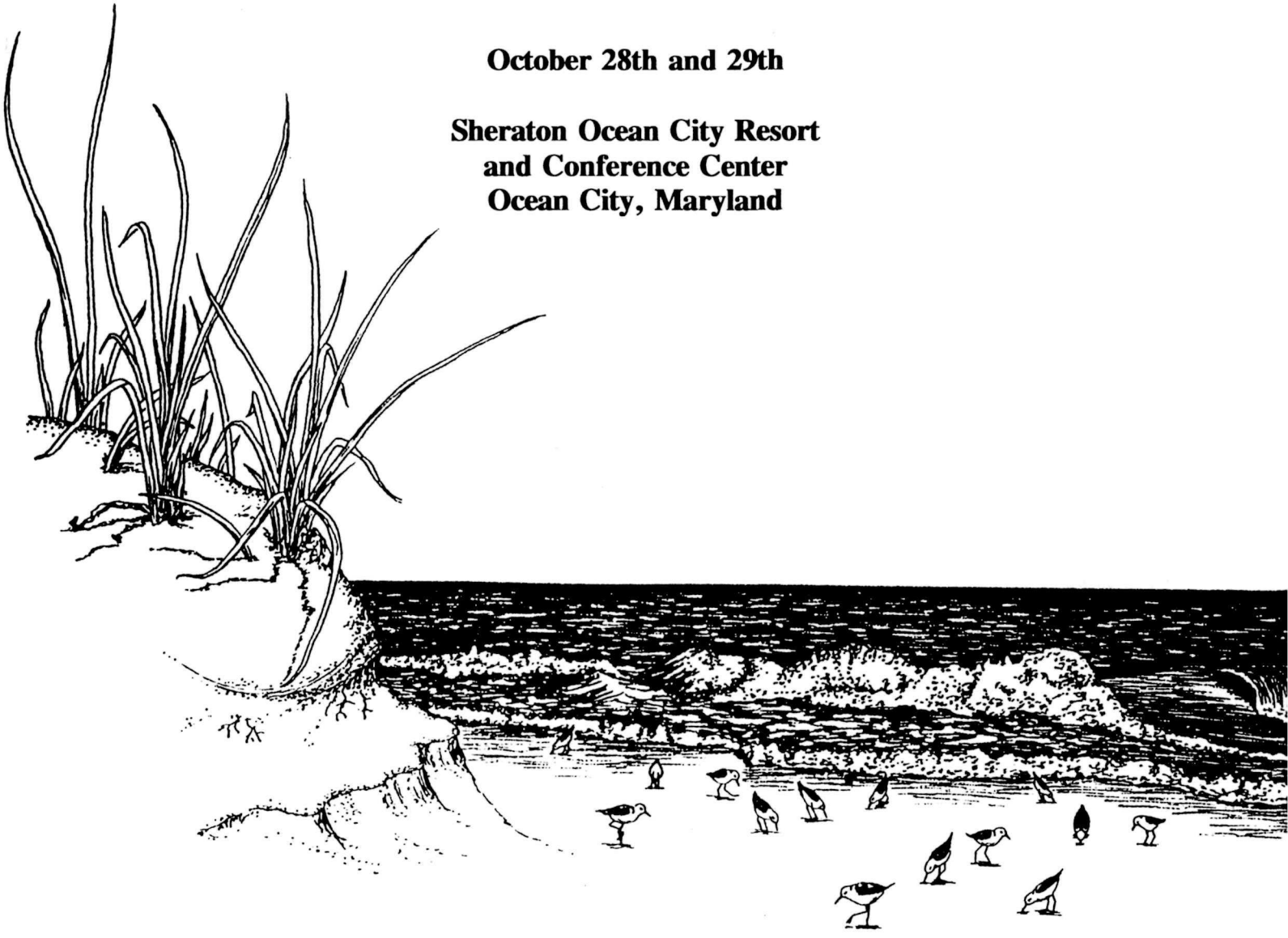
Proceedings of the 1991

ASSATEAGUE ISLAND SCIENCE CONFERENCE

October 28th and 29th

Sheraton Ocean City Resort
and Conference Center
Ocean City, Maryland



Assateague Island National Seashore

United States Department of the Interior
NATIONAL PARK SERVICE
ASSATEAGUE ISLAND NATIONAL SEASHORE
ROUTE 611, 7206 NATIONAL SEASHORE LANE BERLIN, MARYLAND 21811

IN REPLY REFER TO:

February 1, 1992

Dear Friend of Assateague Island:

At long last, it gives me great pleasure to provide you with the Proceedings of the 1991 Assateague Island Science Conference. As you will recall, the two day conference brought together scientists, park professionals and interested members of the public to share their understanding of Assateague Island. 21 researchers presented the findings of their work to an audience of more than 150. By all measures the conference was a resounding success.

The enclosed Proceedings is a collection of abstracts, summaries, and papers submitted by the conference participants. If you have any questions about this material or would like to obtain an additional copy, please do not hesitate to contact me.

Thanks again for your continuing interest in Assateague Island National Seashore.

Sincerely,

Roger K. Rector
Superintendent

Enclosure

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Sponsored by

Assateague Island National Seashore
U.S. Department of the Interior National Park Service

This proceedings is a collection of abstracts, summaries, and papers submitted by the participants of the 1991 Assateague Island Science Conference. The conference was convened to provide a forum for the presentation and exchange of current information relating to research and resource management activities being undertaken at Assateague Island National Seashore and Chincoteague National Wildlife Refuge. For more information about the specific projects reported upon here, contact the individual authors. For information about general research activities at Assateague Island National Seashore, contact the Superintendent, 7206 National Seashore Lane, Berlin, Maryland 21811.

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Waterfowl Use of Assateague Island

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Available waterfowl population monitoring data were obtained from several sources and are in the process of being summarized to determine chronology of use, areas of intensive use, and long-term population trends on Assateague Island National Seashore. Major sources of data were Chincoteague National Wildlife Refuge (CNWR) weekly waterfowl counts (1979-1990) (made primarily on refuge freshwater impoundments along an automobile route and kindly furnished by Irvin Ailes, Refuge Biologist) and Assateague Island National Seashore (AINS) biweekly bird counts (1984-1990) along the beach from an automobile in the Maryland portion of AINS (kindly furnished by Jack Kumer, Seashore Wildlife Biologist). Additional long-term data on population trends are available in the Mid-Winter Waterfowl Survey conducted jointly by Virginia, Maryland and the U.S. Fish and Wildlife Service. These data have been obtained but have not been analyzed yet. Further data on numbers of waterfowl using Assateague waters and on areas of intensive use are being obtained by monthly aerial survey flights during 1991-92.

Major species seen in the CNWR counts (averaging >1500 during peak month) were black ducks (*Anas rubripes*), pintails (*Anas acuta*), Canada geese (*Branta canadensis*), and snow geese (*Chen caerulescens*). Mallards *Anas platyrhynchos*, gadwalls (*Anas strepera*), green winged teal (*Anas crecca*), widgeons (*Anas americana*, shovellors (*Anas clypeata*), blue-winged teal (*Anas discors*), brant (*Branta bernicla*) and tundra swans (*Cygnus columbianus*) averaged between 300-800 individuals during peak months. Other species seen averaged ≤150 during peak months.

Most waterfowl species wintering on Assateague arrive in large numbers in October and peak in November or December. However, a few species [gadwalls, buffleheads (*Bucephala albeola*), old squaws (*Clangula hymenalis*) and red breasted mergansers (*Mergus serrator*)] do not arrive until November. Blue-winged teal migrate through the area in August-October and March-April and a few wood ducks breed on the island but migrate southward for the winter.

The Assateague Beach counts provided information primarily on scoters and old squaws, which use off-shore areas. Scoters (*Melanitta*) spp. arrived at AINS in October, peaked in January and were very low thereafter. In contrast, most old squaws arrived in December and remained until about April.

Initial aerial surveys of Assateague waters have indicated that black ducks, buffleheads, surf scoters (*Melanitta perspicillata*), Canada geese, and brant are the primary waterfowl species using saltwater habitats of Assateague Island National Seashore. More complete data and analyses will be available as the project nears completion.

Piping Plover Research And Management In Virginia

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Abstract--Nesting success of piping plovers was monitored in three nesting areas at Chincoteague National Wildlife Refuge, Virginia for three breeding seasons from 1989 to 1991. Public access to nesting areas was restricted to eliminate disturbance. Mammalian predators were controlled by trapping and all nests were protected through the use of predator exclosures. Piping plover broods were observed until ≥ 25 days old to determine fledgling productivity. All potential nesting habitat was mapped and nests plotted using Loran C. Nesting spatial patterns and density were evaluated by nearest neighbor analysis. Area of home range was measured using the computer program SPADS and defended territory was calculated from estimates of flushing distances of incubating birds. Where nesting density was high, egg loss was high but chick loss was low. Nesting territory represented less than 1.0% of home range.

Introduction

The piping plover (*Charadrius melodus*) is a small ringed plover which is currently listed as endangered at its inland breeding sites in the Great Lakes region and threatened in the remainder of its U.S. breeding range including the northern Great Plains region and along the Atlantic coast where it nests primarily on sandy beaches from Maine to North Carolina (Johnsgard 1981, Haig and Oring 1985, Sidle 1984, Cross 1990). Recent population declines preceding the listing of the piping plover have been attributed mainly to habitat loss, disturbance during the breeding cycle, and depredation of eggs and young by introduced and escalating populations of mammalian and avian predators (Robertson and Flood 1980, Burger 1987, Haig and Oring 1987, U.S. Fish and Wildlife Service 1988).

In Virginia, piping plovers breed almost exclusively on barrier island beaches. Statewide, plover populations have increased by 31.0% since 1987 to 131 breeding pairs but have remained relatively stable (8.26 % increase) in the last three years. Still, Virginia supports 17.7% (1990) of the U.S. Atlantic Coast piping plover population (Virginia Department of Game and Inland Fisheries 1990). Plausibly, the protected status of the Virginia barrier islands is responsible for the recent stability of the Virginia population (Williams et al. 1988). Further, there may be a convergence of birds in mid-Atlantic states resulting from excessive habitat loss at the northern and southern extremes of their breeding range (Haig and Oring 1985).

Habitat loss still occurs at an alarming rate on the Atlantic coast due to commercial and residential development and shoreline stabilization projects on beaches and barrier islands (Sidle et al 1991). Additionally, otherwise suitable nesting habitat may be rendered functionally unavailable by predators associated with human activities or by spatial, territorial, and nutritional requirements of breeding birds converging in a

declining environment (Cross 1990). Narrow-niched species such as piping plovers with specific habitat requirements may not be able to adapt readily to changing environmental conditions to the degree necessary to significantly increase their populations. Within remaining habitat, associations of habitat variables with nest site selection and breeding success is of substantial practical value to resource managers.

Research and management for wildlife are inseparable. This study was conducted at Chincoteague National Wildlife Refuge (NWR), Assateague Island in Accomack County, Virginia from 1989 to 1991 in order to provide long term management guidelines for improvement of piping plover nesting success in Virginia. Aspects of nesting success were examined across gradients of intraspecific nesting density and spatial patterns. The influence of habitat structure on nest site selection was also examined. Lethal and non-lethal predator controls were employed as protective efforts throughout the study. Monitoring of population changes and fledgling productivity provided a means of evaluating management effectiveness. Although the piping plover is protected throughout Virginia, Chincoteague NWR is the most actively managed nesting area. Most breeding areas are remote and require only seasonal signing as protection.

Methods

Chincoteague NWR contains approximately 26.71 km of oceanfront beach. However, 5.31 km of the beach experiences heavy public recreation and/or off-road vehicle traffic and is therefor functionally unavailable as nesting habitat. Of the remaining 21.39 km of beach, piping plovers nest on the southernmost 5.63 km of beach known as the hook and on a 6.44 km section of the northern beach known as the wild beach. A 2.66 x 0.81 km, seasonally drained, waterfowl impoundment (north wash flats) adjacent to the wild beach is a third nesting area. These three nesting areas differ markedly in habitat structure. In Virginia, 9.34 km of Assateague Island beachfront is apparently available to piping plovers as nesting habitat but is not used. Public access to the wild beach is limited to pedestrian use in the intertidal zone and the hook and wash flats are closed to public use during the piping plover breeding season. Human disturbance, then, was not a factor in this study.

Piping plovers were censused by vehicle or on foot in all potential nesting and foraging habitat at least three times weekly from their arrival at Chincoteague NWR. Data regarding activity and habitat were recorded for each piping plover observed during censusing. Piping plover adults and young were banded in this study (and previous local studies) with color band combinations permitting birds to be uniquely identified from a distance. Repeated observations of color marked birds provided information on local behavior and large scale movements between nesting areas and foraging sites.

Nests were located primarily by behavior watching or by tracking. All nests were scheduled for protection from mammalian predators through the use of predator exclosures. Exclosures were constructed by two to four persons as soon as complete four egg clutches were discovered. Later, the procedure was modified to initiate exclosure construction with less than a complete clutches. Exclosures were constructed of 2 in. x 4 in. mesh welded wire, 48 in. tall. A 10 ft. diameter circular design was selected with wire buried 4 in. in the sand and supported by four 5 ft. tall metal rods. Monofilament fishing line was woven across the exclosure top to deter large avian predators. Exclosures do not protect piping plover chicks after they leave the nest. Therefor, red foxes (Vulpes sp.) and raccoons (Procyon lotor) were trapped from February or March throughout the breeding season to reduce predator pressure in plover nesting areas.

Piping plover nests were monitored on alternate days throughout incubation to maintain exclosures and to determine the source of any egg loss. Broods were also monitored, until fledging (≥ 25 days), to assess losses to predators and to establish yearly productivity estimates. Flushing distances were recorded whenever incubating adults left the nest at our approach. Mean flushing distances from all nesting areas were used as the radius of a defended area to estimate the area of theoretical territory.

Physical parameters of habitat structure were measured at each nest after nesting was completed and were used to characterize nesting habitat and identify criteria for nest site selection. All nest locations were recorded as latitude and longitude coordinates using Micrologic, battery operated Loran C navigational computers. Boundaries of suitable piping plover nesting habitat as assessed in the field were also recorded by Loran.

All available nesting habitat was mapped (1:500 scale) using Loran coordinates and nest locations were plotted on the maps. Nearest neighbor distances (Clark and Evans 1954) were calculated by Loran or measured directly and were used to determine spatial patterns of nest sites within available habitat. Departures from random occupancy were tested for significance by t test. In 1991, bivariate normal home ranges (Jennrich and Turner 1969) were measured for 9 pairs of piping plovers (hook = 5, wild beach = 2, wash flats = 2) during the incubation phase of the breeding cycle. All focal pairs involved at least one banded adult (known identity) and observed locations of focal birds were recorded as Loran latitude and longitude coordinates. Home range areas were generated by the computer program, Simplified Plotting Analysis And Data Storage (SPADS) For Telemetry (Neerja et al. 1991).

Management practices were modified between years according to needs established in the previous year(s). Study design was also refined according to the most current information.

Results and Discussion

Utilization of nesting areas, population estimates and nesting success.--During the three years of this study, no nesting of piping plovers occurred outside of the three nesting areas known as the hook, wild beach, and wash flats. A mean of 37 pairs (range = 32 - 42) of piping plovers nested on the refuge yearly (Table 1). Refuge-wide fledgling productivity was highest in 1989 (1.13) and lowest in 1990 (0.57). Mean productivity was significantly lower ($P < 0.05$) on the wild beach than on the hook or was flats. Further, mean productivity (0.83) for the refuge was significantly different ($P < 0.05$) from 2.0 chicks fledged per

Table 1
Hatching And Fledging Success For Piping Plovers In Three Nesting Areas At Chincoteague NWR, 1989-1991.

Area	Year	Nests (N)	Nesting Pairs	Eggs Produced	Eggs Hatched/ Nest	No. Fledged/ Nesting Pair
Hook	1989	20	19	75	2.60	1.15
	1990	33	23	91	1.09	0.70
	1991	25	20	83	2.32	0.95
	Mean	19	21	83	2.00	0.93
Wild Beach	1989	8	7	25	2.88	0.57
	1990	16	13	54	2.50	0.15
	1991	9	9	33	2.89	0.33
	Mean	11	10	33	2.76	0.35
Wash Flats	1989	8	6	27	2.25	1.66
	1990	10	6	34	2.10	1.00
	1991	12	9	43	0.91	0.89
	Mean	10	7	35	2.42	1.18
Refuge	1989	36	32	127	2.03	1.13
	1990	59	42	179	1.64	0.57
	1991	46	38	159	2.07	0.79
	Mean	47	37	139	1.91	0.83

nesting pair recommended as a management goal by the U.S. Fish and Wildlife Service Atlantic Coast Piping Plover Recovery Team.

The area of suitable nesting habitats available differed between nesting areas (hook = 315.8 ha., wild beach = 79.18 ha., wash flats = 159.24 ha.). However, piping plovers did not utilize nesting areas according to availability. Significantly more nesting pairs were found consistently on the hook (G test, 1 df, $P < 0.01$) suggesting differences in habitat quality exist.

Habitat Characteristics--Of all physical parameters measured at piping plover nests, the width of the beach appears to be the most important. Beach widths on the hook were much greater than at nests on the wild beach ($t = 4.94$, $P < 0.001$) in 1990. The antipredator mechanisms of piping plovers include cryptic coloration of eggs, young, and adults as well as behavioral displays used by adult birds to distract or confuse predators. In high density nesting situations plovers often mob avian predators (pers. obser.). In each of these tactics piping plovers would profit from better range of vision and early predator detection offered by wider beaches.

Although beach nesters are vulnerable to flooding of nests by rain or tidal overwash, piping plovers did not select higher nest sites earlier in the season as hypothesized in 1989 ($G = 0.33$, $N = 23$, $P > 0.05$). Flooding is unpredictable to plovers and nest losses to flooding may be catastrophic when nest density is high or semi-colonial in response to declining habitat distribution.

Regardless of beach width, plovers showed a statistical preference (Neu 1974) for inner beach nesting habitats ($P < 0.001$) closer to a marsh, barrier flat or vegetation barrier than to the oceanfront wrackline (mean high tide) in 1989. Inner beach sites may offer greater protection from predators or intertidal disturbances and may improve foraging site diversity. On the hook, tidal pools were common. Plovers frequently used the moist edges of these pools as alternate foraging areas when intertidal sites were inundated or otherwise unavailable. Piping plover nests were close to tidal pools on the hook (mean = 149.14 ± 31.26 ft., $N = 14$).

Alternatives to intertidal surf zone foraging sites may be crucial to nesting piping plovers. Intertidal invertebrates may be depleted during Spring shorebird migration and not recover until late Summer. Newly hatched piping plover chicks find refuge and food at foraging sites away from the surf.

These ideas are supported by an observed shift in piping plover foraging site preference from early season (< 1 May) to late season (≥ 1 May) in 1990. More plovers foraged in the surf zone than away from the surf zone on the hook during the early season (Mann Whitney U-test, $P < 0.05$). But during the late season more plovers foraged at alternative sites (Mann Whitney U-test, $P < 0.05$) illustrating a shift in preference. On the wild beach, however, no shift was observed. Plovers used the surf zone more often in the early season (Mann Whitney U-test $P < 0.01$) but did not use alternative sites more often in late season (Mann Whitney U-test, $P > 0.05$). A greater abundance of prey and diversity of feeding areas likely exists on the hook and may partially account for the greater utilization of the hook by piping plovers.

Functional availability--Predation is one factor which clearly limits piping plover nesting success at Chincoteaegue (Cross 1990) and throughout its breeding range (Rimmer and Deblinger

1990). In some cases, predators may cause abandonment of former nesting areas (Erwin 1979, Cartar 1976) leaving them functionally unavailable. At Chincoteague NWR predation was responsible for most egg loss (41.8%) in 1989, but flooding was the primary agent for egg loss in 1990 (42.68%). In 1991, 93.75% of all egg loss was due to predation or abandonment of the nest as a result of predator pressure.

Egg losses to various causes remain high (mean = 37.61%, SD = 9.79, N = 465) despite the use of predator exclosures from 1989 to 1991. But productivity losses during brood rearing are much higher (mean = 68.32%, SD = 6.98, N = 285) when exclosures offer no protection to free roaming chicks.

Table 2
Distribution And Success of Predator Exclosures Used To Protect Piping Plover Nests at Chincoteague NWR, 1989-1991.

			Exclosed Nests				
Area	Year	Nests (N)	No.	Successful Nests[1] (%)	Failed Nests[2]	G	P
Hook	1989	20	19	16 (84.2)	3	9.765	< 0.01
	1990	33	18	10 (55.5)	8	0.223	NS
	1991	25	22	17 (45.5)	5	6.916	< 0.01
	Mean	26	19.67	14.33 (61.7)	5.3	4.215	< 0.05
Wild Beach	1989	8	4	3 (75.0)	1	1.047	NS
	1990	16	13	10 (76.9)	3	3.977	< 0.05
	1991	9	8	7 (87.5)	1	5.062	< 0.05
	Mean	11	8.33	6.67 (79.8)	1.7	3.235	< NS
Wash Flats	1989	8	4	4 (100.0)	0	4.159	< 0.05
	1990	10	6	3 (50.0)	3	0.00	NS
	1991	12	10	3 (30.0)	7	1.646	NS
	Mean	10	6.67	3.33 (60.0)	3.3	0.00	NS
Refuge	1989	36	27	23 (85.2)	4	14.778	< 0.001
	1990	59	37	23 (62.2)	14	2.213	NS
	1991	46	40	27 (67.5)	13	5.005	< 0.05
	Mean	47	34.67	24.33 (71.6)	10.3	5.771	< 0.05

[1] Successful nests are those where at least one egg hatched.
[2] Failed nests are those where no eggs hatched.

Predator exclosures were used on a total of 104 nests (73.76%) at Chincoteague NWR from 1989 - 1991 (Table 2). Their use increased each year (27, 1989; 37, 1990; 40, 1991). Exclosed nests hatched at least one egg significantly more often than not throughout the study (G = 5.771, df=1, P < 0.05).

Foxes tracks were discovered frequently at exclosed nests (54.8%) during this study and more exclosures were visited by foxes each year (1989, 37.0%; 1990, 48.65%; 1991, 72.5%). Foxes removed eggs from only two exclosed nests, however, in 1991, foxes were responsible for the abandonment of 13 nests (hook = 4, wild beach = 2, wash flats = 7) accounting for 70.31% of all egg loss. At two of these nests, foxes killed a defending adult piping plover. Tracks at exclosures indicate that these are often young foxes from nearby dens. With the increased use of exclosures foxes may encounter them more often. If exclosures prolong the duration of fox visits by keeping them at bay, they may promote abandonment by adult piping plovers or increase the their risk of being captured and eaten.

Egg losses due to flooding are unavoidable and are generally recouped through re-nesting. But predator losses continue through re-nesting. Intensive trapping of foxes and raccoons (fox: mean = 20.8 ± 4.9, range = 22 - 31; raccoon: mean = 89.0 ± 43.3, range = 53 - 137) decreases predator pressure and enhances exclosure success. Modification of exclosure design may be necessary to decrease fox visitation time. Further, changes in the protocol for exclosure use may be required to allow natural defenses to operate where they are most effective. Finally, exclusion of mammalian predators from nesting areas through the use of fencing may be warranted where physiogeographic features are not restrictive.

Intraspecific repelling among nesting pairs resulting from territorial defense may set upper limits on local numbers of piping plovers and thus influence habitat availability. On the hook 84.2% of all plover nests were located in only 59.9% of the available habitat in 1989. In 1990, 79.3% of all nests were located in the same northern half of the hook. A regular (even) rather than random or aggregated spatial pattern of nests was detected there in both years (1989, $R = 16.03$, $P < 0.001$; 1990, $R = 20.86$, $P < 0.001$) indicating competition for available habitat.

High densities of nesting plovers approaching semi-coloniality may influence ultimate nesting success. Predators may be more successful at locating eggs in high density nesting situations resulting in high egg mortality. But plovers may overcome egg losses by improvements in fledging rates resulting from better chick protection mechanisms (eg mobbing, confusion). In 1990, the mean nearest distance between active nests was used to classify nesting density as high or low. On the hook where density was high, egg predation was high (33.3%) but chick survival was also high (50.0%). On the wild beach, where nest density was low, egg predation was low (7.1%) but chick survival was also low (5.0%). Low density nesting appears to be a passive defense against ground predators but may make chicks easier to find. The greatest potential for population recruitment exists where nesting density is high especially if improvements in exclosure design can promote fewer egg losses.

Spacing of nests is determined by the combined forces of habitat preference and territorial interactions. Territorial defense probably functions primarily to protect the eggs but may also assist in pair formation when birds arrive unmated on the breeding grounds (Simmons 1956). Territory may or may not have food importance. Piping plovers defended small territories and generally used neutral foraging sites. Territory size derived from mean flushing distances ranged from 0.19 ha. to 0.70 ha (mean = 0.37 ± 0.29) during this study. However, the estimate may be biased if plovers flush earlier or later at our approach than non-human intruders. Regular spacing and territorial defense are typically associated in birds but defended territories are usually too small to explain the degree of regularity observed (Ripley 1985). Home range estimates may more accurately reflect spatial patterns of piping plover nests.

Mean home range area measured for 9 pairs of piping plovers ranged from 8.8 ha. on the wild beach to 63.8 ha. on the hook (Table 3). Surf zone foraging may have provided the only prey available to plovers on the wild beach, thus most home range focal birds were observed in the surf zone close to the nest.

Comparisons of mean territory size from 1991 to home range estimates from the same period are made in Table 3. Refuge-wide, defended territory represents only 0.43% of the home range of nesting piping plovers during the incubation phase of the nesting cycle. Home range and territory estimates for piping plovers during the later phases of nesting are not available but may be even larger. Measurements are complicated as adults defend mobile territories around broods.

Table 3
Relationship Of Bivariate Normal[1] Home Range Area To Area Of Defended Territory[2] For Piping Plovers During The Incubation Phase Of The Breeding Cycle At Chincoteague NWR, 1991.

AREA	MEAN HOME RANGE AREA (HECTARES) (HR)	MEAN TERRITORY SIZE (HECTARES) (T)	T/HR(100)
HOOK	63.8 (N=5)	0.19 (N=24)	0.30
WILD BEACH	8.8 (N=2)	0.19 (N=8)	2.16
WASH FLATS	50.5 (N=2)	0.32 (N=9)	0.63
REFUGE	48.6 (N=9)	0.21 (N=41)	0.43

[1] Jennrich and Turner 1969.
[2] Defended territory derived from mean flushing distances of incubating birds.

The areas of defended territory and home range are biologically significant to plovers for pair formation, mating, and to ensure adequate food supplies. Piping plovers may require much larger undisturbed areas than indicated by simple presence of the nest or observation of territorial defense. Any disturbances within home range boundaries may be detrimental to nesting success.

Summary

Nesting success of piping plovers is reported from 1989 to 1991 at Chincoteague National Wildlife Refuge, Virginia. Comparisons of fledgling productivity are made between years and between geographically and ecologically distinct nesting areas within the refuge. Differences in the quality of nesting habitats and foraging opportunities are used to explain usage patterns. Productivity losses were high during incubation but were even higher during brood rearing. Most losses resulted from predation. Predator exclosures were effective in protecting most nests but can be redesigned to improve their effectiveness. Red foxes caused abandonment of 13 exclosed nests in 1991 and may have keyed on predator exclosures. Density and spatial patterns of nests appears to influence egg and chick survival. Nesting territories were small compared to home range during incubation suggesting that spatial requirements are large.

Acknowledgments

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1991 PEREGRINE FALCON MIGRATION STUDIES AT ASSATEAGUE ISLAND, MD/VA

CONDUCTED UNDER USFWS ENDANGERED SPECIES PERMIT PRT-675769

Dr. William S. Seegar
Michael A. Yates
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Summary

As part of a continuing research program for the Chemical Research, Development and Engineering Center of the Department of Defense, field studies were conducted on the tundra peregrine falcon, Falco peregrinus tundrius. Field study sites were Sondrestrom, Greenland, Assateague Island, MD/VA, Padre Island, TX, The Dry Tortugas, FL, Cape May, NJ, Peru and Ecuador. This report focuses on the survey at Assateague Island.

Between 20 September and 20 October the survey team expended 630 man-hours in the field, observing 743 peregrines and capturing 227 individuals. Of these 227, 14 were recoveries of previously-banded falcons. Resightings of individuals captured during the survey totalled 127 and recaptures 31. Blood samples were taken from 77 individuals and 10 transmitters were tail-mounted on falcons. Observations of merlins (Falco columbarius) totalled 252.

Background

The presence of migrating peregrines on Assateague each autumn was confirmed by falconers in 1938. Most of these falcons were of the subspecies Falco peregrinus tundrius, a highly-migratory arctic and boreal nesting subspecies. Some few individuals of the subspecies Falco peregrinus anatum were also present; most of these bred on rock faces in the eastern U.S. and appeared on Assateague as generally nonmigratory wanderers in the fall.

Widespread use of chlorinated hydrocarbons (such as DDT) as agricultural pesticides after World War II spelled disaster for peregrines on a global basis. Contamination of food chains resulted in high levels of DDE (the principal metabolite of DDT) in the tissues of peregrines, producing thinner eggshells and increasing reproductive failures. The anatum peregrine was extirpated east of the Mississippi River, and only remnant populations survived elsewhere. By the late 1960's the tundra falcon was also in rapid decline, and soon thereafter was designated an endangered species. Diverse efforts were undertaken to study, monitor and augment peregrine populations. A major focal point of tundra falcon migration and the scene of over 30 years' documented field studies by falconer/banders, Assateague was the perfect site for such a research effort. In 1970, funded by the CRDEC, Dr. F. Prescott Ward initiated the project.

Rather than to serve simply as an index of migratory peregrine populations, the program quickly expanded to include research in diverse locales designed to address contaminant levels, prey selection, preferred habitat, determination of natal origin, and the dynamics of nesting, dispersal, migration and wintering. The approaches have consistently embraced the unconventional and the innovative.

Methods

Assateague consists of the following domains and research is conducted on each: 1) Assateague Island National Seashore (NPS, MD/VA) 2) Chincoteague National Wildlife Refuge (USFWS, VA) 3) Assateague State Park (MD). From mid-September through late October the island is traversed daily from sunup to sundown by two parties in four-wheel-drive vehicles. The survey area is divided into two sectors at the state line, each surveyed in the morning by single vehicles which switch study areas at midday. Observations are made of all raptors and notes taken by microcassette recorder as to time, location and activity at time of sighting. Peregrines encountered are immediately evaluated for capture attempt. Those unmarked with picric acid and in a safe area to conduct trapping are lured in for capture, if possible.

Unbanded peregrines are fitted with a USFWS lock-on band (size 6 for males and 7A for females) and briefly processed according to current research protocols before release at the site of capture. Past protocols have included: 1) Weights and measurements for taxonomic purposes. 2) Feather and pollen samples for natal origin studies. 3) Affixing of color bands whose numerals can be read by binoculars or spotting scope. 4) Collection of a 2cc blood sample from the brachiocephalic vein. Samples are separated, the plasma being used for determination of contaminant levels. Red cells are fixed for DNA analysis and shipped to Los Alamos National Laboratories for use in a joint biogenetics study. 5) Affixing tail-mounted radio transmitters for migration, habitat use and wintering ground studies.

Before release the crop and cheeks of each falcon are marked with picric acid. This yellow tint identifies the individual as one already sampled during the survey, yet fades and is no longer visible after a few months. Each evening samples are processed, taped notes transcribed, and equipment repaired and maintained.

Results and Discussion

The total of 743 peregrines sighted (table 1) was 3rd highest in the 22 years of the survey; number of sightings per 10 man-hours was 5th highest (table 2). The total of 227 falcons trapped was 3rd highest ever; number trapped per 10 man-hours was 2nd highest. Numbers and percentage of adults sighted took a significant dip from those in recent years (table 3). Given the steady increases in peregrine populations shown by arctic nesting studies and the standardized method employed over the length of this survey, however, many of our figures merely show how significantly the vagaries of weather can affect results over the short term.

The 14 recoveries of previously-banded falcons are still being analyzed, but two of these were immature peregrines banded as nestlings last summer by our survey team near Sondrestrom in west central Greenland. A third was similarly banded by a Danish team in their coastal survey area in southwest Greenland.

Sightings and captures by sector (table 4) provide a few surprises. The productivity of Big Levels, tops by unit effort the last two years, dipped somewhat. Although historically the area to trap falcons on Assateague, barrier dune-induced vegetative succession has in the last 25 years made it a "level" in name only. In 1991 the trappable parts were often wet and a new cable system for exclusion of the public made a traverse of the area difficult. Generally the Maryland Beach (where oversand vehicles are present in numbers) was as productive as the McCabe Tract (where they are banned). Under similar circumstances, the Hook was even more productive than the Refuge Beach. Mitigating factors are that: 1) We observe and trap many birds on the Hook and Maryland Beach early in the morning or during inclement weather when fewer vehicles are present. 2) The capture rate on the Refuge Beach is exacerbated by the continually narrowing beachfront due to the stabilized barrier dune system. 3) The McCabe Tract saw more vehicular traffic this year due to the presence of other researchers during the survey period. Depending on time, tide and weather, one trip up the beach by one vehicle can disperse every peregrine utilizing a beachfront.

In 1980 captive-bred peregrines were first released from a hack tower constructed on Wash Flats. In 1981 a pair took up residence, produced young and stayed on territory into the fall

migration of tundra falcons. Since that time residents have been present during each survey, and we have witnessed many territorial attacks on migrants in degrees ranging from the half-serious to earnest attempts to kill. Other individuals of the newly-established eastern population have at times taken territories on the north and south ends of the island, and have been observed defending these territories. It has been clear that the artificial establishment of this coastal population has had a negative impact (here and elsewhere) on a recovering migratory population simply attempting to utilize these habitats as always. At least 6 different females have held the Wash Flats territory during the last 11 surveys, a rate of turnover much more frequent than the norm in healthy populations and perhaps an artifact of the stress involved in defending a territory in prime migration habitat. The 1991 residents were only infrequently territorial until a new male took over late in the survey. At that point the frequency and severity of attacks on migrants increased. In terms of the overall effect of the residents' presence on the ability of migrants to utilize the critical Wash Flats habitat, consider the following: During the 1970-1980 surveys more peregrines (by unit effort) were sighted and captured on Wash Flats than any other sector during 9 of 11 years; during 1981-1991 Wash Flats sightings were tops during only 5 of 11 years and captures 2 of 11.

We affixed tail-mounted transmitters to 5 adult females and 5 immature females during the survey. Colleagues engaged in field studies in Ecuador and Peru will attempt to locate and track these falcons should they pass through or winter in those locales.

An interesting side note to this year's survey is the situation in the Farm Fields, Chincoteague National Wildlife Refuge. Early in the survey refuge personnel completed the task of creating new fresh water impoundments for waterfowl, constructing sand dunes alongside with the displaced fill. Vegetation in adjacent fields was cut, creating habitat where peregrines were increasingly observed and one captured late in the survey.

Recommendations

The work should proceed in the autumn of 1992 in the same standardized fashion employed since 1970. Because of its long-term continuity and standard method for data collection, the project has become the most informative in studying population trends and the ecology and behavior of migrating peregrines. Assateague offers an

unparalleled laboratory for unlocking the remaining secrets of the life history and status of the tundra peregrine.

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We were the beneficiaries of an era of increasing cooperation between the NPS and USFWS. A one-lock, one-key system on all common gates and a new gate (thank you, Mel Olsen!) on the beach at the state line made our daily travels less complex. The addition of Kevin Taylor as a part-time member of the survey team as well as full-time mechanic proved to be inspired. Our excellent relations with the various stewards of the resource make the survey more successful and the work more rewarding. We wish to recognize especially John Schroer and Bob Wilson of Chincoteague National Wildlife Refuge and Bill Simmons of Assateague State Park. In the previous vein as well as for their superb logistical support and in many cases extensive field assistance we wish to acknowledge the personnel of Assateague Island National Seashore, especially Roger Rector, Gordon Olson, Mel Olsen, Ann Bell, Jack Kumer, Clay Bunting, Faith McKee and Polly Angelakis. As usual, Linda Schueck's contributions in the areas of equipment manufacture, field assistance, logistics and morale were indispensible. Finally, we wish to thank those who assisted us in the field for days on end and made it all possible, particularly Donna Leonard, Stewart Somers, Brian McDonald, Janis Seegar, Jack Oar, Bob Whitney, Lew Woyce and Nancy West.

TABLE 1.

1991 TOTALS (EXCLUDING RESIDENTS)

	Observed	Captured	Recaptured	Resighted
Imm. Male	251	92	5	43
Imm. Female	300	103	23	81
Adult Male	9	5	--	--
Adult Female	61	27	3	3
Unidentified	122	--	--	--
Total	743	227	31	127

TABLE 2.

ASSATEAGUE AUTUMN PEREGRINE SURVEY
1970-1991 TOTALS
(EXCLUDING RESIDENT PEREGRINES)

	man-hours expended	peregrines sighted	peregrines sighted per 10 man-hours	peregrines captured
1970	310.0	66	2.13	23
1971	221.1	120	5.43	35
1972	325.6	41	1.26	8
1973	360.7	136	3.77	47
1974	360.7	59	1.64	22
1975	332.8	186	5.59	40
1976	336.8	176	5.23	48
1977	468.2	209	4.46	75
1978	436.2	259	5.94	64
1979	427.4	598	13.99	127
1980	451.1	512	11.35	110
1981	564.7	347	6.15	89
1982	632.3	591	9.35	121
1983	637.2	562	8.82	116
1984	724.9	547	7.55	150
1985	683.0	483	7.07	147
1986	704.1	838	11.90	230
1987	607.4	327	5.38	112
1988	671.7	409	6.09	132
1989	601.2	813	13.52	203
1990	509.3	659	12.94	248
1991	630.3	743	11.78	227

TABLE 3.

SIGHTINGS BY AGE CLASS

	adults sighted	adults sighted per 10 man-hrs	immatures sighted	imm. sighted per 10 man-hrs	percent adults
1970	8	.26	50	1.61	13.79
1971	9	.41	107	4.84	7.76
1972	7	.21	23	.71	23.33
1973	18	.50	111	3.08	13.96
1974	13	.36	40	1.11	24.53
1975	14	.42	153	4.60	8.38
1976	14	.42	120	3.57	10.45
1977	18	.38	167	3.57	9.73
1978	32	.73	199	4.56	13.85
1979	35	.82	501	11.72	6.53
1980	42	.93	408	9.04	9.33
1981	59	1.04	232	4.11	25.54
1982	64	1.01	457	7.23	12.28
1983	47	.73	407	6.39	10.35
1984	76	1.05	397	5.48	16.07
1985	60	.87	353	5.17	14.53
1986	109	1.55	630	8.95	14.75
1987	73	1.20	177	2.91	29.20
1988	87	1.30	246	3.66	26.13
1989	119	1.97	573	9.53	17.20
1990	90	1.77	492	9.66	15.46
1991	70	1.11	551	8.74	11.27

TABLE 4.

PRODUCTIVITY BY SECTOR

	sighted	sighted per 10 man-hrs	captured	captured per 10 man-hrs
McCabe Tract (MD)	85	8.95	33	3.47
State Park (MD)	1	2.58	--	--
Access Road (MD)	1	.81	--	--
Maryland Beach	83	8.79	34	3.60
Big Levels (MD)	36	11.64	14	4.53
Refuge Beach (VA)	137	11.25	41	3.37
Wash Flats (VA)	312	16.75	76	4.08
Service Road (VA)	11	5.16	1	.47
Hook (VA)	77	12.42	28	4.52

IMMUNOCONTRACEPTION OF FERAL HORSES WITH PORCINE ZONAE PELLUCIDAE: A FOUR-YEAR STUDY

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Abstract: Twenty-six free-roaming feral mares inhabiting Assateague Island National Seashore received either two or three inoculations of a porcine zonae pellucidae (PZP) vaccine. The antigen was prepared from pig ovaries, consisted of about 65 µg of protein (about 5000 zonae) and was administered remotely, by means of barbless darts. Control mares received only saline and adjuvant or were untreated. None of the 18 mares receiving three or the eight mares receiving two inoculations produced a foal. The differences in fertility between treated, sham-injected and untreated mares were significant. A single booster inoculation given to 14 mares one year after the initial inoculations resulted in only a single pregnancy, and mares not given a booster inoculation conceived and foaled at normal pre-treatment rates. Ten mares were inoculated for a third and fourth consecutive year and seven of these were monitored for ovarian endocrine function during the breeding season, by means of urinary steroid metabolites. None of these ten mares became pregnant, and four of seven monitored

treated mares failed to demonstrate endocrine evidence of ovulation, and urinary estrogen metabolite concentrations were significantly depressed, compared to those of untreated mares. The results of these experiments indicate that (1) PZP inoculations are greater than 95% effective in preventing pregnancies among feral mares, (2) the vaccine can be delivered remotely, without capture or chemical immobilization, (3) PZP vaccination will not interrupt pregnancies already in progress nor will the health of the foals exposed *in utero* be adversely affected, (4) initial PZP immunocontraception is reversible, (5) social and sexual behavior of treated animals is not significantly affected, (6) a single annual booster inoculation is effective in extending the contraceptive action of the vaccine, and (7) three consecutive years of PZP vaccination may interfere with normal ovarian endocrine function by preventing folliculogenesis, ovulation, and depressing estrogen secretion.

INTRODUCTION

Reducing fertility among free-roaming feral horses (*Equus caballus*) has been the goal of numerous studies in the United States over the past two decades. Initial experiments focused on contraceptive androgens which were delivered to stallions as injectable sustained release microencapsulated compounds (Kirkpatrick et al. 1982; Turner and Kirkpatrick 1982). More recently homogenous silastic implants containing ethinylestradiol and progesterone have been placed in feral mares (Plotka et al. 1989). Both these methods resulted in varying degrees of pharmacological success but the microencapsulated steroids required extremely large doses which interferred with remote delivery, and the silastic implants require capture, restraint and surgery. Additionally, there is concern about the alteration of behavior, the passage of steroids through the food chain, and the unlikely event of these steroids being approved for use in free-roaming animals by the FDA and EPA.

An alternative to steroid-induced fertility control in equids is immunocontraception. One of the more promising approaches to immunocontraception is immunization with porcine zonae pellucidae

(PZP). The zona pellucida is a non-cellular membrane which surrounds the mammalian ovum. It is produced during maturaton of the ovum, prior to ovulation, and it consists of several specific glycoproteins, i.e., protein with a carbohydrate moiety attached. One of these glycoproteins, referred to as ZP3, is the receptor molecule for sperm of that species (Leveille et al. 1987). This ZP3 protein possesses a molecular configuration which is specific for a complimentary protein on the surface of the sperm cell, permitting sperm recognition by, and attachment to the ovum (Sacco et al. 1984).

As early as 1976 it was demonstrated that isolated zonae were effective in preventing fertilization in rats (Tsunoda and Chang 1976a), mice (Tsunoda and Chang 1976b), and hamsters (Gwatkin et al. 1977), by raising antibodies against the zonae sperm receptors of the inoculated species. PZP immunization is effective in causing contraception in a variety of non-human primates including the marmoset (*Callithrix jacchus*) (Aitken et al. 1984), cynomolgus monkeys (*Macaca fascicularis*) (Gulyas et al. 1983), squirrel monkeys (*Saimiri sciureus*) (Sacco et al. 1983, 1987), bonnet monkeys (Bamezai et al. 1986), and baboons (species not given) (Dunbar et al. 1989), and several groups have independently demonstrated that antibodies raised against PZP are effective in blocking *in vitro* human fertilization (Sacco 1977; Hasegawa et al. 1985; Trounson et al. 1980).

In addition to studies with non-human primates, several studies have been conducted with PZP immunization of horses. Liu et al. (1989) demonstrated that PZP immunization could render captive mares infertile and that normal fertility returned the following breeding season. Serum progesterone concentrations and ovarian histology revealed no abnormalities one year after immunization. This discovery formed the basis for our three-year study of remote delivery of PZP to free-roaming feral mares. The primary objectives of our study included (1) assessing the feasibility of remote delivery, (2) assessing the safety of the vaccine for delivery to pregnant mares, (3) confirming the reversibility of the vaccine's effects, (4) determining the effectiveness of annual booster inoculations, and (5) evaluating the long-term effects of PZP immunization upon ovarian endocrine function.

METHODS

Field tests were conducted on Assateague Island National Seashore, a barrier island off the coast of Marlyland. Approximately 150 feral horses inhabit the island and it was the objective of the sponsoring agency - the National Park Service - to stabilize the population in order to minimize ecological damage by the ungulates. Twenty-six mares of proven fertility were selected for initial treatment on the basis of their high fertility rates, which collectively averaged 10% higher than the overall herd rate for the preceeding three years.

The PZP vaccine was prepared from porcine ovaries as previously described by Liu et al. (1989) and stored frozen until used. Between February 29 and March 10, 1988 (year-one of this study) the 26 mares received an initial inoculation of vaccine. The vaccine consisted of an emulsion of 0.5 cc of phosphate buffer (PBS) containing approximately 5000 zonae or about 65 μg of protein, and 0.5 cc of Freund's Complete Adjuvant. The mares were darted in the hip region using a Pax-Arms® 0.527 calibre capture gun and barbless darts.

Between March 12 and 21, the 26 mares received a second inoculation, which was the same as the first except for the substitution of Freund's Incomplete Adjuvant for the complete adjuvant. Between April 18 and 26, 18 of the 26 mares received a third inoculation which was identical to the second. Six mares received either one or two inoculations of only PBS and adjuvant. An additional 11 sexually mature mares, which received no sham injections and which were within the same age range as the experimental animals were selected for a second control group. Identifying markings were recorded for each horse and the animals were observed throughout April for adverse effects and particularly the presence of abscesses at the sites of injection.

During October, 1988, five months after the last inoculation and two months after the end of the breeding season, the mares were located and identified and the presence of foals was recorded. Urine samples were collected from the 26 treated and six sham-injected control mares, without capture, by extracting urine from the soil immediately after urination as described by Kirkpatrick et al. (1988). The urine samples were assayed for estrone conjugates (E_1C) and pregnancy determinations were made on the basis of the

E_1C concentrations as described by Kirkpatrick et al. (1990a). In February, 1989 (year-two),14 of the mares which had received inoculations the previous year and were not pregnant received a single booster inoculation of PZP and Freund's Incomplete Adjuvant, as previously described, and six sham-injected and 16 additional sexually mature mares within the same age range were selected for controls.

In August and October, 1989, foal counts were conducted for the original 26 treated, six sham-injected, and 11 untreated control mares (year-one), and urine and fecal samples were collected from the 14 booster-treated mares and 16 untreated control mares (year-two) for pregnancy assessment as described by Kirkpatrick et al. (1990a).

During March, 1990 (year-three) and 1991 (year four) ten of the booster-treated mares from year-two were given a second booster inoculation as previously described. During May and June, 1990 and 1991, during the peak breeding activity for the Assateague horses (Keiper and Houpt 1984), urine samples were collected every other day from seven of these 10 mares and four untreated mares in order to assess ovarian function, by measuring estrogen and progesterone metabolites (Kirkpatrick et al. 1990a,b, 1991B). In October, 1990 and 1991 all treated mares were again pregnancy tested by means of urinary steroid metabolites. Differences in fertility rates were tested for significance by means of binomial probability distribution (Freedman et al. 1978).

RESULTS AND DISCUSSION

Year-One: Of the original 26 mares inoculated in 1988, 15 were pregnant at the time of inoculation and all 15 produced foals in the spring of 1988. Thirteen of the 15 foals born to the treated mares survived their first year and were in good health as yearlings. None of the 18 mares receiving three inoculations or the eight mares receiving two inoculations produced a foal in 1989. Three of the six sham-injected mares and five of the 11 untreated control mares produced foals. Foaling and pregnancy data based on urinary E_1C measurements showed a 100 % correlation. Of the 26 mares receiving two or three inoculations, the fertility rate was 0.0% versus 53.8 % for each of the two pre-treatment years 1987 and 1988. The fertility rates for the six sham-injected and 11 untreated mares were 50 % and 45.4 % respectively, in 1989. The differences in fertility rates between treated, sham injected and untreated mares were significant at the $P < 0.002$ level of

confidence. The results are summarized in Table 1.

TABLE 1

Foaling rates for treated and untreated mares for pre-treatment and post-treatment, 1987 through 1989 (from Kirkpatrick et al. 1990c)

Treatment Groups	Inoculations/ Horse	No. Horses	% of Mares producing Foals (No.) Pre-treatment 1987	1988	Post-treatment 1989
Treated	3	18	50.0 (9)	51.1(11)	0.0 (0)
Treated	2	8	62.4 (5)	37.4 (3)	0.0 (0)
Control	0	6	33.3(2)	33.3 (2)	50.0 (3)
Untreated	0	11			45.4 (5)

Year-Two: Of the 14 mares given a booster inoculation in 1989, one produced a foal, while six control mares receiving sham inoculations and 16 untreated mares produced three and seven foals, respectively. The differences in fertility between treated mares, sham-injected mares and untreated mares were significant at the $P < 0.01$ and $P < 0.0018$ levels of confidence, respectively. The 12 mares originally inoculated in 1988 (year-one), but given no booster inoculation in 1989 (year-two) produced five foals in 1989, confirming the reversibility of the contraceptive effect. Results for year two are summarized in Table 2.

TABLE 2

Foaling rates for booster inoculated, control and untreated mares (from Kirkpatrick et al. 1991a)

Treatment Group	No. Mares	% Foaling Rate (No.)
Booster PZP	14	7.14 (1)
Control (sham)	6	50.0 (3)
Untreated	16	43.7 (7)

Year-Three: Of the ten mares given booster inoculations in 1990, none was pregnant in October, 1990, while 11 of 20 untreated mares

were pregnant. The difference in fertility rates was significant ($P < 0.001$).

A total of five abscesses have appeared among the 26 treated and six sham injected mares after a total of 144 dartings over three years. The abscesses appeared at the sites of injection about two days after treatment, were about 10-25 mm in diameter, and drained from six-nine days following treatment. Complete healing occurred within 14 days of treatment without complications.

The four untreated mares monitored for ovarian function during May/June 1990, demonstrated normal ovarian endocrine activity, characterized by preovulatory estrogen peaks, concurrent progesterone nadirs at the time of ovulation and breeding activity, and luteal phase progesterone rises following ovulation. Four of the seven mares treated for three consecutive years displayed no evidence of ovulation and urinary E_1C concentrations were significantly ($P < 0.05$) lower than those among untreated mares.

Two major questions to be answered by this study were whether immunosuppression which normally accompanies pregnancy would interfere with the contraceptive effectiveness of PZP immunization, and whether the pregnancies underway at the time of immunization would be successful and the foals healthy. Pregnancy did not alter vaccine contraceptive efficacy nor was the normal progress of pregnancies or the health of the foals affected. These are important considerations with regard to public acceptance of this method of contraception.

A major advantage of the PZP vaccine is the small aqueous volume which facilitates remote administration, which in turn eliminates the need to capture the mare. A minimum of two inoculations is required in order to raise antibody titers sufficiently high to provide contraception for six to nine months (Liu et al. 1989). The first inoculation causes antigen recognition and temporary increases in antibody titers. The second inoculation causes increased titers which last nine months to a year, and each subsequent inoculation increases the duration of elevated titers. Another advantage to the PZP vaccine is its reversibility. Public opinion in the U.S. is such that irreversible sterilization of feral horses is just not a political reality.

Behavioral integrity of the treated animals is important for at least two reasons. First, if we are to consider using contraception for wild free-roaming species, there is a moral, if not legal, obligation to leave behind a behaviorally intact population of animals. Second, zoo ungulate and primate populations, where PZP immunization is already underway, are often the focus of behavioral

studies. In this study, bands with treated mares remained intact during the 18 months following the initial vaccine administration, with only three mares moving to new bands. This incidence of exchange is within normal limits for the Assateague herd. One unforseen behavioral consequence, thus far witnessed in only one mare, has been an unusually strong and uninterrupted bond between the contracepted mare and her last male offspring born before contraception.

The differences in ovarian endocrine function between mares treated with PZP vaccine for three consecutive years and untreated mares suggests that long-term treatment may interfere with normal ovarian function. In some species, such as the rabbit (Skinner et al. 1983), dog (Mahi-Brown et al. 1985), and baboon (Dunbar et al. 1989), there are data which suggest that the antibodies produced by the treated animals attack not only the zonae pellucidae of ovulated ova, but those of developing oocytes as well. The four studies conducted thus far with horses, point to long-term treatment, as opposed to a single treatment, as the causal factor for the alteration of ovarian function. Liu et al. (1989) treated mares for only one breeding season and demonstrated the occurrence of ovulation and normal fertility rates within a year of treatment. These results are consistent with the proposed mechanisms of contraceptive action of PZP in mares, which include fertilization block brought about by steric hindrence of the zona sperm receptor, and a zona-induced acrosome reaction in horse sperm (Arns et al. 1990). Similarly, we demonstrated normal fertility rates among feral horses one and two years following initial PZP inoculation. However, ovarian endocrine abnormalities appeared in mares after three consecutive years of PZP treatment. Taken collectively, the work of Liu et al. (1989) and our three field tests with feral horses, all of which used small doses of the same antigen, suggest the lengthy duration of treatment as the primary cause of ovarian dysfunction.

Remote inoculation of feral mares with PZP is an effective means of fertility inhibition and does not affect intact pregnancies. The process is reversible, does not affect social integrity of horse bands, and the vaccine cannot be passed through the food chain. The remote delivery of PZP offers a potential non-capture technology for feral horse contraception and points the way toward future research directed at the development of a one inoculation vaccine.

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Modelling the Dynamics of Feral Horse Populations on Assateague Island National Seashore

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ABSTRACT

The horses of Assateague Island National Seashore (ASIS) have a long and charismatic history. They were thought to have been survivors from offshore shipwrecks. Some refute that story and suggest that early settlers commonly kept the ponies on adjacent islands to avoid having to pay taxes on them. Nevertheless, the horses have been on ASIS for over three centuries. ASIS was created in 1965, and at that time the horses on the Maryland side of the island were allowed to roam freely to live an essentially wild existence. Today, feral horse populations flourish on several Atlantic coastal barrier islands. In 1985, researchers began experimenting with fertility control in selected ASIS mares. The technology is demonstrably successful, and ASIS has embarked on a precedent-setting program to explore the potential for using immunocontraception as a horse population management tool. Before a full-blown field implementation, however, park and regional managers thought it prudent to develop a model to simulate the implementation of fertility control through computer modelling. A well-constructed computer simulation can provide the manager with knowledge about what is being attempted in a matter of minutes or hours compared to days or years if one were to implement a large-scale field experiment. We propose to develop a stochastic, individual-based population model of feral horse population dynamics using a modified version of GAPPS (**G**eneralized **A**nimal **P**opulation **P**rojection **S**ystem). GAPPS is a simulation language developed to build very specific models of the life-history of animals. GAPPS is extremely flexible, allowing the modeller to work with species with just about any life-history strategy even though it is especially well-suited to small populations ($N < 1000$) of long-lived species. The modifications made to GAPPS permit a map-based, spatial interface between animals and resources. As a result of these modifications, the program is now capable of tracking spatial attributes of every individual in the population. The simulation language allows the specification of density-dependent influences on survival and reproduction through resource depletion, frequency-dependent dynamics relating to social structure and spatial attributes of resource use. Due to the modular nature of horse social structure, special routines are being implemented that will allow the formation and dissolution of bands or harems. From the responses of individuals, emergent properties of the population will be summarized including time and space-specific population size, reproductive and mortality rates and band home range characteristics based upon resource use and depletion.

DISPERSAL IN ASSATEAGUE PONIES

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Wild horses and ponies typically live and reproduce in social units called "bands" or "harem bands." Such bands typically consist of one adult male, one or more adult females, and their dependent offspring. Before reproducing, both sexes generally leave the groups into which they were born ("natal dispersal"); adult females may also move between bands several times during their lifetimes ("adult female dispersal").

Both natal and adult female dispersal were observed in the course of a long-term study of the behavior of feral ponies on Assateague Island, Maryland. The data on natal dispersal are drawn from regular surveys of group composition taken between 1975 and 1988 by RRK and ATR; the data on adult female dispersal were collected by ATR during the summers of 1985 to 1988.

Natal Dispersal

Data on age of natal dispersal were collected for approximately 115 ponies. Males were significantly more likely to have left their natal groups by age five than were females (males, 97%, females 81%), and among ponies that did leave their natal groups, males dispersed slightly earlier than females (at marginal levels of significance; 20.8 months for males, 24.6 months for females).

For males, natal dispersal appeared to be delayed when opportunities existed for peer interaction within the natal band; male dispersal age was significantly correlated with the number of peers within the band, and males that dispersed with peers were significantly older than males that dispersed without peers. Age of dispersal in females was not influenced by presence of peers in the group. Rather, age of natal dispersal in females was correlated with age of first reproduction.

For the most part, natal dispersal appeared to be voluntary. Although a few cases were seen in which band stallions aggressively expelled sons from the band, this was rare. Young females were never seen to be forcibly expelled from the group, nor were they ever observed being "abducted" by bachelor males.

The frequency with which females remain -- and breed -- in their natal groups is considerably higher than that seen in other studies. This is especially puzzling in light of Keiper & Houpt's evidence that close inbreeding reduces female fertility in Assateague's ponies.

Adult Female Dispersal

Data on between-group movements and other behaviors were recorded for 25 adult females distributed among 12 harem stallions.

Compared to other populations of feral equids, Assateague pony mares changed groups relatively frequently. During each summer study period, 16-23% of sample mares changed groups at least once. After mares reached 3 years old, age had no effect on the frequency with which a female changed groups. The frequency with which each mare moved transferred between groups was also uncorrelated with her frequency of foaling within the study period.

While there were a few cases in which mares left bands as an apparent consequence of harassment by other females in the band, generally female-female aggression did not cause females to leave groups. Subordinate females were no more likely to change groups than dominant females, and band stability was uncorrelated with frequency of female-female aggression within bands. Aggression might have encouraged, rather than discouraged, band stability; females entering new bands initially received aggression eight times more frequently than they had in their previous bands.

Stallion characteristics provided the strongest predictors of mare transfer frequencies. Older stallions and stallions who had held bands for 2 years or more had significantly larger and more stable bands. Behavioral evidence also suggested that stallions who participated frequently in male-male aggression had less stable bands than stallions who participated infrequently in male-male aggression, although the correlations were weak.

In general, mare affiliation behavior appeared to be conservative. Mares found established, older stallions and remained with them despite increased aggression in larger groups and short-term fluctuations in reproductive success. Consequently, management of female fertility through contraception should have no effects on group stability, at least in the short run.

Eastern Equine Encephalitis and Mosquitoes

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Abstract

A monitoring and management protocol was developed for mosquitoes and Eastern Equine Encephalitis at Assateague Island National Seashore. The protocol included four levels of monitoring and intervention: 1) Routine surveillance, 2) Intensified surveillance, 3) Public education, and 4) Adulticiding. Specific criteria were developed for progression to each successive level. In 1991, salt marsh mosquito (*Aedes sollicitans*) populations increased significantly the week of 10-17 September, but because of the lack of evidence of EEE activity, monitoring was maintained at Level (2) Intensified surveillance, with no further management action.

Introduction

Assateague Island (ASIS) is a barrier island with salt marshes on the bay side that provide extensive larval habitat for salt marsh mosquitoes. The salt marsh species *Aedes sollicitans* and *Ae. taeniorhynchus* are often abundant following spring tides and other marsh flooding events. *Aedes sollicitans* is of particular concern as a potential vector of Eastern Equine Encephalitis (EEE) virus (Crans 1977). EEE is an extremely rare disease; typically zero to fourteen human cases per year are reported nationwide (Tsai & Monath 1987, CDC 1990). It is quite virulent, however, with mortality rates over 50% (Morris 1988). Therefore, Mosquito Control and Public Health agencies often engage in programs to minimize the likelihood of EEE transmission to humans.

Cases of EEE in horses have been confirmed from Assateague Island (G. Olson, pers. comm.). High mosquito densities on Assateague Island have resulted in requests by Maryland State officials to apply pesticide to ASIS salt marshes to lower populations of *Ae. sollicitans*. Treatment (ULV adulticiding) was permitted in 1989, but not in 1990. However, decision-making was difficult because of the lack of information regarding the risk of EEE transmission. Therefore, in 1991 a monitoring and management protocol was implemented to collect the necessary information to determine when intervention is necessary to reduce the risk of human EEE. Possible interventions included public education and/or pesticide application, depending on the nature and extent of EEE transmission risk. The protocol was developed by G. Olson, J. Kumer, and the author, and was sent to NPS regional and

Washington staff, and to CDC and Maryland State officials for review and comment. The purpose of this report is to outline the monitoring program and management protocol, and to present the results of the 1991 monitoring program.

The Monitoring and Management Protocol

The program includes four levels of progressively intensive monitoring and management actions (summarized below), with specific criteria for advancement to each successive level.

Level (1) - Routine surveillance

Set five CO_2-baited CDC light traps along ASIS - record the number of *Culiseta melanura* and *Ae. sollicitans* per trap. Begin trapping by 15 July and end after 30 September 1991.

Level (2) - Intensified surveillance

Collect parity data (% of females that have gone through at least one egg-laying cycle) for *Ae. sollicitans* (at least 20 individuals from each trap). Perform EEE infection studies on pools of *Cs. melanura* and *Ae. sollicitans*.

Level (3) - Public education and warnings; preparation for possible adulticiding

Inform visitors to park who are likely to encounter large numbers of mosquitoes about mosquito densities, possibility of EEE infection (realistic assessment), and self-protection methods to minimize the number of mosquito bites. Make arrangements for possible adulticiding in case conditions warrant such intervention.

Level (4) - Adulticiding

The CDC must declare a public health emergency before pesticides will be applied. The final decision on adulticiding will be made by the Superintendent or his authorized representative. The extent of adulticiding depends on the extent of infection:

a) Local infection: Only one positive *Ae. sollicitans* or positives all from just one trap with no evidence of EEE infection elsewhere (no EEE in *Cs. melanura* elsewhere, no sick horses or other vertebrates with symptoms compatible with EEE elsewhere)

Intervention: Fog or ULV in area of infection, including freshwater swamp and nearby salt marsh; maintain intense surveillance

b) Dispersed infection: Positive *Ae. sollicitans* in more than one trap **OR** Positive *Ae. sollicitians* in one trap with evidence of EEE activity elsewhere (positive *Cs. melanura* elsewhere, sick horses or other vertebrates elsewhere with symptoms compatible with EEE; lab confirmation of disease in vertebrates not required)

Intervention: Large-scale ULV application of adulticide; maintain intense surveillance

The criteria for moving to successive levels of surveillance and management are outlined in Table 1.

Table 1. Summary of criteria for move to successive levels of surveillance and management. In order to move to the next level, all criteria with asterisks **OR** all criteria with X's in column must be satisfied.

Level	1-2	2-3	3-4
Cs. melanura increase†	*		
Ae. sollicitans increase†	**X**		
high density *Ae. sollicitans* (≥1,000 in at least 1 trap)		**X**	*
increase in parous *Ae. sollicitans*†		*	
evidence of EEE activity (in *Cs. melanura* or vertebrates)		*	
increase in *Cs. melanura* with EEE infection		**X**	
horse or human EEE cases confirmed in lab			*
EEE in *Ae. sollicitans*			**X**

† All "increases" must be statistically significant or involve doubling of trap catch (*Cs. melanura* or parous *Ae. sollicitans*) or tripling of trap catch (*Ae. sollicitans*).

CDC traps were set, mosquitoes were sorted to species and counted, and parity dissections were performed by NPS staff. Pools of frozen *Ae. sollicitans* were sent to S. Tirrell and R. Shope of Yale University, who tested the pools for EEE virus using ELISA and cell-mediated assays.

Results

A total of 68 pools of *Ae. sollicitans*, collected from 7 August through 17 September (at least five pools each week), were tested for EEE activity. None were positive.

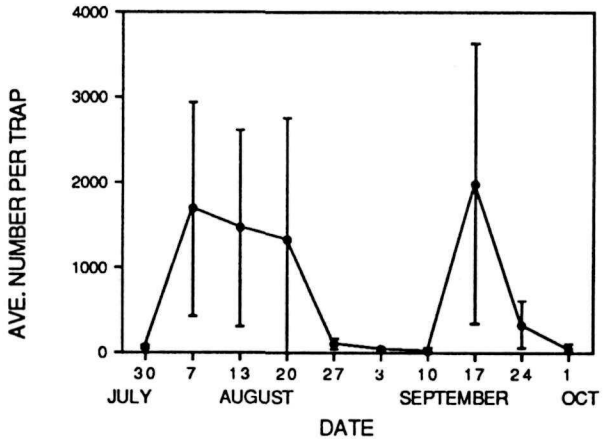

Figure 1. Density of *Aedes sollicitans* at Assateague Island National Seashore, 1991 (±95% C.I.)

Population trends of *Ae. sollicitans* adults at ASIS are shown in Fig. 1. The first sample (30 July) was on a rainy, windy night. Therefore, the only significant increase in mosquito densities was on the week of 10-17 September (paired t-test, t=-3.339, P=0.029). The proportion of dissected mosquitoes that were parous declined during this week. However, problems with the interpretation of the parity dissections do not allow dependable estimates of the density of parous females during this week. These problems were resolved for subsequent parity dissections. Level (2) monitoring was in effect on 10 September. The criteria for progression to Level (3) were not satisfied because of the lack of evidence of EEE activity at that time. Therefore, no warnings were issued or management interventionas applied, and surveillance remained at Level (2).

Discussion

National Parks have a strong conservation mandate. Therefore, interventions with potential ecological impacts, such as broadcast pesticide applications, are avoided unless absolutely necessary. In contrast, mosquito control agencies are responsible for lowering numbers of nuisance mosquitoes and mitigating associated health risks. This often requires vigorous intervention. The result can be conflicting approaches to management of mosquito populations. Nevertheless, protection of public health is a high priority for both types of agencies. This mosquito and EEE monitoring and management program is an attempt to meet the mandates of both types of agencies by developing a mutually agreeable decision-making protocol, and collecting the data needed to make appropriate management decisions.

During 1991, the first year of implementation, techniques were developed and problems resolved. Even with some minor

problems, the data collected were sufficient for decision-making according to the management protocol. The results indicated maintenance of monitoring at Level (2) of the protocol, "Intensified surveillance." In subsequent years, this protocol can continue to provide information and guidance for decisions on EEE mitigation efforts at Assateague Island National Seshore.

Acknowledgement

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The Effects of Grazing by Feral Horses on Spartina alterniflora of Assateague Island, MD

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ABSTRACT

Spartina alterniflora is the dominant salt marsh species on the North American Atlantic coast. It plays a major role in barrier island dynamics by colonizing bayside overwash areas, stabilizing and contributing to the expansion of the salt marsh shoreline. S. alterniflora on the north end of Assateague Island seldom exceeds 25 cm in height. Grazing by feral horses is intense in certain areas of this marsh; S. alterniflora can compose as much as 50% of the horses' diet. Heavy grazing may significantly reduce marsh primary production, alter species composition and change nutrient cycling processes. Where herbivory reduces the density of grasses, the marsh may not trap sediment as effectively, resulting in increased erosion and storm damage.

Within the grazed plant, defoliation may also affect the storage and internal transfer of nutrients. Most perennial grasses store nitrogen and phosphorus below ground between growing seasons, translocating them to new leaves and roots in spring and retranslocating them below ground before the death of leaves and roots in the fall. For plants not adapted to heavy grazing, removing large quantities of live leaf tissue may lower internal nutrient and energy stores available for reabsorption at senescence and for regrowth the following spring. Root growth rate and nutrient absorption rate may also be reduced by heavy grazing, lowering nutrient reserves and nutrient flow. Where root nutrient uptake is reduced, retention of nutrients via retranslocation may increase in importance. If defoliation interferes with retranslocation as well, it could greatly diminish the nutrient status of the plant.

This study examined the effects of herbivory on nutrient dynamics and productivity of short form Spartina alterniflora. In naturally grazed, experimentally clipped, and formerly grazed areas of a S. alterniflora salt marsh, I measured standing crop, net aerial primary productivity, and concentrations and internal exchanges of nitrogen and phosphorus in, and between, live and dead leaves and live rhizomes.

The importance of internal storage and retranslocation of nutrients was shown by clear seasonal patterns of total nitrogen and phosphorus and by a strong negative correlation between the live leaf and rhizome nutrient pools. Clipping and grazing stimulated new growth with elevated nutrient concentrations, indicating some degree of compensation for grazing pressure.

However, other effects of herbivory suggest considerable long-term damage to the S. alterniflora. Relative to ungrazed plots, peak standing crop was reduced by grazing 20% for live leaves, 22% for dead leaves, and 32% for rhizomes, and by clipping 52%, 57%, and 49% respectively. Productivity was reduced 11% by grazing and 18.5% by clipping in year 1, and 22% and 24% respectively in year 2. The total nutrient pools and aboveground nitrogen uptake were reduced by defoliation, indicating a net removal of nutrients from the plant. While defoliation appeared to increase the importance of retranslocation to the plant, it also reduced the potential for storage and the actual transfer of nutrients from below ground to the leaves.

Grazing intensity varied considerably in the area of the study site. The horses returned preferentially to formerly grazed patches, particularly along the water's edge, in which the closely cropped S. alterniflora seldom exceeded 5 cm in height. Intensive sampling was not possible in those areas, which were subject to erosion, but it is likely that the impact of grazing in those areas is far more severe than that observed in the experimentally clipped treatment.

REVEGETATION & RESTORATION OF POST-CONSTRUCTION ROADSCARS

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INTRODUCTION

Assateague Island National Seashore (ASIS) completed a road reconstruction project in 1989. A number of unvegetated areas were created during the project. Most of these bare areas, or scars, were sections of formerly paved road which were not repaved. Other scars remained from staging areas used during the construction. Also, some unvegetated areas were created in median strips and traffic control wedges as a part of the project. All of the scars were in locations highly visible to the public and adjacent to paved roads.

Revegetation of the road scars by native plant communities is desired for two reasons: 1) maintenance of healthy, native ecosystems is a management goal of the NPS, and 2) bare scars or scars covered with exotic plants diminish the aesthetic and educational experiences of park visitors. Revegetation of native species should occur naturally through recruitment from surrounding areas. However, the proximity of the road scars to paved roads makes them susceptible to invasion of aggressive, weedy exotics which may halt or interfere with recolonization by native species.

In 1990, the Natural Resources Management Division surveyed the roadscars to identify, quantify and determine the plant community status of the scars. This unfunded project was dependent upon volunteer labor, and recognizing that plant community descriptions of all the roadscars was not feasible, roadscars that were obviously bare were not considered for plant species data collection. A naturally revegetating roadscar (roadscar B) was selected and plant species distribution and abundance was described for a portion of the scar. All roadscars were mapped and their areas were calculated.

Plant species data were collected from belt transects oriented perpendicular to the roadscar corridor, and located every 10 meters along the corridor.

RESULTS & DISCUSSION

Approximately 8,800 square meters of scars were identified & measured. Fifty-six meters of roadscar B was sampled for plant species distribution & abundance, with the following results:

--- 107 plant species were identified
--- the 2 most abundant and widely distributed species were exotic annuals
--- the next 2 most abundant and widely distributed species were native annual/biennials
--- recruitment of 4 key native dominants was low, but widespread
--- 4 native plants considered rare on ASIS were present, with overlapping distributions
--- 3 aggressive, exotic perennials were present
--- the distribution of 1 of the perennials, Phragmites, overlapped the distribution of the rare native plans

Although exotic annuals were the most abundant and widely distributed plants, they require open ground and are expected to decline as other plants shade them out. The 3 exotic perennials, Phragmites communis - common reed, Lespedeza cuneata - bush clover, and Lonicera japonica - Japanese honeysuckle, are potential problems due to their ability to form dense monocultures which can crowd out native plants. Of these, Phragmites is considered the greatest threat since it is colonizing the same areas as rare native plants.

Since the status of a naturally revegetating roadscar was demonstrated to be tenuous, and many other roadscars were not even revegetating, ASIS sought funding support for exotic plant control and native plant restoration in 1991. Under the Federal Lands Highway Program, a memorandum of agreement was developed between the National Park Service (NPS) and the Soil Conservation Service (SCS) for production of native plant materials by the SCS to be used to revegetate ASIS roadscars.

The agreement calls for the Cape May Plant Materials Center in New Jersey to produce seed for 3 native grasses, and seedlings for 3 native forbs, 5 native shrubs and 3 native trees. Whenever possible, propagules from plants on ASIS will be used to produce the Cape May stock. The plant materials will be produced and delivered to ASIS for planting over the next 4 years. These plant materials will be used to revegetate bare roadscars and boost recolonization of natives in roadscars naturally revegetating with a mix of natives and exotics.

DIRECT AND INDIRECT EFFECTS OF ABIOTIC FACTORS ON A SALT MARSH FISH ASSEMBLAGE

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Abbreviated title: Salt marsh fish

Key words: competition, predation, salt marsh, estuary, fish, sympatry, toxicity, ecotoxicology

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Abstract: Five fish that co-occur in intertidal salt marshes in coastal Virginia showed some interspecific differences in tolerance to abiotic stresses. This is noteworthy since these sympatric fish would appear to be adapted to and constrained by similar environmental conditions. In preliminary acute range-finding tests there were significant overall differences among species (as judged by one-way ANOVA) in tolerance to high temperature, low pH, and hyposaline transfer. There were also significant differences between species in median lethal high temperatures and low pH at 96 h. The 96 h pH_{50} in sea water was especially divergent, with Menidia beryllina being the least tolerant (pH_{50} = 4.62), and Fundulus luciae the most tolerant (pH_{50} = 3.60). The hierarchy of tolerance among species was not consistent across all abiotic stresses. The growth of L. parva or F. heteroclitus was not generally affected by salinity between 3.5 - 35 ppt or 0 - 35 ppt respectively. These results suggest that selective pressures on each species have resulted in different suites of physiological adaptations to resist spatial and/or temporal changes in the abiotic environment. Such differences in tolerance might affect competitive and/or predaceous interactions among these fishes in a varying abiotic environment. The physiological tolerances of each species and the effect of any such differences on the fish assemblage of intertidal marshes need to be studied further. The indirect effects of variations in abiotic factors on fish may also be considerable. Simulated pools (mesocosms) of about 100 l were set up at low (1.9-4.3 mM Na) and high (20-39 ppt) salinities. Grass shrimp (Paleomonetes) were excluded by low salinity and a

predatory naucorid bug (Pelocoris) by the high salinity. L. parva were significantly fewer and larger at low salinity, probably due to predation by Pelocoris and partial release from food limitation. Cyprinodon variegatus were less affected. These small mesocosms apparently provided acceptable habitat for growth of larval fish and should be an effective technique for experimental simulation of salt marsh food webs, either for basic ecological or ecotoxicological studies.

The Distribution of Two Tiger Beetles, Cicindela dorsalis media and C. lepida, at Assateague Island National Seashore

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The objective of this study was to determine the distribution and abundance of two rare tiger beetles, which in Maryland occur only at Assateague. One of these species, C. d. media, was studied in relation to beach use along the ocean shoreline. Adults were sampled by walking along the whole Maryland shoreline of Assateague in early July of 1985, 1988 and 1990. This direct count method is effective since during peak season on warm, sunny days most of the adults at a site will be actively foraging along the tidal zone.

Total adult numbers for the whole Maryland shoreline were 275 in 1985, 201 in 1988 and 402 in 1990. In all years beetles were highly concentrated along the northern portion of the island. In 1990 when distribution was most closely studied, we found 389 adults along the northern 3 miles of the island and 13 others within a piping plover exclosure in the ORV zone. Limited checks along the Virginia portion indicated small numbers of beetles in the northern protected beach zone, none in the public use area, and (in 1990) over 1000 adults on the bay side of Toms Cove Hook. Censuses of larvae within two-meter wide transects across the beach at approximate 1 km intervals along the shoreline indicated a distribution comparable to that of adults. Limited surveys of the natural, undisturbed beaches of Hog, Cobb, and Fisherman Islands in Virginia revealed populations of over 1000 each.

These results suggest the distribution of these insects is determined by patterns of beach use at Assateague. Vehicle and pedestrian use is much lower on the northern part of the island relative to the State Park, Sinepuxent and ORV portions. Other studies we have done indicate the extirpation of the related subspecies, C. d. dorsalis, was the result of disturbance and destruction of natural beach habitats in the northeast due to high levels of pedestrian use and vehicles (Knisley and Hill, unpublished). Such effects are probably greatest on the larvae which live in burrows of the upper intertidal zone.

Cicindela lepida is an inland sand dune species which occurs commonly and is widespread over much of the central United States, but is uncommon in the east. We censused nine areas in the ORV portion of Assateague where potential habitat (well developed inland dunes and interdunal flats with deep, fine sand behind the primary dunes) was found. Scattered individuals were found at four sites and a large population of over 55 adults occurred in a well developed inland dune with no evidence of human impact or disturbance. Larvae were also found at this latter site indicating a viable, breeding population. Although all possible sites for C. lepida were not surveyed, it is likely that this species is rare and should be listed by the state of Maryland as endangered.

THE HISTORICAL DEVELOPMENT OF OCEAN CITY INLET EBB SHOAL AND ITS EFFECTS ON NORTHERN ASSATEAGUE ISLAND

by

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ABSTRACT

Tidal inlets represent an interruption to the continuity of beach processes along the coast. Sediment transport around tidal inlets is one of the greatest concerns to coastal engineers. Depending upon local coastal conditions, sediment accumulation may occur both landward (flood tidal delta) and seaward (ebb tidal delta) of the inlet at the expense of sediment in the littoral transport system. Downdrift of the ebb delta, the littoral system is consequently undernourished resulting in high erosion rates. However, once this ebb shoal has reached an equilibrium condition, natural sediment bypassing may occur, restoring much needed sediment flow to downdrift beaches. Since the ebb shoal is typically a shallow area, it serves as an energy dissipater of wave energy. If the ebb shoal causes waves to break offshore, adjacent shorelines are sheltered from erosional impacts.

Ocean City inlet is located along the Delaware-Maryland-Virginia (Delmarva) peninsula coast, separating Fenwick Island to the north and Assateague Island to the south. The inlet was formed during the 1933 hurricane and subsequently stabilized by jetties in 1935. Since stabilization, pronounced alterations of the adjacent shorelines of Fenwick and Assateague Island have occurred. The littoral drift direction is from north to south. Ebb-tidal shoal sediment volume increased steadily from 1935 to mid-1970s at a rate of approximately 270,000 cu m/yr. Since this time, sediment accumulation on the shoal has been irregular, with an overall average rate of 30,000 cu. m/yr (Underwood and Anders, 1989). This irregular behavior may reflect an approach to a dynamic equilibrium condition where the ebb shoal, which previously acted as a sediment sink, is now allowing sediment to bypass to Northern Assateague Island. Northern Assateague Island has exhibited a decrease in shoreline erosion since the late 1960s, corresponding to the slower rate of shoal growth since 1967. Immediately north of Ocean City Inlet the shoreline has experienced accretion compared to erosion as high as 10 m/yr along Assateague Island which lies to the south. However, the historical loss of sand from the littoral system into the ebb-tidal shoal is the primary cause for rapid shoreline retreat along northern Assateague Island.

Based on these results, the National Park Service (NPS) is conducting a study to provide a comprehensive history of the growth and morphodynamics of Ocean City Inlet ebb shoal. This includes detailing evolutionary stages, sediment volumes, process effects, and updating shoreline changes along Northern Assateague Island. The effects of updrift beach nourishment and specific patterns of erosion and accretion on the ebb shoal will be studied. Defining these factors will allow engineers and scientists to better understand the impact of the ebb shoal on Northern Assateague Island. Complete understanding of the local sedimentological processes will provide improved planning and design for physical monitoring programs, provide an updated sediment budget, and establish the importance of the ebb shoal in providing erosion control on adjacent Northern Assateague Island.

Seagrass Distribution and Abundance Patterns in Chincoteague and Sinepuxent Bays

By

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Contribution No. 1729 from the Virginia Institute of Marine Science, School of Marine Science, College of William and Mary

ABSTRACT

Seagrasses are an important natural resource found in many shallow water coastal lagoons of the world. Seagrasses have been monitored in Chincoteague and Sinepuxent bays using aerial photography in 1986, 1987, 1989, and 1990. There were 2,494 hectares of seagrass mapped in 1990, an increase of 14% since 1986. This is a marked increase over that reported by Anderson in 1970 and the lack of vegetation reported by Cottam and Munro in 1954. Seagrasses are currently found along the eastern side of the bay in four major areas: Tingles Island area, West Bay, Green Run Bay, and at the northern end of Chincoteague Island. Only Zostera marina (eelgrass) and Ruppia maritima (widgeongrass) have been reported species in these areas. The current abundance of seagrass in Chincoteague Bay (2,494 ha) represents 7.7% of the total bottom area in the bay (32,536 ha). Most of the seagrass over the four survey years was moderate (83.5% in 1990) to dense (9.8% in 1990) in coverage. Chincoteague Bay is the only coastal lagoonal system in the mid-Atlantic from New Jersey's Barneget Bay to North Carolina's Albemarle-Pamlico Sound, to have seagrass. Good water quality will be a major factor determining the long term survival of seagrasses in this region.

INTRODUCTION

Seagrasses are an important natural resource found in many shallow coastal lagoons of the world. These communities of underwater plants contribute significantly to the overall productivity and value of the systems by providing a food source to many species of waterfowl, habitat and nursery areas for a large number of vertebrate and invertebrate species, and otganic material which is decomposed by the detrital food chain. In addition, seagrasses baffle waves and currents, thereby stabilizing bottom sediments, and play an important role in nutrient cycling (Thayer, et al., 1975, 1984; Orth, et al., 1984).

Despite the reported abundance of seagrass in Chincoteague and Sinepuxent bays (Orth and Nowak, 1990, Orth, et al., 1987, 1989, 1991), there is a dearth of information on these plant communities. The previous absence of seagrasses in these bays for several decades following the worldwide eelgrass decline in the 1930's (Rasmussen, 1977), despite reported transplanting efforts (Cottam and Munro, 1954), may be the primary reason for the paucity of studies in this region. There are no documented records as to the severity of the decline in Chincoteague Bay, but anecdotal accounts indicate that almost all of the eelgrass had declined. However, our examination of aerial photography available from the Soil Conservation Service for 1937 revealed what appeared to be seagrass in lower Sinepuxent Bay, although no ground truth data are available for this period (Orth, et al., 1987). Thus, sparce but unreported patches of seagrass may have persisted during this time.

Anderson (1970) reported seagrass (both Zostera marina (eelgrass) and Ruppia maritima (widgeongrass)) between Tingles Island and Goose Point and between West Bay and Green Run Bay. Seagrass was scarce betwenn Sugar Point and north to below Tingles Island. He reported Z. marina growing in the deeper, more sandy areas, while R. maritima was found in shallow, more muddy areas, a condition found currently in Chincoteague Bay and in Chesapeake Bay populations (Orth and Moore, 1988a). R. maritima was apparently more widespread than Z. marina. No seagrass was found along the western shore.

Interest in seagrass communities in Chincoteague Bay was heightened by the dramatic and large scale changes that were occurring in seagrass communities in nearby Chesapeake Bay. An unprecedented decline of all species was observed in many areas throughout Chesapeake Bay in the 1960's and 1970's. This decline has been associated with increasing anthropogenic inputs of nutrients and sediments (Kemp, et al., 1983; Orth and Moore, 1983a), with the resulting loss of seagrass in many areas in Chesapeake Bay.

Seagrass communities in Chincoteague Bay are unique for several reasons. First, seagrasses were apparantly increasing in abundance during the time when declines were occurring in Chesapeake Bay. Second, and most importantly, Chincoteague Bay is the only coastal lagoonal system to have seagrass in the mid-Atlantic from New Jersey's Barneget Bay to North Carolina's Albemarle-Pamlico Sound. Delaware's inland bays have been devoid of seagrass since the late 1960's and water quality there does not appear adequate to support seagrass today (Orth and Moore, 1988b). Seagrasses have been absent from Virginia's coastal lagoon's since the 1930's eelgrass decline (Orth, 1978).

An ongoing monitoring program of Chesapeake Bay seagrasses was initiated in 1978 using aerial photography. It was expanded in 1986 to include Chincoteague and Sinepuxent bays (Orth et al., 1987). Subsequently, seagrasses in Chincoteague and Sinepuxent bays were monitored concurrently with Chesapeake Bay seagrasses in 1987, 1989, and 1990 (Orth and Nowak, 1990; Orth, et al., 1989, 1991). The objective of this paper is to report on the distribution and abundance of seagrasses in Chincoteague and Sinepuxent bays over the period of the aerial survey monitoring program and to compare these data to earlier times.

METHODS

Data on the distribution and abundance of seagrasses have been obtained from aerial photographs taken with standard aerial mapping cameras, using either black and white, or color film. Photographs have been taken at an altitude of 12,000 feet, yielding a photographic scale of 1:24,000. Survey flight lines for this region covered all shorelines and adjacent shallow water areas that currently or could potentially support seagrass.

Photographic missions were flown to provide optimal imagery of seagrass beds, which includes photographing under conditions of low tide, low sun angle, no or minimal cloud cover, low ground wind speed, low tide, and when seagrass are near or at maximum standing crop.

Delineation of boundaries of seagrass beds onto standard USGS 1:24,000 topographic quadrangles was accomplished by superimposing the appropriate mylar quadrangle onto the appropriate photograph, as both the quadrangle and photograph are the same scale. Where minor differences were evident, a best fit was obtained between the photograph and mylar quadrangle.

Percent cover of seagrass within each bed was estimated by using an enlarged density scale originally developed by the U. S. Forest Service for estimating tree crown density. Bed density was classified into one of four categories: 1 = very sparse or <10% coverage; 2 = sparse or 10-40% coverage; 3 = moderate or 40-70% coverage; and, 4 = dense or 70-100% coverage. All beds were coded with a distinct code for subsequent analysis or retrieval.

The perimeter of all seagrass beds mapped from aerial photographs was digitized using a Numonics Model 2400/2200 Digitablet Graphics Analysis System. Coordinates were stored in a computer based Geographical Information System (GIS) for area calculation and data manipulation. A standard operating procedure was followed which aided in an orderly and efficient processing of data, and complied with the need for consistency, quality assurance, and quality control.

Field surveys of seagrass communities were conducted by a number of state and federal agencies, as well as independent citizen groups. Information collected was normally presence/absence data, and all data were synthesized in the annual mapping report.

A more detailed accounting of the methodology described above can be found in Orth and Moore, 1983b, and Orth, et al., 1990, 1991.

RESULTS AND DISCUSSION

Data collected from the aerial monitoring program for 1986, 1987, 1989, and 1990 showed seagrasses to be very abundant in several distinct areas. Table 1 presents the total amount of seagrass mapped for those quadrangles covering the Chincoteague and Sinepuxent bays for the four years that seagrass was photographed. Table 2 presents the number of hectares of the four different density classes for each quadrangle where seagrasses were mapped in 1990. Photoreductions of those quadrangles showing all seagrass beds by density class as well as ground truth data produced and collected in 1990 are given in Appendix A.

Seagrasses are concentrated in four areas in this region (Fig. 1), all located on the east side of the bay behind Assateague Island: the northern end of Chincoteague Island surrounding Coards Marsh, West Bay, Green Run Bay, and the Tingles Island area. Seagrasses in Sinepuxent Bay are located primarily in the southern portion and are found along both shores. Most of the seagrass cover over the four survey years was moderate (83.5% in 1990) to dense (9.8% in 1990).

Two species of seagrass were reported from ground studies, Zostera marina and Ruppia maritima, the same species reported by Anderson (1970). Their distribution patterns appear similar to what has been reported for Chesapeake Bay: R. maritima predominating in intertidal to very shallow subtidal areas (MLW (mean low water) - 0.3 m MLW), Z. marina in deeper subtidal areas (0.6 to >1 m MLW), and a mixture of the two species at intermediate depths (0.3 - 0.6 m MLW) (Orth and Moore, 1988a).

There was a reported 14% increase in seagrass distribution between 1986 and 1990, with both increases and decreases observed in individual quadrangles (Table 1). The changes in individual quadrangles could be a result of interannual variations in R. maritima abundance. This species has been noted to undergo large interannual fluctuations in distribution and abundance in other areas (personal observation).

There has been no seagrass mapped using aerial photographs for the western side of Chincoteague Bay similar to what Anderson reported twenty years earlier, although surveys by citizen volunteers have reported both Z. marina and R. maritima in several locations here (Appendix A). Water clarity along the western shore appears to less than along the eastern side. This may be the result of prevailing winds during the summer from the south and southwest which may result in re-suspension of the fine grained sediments found along this shoreline, effectively reducing the light available for plant growth. Citizen observations may be of plants that have become recently established from seed dispersal from the large beds present on the eastern side. However, these patches apparently never survive more than one year.

The current abundance of seagrasses in Chincoteague Bay (2,494 ha) represents 7.7% of the total bottom area in the bay (32,536 ha (Pritchard, 1960)). Because of the lack of historical distribution data there are no data for total seagrass coverage prior to the eelgrass wasting disease of the 1930's, nor on the rate of recovery since that period. If seagrasses were absent or very sparse in the 1950's as indicated by Cottam and Munro (1954), recovery must have rapid in the 20 years prior to Anderson's (1970) report. He suggested there may have been as much as 1000 hectares in the Maryland portion in 1970, but this was a crude estimate based on cursory examinations of aerial photographs of the region. If there were 1000 hectares in 1970, today's estimates for the Maryland portion are 60% greater.

The presence today of large stands of seagrass, as compared to almost no seagrass in the early 1950's, and somewhat greater abundance in 1970, may be a result of a combination of natural revegetation from very sparse beds that may have survived the 1930's demise and appropriate water quality necessary for seagrass to grow, spread, and survive. Anecdotal information indicated that attempts were made subsequent to the 1930's decline to transplant Z. marina into Chincoteague Bay from existing Chesapeake Bay populations by U. S. Fish and Wildlife scientists. However, there is no confirming documentation (e.g. annual reports, data summaries, etc.) to determine whether these transplants had survived the timing and methodology used.

The increase in seagrass to approximately 2500 hectares in 1990 (with a 14% increase since 1986) predominantly along the eastern boundaries of the bay indicates that water quality is adequate in this region to support healthy stands of seagrass. This is in contrast to many areas in the Chesapeake Bay which no longer support seagrass (Orth, et al., 1991; Batiuk, et al., in press). Because seagrasses are absent from the western shore despite broad expanses of shoal areas less than 1 meter, water quality may be inadequate to support viable, perennial populations of seagrass here. The pressures from increasing growth from surrounding localities, in particular the expanding Ocean City area, can have a severe impact on water quality in the bay region, which may ultimately affect seagrass populations along the eastern side of the bay. Seagrasses require good water quality and if they are to survive or continue to increase and remain an important natural resource, nutrient and sediment control strategies must be implemented now for the surrounding watershed before it is too late.

ACKNOWLEDGEMENTS

We gratefully acknowlege the continuing financial commitment of numerous state and federal agencies for support of the annual SAV mapping program, in particular the U. S. EPA Chesapeake Bay Program (X003296-02, X003301-01, X003465-01,02), U. S. Fish and Wildlife Service (14-16-0005-86-028, 14-16-0005-87-9005, 14-16-0005-90-9031), Maryland Dept. of Natural Resources (C057-88-031, C188-90-002, C225-91-004), NOAA Coastal Zone Management Program (NA88AA-D-CZ-091,092, NA89AA-D-CZ-134, NA90AA-H-CZ796), Committee to Preserve Assateague Island, U. S. Army Corps of Engineers, Norfolk and Baltimore Districts, and the Allied-Signal Foundation.

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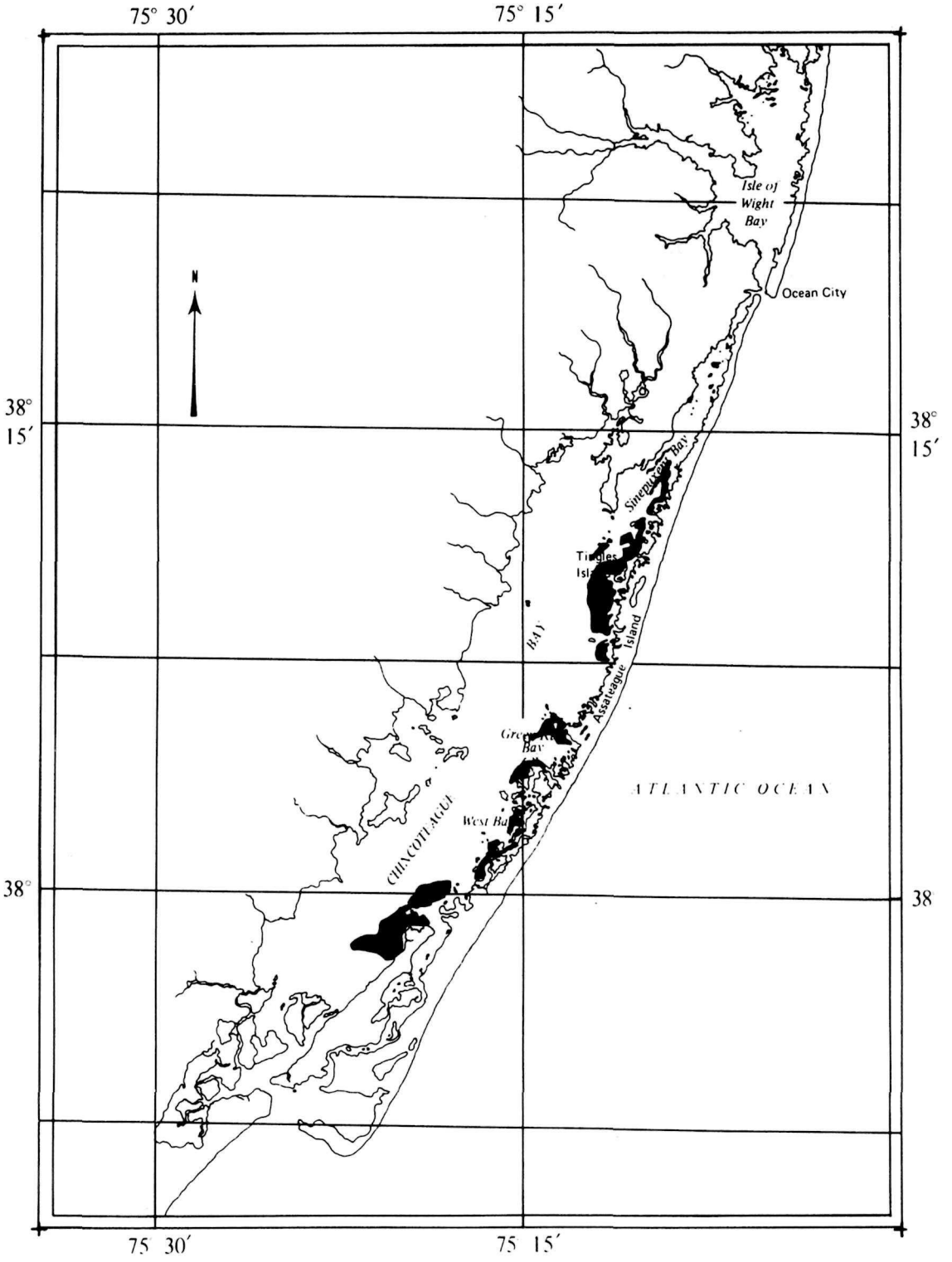
Figure 1. Distribution of seagrass (darkened areas) in Chincoteague and Sinepuxent bays in 1990 (from Orth, et al., 1991).

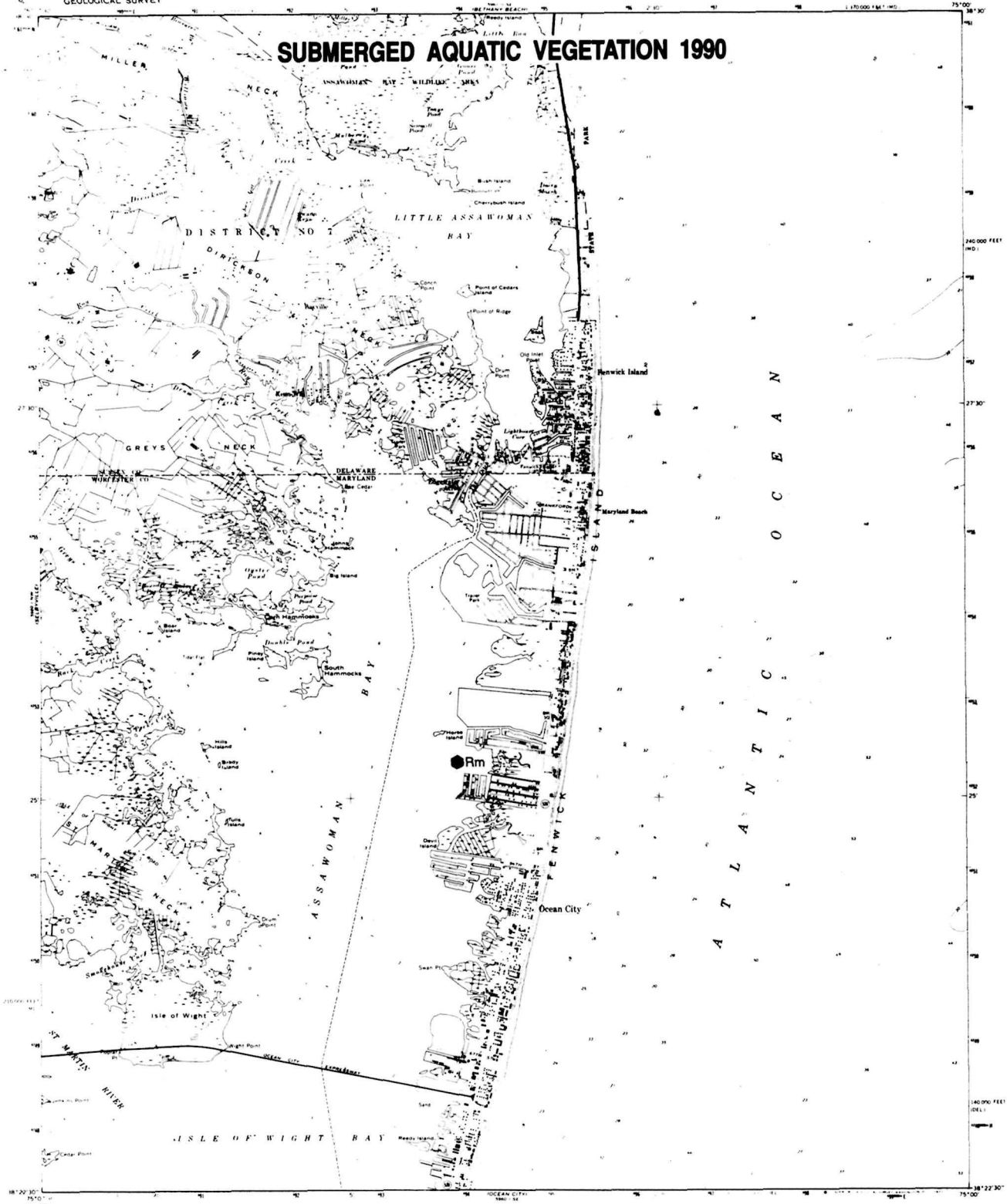

75° 30′
75° 15′
Isle of Wight Bay
Ocean City
N
38° 15′
38° 15′
Sinepuxent Bay
Assateague Island
BAY
ATLANTIC OCEAN
CHINCOTEAGUE
38°
38

Appendix A. Photo-reductions of U. S. Geological Survey topographic quadrangles for Chincoteague and Sinepuxent bays, as well as the Ocean City area, showing actual seagrass distributional data based on the aerial photographic survey in 1990. Each seagrass bed has distinct code. Number represent percent coverage by seagrass for that bed. Species information, if available from the different ground surveys (note coded symbols), was placed as close to the position the data were gathered.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ASSAWOMAN BAY QUADRANGLE
MARYLAND - DELAWARE
7.5 MINUTE SERIES (TOPOGRAPHIC)

SUBMERGED AQUATIC VEGETATION 1990



SPECIES

Zm	*Zostera marina* (eelgrass)
Rm	*Ruppia maritima* (widgeon grass)
Ms	*Myriophyllum spicatum* (Eurasian watermilfoil)
Ppf	*Potamogeton perfoliatus* (redhead-grass)
Ppc	*Potamogeton pectinatus* (sago pondweed)
Zp	*Zannichellia palustris* (horned pondweed)
N	*Najas* spp. (naiad)
Ec	*Elodea canadensis* (common elodea)
Va	*Vallisneria americana* (wild celery)
Tn	*Trapa natans* (water chestnut)
Pe	*Potamogeton epihydrus* (leafy pondweed)
U	Unknown species composition
Hv	*Hydrilla verticillata* (hydrilla)
Hd	*Heteranthera dubia* (water stargrass)
Pcr	*Potamogeton crispus* (curly pondweed)
Cd	*Ceratophyllum demersum* (coontail)
Ppu	*Potamogeton pusillus* (slender pondweed)
Ngu	*Najas guadalupensis* (southern naiad)
Ngr	*Najas gracillima* (naiad)
C	*Chara* sp. (muskgrass)
Nm	*Najas minor* (slender naiad)

SCALE 1:24,000

1 .5 0 1 MILE

1 .5 0 1 KILOMETER

SURVEY STATIONS

- ▲ VIMS Field Survey
- ✱ Harford Community College
- ✖ University MD-HPEL
- ★ USF & WS Survey
- ♥ Council of Governments
- ■ MD Charter Boat Field Survey
- ⬢ Citizens Field Observation
- ● MD-DNR

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ASSAWOMAN BAY, MD
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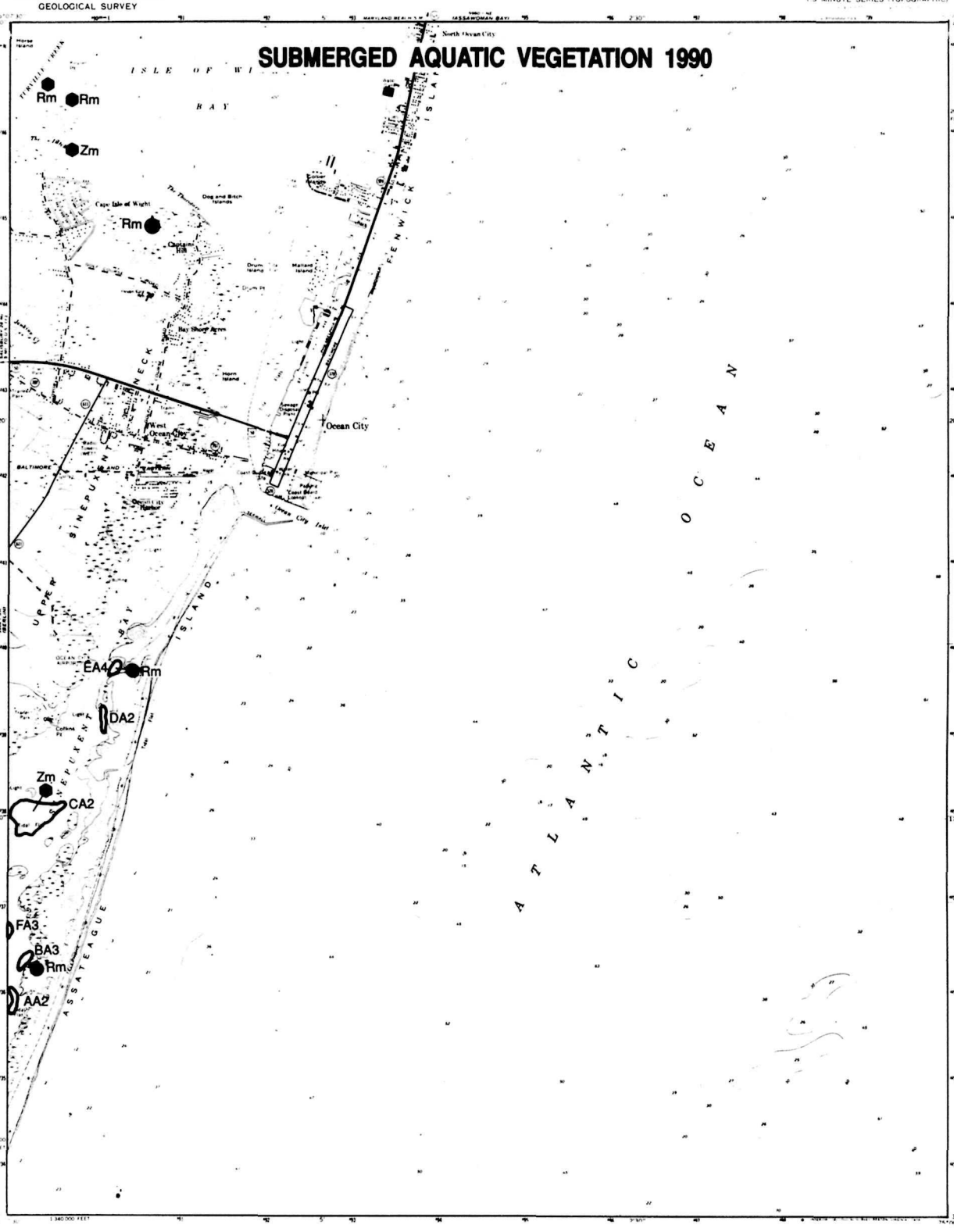
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OCEAN CITY QUADRANGLE
MARYLAND-WORCESTER CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

SUBMERGED AQUATIC VEGETATION 1990



SPECIES			
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N	*Najas* spp. (naiad)	Ngr	*Najas gracillima* (naiad)
Ec	*Elodea canadensis* (common elodea)	C	*Chara* sp. (muskgrass)
Va	*Vallisneria americana* (wild celery)	Nm	*Najas minor* (slender naiad)
Tn	*Trapa natans* (water chestnut)		
Pe	*Potamogeton epihydrus* (leafy pondweed)		
U	Unknown species composition		

SCALE 1:24,000

1 .5 0 1 MILE

1 .5 0 1 KILOMETER

SURVEY STATIONS

- ▲ VIMS Field Survey
- ✱ Harford Community College
- ✖ University MD-HPEL
- ★ USF & WS Survey
- ⬟ Council of Governments
- ■ MD Charter Boat Field Survey
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SPECIES

Zm	*Zostera marina* (eelgrass)
Rm	*Ruppia maritima* (widgeon grass)
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N

SCALE 1:24,000

1 .5 0 1 MILE

1 .5 0 1 KILOMETER

SURVEY STATIONS

- VIMS Field Survey
- Harford Community College
- University MD-HPEL
- USF & WS Survey
- Council of Governments
- MD Charter Boat Field Survey
- Citizens Field Observation
- MD-DNR

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167

SPECIES

Zm	*Zostera marina* (eelgrass)	Hv	*Hydrilla verticillata* (hydrilla)
Rm	*Ruppia maritima* (widgeon grass)	Hd	*Heteranthera dubia* (water stargrass)
Ms	*Myriophyllum spicatum* (Eurasian watermilfoil)	Pcr	*Potamogeton crispus* (curly pondweed)
Ppf	*Potamogeton perfoliatus* (redhead-grass)	Cd	*Ceratophyllum demersum* (coontail)
Ppc	*Potamogeton pectinatus* (sago pondweed)	Ppu	*Potamogeton pusillus* (slender pondweed)
Zp	*Zannichellia palustris* (horned pondweed)	Ngu	*Najas guadalupensis* (southern naiad)
N	*Najas* spp. (naiad)	Ngr	*Najas gracillima* (naiad)
Ec	*Elodea canadensis* (common elodea)	C	*Chara* sp. (muskgrass)
Va	*Vallisneria americana* (wild celery)	Nm	*Najas minor* (slender naiad)
Tn	*Trapa natans* (water chestnut)		
Pe	*Potamogeton epihydrus* (leafy pondweed)		
U	Unknown species composition		

SCALE 1:24,000

1 .5 0 1 MILE

1 .5 0 1 KILOMETER

SURVEY STATIONS

- VIMS Field Survey
- Harford Community College
- University MD-HPEL
- USF & WS Survey
- Council of Governments
- MD Charter Boat Field Survey
- Citizens Field Observation
- MD-DNR

VIRGINIA INSTITUTE OF MARINE SCIENCE

DATE FLOWN
6-13-90

TINGLES ISLAND, MD
170

SUBMERGED AQUATIC VEGETATION 1990

SPECIES

Zm	*Zostera marina* (eelgrass)
Rm	*Ruppia maritima* (widgeon grass)
Ms	*Myriophyllum spicatum* (Eurasian watermilfoil)
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Nm	*Najas minor* (slender naiad)

N

SCALE 1:24,000

1 .5 0 1 MILE

1 .5 0 1 KILOMETER

SURVEY STATIONS

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- ✱ Harford Community College
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- ● Council of Governments
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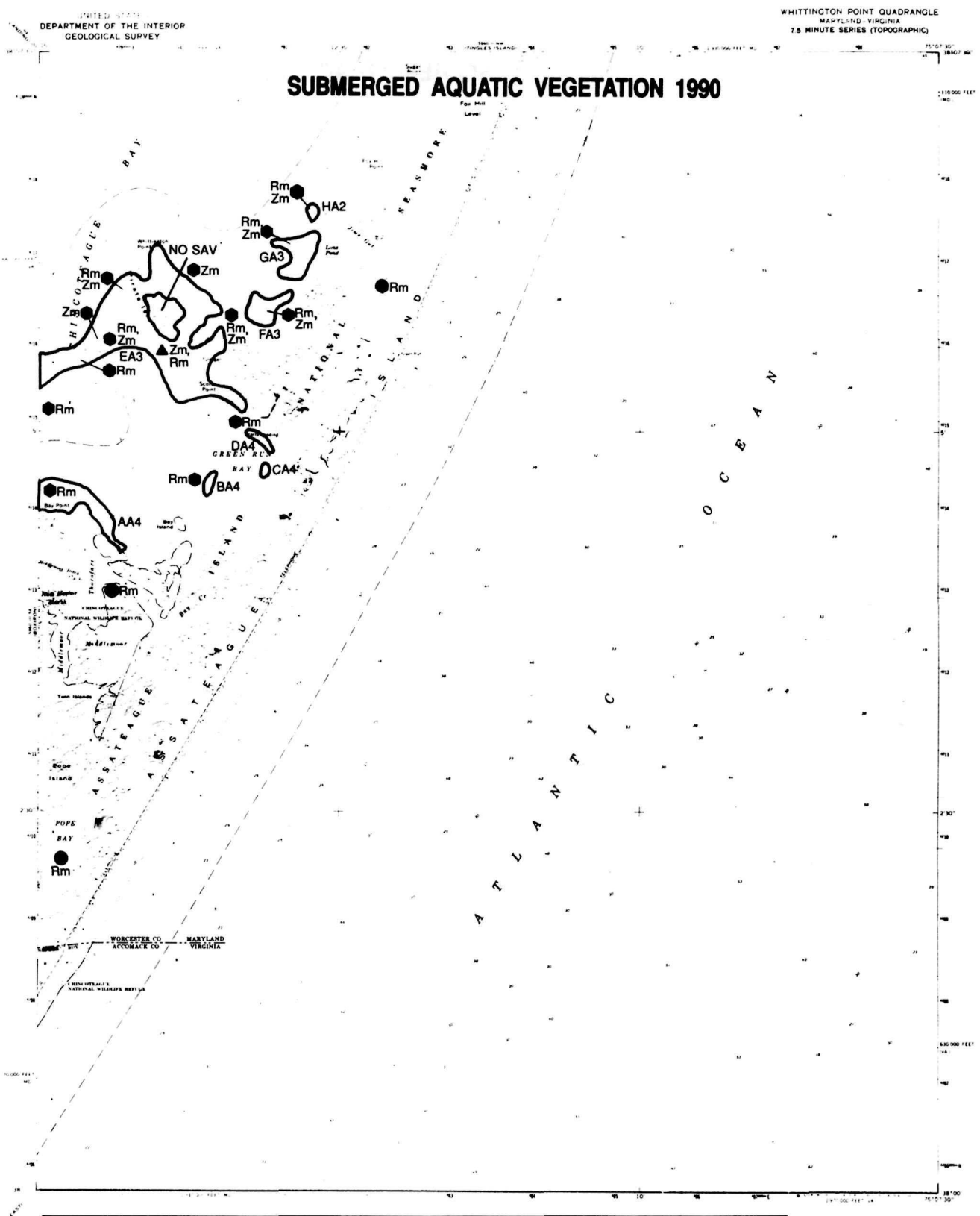
- ⬢ Citizens Field Observation
- ● MD-DNR

VIRGINIA INSTITUTE OF MARINE SCIENCE

DATE FLOWN
6-13-90

BOXIRON,
MD-VA
172



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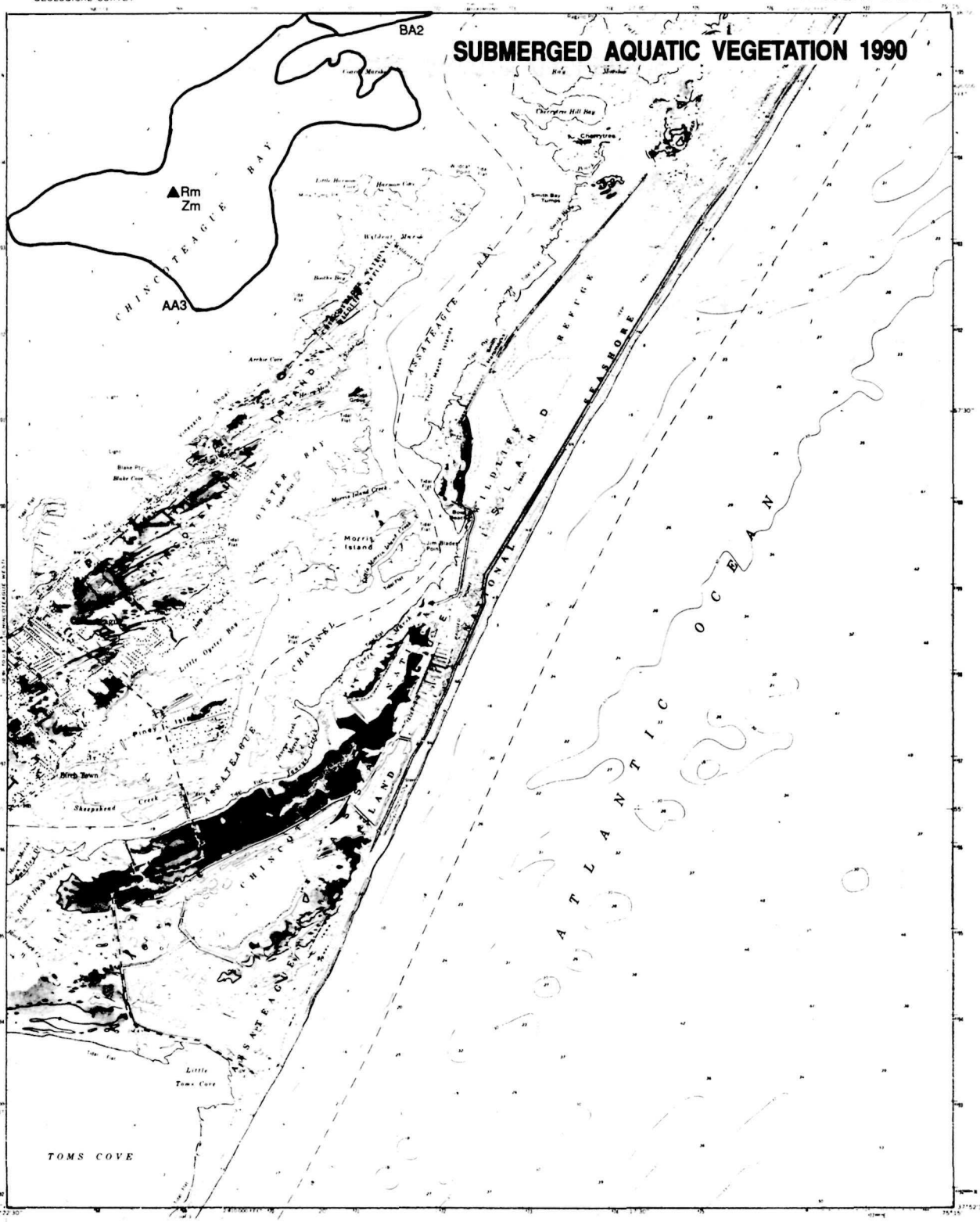
- ● Council of Governments
- ■ MD Charter Boat Field Survey
- ⬢ Citizens Field Observation
- ● MD-DNR

VIRGINIA INSTITUTE OF MARINE SCIENCE

DATE FLOWN
6-13-90

WHITTINGTON POINT, MD-VA
173

SUBMERGED AQUATIC VEGETATION 1990



SPECIES

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VIRGINIA INSTITUTE OF MARINE SCIENCE

DATE FLOWN
6-13-90

CHINCOTEAGUE
EAST, VA
175

Survey of Freshwater Ponds on Assateague Island

Lawrence C. Hoyer, ScD.
Wilde Lake High School
Howard County, Maryland

The objectives of this study are to monitor the physical and biological parameters of the freshwater ponds on Assateague Island, and to provide educational and research opportunities for high school students. The success of the educational and research opportunities for high school students can be measured by the more than two dozen students that have participated in this project and the presentation made at this conference by my student Shamim Sinnar.

We are currently studying twenty-three ponds from the North end of the island to Pope's Bay (fig. 1). We have followed procedures etablished by Dr. Terry Bashore and his students who's work is included in this report. His data includes the 1988 and 1989 data. Five ponds have been added to the list since this work began and three have been lost. North Beach 1 was lost to road improvements, Pope's Bay 2 was overgrown with vegetation, and Clark 2 was dry in 1990 and 1991.

The physical data has remained very stable over the years. These include salinity 0-2 ppT, pH at a low of 6.0 at Jim's gut to a high of 8.0 at highwinds pothole. The nitrite, nitrate, ammonium and lead have remained at acceptable limits. Special attention was given to the presence of lead especially in the areas where hunting is permitted. Water and mud samples from the ponds showed no traces of lead as measured by one of my students using chromatography methods at the R.W. Grace, Company at Clarksville, Maryland under the direction of Dr. Bob Collins. Students are working on plankton analysis, as well as terrestial and aquatic vegetation. These will be quanitated in the future.

The greatest changes have occurred in the fish populations (fig. 2). Five ponds no longer support any fish, while ten ponds show a decrease in species diversity and two ponds show the addition of species. Most notably the appearance of the American eel (Anguilla rostrata) in the pond at Dune Crossing 10. Eels had been previously found in the State Park pond only. The mosquitofish (Gambusia affinis) shows no change since 1988 while the Rainwater killifish (Lucania parva) were present in nine ponds in 1988 and four ponds in 1991. The sheephead minnow (Cyprinodon variegatus) presence disappeared from seven ponds, the silversides (Menidia sp.) from three and the Mummichog (Fundulus heteroclitus) from eleven. It would appear that the mosquitofish are better able to adapt to the freshwater than the other species. However, the success or lack there of may depend on any number of factors. For example, changes in water volumn could lead to more rapid changes in water tempeature that could stress some species more than others.

If these ponds are totally dependent on rainfall to maintain them, then the precipitation data for the island might shed some insight as to the reduction in water volumn in many of the ponds (fig. 3). Yearly rainfall shows very little variation except 1989 when Hurrican Gloria came through. Furthermore the three months preceeding our sampling the average was 9.5 inches. Therefore I do not think a lack of rainfall would account for the loss of water in the ponds at Clark, Foxhill, Jim's gut, and Pope's bay.

Another interesting observation was the sudden appearance of an ectoparasite in the fish populations in the State Park pond. It should be noted that this pond is a favorite spot for herons and many other wadding birds who might be the definitive host for this parasite.

It is evident that the island animals are very dependent on these freshwater sources since their trails always lead to the ponds. Consequently, any information concerning the fresh water ponds may provide an insight to other movement or changes of the other animals on the island.

Fig. 1

Pond Locations on Assateague

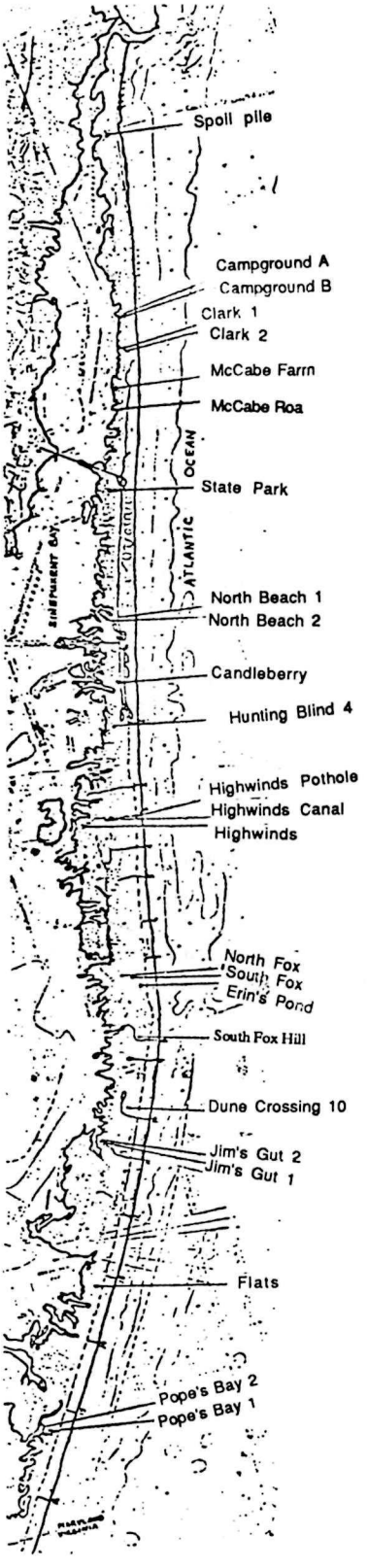

Fig. 2

Precipitation for Assateague Island
(Days of Precipitation)

Month	1985	1986	1987	1988	1989	1990	1991	Average
January		3.28 (9)	9.49 (10)[1]	4.14 (10)	1.84 (10)	4.40 (15)	3.79 (13)	4.49 (11.2)
February		2.77 (15)	Missing	3.12 (10)	4.07 (18)[3]	3.94 (14)	1.43 (12)	3.07 (13.8)
March		0.38 (4)	4.59 (12)	Missing	7.70 (15)	3.59 (11)	4.36 (13)	4.12 (11.0)
April		2.13 (13)	3.92 (13)	3.45 (6)	4.60 (11)	3.39 (12)	5.42 (11)	3.82 (11.0)
May		1.24 (4)	3.58 (8)	2.86 (13)	2.69 (11)	4.39 (11)	0.76 (6)	2.59 (8.8)
June		1.71 (10)	2.10 (9)	1.07 (6)	2.86 (13)	1.47 (3)	6.06 (7)	2.55 (8.0)
July	3.53 (11)	2.02 (10)	5.24 (9)	4.75 (11)	6.64 (10)	2.26 (10)	4.12 (13)	4.08(10.60)
August	12.73 (7)	9.40 (10)	1.52 (10)	4.27 (17)	20.88(17)[4]	5.13 (11)	2.78 (7)	8.10 (11.3)
September	5.66 (7)	1.52 (7)	1.39 (10)	4.80 (11)	4.40 (10)	1.51 (7)	2.88 (9)	3.17 (8.7)
October	2.64 (9)	1.71 (9)	3.37 (11)	3.25 (9)	5.12 (10)	2.40 (5)		3.08 (8.8)
November	3.57 (13)	3.54 (17)	3.56 (11)	3.78 (13)[2]	4.33 (10)	2.27 (7)		3.51 (11.8)
December	1.81 (8)	7.12 (16)	3.37 (17)	0.64 (6)	1.55 (7)[5]	3.29 (14)		2.96 (11.3)

Ave/Month 4.99 (9.20) 3.07 (10.3) 3.8 (10.2) 5.55 (11.8) 3.17 (10) 3.5 (10.1)

Total Precipitation 29.94(6mo) 36.82(12mo) 41.88(11mo) 36.13(11mo) 66.68(12mo) 38.04(12mo) 31.6(9mo)

1. January 1987 6" snow = N 1/2" water
2. November 1988 1/2" snow
3. February 1989 13.65" snow = N 1.92" water
4. Agust 1989 Gloria 10+" in one day
5. December 1989 9.41" snow = N 1.40" water

Fig. 3

Fish Populations in the Freshwater Ponds on Assateague Island

Name of Pond	1988	1989	1990	1991
Spoilpile	1	G,L,C,M	G,L,C,M	G,L,C,M
Campground A	1	C,M	C,M	C,M
Campground B	1	1	C,M,F	C,M
McCabe Road	L,C,F	G,L,C,F	1	G
McCabe Farm	G,L,C,M,F	C	C,M	L,C,M
Clark 1	G,L	3	3	3
Clark 2	C	3	3	3
State Park	L,C,M,F,A	L,M	G,L,C,A	G,M
North Beach 1	C,M,F	2	2	2
North Beach 2	C,F,	L,M	L,M	L,M
Scotts				
Candleberry	G,L,FqG,L	G	G	
Hunting Blind 4	L	L	1	1
Highwinds	1	G	G,F,	G
Highwinds Canal	F,L,C,M,F	G	G	G
Highwinds Pothole	3	3	3	3
North Fox	C	G,C	G,C,M,F	G
South Fox	L,D,M,F	4	4	4
Erin's Pond	1	G	G,L	G
Jim's Gut 1	L,F	3	3	3
Jim's Gut 2	1	1	1	1
Jackson's	1	1	1	1
Pope;s Bay 1	F	3	3	3
Pope's Bay 2	3	3	3	3
Dune Crossing 10	G,L,D,F	G	1	F,A
Flats	1	1	G,C,F,	G,C,F

1. Not Sampled
2. Lost to road construction
3. No Fish
4. Not located

G - Gambusiz affinis, Mosquitofish
L - Lucania parva, rainwater killifish
M - Cyprinodon variegatus, sheepshead
F - Fuvdulus heteroclitus, Mummichog
A - Anguilla rostrata, American eel

Isozyme Analysis of Fish Populations From Freshwater Ponds on Assateague Island

Shamim Sinnar, Wilde Lake High School
Howard County, Maryland

Assateague Island National Seashore has approximatly twenty-three fresh water ponds in the Maryland section. These ponds contain a variety of fish populations that include the sheepshead minnow (Cyprinodon variegatus), mummichog (Fundulus heteroclitus), rainwater killifish (Lacania parva), silverside (Menidia sp.), American eel (Anguilla rostrata), and the mosquitofish (Gambusia affinis). An earlier study by Dr. Bashore and his students also reported the presence of sticklebacks in the McCabe Farm poind. The sticklebacks have apparently disappeared since we have not found them in any of the samples from the last three years.

My interest has centered on the mosqitofish since it is widely distributed in temperate waters of the New World and has been studied extensively. Furthermore, Assateague Island is near the northern limits of the mosquitofishs' range, suggesting that substantial genetic changes may have taken place to allow this species to adapt to the temperature extremes they experience this far north. In addition, studies conducted in Texas by Hodges and Whitmore, in 1977, showed considerable differences in muscle isozymes between population locations within rivers, as well as between different rivers. With this in mind, I decided to investigate the different mosquitofish populations from the Assateague ponds, following the electrophoretic procedure of Hodges and Whitmore, to determine if any genetic changes had taken place as a result of isolation. Since many of the ponds are located a considerable distance from the Sinepuxent Bay and frequently are themselves many miles apart, it is possible that these populations may have been isolated from each other for a substantial period of time. This georgraphic isolation could possibly contribute to some genetic drift between the ten ponds that currently contain mosquitofish populations.

Fish were collected in October of 1989 and February of 1990 by Dr. Hoyer and his students. These fish were used for the initial studies by Erin White under the direction of Dr. Benson at the University of Maryland at College Park. In July of 1990, Dr. Hoyer and I collected fish from the ten Assateague ponds. During the fall and winter of 1990 and 1991, I used these fish in electrophoretic studies, also under the direction of Dr. Benson and through a grant from the University of Maryland.

These gels produced two major bands and a couple of minor bands (fig. 1). Rabbit, guppy and trout standards were used in order to find one that would give the greatest distribution of banding. The mosquitofish, as well as the other species sampled, showed distinct patterns (fig. 2). No differences were apparent between the mosquitofish from the various ponds. However,

Fig. 1

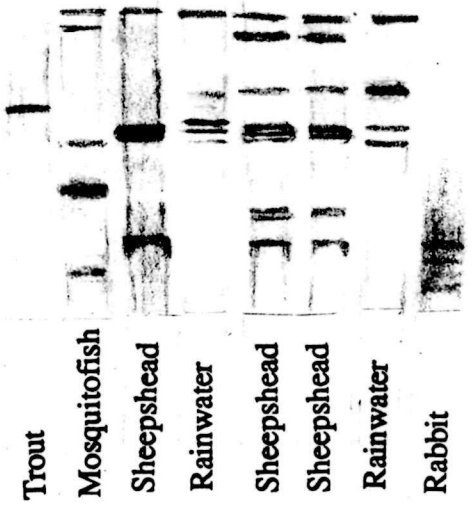

Fig. 2

Mosquitofish from four different ponds

my results suggest that there are significant differences between the Texas populations and those on the island. In addition, there also appears to be substantial differences between those collected in the summer and winter. The lower bands are not as evident or appear to be missing completely (fig. 2). The upper band does not show the two distinct bands seen in fig. 1. This may have resulted from inadvertent procedural changes; however, looking back at the results obtained by Erin White, who used fish collected in the winter, it is interesting to note that these recent results are similar to her's.

This has raised the possibility that there might be seasonal differences in the isozyme patterns. This remains to be seen, but I hope to check that this winter by running last year's samples with this year's on the same gel. This will be possible since portions of each sample have been saved and frozen. There may not be any differences beteeen the mosquitofish populations on Assateague but there does appear to be differences from those in the Texas study. Peterson's Field Guide of Atlantic Coast Fishes suggests that the eastern and western populations may be distinct species. Our results tend to support this idea; however this theory still remains to be proven. I need to test the members from different geographic regions to determine whether they have become genetically or reproductively isolated. Unfortunately, we have not been successful in raising the mosquitofish in aquariums. Until we can do this successfully we will be unable to determine for sure if eastern and western populations have evolved into distinct species.

Assateague Island Bay Water Quality Monitoring

John Kumer
Assateague Island National Seashore
1756 National Seashore Lane
Berlin, Maryland 21811

Abstract

From 1987 through 1990, the resource management division at Assateague Island National Seashore collected baseline water quality parameters in the Chincoteague-Sinepuxent Bay complex. Fecal coliform, nutrient and related physical data were collected from spring through fall. Coliform and nutrient data were quite variable, and except for infrequent high levels in the Newport Bay area, these water quality parameters appear to be good.

Introduction

Assateague Island National Seashore was established by congress in 1965 for public outdoor recreation use and enjoyment. (PL 89-195). Further, legislation directs the park service to develop measures for the full protection and management of the natural resources and natural ecosystems of the seashore. (PL 94-578). The authorized boundary of the seashore encompasses approximately 52,000 acres of which almost 33,000 acres, or 63% of the park, is made up of waters adjacent to the barrier island, including areas of the Atlantic ocean, Sinepuxent and Chincoteague Bays.

The water monitoring program at Assateague is intended for the establishment of baseline water quality data in the Chincoteague - Sinepuxent bay complex. Bay water quality monitoring was started by park personnel in 1987 through the help of special funding to the park. Initially, nine monitoring stations were established, four in the Sinepuxent, five in the Maryland portion of Chincoteague Bay. At each of these nine stations, data on 17 water quality parameters, and supporting physical and environmental data, were generally collected monthly by park personnel from April through October. Initially, the program ran from 1987 through 1990. Sampling was expanded into the Chincoteague Bay waters of Virginia in 1991, with funds to support the program through 1992.

Results and Discussion

Analysis of the first four year's data base is now nearing completion, (NPS/WRD 1991). The results indicate that the overall water quality in the Maryland Chincoteague-Sinepuxent Bay complex is good. Except for localized, infrequent events, water quality is well within the acceptable ranges specified by Maryland water quality regulations.

Total nitrogen (TN) fluctuated seasonally. The highest levels of TN were recorded during the summer months, tapering off into the

spring and fall. Concentrations ranged from a minimum of 23.8 um to a maximum of 121 um. The mean level of TN in Newport Bay near the outlet of Trappe Creek was significantly greater ($P<.05$) than the mean levels at the other eight sites.

Total nitrogen filtered (TNF) likewise fluctuated seasonally with higher summer levels. As with total nitrogen, TNF at Newport Bay was significantly greater ($P<.05$) than the other sites, with a mean of 41.62 um.

The arithmetic mean concentrations at the two sample sites located near the Ocean City Inlet for both TN and TNF were significantly lower than any other site in the Chincoteague-Sinepuxent Bay complex.

There was no apparent seasonal fluctuation, but a great deal of variability in both dissolved ammonium and nitrate/nitrite data. Levels of dissolved ammonium ranged from 0.07 to 13.0 um. Nitrate/nitrite concentrations ranged from below detection to 6.86 um.

Total phosphorus and total phosphorous filtered and orthophosphate concentrations exhibited the same seasonal trend as total nitrogen and TNF, with the Newport Bay site showing significantly higher concentrations than other sites. TN/TP ratios were 22:1, NO3/PO4 ratios were extremely variable.

Fecal Coliform (FC) counts were extremely variable, ranging from minimum detectible at all locations to 240 mpn/100ml at the Newport Bay site. Geometric means in the bay complex ranged from 2.15 to 7.84 mpn/100ml. The geometric mean at Newport Bay was 3 times greater than other sites.

Salinity, pH, temperature, Chlorophyll a, and dissolved oxygen all showed variable measurements but were generally within state standards.

Summary

The overall water quality of the Chincoteague-Sinepuxent Bay complex, as characterized by the parameters and sample locations collected by the National Park Service water quality monitoring program, is good. The primary pollution problems appear to be somewhat localized in the confined tidal areas of the Newport Bay and event related.

Citations:

NPS/WRD 1991 National Park Service/Water Quality Division. Assateague Island National Seashore Water Quality Monitoring 1987-1990 Data Summary and Report. Technical Report NPS/NRWRD/NRTR-91-06. 1991. Technical Information Center, Denver Service Center, P.O. Box 25287, Denver, CO 80225-0287.