Distribution and dispersal of mosquitoes, Fire Island National Seashore, New York.

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Introduction

Insect dispersal has received considerable attention in the entomological literature (Southwood 1962, Johnson 1969, Dingle 1978, Gauthreaux 1980). Knowledge about dispersal patterns can help in predicting local outbreaks of potential pest species and in developing pest management programs (Gunn and Rainey 1979, Stinner et al. 1983). Dispersal patterns of numerous mosquito species have been described (Service 1976), including several species of the genus *Aedes*. One purpose of the present study is to describe dispersal patterns of *Aedes sollicitans*, the white banded salt marsh mosquito, from breeding sites in the vicinity of the Fire Island National Seashore.

Aedes sollicitans breeds in large numbers in salt marshes and temporary pools (Means 1979). There are several such areas on Fire Island, in the William Floyd Estate, and at several sites in the Mastic-Shirley area. Crans and coworkers (1976) reported inland dispersal of *Ae. sollicitans* from salt marshes in New Jersey. Also, prevailing winds during the summer blow from Fire Island toward the south shore of Long Island. It is possible, therefore, that mosquitoes that breed on Fire Island or in the Floyd Estate can migrate, under certain conditions, to Mastic Beach and Shirley, creating a pest problem. However, we do not know whether this actually occurs or, if it does, what percentage of the pest mosquitoes in residential areas originated from Fire Island. The salt marshes of Fire Island are biotically interesting (Conard 1935, Taylor 1978, Chapman 1974) and probably

important in local nutrient dynamics, so mosquito control measures that would disrupt this habitat should be avoided unless necessary.

The purpose of this study is to describe the distribution of breeding sites of *Ae. sollicitans* on Fire Island and the south shore of Long Island near Mastic Beach and Shirley, to describe species composition of adult mosquitoes in the study area, and to determine whether mosquitoes migrate in significant numbers from breeding sites on Fire Island to the Mastic-Shirley area. The results of this study will be used to establish a long-term monitoring program for *Ae. sollicitans* in this area.

Background Information

Study species

The white banded salt marsh mosquito, *Aedes sollicitans* (Walker), occurs along the Atlantic and Gulf Coasts and inland in suitable breeding habitats (Carpenter and LaCasse 1955, Berlin 1977, Fleetwood et al. 1978). It breeds primarily in saline water, but has a wide chloride tolerance range (1,000-30,000 ppm) (Zimmerman and Turner 1982), and is sometimes found in brackish and even fresh water (Ostergaard et al. 1961).

Aedes sollicitans is a multivoltine species that overwinters in the egg stage (Smith 1904). In Long Island salt marshes eggs hatch around mid April after inundation by tides (Means 1979). *Aedes* larvae go through four instars before pupating (Gillett 1971) and adult *Ae. sollicitans* appear around mid May (Crans et al. 1976). A female can lay up to 200 eggs, which she deposits singly (Smith 1904). In order for eggs to hatch a brief drying period is required, followed by flooding with water. Some eggs require a second or third flooding, and can remain viable for several months.

As in other mosquito species, adults feed largely on nectar and other sweet fluids (Gillett 1971, Magnarelli 1977, 1978). The females take blood meals for protein used in egg production. Blood feeding takes place mostly at night, with activity peaks around dawn and dusk (Carroll and Bourg 1977, Ebsary and Crans 1977). During the day adults rest on vegetation, but will fly and bite if disturbed (Smith 1904) and will visit flowers during daylight hours (Magnarelli 1979). *Aedes sollicitans* is a fierce biter and can be a serious pest to humans and domestic animals (Means 1979, Abbitt and Abbitt 1981). The preferred hosts are horses and other large mammals such as deer and cattle (Crans 1962, Thompson et al. 1963). However, a wide variety of animals are attacked including smaller mammals, birds, and occasionally even reptiles (Murphy et al. 1967). Several viruses have been isolated from *Ae. sollicitans* including those of Eastern, St. Louis, and California encephalitis (Kandle 1967, Goldfield et al. 1968, Sudia et al. 1971, Crans 1977) and it is a potential vector

of dog heartworm (Beam 1965). However, its status as a vector of these pathogens has not been definitively established.

Adults disperse from breeding sites (Crans et al. 1976) and have been found 28 miles out over a body of water (MacCreary and Stearns 1937). They are apparently carried by the wind (Gordon and Gerberg 1945) and some of the long-distance flight records probably result from passive carrying on wind currents. However, oriented migratory flight may also be important. Most individuals collected far from breeding sites are nulliparous, so dispersers are probably young adults that have not yet taken a blood meal (Crans et al. 1976, Fbsary and Crans 1977).

Aedes species vary considerably as to the distance of their dispersal flights. Some, such as *Aedes taeniorhynchus*, typically disperse long distances (30 km) after adult emergence and before taking blood meals (Provost 1952). Other species, such as *Aedes aegypti*, take relatively short migratory flights (Morlan and Hayes 1958). *Aedes sollicitans* is generally considered one of the longer distance dispersers (Gillett 1971), although Weaver and Fashing (1981) claim that it lacks a long distance non-appetitive migratory flight such as that of *Aedes taeniorhynchus*.

Field techniques

Mosquito sampling methods have been reviewed by Gillies (1974), Service (1976, 1977), and Southwood (1978). Active

adults can be captured with an aerial net or collected while attempting to bite a field worker (biting sample). Traps for active adults can be either non-attractant traps or can utilize an attractant such as light or carbon dioxide (which mimics the breath of vertebrates). I plan to capture, mark, and release large numbers of adults for the dispersal study so I will need attractant traps that do not harm the specimens. A standard trap that is currently widely used is the CDC light trap (Sudia and Chamberlain 1962), which consists of a battery-powered light source beneath a protective cap, with a small fan that pulls mosquitoes into a net bag. An air-actuated valve prevents captured mosquitoes from escaping. Dry ice can be hung near the trap to release carbon dioxide. The addition of carbon dioxide to light traps can increase catches over 17 times (Service 1976, Feldhaufer and Crans 1979).

The use of light and carbon dioxide as attractants will bias samples toward night-flying mosquitoes that are actively seeking a blood meal but will less effectively sample males, nost-biting females, and individuals of day-flying species (Service 1976, Sinsko and Craig 1979). I will therefore set sticky traps without an attractant to sample randomly from the passing air (Southwood 1978). Mosquitoes can be captured on sticky traps with grease as the adhesive (Provost 1960) or with a light layer of Tanglefoot. I will use cylindrical traps because flat surfaces produce wind eddies and catch fewer insects. These traps will also provide data on direction of mosquito movement (Gordon and Gerberg 1945). In addition to trap samples I will

take biting samples in Mastic Beach and Shirley to determine which mosquito species are attacking humans.

Mosquitoes can be marked with radioisotopes, trace elements, dyes, paints, or colored powders (Service 1976). Flourescent powders are most suitable for my mark-recapture experiment because they can be applied rapidly to large numbers of individuals with a powder insufflator (Crumpacker 1974). Small particle dusts that flouresce under UV light (Helecon flourescent pigments) are well-suited for insect marking (Bailey et al. 1962) and are commercially available in several colors. They can be applied directly, are long lasting, are not transferred between individuals, and do no apparent harm to the insect (Crumpacker 1974, Lillie et al 1981). Wild-caught mosquitoes sometimes have spots that flouresce under UV light (Reeves at al. 1948) so it is important to use colors that are not found on local mosquitoes.

One purpose of this study is to determine whether mosquitoes that breed on Fire Island disperse to Mastic-Shirley. Several approaches to this problem have been devised (Seber 1973, Service 1976, Southwood 1978). Some require repeated marking and release of recaptured individuals (Iwao 1963). However, since the number of colors for marking is limited, I will use the technique developed by Darroch (1961) in which individuals are marked once according to site of origin, and maximum-likelihood estimates are calculated for the probability of movement between sites. I will mark mosquitoes distinctly from each of five sites, and recapture to determine movement patterns between sites. This technique

employs modified Peterson estimates and has similar assumptions, but takes emigration and mortality into account and in fact estimates migration between sites. The assumptions (Seber 1973) are:

a) All individuals that haven't died or left the entire area are somewhere in the sample sites.

b) All individuals within a site have an equal probability of being captured.

c) Marked individuals behave independently of one another in regard to moving between sites and being caught.

d) The probability that an individual marked at site A is caught at site B is equal to the probability that an individual in A moves to B times the probability that an individual that is present in site B will be caught there.

e) The matrix of probabilities of transfer between sites is non-singular.

f) The probability of survival is the same in each sample site.

For the most part these assumptions are satisfied. The major departures are from assumptions a) and b) because some individuals may be moving between sample sites during a trapping episode, and because not all individuals are equally likely to be captured. There will probably be relatively few individuals between sample sites, so the departure from a) is probably not

serious. However, the departure from b) may be more serious because after being captured and marked females will probably soon take a blood meal, and so will be unlikely to be captured until after oviposition, two to five days later (Conway et al. 1974). Since Ae. sollicitans apparently migrates before biting (Crans et al. 1976) this problem is not likely to be important in the present study. Also, Ae. sollicitans has been taken in light and carbon dioxide traps with blood in the gut (Thompson et al. 1963), so the CD_C traps will capture at least some post-biting females. Finally, we will continue to take samples for weeks after the marking episode, so we will be trapping when marked individuals reenter the biting population. The assumptions of this technique are therefore met quite well by Ae. sollicitans in this area.

Darroch's (1961) technique will give estimates of the rate of movement between sites and of population size. The estimates of population size can be compared to estimates calculated by the method of Ito (1973). This method, which is a modified form of the positive method developed by Jackson (1939), requires a single marking episode and several recaptures, and so can be applied to the data from the present study.

Larval populations

To assess breeding areas of salt marsh mosquitoes it will be necessary to sample larval populations from all potential breeding sites in the study area. The standard technique for

sampling mosquito larvae is manual use of a larval dipper, which is a white container on a long handle (Hagstrum 1971). This technique can give biased samples because the tendency to stay at the surface (and thus be caught by a dipper) varies between instars of some *Aedes* species (Nielson and Nielson 1953). Other techniques include the use of nets, floating and stationary quadrats, and a variety of traps (Service 1976).

Mosquito larvae are almost invariably contagiously distributed on a microtopographic level (Service 1976), so a large number of samples are necessary to get reliable population estimates. The number of traps required would be prohibitively large. Nets must be emptied into containers and the larvae extracted, which is quite time consuming. Therefore, standardized dip samples within randomly-placed quadrats provide the best alternative for a breeding area survey of the magnitude needed for this study. Relative population estimates should be sufficient to identify areas with high larval populations. These can be obtained with a dipping technique standardized so that any biases are equal in all sample sites.

Proposed research

Adult dispersal

The purpose of this study is to estimate the proportion of mosquitoes in Mastic Beach and Shirley that originated from breeding sites on Fire Island and in the William Floyd Estate (Fig. 1). I will delineate five sample sites (subregions or strata of Darroch 1961) and mark adult mosquitoes with a different color of flourescent dust at each site. There will be two sites in Mastic Beach and Shirley (B) plus three sites from which mosquitoes are likely to migrate: the Floyd Estate (A), Hospital Point (D), and Bellport Beach (E). These sites may be changed based on preliminary data.

When large numbers of *Aedes sollicitans* adults emerge (there are four to six large emergences over the season) young adults will be captured in CDC traps, marked by puffing flourescent dust through the net bag, and released. Before release, we will count the number of mosquitoes settling in a small area within the net bag, and take a sample of mosquitoes from the trap. These specimens will be used to determine if mosquitoes in the trap were effectively marked with flourescent powder. The total number of mosquitoes that are marked and released will be estimated from a regression that we will prepare of the number of mosquitoes per net bag as a function of the number settling in a small area within the net.

The CDC traps must be set with a charged battery and with dry ice the evening of the sample, and insects must be marked and released early the next morning to avoid mortality from overheating and dessication in the trap. The labor required

limits the number of traps and the number of sites that can be studied. I will randomly place traps at each of the five sample sites (total twenty five traps). On each marking night three teams of two workers each will set traps as rapidly as possible until all twenty five traps are set. The field workers will return the next morning and mark, sample, and release the mosquitoes in each trap before 1000 hours.

Marking will continue for one, two, or three nights depending on the number of mosquitoes marked per night. It will be necessary to mark large numbers of mosquitoes because recapture rates are often quite low. Morlan and Hayes (1958) recaptured 4.7% of the 9,615 *Aedes aegypti* they released while Jenkens and Hassett (1951) recaptured only 0.005% of 3,000,000 *Aedes communis* they released. Numerous studies with other *Aedes* species fall between these limits (Service 1976). Because maximum-likelihood estimates require reasonably large sample sizes to be accurate, we will have to mark very large numbers of mosquitoes to ensure numerous recaptures. Previous experience with CDC traps on Fire Island and the Floyd Estate (Bobinchock pers. comm.) has shown that catches during adult emergence can range from a few hundred to over eighty thousand mosquitoes per trap per night. We will attempt to mark several thousand adults, at least, during each emergence period.

After marking mosquitoes we will begin a recapture program that will last until the next large adult emergence (three weeks to a month, Crans et al. 1976, Bobinchock pers. comm.). Each

week, CDC traps will be set on two days (Monday and Thursday, if possible) and net bags collected the next day. We will use different net bags than those used during the marking period to avoid contamination by flourescent dust. The entire sample from each trap will be brought to the lab to determine species composition and numbers of marked and unmarked females. Public exposure to mosquitoes occurs primarily in Mastic Beach and Shirley, so traps at this site will be run every night for about five days following each marking episode.

To determine directly which mosquito species are attacking humans, biting samples will be taken from problem areas in Mastic Beach and Shirley that are identified by public complaints. Mosquitoes landing on a field worker over a given time period will be captured to determine landing rates and nuisance levels (Crans et al. 1976). If time permits, these individuals will be dissected in the lab to determine parity, which is related to vector potential (multiparous mosquitoes are most likely to have ingested viruses).

Cylindrical sticky traps will be run continuously during the summer. These will randomly sample mosquitoes in the air, and will ensure that any migration event will be recorded, even if it occurs on days between CDC trap samples. They will also provide information on direction of insect movement. The directional data will be suggestive only, but may corroborate conclusions drawn from CDC trap samples.

Species composition

I will use data from CDC traps, sticky traps, and biting samples to describe the species composition of common adult mosquitoes in the study area. The traps will be randomly placed, so standard statistics can be performed on population trends over the season at each site for each of the common mosquito species.

Species composition and percentage marked females in biting samples will help determine what percentage of pest mosquitoes in Mastic-Shirley dispersed from Fire Island. This is important because even if *Ae. sollicitans* does disperse to Mastic Beach and Shirley, the nuisance mosquitoes in residential areas may be mostly other species.

Larval populations

One field assistant will sample larval populations of *Ae. sollicitans* in the entire study area. Early in the season the principal investigator will set up permanent larval sampling quadrats in each breeding site. There will be ten quadrats (each 20m x 20m) at each site, randomly selected from grids on maps and aerial photographs.

Samples will be taken once weekly from each site. For each sample the field assistant will randomly select two 20m transects within each quadrat (new transects each week to avoid excessive trampling of one area) and take samples while slowly walking the

transect. He/she will take twenty dips per transect (one each step) and record the number of larvae per dip. Dips will be taken in a uniform manner with the dipper held in front of the field worker. If possible, different instars will be recorded separately. The contagious distribution of larvae will result in numerous dips with no insects, as has been the case in previous dip samples from this area (Bobinchock pers. comm.). Therefore, the total number of larvae collected in a quadrat (total of forty dips) will comprise one data point. Thus, there will be ten data points per sample site per week. Of course, a population outbreak could occur outside of the sample quadrats. Therefore, a field assistant will sample known breeding areas outside of the random quadrats and will comb the entire study area for outbreaks of larvae.

Future monitoring program

The data from this study will be used to establish a long term monitoring program for mosquitoes in this area. Ideally, samples from just a few traps and larval sampling sites would be sufficient, along with tide and weather data, to predict mosquito outbreaks in Mastic Beach and Shirley. Unfortunately, data from just one year could be anomalous, and a longer term study would be required to establish a reliable monitoring program.

Anticipated results and scope of the study

The study outlined above should provide estimates of population sizes and distribution of *Aedes sollicitans* larvae and adults, rates of dispersal between sites, and proportion of pest mosquitoes in Mastic Beach and Shirley that dispersed from Fire Island or the Floyd Estate. Migration events can be correlated with temperature and wind data from nearby weather stations. However, in view of the low recapture rates in previous studies of *Aedes* dispersal, it is quite possible that there will be no recaptures, or too few to get reliable estimates of population sizes and transfer rates between sites. *Aedes sollicitans* dispersal has never been studied under these circumstances so I have no way to accurately estimate recapture rates ahead of time. Data from the first year of the study can be used to design a sampling program for future years that would provide more reliable estimates of adult dispersal rates.

Year-to-year differences in tides, temperatures, and wind patterns undoubtedly result in yearly differences in population sizes and dispersal patterns of *Aedes sollicitans*. Therefore, results of a one year study cannot be taken as typical. Data from several years are required to establish patterns that can be used to reliably predict population performance and dispersal patterns. A three year study, at least, would be needed to quantify year-to-year variation in these population parameters. Data from the first year will help pinpoint the breeding sites of biting mosquitoes in Mastic Beach and Shirley. The major problem

sites can be studied intensively in the second and third year to get better estimates of dispersal rates between these sites and residential areas.

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Personnel

Co-Investigator/Field Entomologist

Howard S. Ginsberg, Ph.D., Cornell University
Postdoctoral Research Assoociate, Department of Ecology and Evolution, State University of New York at Stony Brook

Dr. Ginsberg will design the sampling program and physically lay out the trap sites and quadrats. He will also instruct all field personnel in sampling techniques, run the sampling program, analyze data, and prepare a report on the results. Major results will be published.

Principal Investigator/Biostatistician

F. James Rohlf, Ph.D., University of Kansas
Professor, Department of Ecology and Evolution, State University of New York at Stony Brook

Dr. Rohlf will help design the sampling program, provide statistical advice, and help analyze data. He is a world-renowned expert in biostatistics and has co-authored one of the standard textbooks in the field (Biometry, by R.R. Sokal and F. James Rohlf, Freeman, 1981).

Consulting Entomologist

Roy Sofield, Ph.D., Rutgers University

Mosquito surveillance, New Jersey Mosquito Research and Control, Rutgers university

Dr. Sofield will confirm identifications of larval and adult mosquitoes, give instruction on dissection techniques to determine parity of females, and provide advice on trap placement, larval habitat preferences, and sampling procedures.

Field and lab assistants

Steve Redhead, Graduate student, Dept. of Ecology & Evolution, SUSB

Daniel Ciccarone, Undergraduate Assistant

Figure 1. Map of the study area.

A. William Floyd Estate

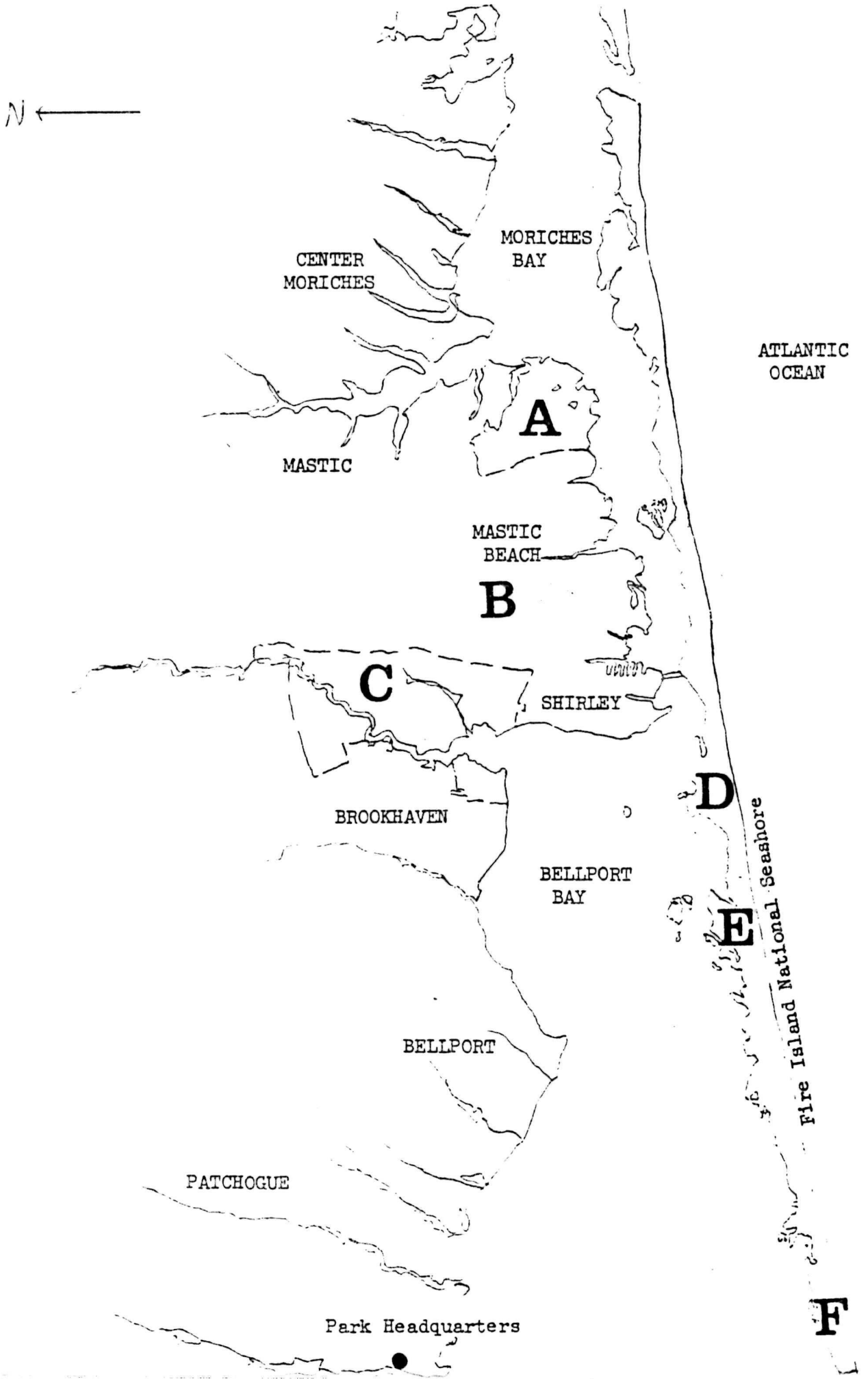
B. Mastic-Shirley site

C. Wertheim National Wildlife Refuge

D. Hospital Point site

E. Bellport Beach site

F. Watch Hill site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BELLPORT BAY
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Fire Island National Seashore
BELLPORT
PATCHOGUE
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Park Headquarters

RESEARCH BUDGET CONTRACT PROPOSAL

I assume that equipment, lab space, a place to stay overnight, some transportation around the study area, and field sampling assistance by National Park Service employees are provided without charge.

A) SALARIES AND WAGES			
1. Senior Personnel			
a. Co-Investigator, Howard Ginsberg Postdoctoral Research Associate full-time, 2 summer months and 5 acad. yr. months (total of 7 months) @ $1,428.58/month	$10,000		
b. Principal Investigator, F. James Rohlf Professor, 4.2% time, 2 summer months	500		
Sub-total, senior personnel		10,500	
2. Other Personnel			
a. Research Assistant (Graduate Student) Charles Stephen Redhead, 35% time, summer	1,650		
b. Undergraduate Research Assistant Daniel Ciccarone, 40 hrs./wk., 13 wks. (3.35/hr.)	1,742		
Sub-total, other personnel (graduate & undergrad students)		3,392	
Total, salaries and wages			13,892
B) FRINGE BENEFITS, 25% of salaries and wages, of 10,500 (excludes graduate and undergrad students)		2,625	
Total, salaries & wages, and fringe benefits			16,517
C) CONSULTANT SERVICES, Roy Sofield, Mosquito surveillance, Rutgers Univ., at least 3 visits, identifications of specimens, dissection techniques, and field sampling advice		1,100	
D) SUPPLIES			
1. battery charger	218		
2. other supplies	440		
Total, supplies		658	

RESEARCH BUDGET (cont'd)

E) TRAVEL, use of personal vehicles to travel around study site	$ 380	
F) PUBLICATION COSTS	850	
G) OTHER COSTS		
1. Computer costs (MODCOMP minicomputer in Department of Ecology & Evolution at Stony Brook)	500	
2. Preparation costs (figures, word processing, etc.)	350	
Sub-total, other costs		850
TOTAL DIRECT COSTS (A through G)		20,355
H) INDIRECT COSTS, off campus, 24.9% MTDC (of $18,655)		4,645
TOTAL COSTS (G through H)		$ 25,000