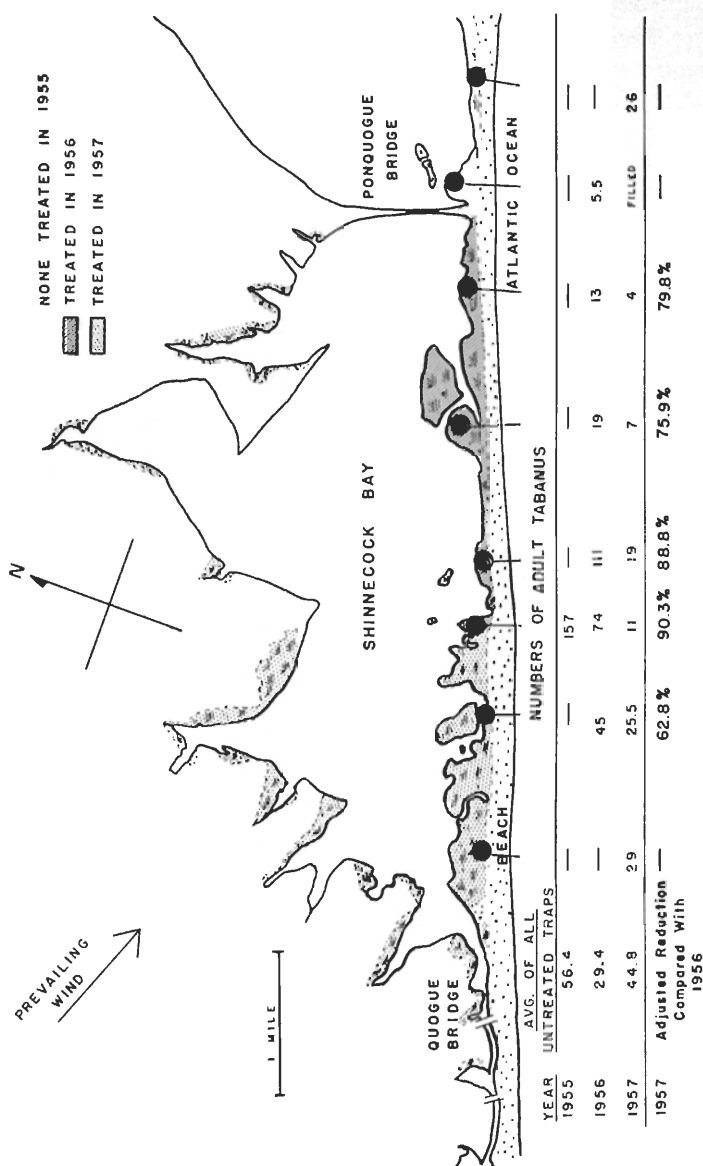


Figure 12. Adult *Tabanus* populations in the salt marsh bordering Shinnecock Bay, in 1955, 1956 and 1957, as indicated by the highest weekly trap counts for each year. Trap locations are indicated by black dots.

count in 1957 for each trap site in the control area and comparing this figure with the number of flies *actually captured* at these sites. The adjusted differences were then assumed to be attributable to larval control measures. Abbott's formula was used to determine the percent reduction, for example:

Where 29.4 = the average highest weekly count for all untreated area traps in 1956

44.8 = the average highest weekly count for all untreated area traps in 1957

111 = the *actual* highest weekly count on a trap in the treated area in 1956

X = the *expected* highest weekly count on this trap in the treated area in 1957

$$29.4:44.8 = 111:X \quad X = 169.1$$

The actual highest weekly count on this trap in 1957 was 19.

Applying Abbott's formula $\frac{169.1-19}{169.1} \times 100 = 88.8$ percent

reduction.

The other adjusted reductions shown in figure 12 were arrived at in a similar manner. They range from 90.3 in the center of the treated area to 62.8 percent toward the western margin. The proportionally lower reduction toward the western side of the treated plot may be due, in part, to the prevailing winds, which may tend to favor migration from that quarter (figure 12).

Collections were made on one trap in the Tiana Beach area for a full season before any marsh was treated. This trap was located in untreated marsh in 1955, which was just inside the area treated in 1956, and was in the middle of the combined 1956-57 treated areas. The adjusted reduction from 1955, when this site was not treated, to 1956, when it was on one edge of the treated zone, was too slight to be considered significant (9.4 percent). The adjusted reduction from 1955 to 1957, when it was in the middle of a large treated area, was 91.1 percent.

The other large plot (105 acres) that was treated in 1956 was a relatively isolated salt marsh bordering North Sea Harbor. Portions of this marsh are bordered by tall trees, which, in 1956, caused a few marginal areas to be incompletely covered. In 1957 these areas, totaling approximately 32 acres, were retreated.

Tabanus larval samples taken before and following treatments at North Sea Harbor indicated that larval populations were greatly reduced following treatments (table 7). Two adult traps were set up in the center

of the main portion of this marsh in 1955, 1956 and 1957. The highest weekly counts for each of these years are shown in table 9. These indicate that adult *Tabanus* populations were reduced approximately 80 percent to 90 percent following treatments. The calculated reduction was slightly greater in 1956 than in 1957 in spite of the fact that larval population counts were lower in 1957.

TABLE 9

The Highest Weekly Counts of Adult *Tabanus* on Traps in a Treated Isolated Salt Marsh Compared with the Average Counts for Untreated Marshes

Location of traps	Highest weekly count			Percent reduction (adjusted)	
	1955	1956	1957	1956	1957
North Sea Harbor					
Facing north-south	140	10	26	86.3	76.6
Facing east-west	86	1	6	97.8	91.2
Average of traps from untreated salt marsh.	56.4(16)	29.4(23)	44.3(18)	0	0

The number of traps in untreated marshes is given in parentheses. Figures in bold-face are for untreated areas or for samples taken before treatment.

FEASIBILITY AND COSTS OF CONTROL

While the methods of larval control reported here appear to be effective in reducing adult greenhead populations under certain conditions, control procedures are still in a developmental stage and will require additional field-testing and improvement before they can be recommended for routine use. A method of aerial application of granules that will give a uniform swath of 50 feet or more would be highly desirable.

The desirability and feasibility of control will depend on a number of factors, including: the number of people living in, or using, a given area; the degree of annoyance caused by the greenheads; the amount of salt marsh that must be treated to obtain control, and the possible injury to desirable wildlife (see following section). Probably the most promising type of situation for control is the isolated marsh of a few hundred acres adjoining or nearly surrounding an intensively used beach where the greenheads are abundant and annoying.

The costs of control depend on the size of the area to be treated, the availability of properly equipped aircraft, type of terrain, and cost of insecticide. In general, costs of application of insecticide to plots of a

few hundred or so acres range from \$1 to \$3. The 2.5 percent dieldrin granules used in our experiment cost about \$0.12 cents per pound or about \$1.20 per acre. Data collected in 1956 and 1957 suggest that dieldrin granules applied at the rate of 0.3 pound per acre (technical) in late May will retain their residual effectiveness until after the *Tabanus* larvae hatch from egg masses laid that same year. In effect this gives two years' control with a single application and would reduce the annual cost by one-half.

SOME EFFECTS OF DIELDRIN ON SALT-MARSH FAUNA

The coastal salt marshes and adjacent beaches of New York State provide food and cover for numerous shore birds, migrating and overwintering waterfowl, bait fish, eels, crabs, shellfish and smaller animals of many kinds. According to the Fish and Wildlife Service (Aron, 1955), the marshes and shallow water areas along the south shore of Long Island from Peconic Bay to Jamaica Bay are among the most valuable migration and wintering grounds for birds along the Atlantic Coast.

The salt marshes also serve as a protective buffer zone between the ocean and mainland during unusually high tides and storms. It is desirable to avoid, insofar as possible, disrupting normal plant and animal relationships in the marshes and along the beaches. An attempt to control one segment of the salt marsh population, e.g., greenheads, should take into consideration the possible effects on other fauna. A review of the literature dealing with the effects of dieldrin on wildlife and information on this subject obtained in the course of our studies is presented below.

Information from the Literature

It appears from the literature that dieldrin is one of the more toxic chlorinated hydrocarbon insecticides and that it has a relatively long residual effectiveness. Under field conditions, the effects of treatment on wildlife are difficult to assess, but there is considerable evidence that both invertebrates and vertebrates may be injured by it. Laboratory studies indicate that the production and viability of the eggs of some birds may be adversely affected by otherwise apparently harmless exposure to dieldrin. Reports of its effects on wildlife have been reviewed by Rudd and Genelly (1956). The following summary of the effects of dieldrin on wildlife under field conditions includes both the sources cited by them and papers published since their review appeared.

There have been a number of instances where dead birds and mammals have been found following application of dieldrin at relatively high

dosages ranging from 3 to 4.8 pounds per acre (Henderson and Shaw, 1954; Smalley, 1956; Scott and Willis, 1954). Horsfall (1953) noted that dieldrin can be used effectively to reduce populations of pine mice and meadow mice in orchards when applied at the rate of 4 to 4.5 pounds per acre.

Mortality of birds and mammals has also been reported following application of lesser amounts of dieldrin. Ryckman *et al.* (1953) reported that several dead squirrels and rabbits were found following application of dieldrin spray applied at the rate of 1.04 pounds per acre. Rudd and Genelly (1955) stated that dead birds and mammals were recovered following application of dieldrin spray at the rate of 0.5 and 1.5 pounds per acre for stink bug control. They also noted that dieldrin spray "carelessly applied" at a nominal rate of 0.5 pound per acre for rice leaf miner control killed large numbers of birds and fish. However, an immediate drop in mortality was noted when the material was properly applied.

There are fewer data on the effects of dieldrin on reptiles and amphibians. Smalley (1956) noted a dead water snake (*Natrix sipedon*), a dead garter snake, (*Thamnophis sirtalis*), and a dead frog (*Rana pipiens*) following application of dieldrin granules at the rate of 4.8 pounds per acre. Mathis and Quarterman (1953) reported that dieldrin emulsion in small ponds killed frogs when applied at the rate of 1 pound per acre but that tadpoles hatching later were apparently unaffected. Rudd and Genelly (1955) also reported that dead snakes were found following application of dieldrin spray at the rates of 0.5 and 1.5 pounds per acre.

Dieldrin appears to be one of the more toxic insecticides affecting fish. Tarzwell and Henderson (1957) collected run-off rainwater from a slope treated with 4.66 pounds per acre of dieldrin granules. They noted that some fathead minnows (*Pimephales promelas*) kept in this water were killed even when it was diluted 1 to 3 with uncontaminated water. The run-off from subsequent rains became successively less toxic. Mathis and Quarterman (1953) reported that dieldrin emulsion, when applied at the rate of 1 and 3 pounds per acre to small ponds, is decidedly harmful to fish and other aquatic organisms. Rudd and Genelly (1955) recorded extensive fish injury following treatment with dieldrin spray "carelessly applied" at the nominal rate of 0.5 pound per acre.

Ginsburg and Jobbins (1954) reported many dead fish, other forms of aquatic life, and some birds were found within three days following application of dieldrin dust at the rate of 0.3 pound per acre in salt marsh.

Webbe (1957) recorded mortalities of 21.7 percent at 0.1 pound per acre and 48.4 percent at 0.2 pound per acre for three species of the fish

Tilapia, held in ponds treated with dieldrin granules for three weeks and kept for an additional three weeks in uncontaminated water.

Hogan (1950) noted that ricefield water treated with 0.1 pound dieldrin per acre was still toxic to fish 10 to 20 days after treatment.

Webbe (1955) reported that eight treatments with 1 percent dieldrin granules applied at weekly intervals at the rate of 0.05 pound per acre to small ponds caused injury to some invertebrate fauna. In addition to mosquito larvae, there was obvious mortality among the mayfly naiads, bugs, water boatmen, and water beetles following the first treatment. In addition to these groups, dragonfly and damselfly naiads were absent after the third treatment. Some dead snails were found but tadpoles, frogs and crabs were apparently unaffected. Representatives of these groups were present in two of the ponds four to five weeks after the final treatment.

A study of the effects of dieldrin granules applied at the rate of 1 pound per acre to tidal salt marsh in Florida was made by Harrington and Bidlingmayer (1958). It is considered separately here since conditions in their studies were, in some ways, similar to those in the Long Island area. Their observations were confined to the effects on fish, crabs and, incidentally, molluscs. There was an extensive kill of the fish inhabiting the salt marsh ditches, and the marsh itself at high tide, almost immediately following treatment. Aquatic crabs succumbed more slowly and were seen foraging on the dead fish. They were annihilated by the treatment. Fiddler crabs were brought close to annihilation. Molluscs, including snails and oysters and nudibranchs, were apparently uninjured by the treatment. The snails were observed feeding on the dead fish two weeks following treatment, and thereafter no more dead fish were found. Aquatic crabs were eliminated for the 17-week observation period following treatment. Within a month an increase in fish populations became apparent, and by the tenth week the populations had increased to a point where no direct effects were apparent.

Although some of the deaths reported in the studies cited above may have been due to other causes, they indicate, rather conclusively, that dieldrin was injurious to many vertebrates as well as invertebrates and that even mammals may be killed by dieldrin as it has been applied under field conditions.

Data from Studies on Long Island

In our studies, granulated dieldrin was applied by helicopter to tidal marshes at the rate of about 0.3 pound per acre. Three salt marshes were included in the study. The Cow Neck and North Sea Harbor salt marshes border Peconic Bay. The Shinnecock Bay salt marsh borders

Shinnecock Bay and consists of a barrier beach marsh and marsh bordering the mainland. The vegetation in these marshes consists of salt-marsh cordgrass (*Spartina alterniflora*), salt meadow grass (*Spartina patens*), and lesser amounts of glasswort (*Salicornia* spp.), spike grass (*Distichlis spicata*) and in some places groundsel-bush (*Baccharis halimifolia*) and marsh elder (*Iva frutescens*) and also reed grass (*Phragmites communis*) and bulrush (*Scirpus* spp.). These marshes are largely covered by average high tides, those adjoining Peconic Bay to a depth of 1 to 2 feet and those along the barrier beach to about a foot or less. All these marshes have been extensively ditched for mosquito control.

METHODS OF STUDY

Two methods of studying the effects of the treatments on wildlife were employed, depending on the organisms under consideration: (1) For the smaller invertebrates, counts were made from square-foot samples of salt-marsh sod brought into the laboratory for detailed study. (2) For the larger animals, which included birds, fish, crabs and some molluscs, field survey methods were used. These consisted of searches for dead or abnormal specimens and observations on the live and apparently normal specimens.

THE SMALLER INVERTEBRATES

The effects of treatment on some groups of smaller salt-marsh invertebrates were determined by taking samples inside and outside the treated marshes before and after treatment.

Each sample comprised 1 square foot of salt-marsh sod $1\frac{1}{2}$ inches thick (with some variation due to surface irregularities). Plugs of salt-marsh sod were cut with a flat spade and the top inch and a half layer sawed off. This piece of sod was placed in a pliofilm bag and taken to the laboratory where it was placed in a Berlese funnel (figure 5). A 100-watt bulb in each funnel speeded drying. The animals that emerged from the sod as it dried and that crawled downward were collected in a jar of salt-marsh water attached to the bottom of each funnel. The specimens in the jars were counted and removed at intervals of one or two days. Each sample was kept in a funnel for seven days or until it was thoroughly dry. In some instances the specimens in a given group were too numerous and active to permit complete counts. In these cases, partial counts and estimates were made. The springtails (*Collembola*) and mealybugs (*Coccidella*) were particularly difficult to count.

The numbers of eight representative groups among the smaller invertebrates were recorded. These included the most conspicuous or abundant forms in the marsh fauna, namely: dipterous larvae, mealybugs, springtails, mites, spiders, amphipods, isopods, and snails.

TABLE 10

Average Numbers of Specimens in Selected Invertebrate Groups Taken in Berlese Funnel Samples of Salt-Marsh Sod before and after Application of Dieldrin Granules Applied at the Rate of About 0.3 Pound Per Acre

Group	Untreated		After treatment	
	Mar.-May	July-Aug.	10-12 months March-May	1-15 months July-Aug.
Diptera (larvae only)	50.6	68.1	3.8	6.3
Pseudococcids	23.7	88.7	85.4	280.7
Collembola	65.5	65.6	75.0	185.9
Mites	178.2	143.8	186.6	194.9
Spiders	1.4	2.1	1.4	1.6
Amphipods	24.6	18.1	10.3	9.0
Isopods	3.4	2.3	3.2	1.5
Snails	2.2	2.9	3.0	4.5
Average No. per sample	348.6	260.4	368.7	684.5
No. of samples	(69)	(44)	(30)	(24)
Numbers of the commonly occurring dipterous larvae				
<i>Tabanus</i>	3.5	3.8	0.03	0.08
<i>Chrysops</i>	0.9	0.6	0	0
<i>Culicoides</i>	1.9	0.3	0.3	0.04
<i>Dasyhelea</i>	5.8	5.8	0.06	0
Heleids (other)	2.8	7.8	0	0
Dolichopodid	12.6	26.2	0.3	1.4
Cecidomyiid	0.5	0.5	0.5	0.3
Psychodid	7.4	13.3	0	0.04
Stratiomyiid	2.2	3.6	0.1	0.3
Scatopsid	9.4	2.8	2.0	0.04
Ephydrid	0.7	2.3	0	1.5
Scatophagid	0.8	0.9	0.4	2.1
Other	2.1	0.2	0.1	0.5

Groups that were not included in counts because they were scarce, too small to be readily seen under a microscope, or highly irregular in distribution, include, among the Hemiptera and Homoptera, salt-ticks, fulgorids and aphids; among the Coleoptera, hydrophilids, staphylinids, melyrids and others; lepidopterous larvae, dragonfly naiads, ants, pseudoscorpions, nematodes, copepods and a few others.

Table 10 summarizes the data on the groups counted in Berlese funnel samples. These indicate a clear-cut reduction in dipterous larval populations and an increase in the numbers of mealybugs (pseudococcids) following treatment. These mealybugs were found on the roots of *Spartina alterniflora* just beneath the soil surface. Representative specimens have been identified as *Coccidella maritima* (Ckll.) by H. Morrison, Entomology Research Division, U. S. Department of Agriculture. The numbers of Collembola present in treated plots also appear to have increased. Less clearly indicated was a temporary increase in amphipods during the summer following spraying and a possible increase in the number of snails. Among the dipterous larvae, the cecidomyiids, ephydriids and scaphognathids appear to be less affected than the other groups. Similar increases in the numbers of certain soil-inhabiting fauna following application of insecticides have been noted by other workers (see reviews by Brown, 1951, and Satchell, 1955).

THE LARGER ANIMALS

Under this heading are included the birds, fish, crabs, and larger molluscs. No attempt was made to determine the effects on mammals because of their relative scarcity in the marshes and their elusive habits. The mobility of some of the animal groups, possible repellent effects of the insecticide, and the possibility that individuals that had been affected by the treatment might leave the survey area are factors that tend to reduce the reliability of the field survey method of studying the effects of insecticides on these groups of animals. In the absence of detailed studies, however, this method probably is sufficiently reliable to determine whether or not extensive direct injury occurred in these larger and more conspicuous groups.

Field studies of the effects of dieldrin application (made on May 22 and 28, 1957) on birds were made by Mr. J. Bryant, U. S. Fish and Wildlife Service, in the marshes bordering Shinnecock Bay. Mr. Bryant was then in charge of the Morton National Wildlife Refuge, Noyack, L. I., and was familiar with the species of birds present in this region,

their normal population changes, and with the salt marsh itself. We have summarized his observations, with his permission, as follows:

Bird populations in the Shinnecock Bay area were observed following application of dieldrin granules to the salt marsh. The insecticide was disseminated over the marshes at the rate of about 0.3 pound per acre (technical) on May 22 and 28, 1957. Some species such as the red-winged blackbird (*Agelaius phoeniceus*), certain sparrows (*Ammospiza* spp.) and gulls (*Larus* spp.) were present in large numbers and well suited for close observation. Others were less widespread, their distribution being limited by the presence or absence of suitable habitats within the marsh. During the period of observation, from mid-April to mid-June, no dead, lethargic or otherwise abnormal specimens of any species of birds were observed. Their abundance and behavior were similar in the treated and adjoining untreated areas with normal increases and decreases in numbers and activity due to the time of day, season and status of the weather and tide.

Incidental observations of other marsh fauna showed:

1. Some dead, moribund and abnormal fish, mainly *Fundulus* spp.³

2. A considerable number of dead, moribund or lethargic green crabs (*Carcinides maenas*) and blue crabs (*Callinectes sapidus*). It appeared that the major portion of the population of these species was affected. Most of the specimens examined were of small size, up to 3 inches in shell width, and no normal appearing individuals were observed until three days after spraying.

3. No apparent injury to the horseshoe crab (*Limulus polyphemus*) that were present before and after the application of dieldrin.

4. An almost complete lack of fiddler crabs (*Uca pugnax*) although numerous burrows were noted in various sections of the marsh. This was also true before application of granules, presumably because they had not emerged yet following their period of cold weather inactivity. It would be expected that a few individuals of the population would be observed prior to normal activity in the spring of the year, but none were seen.

5. No apparent injury to other typical invertebrates such as the ribbed mussel (*Modiolus plicatulus*), salt-marsh snails (*Littorina saxatilis* and *Melampus bidentatus*), and mud snail (*Hydrobia ulvae*).

³ A considerable number of apparently unaffected fish were also noted. Observations were limited to shallow water species generally not exceeding 3 inches in length.

The possible effects on fish of the 1956 treatment in North Sea Harbor were studied by H. Udell. Shellfisheries Management Unit, Division of Fish and Game, New York State Conservation Department. The entire salt-marsh area bordering North Sea Harbor was treated in 1956. As mentioned earlier, coverage was good except in a few marginal portions of marsh bordered by woods. Mr. Udell's observations are summarized, with his permission, as follows:

Large numbers of bait fish (mostly *Fundulus heteroclitus* and *F. majalis*) were found throughout the marsh before treatment. Two days after treatment, net samples and visual observation indicated no reduction in number of fish present. No dead, moribund or lethargic fish were located. On June 12, 17 days after treatment, the area was again visited: as on the previous occasion there was no indication of fish kill. However, the number of fish present had apparently decreased. This is typical of these species after spawning has occurred and was not attributed to the spraying operation.

It was interesting to note that small pools, created in connection with studies of the smaller invertebrates, were literally teeming with post-larval *Fundulus* spp., measuring 5-6 mm. These fish all appeared normal, which would indicate that the spraying had no deleterious effect on the eggs or larvae of these fish. At this time numerous lethargic fiddler crabs were seen. A few dead ones were observed. These were mostly small females.

In addition to observations made by these two groups, State Science Service and Suffolk County Mosquito Control Commission personnel made field surveys to determine the gross effects on wildlife.

In 1956 live cages containing fish were set out in the treated section of marsh bordering Shinnecock Bay and in adjacent untreated marsh. Two cages in the treated area contained an aggregate of 18 *Fundulus* spp., 3 broad killifish (*Cyprinodon variegatus*) and 6 silversides (*Menidia* spp.). All were alive and apparently unaffected when they were examined three days after treatment. Several fish pots in the treated area were examined. A total of 9 live green crabs (*Carcinides maenas*) and 25 assorted bait fish (*Fundulus* and *Cyprinodon*), all alive and apparently normal, were counted in three pots on the same day.

The mosquito ditches in the treated area were searched for dead fish the day following application and again three days after treatment. The day following treatment, 5 dead *Fundulus* spp., all about 1.5 inches long, were found in three hours' search. At the same time numerous live bait fish were seen in the ditches. Three days after treatment about 30 dead eels (*Anguilla rostrata*), all about 2 inches long, were observed at one spot. Three small live eels and 3 broad killifish were seen swimming

near the dead eels, apparently unaffected by the treatment. Fish were observed in large numbers in this marsh and at Towd Point almost daily during the summer following treatment. Live fish were abundant in the ditches and dead fish very rare except for those taken within a few days after treatment. No fiddler crabs were observed either before or shortly after treatment, presumably because they had not emerged from hibernation at the time of treatment (May 24 and 25). During the summer large numbers of dead or lethargic fiddler crabs (*Uca* spp., mostly *pugnax*) were seen in both of the treated marshes. At the same time some apparently normal ones were seen in these same marshes.

In 1957 another portion of the Shinnecock Bay salt marsh was treated on May 22 and 23. Several pounds of granules, which had inadvertently been spilled during loading, were blown into a small pool (about 250 sq. ft.) by the helicopter. Before treatment this pool contained numerous live killifish and broad killifish. On May 30 hundreds of dead fish were seen. There was apparently no survival of fish in the pool. The pool was examined at irregular intervals thereafter. On August 9 numerous small broad killifish less than an inch long were seen for the first time following treatment. Live bubble shell snails (*Haminea solitaria*) were also present.

In the ditches, channels and pools of the treated portion of marsh, there was some evidence of fish mortality. During the week following treatment, 36 dead *Fundulus* spp., 2 *Apeltes quadracus* and 4 *Cyprinodon variegatus* were found in about 15 hours of searching. A few abnormal, i.e., poorly coordinated fish were seen during this period, but not later. At the same time, numerous small, apparently normal, bait fish, mostly killifish and broad killifish, were observed in these same ditches, channels and pools. In June numerous schools of apparently unaffected bait fish fry were observed in the treated area. The horseshoe crab, *Limulus polyphemus*, was abundant in May before and after treatment. Dead, abnormal and apparently normal ones were seen during the week following treatment. The abnormal ones were frequently seen lying on their backs with their gills moving slowly and the tail spine pushing downward toward the ground. Dead specimens were also found in the adjacent check area. The mortality in this case may be due, at least in part, to natural death following egg deposition.

The effect of treatment on crabs was assessed by counting the live and dead ones observed while wading in channels cut through the marsh. During the week following treatment, 22 dead or abnormal blue crabs (*Callinectes sapidus*) were found and no normal ones seen. In addition, 22 dead or abnormal green crabs (*Carcinides maenas*) were seen and 2 apparently normal ones. Specimens were considered abnormal if they were found lying on their backs or could be picked up without assuming

their typical defensive posture. All specimens recorded were picked up and examined to make sure no cast skins were included in counts. During June, 22 dead or abnormal and 24 apparently normal blue crabs were collected and 11 dead or abnormal and 28 apparently normal green crabs. Few fiddler crabs were seen at any time during the summer. Only 6 dead or abnormal specimens and one apparently normal specimen were recorded.

The mud whelk, *Ilypnassa obsoleta*, which is found in water bordering the marshes and in ditches and channels running into it, was apparently unaffected by treatment. Large numbers were observed before and at intervals after treatment. The salt-marsh snails, *Littorina saxatilis* and *Melampus bidentatus*, which are found in the intertidal zone of the salt marsh, appeared to be unaffected by treatment. *Modiolus plicatulus*, the horse mussel, which is the only bivalve found commonly and in large numbers at the surface of the marsh, was apparently unaffected a month following treatment. Later in the summer, on August 21, 23 and 29, large numbers of this species were found dead inside the treated area. Conservation Department personnel estimated that about 95 percent of the *Modiolus plicatulus* in the treated area were dead. There appeared to be little mortality on either side of the treated area. The Shellfisheries Management Unit, New York State Conservation Department, reported that these mussels were analyzed chemically shortly after the dieldrin was applied and again five months later. In neither instance was a significant amount of halogenated hydrocarbon found in the mussels tested. From this, they concluded that the dieldrin granules, at the dosage used, did not *directly* contribute to the mortality of these mussels.

DISCUSSION

Dieldrin granules as applied in these tests over salt marshes at a rate of about 0.3 pound per acre appear to be effective in reducing populations of ground-inhabiting dipterous larvae including the tabanids. The most obvious direct effect on other fauna is injury to blue crabs. Where this species is abundant and economically important, there are a number of steps which, taken individually or together, would probably reduce crab mortality.

For example:

1. If the insecticide were applied in early March rather than in late May, direct effect on the blue crabs might be largely avoided, since they overwinter in deep water. By the time they returned to the marsh areas late in the spring, the dieldrin that fell into ditches and channels, flushed by the tides, would be greatly diluted.

2. More care could be taken in applying granules near channels, inlets and pools where the crabs may occur in large numbers.

3. A lower dosage might be used. Dosages of 0.1 pound per acre or less have given control in small plots. The higher dosages applied in our tests were used in an attempt to obtain two-year control with a single application.

4. Different formulations of insecticide having a slower release rate might be less injurious to crabs.

5. Improved distribution apparatus for granules would assist in obtaining a wide, uniform swath that would reduce inequalities of distribution, which undoubtedly occur with the relatively primitive equipment used in these tests.

The field survey data obtained by three separate groups of observers studying the effects of dieldrin in salt marshes were in substantial agreement where they overlapped. There was no apparent direct injury to birds, either immediately following treatment or during the summer months thereafter. Small numbers of dead bait fish and immature eels were found within a few days following treatment. At the same time many live and apparently normal bait fish and eels were present. Later, numerous schools of apparently normal fingerlings were observed. Many (probably most) of the blue crabs and green crabs present at the time of the application were affected and eventually died. A lessening degree of mortality persisted for at least five weeks following treatment. Dead fiddler crabs were found in treated marshes during the summer following treatment. The three most common species of snails were apparently unaffected. Numerous dead horse mussels, the only bivalve commonly occurring in the vegetated portion of the salt marshes, were found in August three months after treatment in the treated portion of the marshes but not on either side in untreated marsh. Among the smaller invertebrates studied, dipterous larvae appeared to be greatly reduced by the treatment and mealybugs and springtails increased somewhat. Changes in other groups were less clear-cut.

SUMMARY

The salt-marsh greenhead, *Tabanus nigrovittatus* Macq., was found to be the most abundant and annoying of the salt-marsh breeding species of tabanids in coastal areas of New York. Other salt-marsh breeding species commonly collected were *Tabanus lineola* Fab., *Chrysops atlantica* Pech. and *Chrysops fuliginosa* Wied. The immature stages of some salt-marsh-breeding species are described and observations on their life histories are given.

Larval control studies carried out on Long Island indicate that granulated dieldrin, applied at the rate of about 0.3 pound per acre by aircraft over the marshes, greatly reduced *Tabanus* larval populations. In some instances, this reduction was reflected in reduced adult populations within the treated area.

Studies on the effects of treatment on other fauna indicated that birds and fish are little affected by the treatment. Dipterous larvae, crabs, and horse mussels appear to be adversely affected while mealybugs and spring-tails increase in numbers. Changes in the population levels of mites, spiders, amphipods, isopods and snails were less clear-cut.

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PLATES

PLATE I

Eggs

Figure 13. *T. lineola* mass, lateral aspect

Figure 14. Cross section anterior end showing micropyle cone

- a. *C. fuliginosa*
- b. *C. atlantica*
- c. *T. nigrovittatus*
- d. *T. lineola*
- e. *T. atratus*

Larvae

Figure 15. Abdominal segments, dorsal aspect

- a. *T. lineola*
- b. *T. atratus*

Figure 16. *T. lineola*, lateral aspect

Figure 17. *T. atratus*

- a. Thorax, lateral aspect
- b. Posterior end, lateral aspect

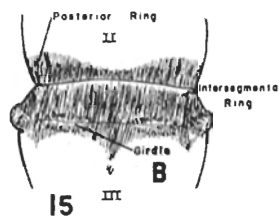
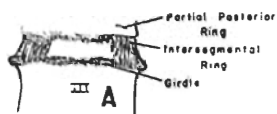
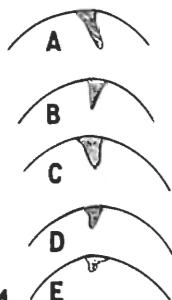
Figure 18. *T. nigrovittatus* posterior end, lateral aspect

Figure 19. *T. sp. A.* posterior end, lateral aspect

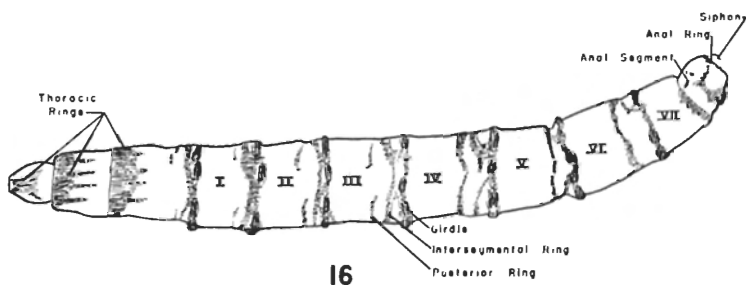
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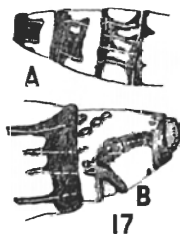
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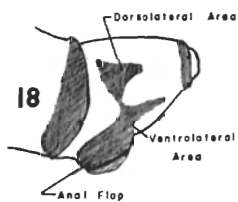
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PLATE 11

Larvae (*cont.*)

Figure 20. *C. fuliginosa* posterior end, lateral aspect

Figure 21. *C. atlantica* posterior end, lateral aspect

Pupae

Figure 22. *T. nigrovittatus* aster, posterior aspect

Figure 23. *T. lineola* aster, posterior aspect

Figure 24. *C. fuliginosa* aster, posterior aspect

Figure 25. *T. nigrovittatus* operculum, frontal aspect

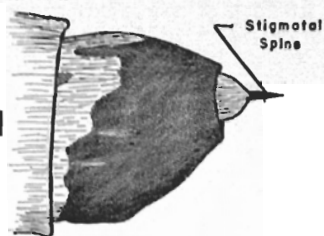
Figure 26. *T. lineola* thoracic spiracle, frontal aspect

Figure 27. *C. fuliginosa* thoracic spiracle, frontal aspect

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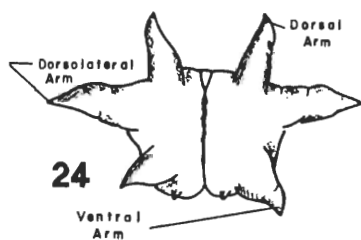
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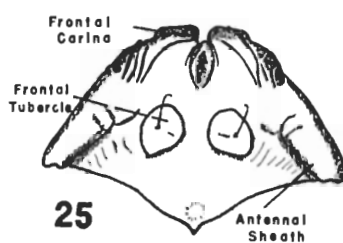
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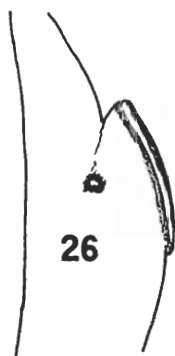
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