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IMPOUNDED WATER AS A MAJOR PRODUCER OF *CULEX SALINARIUS* (DIPTERA: CULICIDAE) IN COASTAL AREAS OF NEW JERSEY, USA[1,2]

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Abstract. *Culex salinarius* was found to be the dominant species in 9 of the 10 largest *Culex* populations in New Jersey, USA. Sampling revealed that larval habitats included coastal brackish and freshwater impoundments, a stop ditch and a dredge deposit zone. Virtually all of these habitats were man-made, and many were constructed to control the saltmarsh mosquito, *Aedes sollicitans*. These data demonstrate the need for more thorough evaluation of marsh management techniques to avoid replacing one nuisance species with another.

Culex salinarius Coq. is a common mosquito that is most abundant along the Atlantic and Gulf coasts of the United States (Carpenter & LaCasse 1955). The species accepts a wide variety of bloodmeal hosts (Murphey et al. 1967, Edman 1974) and is considered a major nuisance to humans (Steelman 1975). Chamberlain et al. (1958) implicated *Cx. salinarius* as a possible vector of eastern equine encephalitis along the eastern seaboard. Clark et al. (1977) suggested that the species may also be important in the transmission of St. Louis encephalitis. Although Smith (1904) originally classified *Cx. salinarius* as a salt-marsh mosquito, the species is widely distributed throughout the inland states (Eldridge et al. 1972). Larval habitats include a variety of brackish or freshwater sources that are rich in emergent vegetation and decaying plant material (Horsfall 1955, Murphey 1961).

The state of New Jersey, USA, has been monitoring mosquito populations with standard New Jersey light traps since 1931 (Headlee 1932) and has a continuous record of the major pest species in most areas of the state. The traps, operated primarily by county mosquito control agencies, are used to compare mosquito abundance from one year to the next and identify problem areas where control is needed to alleviate mosquito nuisance. Records from this monitoring system indicate that *Culex* mosquitoes are extremely abundant in many coastal areas of the state. Because of the coastal distribution, the populations are assumed to be composed primarily of *Cx. salinarius*, but the actual percentage of this species in local collections has never been well defined. *Culex* mosquitoes collected by light trap are usually rubbed and fairly difficult to accurately identify to species (Headlee 1945, Siverly 1972). As a result, most New Jersey light trap record sheets group *Culex* species as a complex, which includes *Culex pipiens* L., *Culex restuans* Theo. and *Cx. salinarius*.

In 1978, a study was initiated to determine if *Cx. salinarius* was actually the dominant *Culex* along the New Jersey coast. Studies were also undertaken to define the primary larval habitats in areas where the species was a major pest.

MATERIALS AND METHODS

Records from approximately 335 county light traps were examined to determine those that collected the largest number of *Culex* mosquitoes on an annual basis. The 10 traps that showed the highest populations from 1973 to 1977 were ranked according to the mean total number of *Culex* collected during the month of August, the peak period for *Cx. salinarius* in the middle Atlantic region. Each of the traps was then located and the trap sites were visited for related field studies.

In 1978 and 1979, pigeon traps were employed in the vicinity of each light trap site to collect *Culex* specimens that could be accurately identified to species (Ehrenberg 1966, Downing & Crans 1977). Two pigeon traps were operated biweekly at each of the 10 sites during July and August of the 2-year period. Pigeon trap collections were frozen as soon as possible, and the specimens were examined to determine the percentage of *Cx. pipiens*, *Cx. restuans* and *Cx. salinarius* in the samples. In

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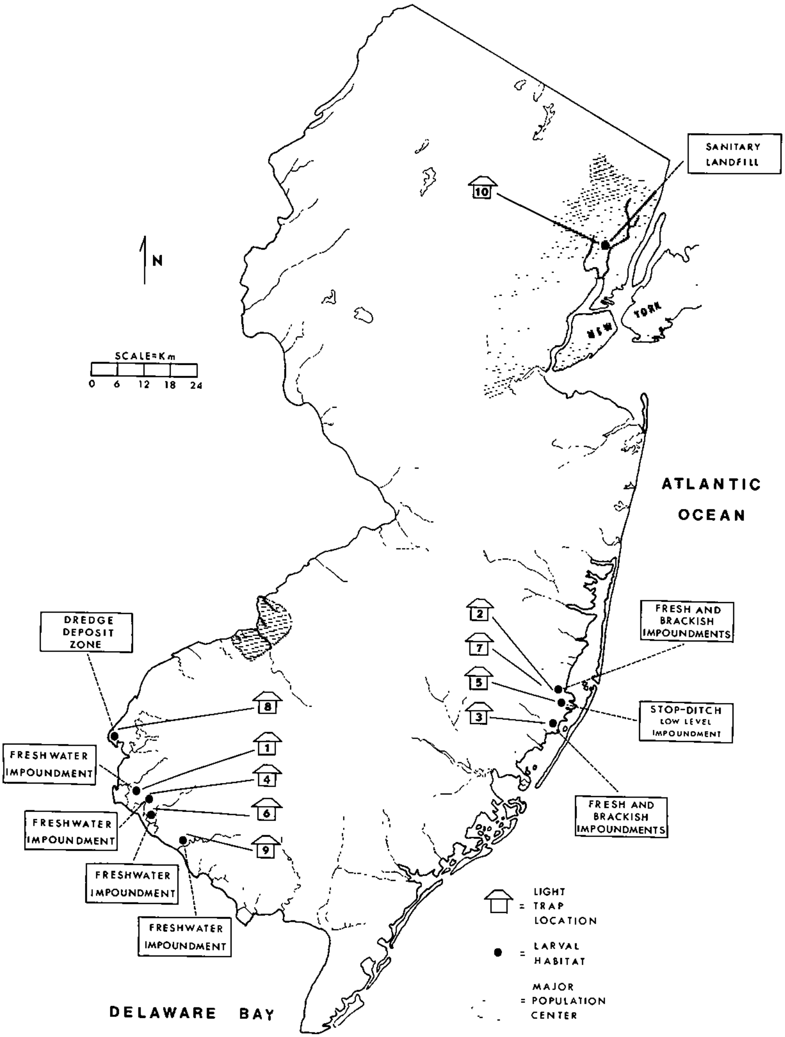

FIG. 1. The geographic location of New Jersey's 10 largest light trap collections of Culex mosquitoes and the respective larval habitats.

areas where *Cx. salinarius* constituted at least 50% of the *Culex* population, potential larval habitats within a 3-km radius of the light trap were sampled using a standard mosquito dipper. Whenever *Cx. salinarius* larvae were located, the habitat water was assayed for salinity, and associated mosquito larvae and vegetation were taken for identification.

RESULTS

The geographical distribution of the 10 light traps that averaged the greatest number of *Culex* mosquitoes in New Jersey from 1973 to 1979 is illustrated in Fig. 1. The numerals within each light-trap symbol rank the traps from 1 to 10 according to the average total collection for August during the 5-year period. The trap sites all bordered either the Atlantic Ocean or Delaware Bay, and all but light trap 10 were within 6 km of the coast. Traps 1–9 were situated in relatively rural areas on the coastal plain in the southern portion of the state. Trap 10 was much farther inland in a heavily populated region in metropolitan northeastern New Jersey.

Table 1 shows that the average August collections in these traps ranged from a high of 23,379 *Culex* mosquitoes in trap 1 to a low of 1952 in trap 10. Pigeon trap sampling showed that *Cx. salinarius* was the dominant *Culex* species at all the sites in the southern portion of the state; *Cx. pipiens* and *Cx. restuans* were detected in low numbers at some of the southern sites. In the single trap (site 10) located in the urban northeast, however, *Cx. pipiens* represented over 92% of the *Culex* population, and *Cx. salinarius* was found only in low numbers.

Larval sampling revealed that each of the 10 largest *Culex* populations detected by the light traps originated from a nearby permanent or semipermanent water source. Although many of the traps were stationed on or adjcent to vast acreages of transient coastal marsh, all the *Culex* mosquitoes, including *Cx. salinarius*, were utilizing more permanent bodies of water as the major breeding sites.

Table 2 lists the primary breeding habitat associated with each of the light traps monitored in this study. In the southern portion of the state, some form of impounded water was responsible for producing each of the local *Cx. salinarius* populations that was reflected by the abnormally high trap counts. In the northeast, a sanitary landfill produced the *Cx. pipiens* that were collected at trap-site 10.

TABLE 1. Percentages of *Culex salinarius* in New Jersey's 10 largest *Culex* populations.

No. of *Culex* in light traps: Trap no.	August avg.	Distance from coast (km)	% *Culex* as measured by pigeon traps: *pipiens*	*restuans*	*salinarius*
1	23,379	0.9	1.3	0.7	98.0
2	16,801	1.3	0.8	0.3	98.9
3	5272	2.0	5.1	0	94.9
4	5083	6.0	9.2	6.1	84.7
5	3860	5.0	0.4	0.1	99.5
6	3597	6.0	0	0	100
7	2957	3.0	0.8	0.3	98.9
8	2040	0.1	32.0	8.0	60.0
9	2003	3.8	0	0	100
10	1952	27.0	92.3	2.9	4.8

The impoundments on the eastern coast of New Jersey that were producing large numbers of *Cx. salinarius* (trap-sites 2, 3 and 7) were originally created to control the saltmarsh mosquito, *Aedes sollicitans* (Walker). In each case, several hundred hectares of salt marsh were diked and inundated with fresh water to prevent the alternate flooding and drying conditions that favor the salt-marsh *Aedes*. None of the impoundments was more than 20 years old, and salinity readings during 1978 and 1979 indicated that the water contained less than 2.0 ppt of salt when larval sampling was conducted. *Cx. salinarius* larvae were most often associated with vegetation comprising *Phragmites communis*, *Typha* sp. and *Scirpus* sp. At one of the sites (trap 3), larvae were collected in small numbers within stands of *Spartina alterniflora* that remained from the original salt-marsh ecosystem.

Larval sampling near trap-site 5 on the eastern coast of the state showed that *Cx. salinarius* larvae were abundant in an area where salt-marsh drainage ditches had been blocked 3 years earlier to create a low-level impoundment for the control of *Ae. sollicitans*. The technique, often referred to as "stop ditching" (Shisler 1978), interrupts tidal flow and allows water from upland areas to flood the marsh to a depth of approximately 15–30 cm. Salinity varied from 0.5 to 10.0 ppt while larvae were being sampled. *Distichlis spicata* and *S. alterniflora* were the dominant plants in areas where *Cx. salinarius* larvae were most numerous.

The impoundments along the Delaware Bay coast of New Jersey that were producing large numbers of *Cx. salinarius* (trap-sites 1, 4, 6 and 9) were constructed to convert marshes to farmland more than 50 years ago. These impoundments

TABLE 2. Primary breeding habitats of New Jersey's 10 largest *Culex* populations.

No. *Culex* in light traps		% *Culex salinarius*	Larval habitat		
Trap no.	August avg.		Type	Salinity (ppt)	Associated vegetation
1	23,379	98.0	Freshwater impoundment	0	*Phragmites communis*
2	16,801	98.9	Freshwater and brackish impoundments	0*	*P. communis* *Typha* sp.
3	5272	94.9	Freshwater and brackish impoundments	1.0–2.0	*P. communis* *Spartina alterniflora* *Scirpus* sp.
4	5083	81.7	Freshwater impoundments	0	*P. communis*
5	3860	99.5	Low-level impoundment (stop-ditch)	0.5–10.0	*Distichlis spicata* *S. alterniflora*
6	3597	100	Freshwater impoundment	0	*P. communis*
7	2957	98.9	Freshwater and brackish impoundments	0*	*P. communis* *Typha* sp
8	2040	60.0	Dredge deposit zone	0	*P. communis*
9	2003	100	Freshwater impoundment	0	*P. communis* *Scirpus* sp
10	1952	1.8	Sanitary landfill	0	None

* Although salinity readings indicated fresh water throughout this study, extreme high tides occasionally flow over the dikes of these impoundments to create brackish conditions.

trap fresh tidewater from the mouth of the Delaware River and keep the adjacent upland drained well enough to farm. Water samples from the impoundments yielded salinity readings of 0 ppt throughout the year. Considerable aquatic vegetation had grown up in the flooded areas, and large muskrat populations currently provide the property owners with an important source of income. *Cx. salinarius* larvae were found in dense stands of *P. communis*, the dominant vegetation in the impounded areas.

Larval sampling near trap-site 8 on Delaware Bay showed that *Cx. salinarius* was breeding heavily in a dredge deposit zone. The habitat is actually a high dike impoundment created to hold the mixture of mud and water that is pumped from dredging operations to deepen navigable waterways. The impoundment remained flooded throughout the period of larval sampling, but complete evaporation of this habitat is possible because rainwater is the only source of replenishment when pumping operations cease. Salinity readings indicated 0 ppt throughout the 2-year investigation, and *Cx. salinarius* larvae were most abundant in the dense stands of *P. communis* that were overtaking this area.

A number of mosquito species were frequently collected along with *Cx. salinarius*. The impoundments most often yielded freshwater species including *Anopheles punctipennis* (Say), *Anopheles quadrimaculatus* (Say), *Culex territans* Walker and *Uranotaenia sapphirina* (Osten Sacken). Lesser numbers of *Cx. restuans* and *Culiseta silvestris minnesotae* Barr were detected in some of the impounded areas. *Aedes cantator* (Coq.), a floodwater species, was the only salt-marsh mosquito associated with *Cx. salinarius* in freshwater impoundments, and was also the only species associated with *Cx. salinarius* in the more saline low-level impoundment and in the transient dredge deposit zone.

Although *Cx. salinarius* amounted to less than 5% of the *Culex* mosquitoes collected at trap-site 10 in the urban northeast, larval sampling was conducted to determine the source of the *Cx. pipiens* that accounted for that trap's high mosquito population. Numerous *Cx. pipiens* larvae were located in a nearby sanitary landfill that encompassed several hundred hectares of heavily polluted stagnant pools and discarded containers. No *Cx. salinarius* were found in the landfill area, but larvae were collected from a nonpolluted freshwater impoundment approximately 4 km southeast of the light trap location.

DISCUSSION

There is substantial evidence to show that impoundments constructed in coastal areas will produce large populations of *Cx. salinarius*. Such an occurrence was documented in New Jersey by a comprehensive 3-year study designed to determine the influence of wildlife impoundments on mosquito breeding (Chapman & Ferrigno 1956), and concurrent research in Delaware provided essentially identical results (Springer & Darsie 1956, Florsbutz 1959). The studies concluded, however, that the rise in *Cx. salinarius* populations was not a serious problem. Additional work has shown that impoundments in the southern United States have a similar effect. In Florida, Clements & Rodgers (1964) reported a substantial increase in *Cx. salinarius* from a freshwater impoundment constructed to control salt-marsh *Aedes* species. Comparable results were obtained in Louisiana by Fleetwood et al. (1978), who noted that wildlife impoundments produced significantly more *Cx. salinarius* than undisturbed salt marsh. In all of these studies, the habitats that led to an increase of *Cx. salinarius* were brackish or freshwater regions that contained large amounts of emergent vegetation.

Results from the present investigation agree with the earlier studies, but indicate that the problem is widespread and more serious than originally believed. Virtually all of the largest *Cx. salinarius* populations in New Jersey emanate from some form of freshwater or brackish impoundments, many of which were originally designed to protect the public from salt-marsh mosquito nuisance.

Although *Cx. salinarius* is common along the Atlantic and Gulf coasts of the USA, the impact of the species appears to be overshadowed by salt-marsh *Aedes* such as *Ae. sollicitans, Ae. taeniorhynchus* and *Ae. cantator*. As a group, the salt-marsh *Aedes* can be severe pests. They are capable of flying considerable distances from the larval habitat (Smith 1904, Provost 1952), feed almost exclusively on mammalian hosts (Edman 1971) and feed avidly during the day as well as the night (Headlee 1945, Ebsary & Crans 1977). *Cx. salinarius* is known to be a pest species (Griffiths 1928, Steelman 1975) and a potential disease vector (Clark et al. 1977), but is less apparent than most salt-marsh *Aedes*. *Cx. salinarius* is more apt to be a local nuisance because the species has a limited flight range (MacCreary & Stearns 1937), accepts blood from birds as well as mammals (Murphey et al. 1967) and seeks a host almost exclusively after sunset (Murphey & Darsie 1962). As a result, large populations of *Cx. salinarius* can be overlooked in favor of controlling the more aggressive salt-marsh *Aedes*. New Jersey provides the perfect example in this regard. *Ae. sollicitans* populations are monitored continuously with landing rate counts taken during daylight hours, and the state operates an airspray program for adult control when the species reaches nuisance levels (Sutherland & Kent 1977). Unpublished data from the New Jersey Agricultural Experiment Station show that *Culex* species outnumber *Ae. sollicitans* in many coastal areas, but the members of the complex are not separated in most state and county light-trap records and control is not subsidized with state funds.

Impoundments represent one very effective method of controlling the salt-marsh *Aedes* that breed along the coast. By inundating portions of salt marsh that would normally produce 3 or more broods during a season, annoyance by these species can be greatly reduced. Impoundments frequently provide side benefits as well, e.g., enhancing waterfowl usage and recreational benefits (MacNamara 1952) and maintaining upland water tables for agricultural purposes (Harris 1937). Many *Culex* species, however, are aided by man's activities and thrive near human populations. *Cx. salinarius* is no exception and appears to be quite capable of exploiting a man-made ecosystem. Impounded areas offer an expanse of fresh water that quickly supports the emergent vegetation favored by the species. In a relatively short time, *Cx. salinarius* can become a serious pest.

As human activities increase in coastal areas of the country, greater numbers of people will be affected by the mosquitoes that breed in these regions. The replacement of one pest with another does not represent a logical pest-management strategy. Every effort should be made to develop an integrated approach for coastal areas that includes *Cx. salinarius* as well as the classical salt-marsh pests.

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