ASSATEAGUE ECOLOGICAL STUDIES

Final Report

Part II. Environmental Threats

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Part II

Environmental Threats

This section brings together our own and other research which has bearing on potential threats to the Assateague environment. We have treated three areas: Dredging, Assateague land disturbance and insect control. In the first, the comments presented summarize present estimates of the probable results of dredging in Chincoteague Bay near the shore or in deeper water. In relation to land disturbance and insect control, we have brought together information and comments from other sources which seem pertinent to this location. These appear to be useful in the evaluation of alternative possibilities.

Dredging

I. Inshore dredging in Chincoteague Bay

Part of the original motivation of the contract was to provide the National Park Service with information relevant to proposed dredging at three inshore Assateague sites: the Pope Bay area, Fox Hill Levels, and North Beach (Figure 1). Most of the inshore areas are quite shallow, less than 5-6 feet deep, so that extensive dredging will have considerable effect in deepening the inshore areas. Thus, the following should be considered:

----Primary production studies indicate that phytoplankton contribute approximately 72% of all the organic matter produced in the bay each year. The marshes contribute approximately 26%, while the rooted aquatics contribute approximately 2%. Both distribution and production of the first two are of the same order of magnitude throughout the central portion of the bay. Therefore, it is probable that if dredging operations were not widespread, the total baywide phytoplankton and marsh production would not be measurably changed. However, the eastern Assateague shallows contain most of the rooted aquatic plants, widgeon grass (Ruppia) and eelgrass (Zostera), in the bay. Moreover, these plants appear to be limited to depths shallower than four feet. It has been shown that these plants are adversely affected by increased turbidity. Therefore, dredging would affect the rooted aquatic plants more than any of the other communities of primary producers (see reports of Boynton, Keefe and Boynton, and Anderson, in Part I of these studies).

----Despite their relatively small contribution to the total primary production in Chincoteague Bay, Ruppia and Zostera loss may significantly affect wintering waterfowl at the Assateague shore, particularly the black Brant. Ninety-five percent of Chesapeake area Brant winter in the Assateague area and their predominant foods are the rooted aquatic plants, eelgrass and widgeon grass (Stewart, 1962).

----Ten years ago, researchers reported that no bay scallops (Pecten irradiens) were found in Chincoteague Bay. During the 1968-69 season, commercial clammers reported dredging about 50 scallops a day in the area of the Maryland-Virginia border. The size of the population has not been determined, but qualitative measurements indicate that their spread is from the vicinity of the State line to Green Run Bay, only on the eastern side of the bay. Scallop reinvasion appears to directly follow the reinvasion of eelgrass in the bay. Scallops represent a potentially profitable industry in the future (Michael Castagna, personal comm.).

----Shallow water areas in Chincoteague Bay appear to be important finfish spawning and nursery areas (See report of Wiley et al. in Part I of these studies). Wiley found large numbers of certain forage fishes and many juveniles of important sport and commercial species in the Assateague shallows, including menhaden, perch, spot, mullet and flounder. Moreover, in trawl samples of old borrow areas in the Isle of Wight Bay, he found fish species which are characteristic of deeper waters of Chincoteague Bay. Deepening of the shallows by dredging will alter the suitability of these important finfish spawning and nursery areas.

----Shallows at Assateague hold potential for an important recreational hard-shell clam harvest. Such a resource would be dependent on the extensive sand bottom shallows which now exist, particularly in the Fox Hill Levels and Green Run Bay areas. Dredging these areas may render them too deep for recreational clamming by wading. Also, there is a strong probability that the sandy substrate (preferred for recreational clamming) may be changed to a muddier substrate, reducing the crop. The old borrow areas have not only retained their steep edges, but have acquired a muddy substrate. (See report of Drobeck, et al. in Part I of these studies concerning observations at old borrow areas in the Ocean City area).

----Inshore dredging will have little effect on the total clam populations or overall benthic animal populations of the bay, since they are so ubiquitous.

----Equipment, vehicles and pipelines associated with inshore dredging may significantly alter or destroy unique land areas of the Island. (See Special Interest Section in Part III of these studies).

----Inshore dredging and deepening may alter erosion rates of inshore *Spartina* islands of Chincoteague Bay. The mid-Chincoteague *Spartina* islands are in a state of natural regression whereas those islands near ocean inlets are presently building. Deepening around the mid-bay islands will hasten erosion rates due to loss of shelter from wind-driven waves. A possible loss of rooted plants with deepening may have the same effect since underwater plants are known to have moderating effects on waves (see report of Biggs in Part I of these studies).

II. Offshore borrow areas in Chincoteague Bay.

----Mid-bay surface sediments are composed of muds and clays in contrast to the more sandy inshore sediments. This may make them less suitable for landfill (see report of Bartberger and Biggs in Part I of these studies).

----Equipment, vehicles and pipelines associated with offshore dredging may significantly alter or destroy unique land areas of the island (see Special Interest section in Part III of these studies).

----Several commercial clamming grounds are located offshore. Mr. Fred Sieling,of the Maryland Fish and Wildlife Administration,has wide experience with Chincoteague commercial clamming and should be contacted in this regard.

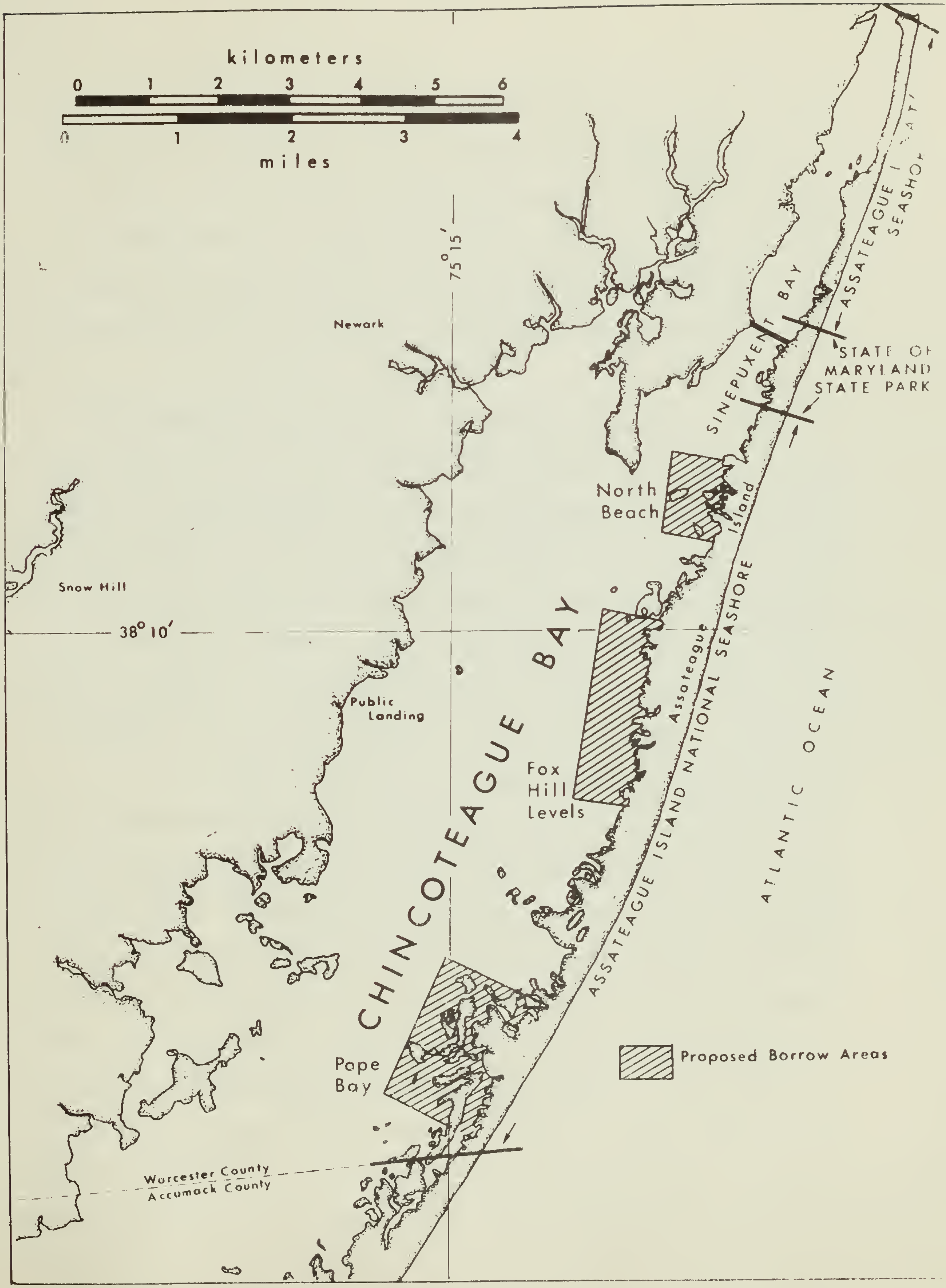

Figure 1. The Assateague Island National Seashore-Chincoteague Bay area showing proposed inshore sediment borrow areas.

Land Disturbance

The unsurpassed beach and back dune areas of Assateague Island rank high as some of the island's most valuable natural resources. They provide aesthetically pleasing recreation areas for a growing number of people, and serve as a buffer zone protecting the road and recreation facilities, coastal ponds, and wildfowl impoundments, as well as the bay and mainland.

These resources and, indeed, major portions of the island are constantly threatened by the natural processes of wind and wave action which can wash away sand, undercut dunes and occasionally inundate and change portions of the island. Additionally, protective areas are becoming increasingly subject to the unnatural pressures of visitation (foot travel, buggie use and camping areas). On Assateague, land disturbance is a double problem, in that the island is naturally susceptible to alterations and, secondly, susceptible to alterations through the weakening of stabilizing forces induced through visitation pressures.

The problem of protecting existing shorelines and associated back dune areas is not unique to Assateague Island; all coastal states have similar problems. Nor is it a new problem, as it was recognized as a problem as early as 1714, when Provincetown, Massachusetts was in danger of being swept into the sea. "This was the town..."wrote Henry David Thoreau, "...where in some pictures the persons of the inhabitants are not drawn below the ankles, so much being supposed to be buried in the sand." (Hay and Farb, 1966). At that time, grasses were planted along the shoreline which prevented sand from blowing away and permitted sand dunes to develop (Jagschitz and Bell, 1966). Through the years, many other dune and waterfront stabilization projects have been conducted, most notably on Cape Cod, Cape Hatteras, and on the New Jersey and Rhode Island coasts.

For the purposes of this discussion, perhaps the most reasonable approach to an investigation of the problem of land stabilization is to investigate the relative tolerance or intolerance of several critical island environments to natural and human pressures and then relate several previously tested land stabilization plans that might be applicable to Assateague, particularly in areas slated for heavy use. The noted landscape architect, Ian McHarg, gives the following analysis of a barrier island in terms of natural tolerance.

"The first zone is the beach and, fortunately for us, it is astonishingly tolerant. It is cleaned by the tides twice a day of the debris that men leave, and even the most vulgar residues achieve a beauty when handled by the sea. The creatures that live in this area do so mostly in the sand and, thus, escape destruction from humans.--- The next zone, the primary dune, is absolutely different: It is absolutely intolerant. It cannot stand any trampling. It must be prohibited to use. If it is to be crossed, and crossed it must be to reach the beach; then this must be accomplished by bridges. Moreover, if the dune is to offer defense against storms and floods, then it must not be breached. As a consequence, no development should be permitted on the primary dune; no walking should be allowed and it should not be breached at any point. The trough is much more tolerant; development can occur here...it is protected from wind, storm and blowing sand by the primary dune. The inland dune is the second line of defense and is as vulnerable as the primary dune. It, too, is intolerant and should not be developed." (McHarg, 1969, p. 13).

The validity of these guidelines has been demonstrated many times, most notably along the New Jersey coast and, indeed, on Assateague Island in the spring of 1962. McHarg notes that the barrier islands of the east coast are in the path of hurricanes; there is no assurance that the last storm was the worst (McHarg, 1969). This situation points to the importance of coming to grips with the double problem of land stabilization: stabilizing critical areas whenever possible, and protecting those areas from visitation pressures that tend to weaken their protective functions.

Following McHarg's analysis, the beach, although heavily used, appears secure. The trough which will also be used, probably as a camping, picnic and roadway area, also seems to be a stable area. The remaining two areas, the primary and scattered secondary dunes, are sensitive, yet they lie in the path of many activities. Most of the stabilization work discussed here is concerned with these last two areas.

In 1966, the Rhode Island Agricultural Experiment Station published a report entitled: "The Restoration and Retention of Coastal Dunes with Fences and Vegetation." In this report, a number of dune construction and dune stabilization methods were discussed. The report, based on research conducted along the Rhode Island Coast in 1956, concluded that fences and vegetation are economical and effective materials to aid in dune rebuilding. Sand arresting barriers should be porous or slatted. Brush, Christmas trees, or snow fences, rather than solid structures, proved superior, since they were better able to withstand typical beach weather conditions. Furthermore, it was found that four-foot fences, in either a single or double line, are as effective in collecting sand as are diamond, box, saw-tooth, or zigzag arrangements. It was found that fences should be erected in front of areas to be protected, above the high-tide line, on slopes facing the ocean and across blowouts and washouts. The sand collecting ability of these artificial structures varied considerably depending on the amount and grainsize of the sand available; areas with smaller grain sand yielding the best results. Dune growth of several feet per year was reported with these methods (Jagschitz and Bell, 1966).

Once a dune has reached a desirable height, it must be stabilized if it is to endure adverse weather conditions. It appears that there are two general methods used to stabilize a dune; the first being inorganics such as oil, gravel, stone, or dead brush and, the second, live vegetation including a variety of grasses, shrubs, and trees (Jagschitz and Bell, 1966). While inorganics have been found to be effective, their useful lifespan is short and they produce unsightly areas. In the case of oil, there may be adverse ecological effects.

It is generally agreed that live vegetation is the best means for stabilizing dune areas. The forms best suited for stabilizing purposes in the primary dune area grow upward through new sand accumulations and spread laterally by stolons or rhizomes to form a dense anchoring mat. Additionally, the vegetation must be able to withstand strong winds, blowing sand and deposition, salt spray, occasional ocean flooding and infertile soils (Hay and Farb, 1966). Despite these stringent requirements, a number of grasses and legumes have proven to be effective dune and back dune stabilizers and are listed in Table I.

The success of transplanting vegetation depends on a number of factors. These include the time of introduction, moisture and nutrient content of the soil both at the time of the transplant and later in the growing season, predominant grainsize of the sand involved, condition, age, and size of the transplant and the spacing of the transplant (Sand-blow Stabilization, U. S. Dept. of Agriculture Information Sheet MA-13, September, 1959). It appears that the best vegetative cover can be established using transplants (Jagschitz and Bell, 1966), but some success has been achieved using seeds, especially in more protected areas (Zak, 1967).

In the primary dune area, American beach grass (Ammophila breviligulata) has been found to give the most stabilizing effect when properly fertilized. It will grow to heights of four feet and form a natural barrier to visitors and will recover very quickly when dug or disturbed (A. C. Lane, personal comm.). Other grasses have been tried as stabilizers in the primary dune area, including domestic ryegrass (Loluim sp.), switchgrass (Panicum virgatum L.), weeping lovegrass (Eragrostis curvala Nees), and many others, but few have been as successful as American beach grass (Lane, 1968).

Once a dune is established and stabilized, it is necessary to continually monitor the status of the vegetation, fertilize, and add plants when necessary. Numerous stabilization projects have ended in failure because of lack of maintenance after the initial stabilization (Zak, 1967).

A second area on the strand that has received attention regarding land stabilization is the back or secondary dune area. Again, the problem here is one of stabilizing structures against the naturally destructive forces mentioned earlier and against the potentially destructive effects of intense longterm use of the back dune area by park visitors and campers. Considerable practical testing of stabilization techniques has been completed in the back dune areas that offer good solutions (Sharp, 1968).

Since the back dune area is somewhat protected from salt spray, wind and inundation, there is a wider range of vegetation types that will grow well to effectively stabilize these areas. This group includes the various grasses listed in Table I and also includes a number of woody plants. On Cape Cod, in 1965, vegetation types other than American beach grass were introduced in both open areas and protected areas already covered with grass. The following plants did very well in protected areas and, when fertilized, grew beyond all expectations (Lane, 1968).

Seaside goldenrod	Bayberry
Beach pea	Japanese black pine
Hudsonia	Beach plum
Dusty miller	Rugosa rose
Augumn olive	

In addition to these plants, a variety of other woody plants adapted to secondary coastal dune environments have been evaluated in the Cape Cod area. The most successful include bristly locust, Japanese sedge, Amus honeysuckle,flame leaf sumac, green brier, and choke cherry. A more complete list of seashore plants is contained in Table II.

Aside from the stabilizing function these plants perform so well, they have several additional benefits. Japanese sedge, green brier, and other shrubs and trees act as natural barriers and discourage unrestricted foot travel on certain sections of the island. This is most important in the primary dune area, as already emphasized, but can be employed to good advantage in other critical heavy use areas (Lane, 1968). Secondly, vegetation can be used as an effective wind barrier and provides a sense of privacy in camping and picnic areas, that at present is obviously lacking in many areas.

Table I. Performance of various grasses transplanted in active and still-sand using mature plants.

Name		Initial	Growth and density (growing season)				Spread	Av. height
Scientific	Common	Survival	1	2	4	7	ability	inches
Ammophila arenaria	European beachgrass	Exc.	Exc.	Exc.	Fair	None	None	28
Ammophila breviligulata	American beachgrass	Exc.	Good	Exc.	Exc.	Exc.	Exc.	20
Cynodon dactylon	Salem bermudagrass	Good	Good	Good	Good	Good	Good	3
Elymus giganteus	Volga wildrye	Good	Good	Exc.	Fair	Poor	Fair	26
Elymus triticoides	creeping wildrye	Poor	Poor	None	----	----	None	6
Elymus vancouverensis	Vancouver dunegrass	Exc.	Exc.	Good	Good	Fair	Exc.	18
Eragrostis curvula	weeping lovegrass	Exc.	Good	None	----	----	None	18
Panicum amaralum	coastal panicgrass	Good	Good	Good	Good	Good	None	32
Panicum amarum	dune panicgrass	Good	Good	Good	Fair	Fair	Fair	10
Spartina patens	saltmeadow cordgrass	Fair	Good	Good	Good	Good	Good	14
Tripsacum dactyloides	eastern gamagrass	Good	Good	Fair	Poor	Poor	None	12
Uniola paniculata	seaoats	Good	Good	None	----	----	None	22

Exc. = excellent

Table taken from J.A. Jagschitz and R. S. Bell, 1966. Restoration and Retention of Coastal Dunes with Fences and Vegetation. Rhode Island Agricultural Experiment Station. Contribution 1149.

Table II. Seashore Plants

Deciduous trees

Common name	Scientific name
Thornless Honey Locust	Gleditsia triancanthos inermis
Common Honey Locust	Gleditsia triancanthos
Moraine Locust	Gleditsia triancanthos inermis "Moraine"
Sunburst Locust	Gleditsia triancanthos "Sunburst"
Tree of Heaven	Ailanthus altissima
Sycamore Maple	Acer pseudoplatanus
Tupelo	Nyssa sylvatica
Evergreen Trees	
Red Cedar	Juniperus virginiana
Austrian Pine	Pinus nigra
White Spruce	Picea glauca
Cryptomeria	Cryptomeria japonica
Japanese Black Pine	Pinus thunbergi
Tigertail Spruce	Picea polita
Colorado Blue Spruce	Picea pungens Engelm.
Shrubs	
Beach Plum	Prunus maritima
Bayberry	Myrica pensylvanica
Russian Olive	Elaeagnus angustifolia
Autumn Olive	Elaeagnus umbellata
Inkberry	Ilex glabra
Shadbush	Amelanchier canadensis
Spreading Cotoneaster	Cotoneaster divaricata
Rock Cotoneaster	Cotoneaster horizontalis
Early Cotoneaster	Cotoneaster adpressa praecox
Tamarix	
Dwarf Willow	Salix purpurea
Summersweet	Clethra alnifolia
Blue Hydrangea	Hydrangea macrophylla variety
French Pussywillow	Salix caprea variety
Highbush Blueberry	Vaccinium corymbosum
Privet	Ligustrum
Fragrant Sumac	Rhus aromatica
Arrow-wood	Viburnum dentatum
Whitherod	Viburnum casinaides

Table II. (Continued) Seashore Plants

Evergreen Shrubs	
Pfitzer's Juniper	Juniperus chinensis pfitzeriana
Andorra Creeping Juniper	Juniperus horizontalis plumosa
Sargent Juniper	Juniperus chinensis sargenti
Dwarf Yew	Taxus cuspidata nana
Scotch Broom	Cytisus scoparius
Warminster Broom	Cytisus praecox
Ground Covers	
Climbing Hydrangea	Hydrangea petiolaris
Woodbine	Parthenocissus quinquefolia
Bower Actinidia	Actinidia arguta
Bearberry	Arctostaphyllos uva-ursi
Silver Mound Artemisia	Artemisia schmidtiana nana
Border Gem Thyme	Thymus vulgaris varietv
Woolly Thyme	Thumus serpyllum variety
Dusty Miller	Artemisia stellarinana
Rugosa Rose	Rosa rugosa
Climbing Roses	
Dwarf Lace Flower	Polygonum reynoutria
Stonecrop or Live-For-Ever	Sedum
Sweet Fern	Comptonia asplenifolia
Adams Needle	Yucca filamentosa
Beach Grass	Ammophila
Love Grass	

Prepared by Cape Cod Extension Service.

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INSECT CONTROL

Salt marshes along the Atlantic Coast have long been known for their production of tremendous numbers of troublesome insects: midges, greenheads and mosquitoes. Assateague Island is certainly no exception. To the day visitor and camper, these animals can be almost intolerable pests, to be avoided if possible, and endured for only a short time -- and then with the help of repellents. However, in the natural process of the marsh, the insects occupy specific niches; they feed and are fed upon,and compete for space and suitable areas to reproduce. Their stay on the marsh is regulated by the seasons. They are as much a part of the natural marsh system as the less obvious fiddler crabs, mussels, and wildfowl.

On Assateague Island, troublesome insects render portions of the island, at certain times of the year, virtually unusable for the visitor. As visitation increases, the pressure to expand facilities to remote portions of the island, most notably the back dunes and marshes, will also probably increase. If a form of insect control were to be instituted to make the marsh, or any area west of the road, more pleasant for the visitor, there is the possibility that unfavorable ecological changes could result from such actions. This represents a possible environmental threat.

The following section describes several different types of insect control that have been used in the past, summarizes a small portion of the findings to date concerning the ecological effects of the various forms of insect control, reviews several successful control projects, and briefly surveys future insect control techniques.

Insect control methods generally fall into two groups, those that do not immediately change the marsh, but attack the insect directly, such as pesticides; and those such as ditching, that change the marsh so it is no longer a suitable pest habitat (Teal and Teal, 1969).

There are some serious objections to almost all of the control methods used in the past. The Teals note that ditching is damaging since it drains the entire marsh; pools are emptied that formerly attracted and maintained wildlife; and the species composition of the marsh is changed with an acceleration towards the high marsh. A 12-year study of the biological effects of ditching tidewater marshes in Delaware for mosquito control showed that marked ecological changes in the floral cover and invertebrate fauna followed such operations. Systematic ditching resulted in shrubby growths succeeding the natural marsh vegetation and reduction in the number of invertebrate fauna, especially mollusks, by 30% to 82% (Bourn and Cottam, 1950).

Another modification, the opposite of ditching, is building dikes to create impoundments, thus, inundating dry areas suitable for egg-laying by the salt marsh mosquito (*Aedes sollicitans*). Small fish tend to invade the pools and quickly destroy the mosquito larvae that are deposited in the water (Ferrigno, Jobbins, and Shinkle, 1967). In a study conducted to determine the feasibility of modifying shallow shorelines and, thus, eliminate the breeding places for *Aedes dorsalis*, it was found that if the inshore areas were deepened, there was a signficant reduction in the population of some mosquito pests (Rees and Winget, 1968).

Although these techniques make the marsh unsuitable for mosquito production, they also make the area unsuitable for *Spartina*, hasten the filling of the marsh with sediments and deprive the estuary of nutrients usually provided by the marsh. Modifications in these techniques, which minimize the harm done to the marsh, yet still remain effective as control methods, have been developed and successfully used on Cape Cod (Teal and Teal, 1969).

The second type of control involves the use of insecticides. When DDT was first discovered, it was hailed as a milestone in insect control. Its use resulted in spectacular control of disease by destroying insects carrying diseases (Report of the Secretary's Committee on Pesticides and Their Relationship to Environmental Health, 1969), made many areas more suitable for recreational uses (Hazeltine, 1962), and increased crop yields (Teal and Teal, 1969). However, in the early 1950's it was discovered that pesticide use, particularly the use of DDT, had some alarming consequences. The biota of treated areas concentrated the pesticide and passed this concentration up the food chain, resulting in the death of large numbers of fish, wildfowl, and other commercially valuable organisms (Hazeltine, 1962), (see Table 1). Since this discovery, a tremendous amount of research has been directed toward understanding the specific and overall effect of insecticides on the environment.

It has been found that organochlorine pesticides remain a long time in both aquatic and terrestrial environments. There is a rapid initial loss of pesticides through volatilization and then extremely slow losses through degradation and leaching (Barthel, Murphy, Mitchell, and Corely, 1960).

One longterm experiment showed that after 14 years, between 10 and 40 percent of a wide variety of tested insecticides remained active in the soil (Nash and Woolson, 1967). DDT residues in the soil of an extensive salt marsh in Long Island averaged more than 13 lbs/acre (Wodwell, Wurster, and Isaacson, 1967). In aquatic situations, most pesticides are not quickly carried away by currents, but persist for unusually long periods of time due to the insoluble nature of many pesticides in water. L. F. Stickel (1968) notes in a report entitled Organochlorine Pesticides in the Environment: "In aquatic systems, the greatest magnification of organochlorine residues is physical, for the low solubility of most of these compounds in water and their absorbent properties lead to concentrations of residues in bottom mud that may reach millions of times the concentrations in water." A Florida study indicated that DDT tended to accumulate in the populous lower marsh areas (Croker and Wilson, 1965). In addition to physical retention of residues, there may be a widespread ability for microorganisms to accumulate DDT and dieldrin by nonmetabolic processes. This action may play a role in the retention of these compounds in the soil (Chacko and Lockwood, 1967). It has been suggested that perhaps the large surface area and lipidlike character of bacterial cell walls favor the rapid uptake of DDT (B.C.F. Circular 247, 1965).

Research has shown that persistent pesticides adversely affect a number of ecosystem components. Several species of diatoms have been tested and were found to be resistant to dieldrin concentrations that were considerably higher than the fraction of a part per million reported as lethal for fish and other aquatic invertebrates. However, these plants did concentrate pesticides and if this is a general phenomenon among algae, they may very well enter the food chain as "toxic plants." The fact that algae accumulate insecticides is particularly significant since a gross effect upon organisms low in the food chain could produce changes throughout the system. It has been demonstrated with natural populations of phytoplankton that various concentrations of a wide range of herbicides and pesticides will decrease growth from 0 to 89 percent during a 4-hour exposure (U. S. Dept. of Interior, 1964). It would be meaningless to talk about fish survival if their food supply was devastated (Cairns, 1968).

Various levels of insecticides have been found in mollusks, including the American oyster, Crassostrea virginica (U. S. Dept. of Interior, 1964). Filter feeding organisms such as the oyster have a remarkable ability to concentrate pesticides, as well as other pollutants. L. F. Stickel (1968) notes that "a 10-day exposure of oysters to a mixture of pesticides, at a concentration between .001-.05 ppm, resulted in tissue concentrations of 1-28 ppm. Concentration factors varied from 60 times for lindane to 17,600 times for heptachlor. The concentration factor for the DDT group was 15,000." It has been estimated that about 90% of all shellfish occurring between Boston, Massachusetts and Portland, Maine are contaminated with toxic pesticides and other pollutants (Hay, 1966).

Pesticide residues have also been found in many other components of the estuarine system including shellfish, other invertebrates (Ruber, 1962), fish (U. S. Dept. of Interior, 1964), and birds (Stickel, 1968; U. S. Dept. of Interior, 1964; Peakall, 1970; Moore and Walker, 1964; Risebrough, Menzel, Martin, and Olcotte, 1967). DDT residues have also been detected in such remote areas as the Anarctic in Adelie penguins (U. S. Dept. of Interior, 1964). Alaskan peregrine falcons were found to contain an average of 95 ppm (dry wgt.) of DDT and its metabolites (Stickel, 1968). In a Connecticut woodland never sprayed with pesticides, invertebrates, birds, and small animals contained DDT (Turner, 1965). In referring to the pesticide situation, biologist David Ehrenfeld wrote that, "Even man may now qualify for a niche in the red data book. There is so much DDT in human fat, that if man were edible, he would be banned from the market." (Time Magazine, June 8, 1970).

The trend for animals of higher trophic levels, that is mammals, fish, birds, reptiles, and amphibians, to contain higher concentrations of persistent pesticides has been shown to be generally true and appears to be the result of magnification of persistent pesticide concentrations through trophic levels (Meeks, 1968). However, it appears that there are some exceptions to this trend. Meeks (1968) notes that in a freshwater marsh, adult frogs usually contained lower whole body and tissue residues than did fish, snakes and birds. Both food habits and physiology could be involved. It was postulated that the frogs may have been feeding on insects outside of the treated area and, thus, took in a smaller amount of pesticide. Also, it has been found that the fatty acids of several frog tissues have a high turnover rate and,thus, their DDT excretion may be greater than that of other animals (Meeks, 1968).

Mass mortalities in animal populations are dramatic and easily noticed. Some have been well documented and, in many cases, proven to be caused by pesticides (Peakall, 1970; Young and Nicholson, 1951; Scott, Willis, and Ellis, 1959; Holland and Lowe, 1966; Bureau of Sport Fisheries and Wildlife, Circular 166, 1962; U. S. Dept. of Interior, 1964). Of equal or greater concern is the possibility that low levels of persistent pesticides are causing equally serious, but less noticeable, changes in animal and plant populations in estuarine and other areas. These changes may not be exhibited by the death of the contaminated animal, but seen through more subtle changes in behavior, physiology, reproductive success, food competition and, eventually, species composition of the community.

The decrease in the rate of carbon fixation in natural phytoplankton populations, resulting from exposure to pesticides, was noted earlier. Crustacea, especially shrimp, are susceptible to the toxic effects of endrin. At levels of .025 ppb, only 15 percent of a population of shrimp survived for 2 months and exhibited body residues of less than 5.0 ppb of pesticide (U. S. Dept. of Interior, 1964). In another study, juvenile blue crabs were reared in flowing sea water containing sublethal concentrations of DDT. The crabs fed, molted, and grew for 9 months in seawater containing 0.25 ppb (micrograms/liter) DDT, but could survive only a few days in water containing DDT in excess of .5 ppb. It was suggested that blue crabs could survive in chronically polluted estuarine areas. However, a slight increase in concentration above the "threshold" concentration of the residue could prove disastrous (Lowe, 1965).

In oysters, a major portion of accumulated residues is stored in the gonads. It has been found that gametes contained equally high residues, so their viability might seriously be threatened. The actual effect of such concentrations in gametes has not yet been clearly determined (U. S. Dept. of Interior, 1964). It has been found that the growth of marine bivalve mollusks was measurably reduced when they were subjected to low levels of organochlorine insecticides (Eisler and Edmun, 1966).

Deleterious effects of insecticides on the mosquito fish (*Gambusia affinis*) have been noted. A pregnant female may abort at almost any stage when exposed to insecticide concentrations above the threshold toxicity of a compound (Boyd, 1964). A population of sheepshead minnows was found to be able to tolerate an occasional heavy mortality resulting from pesticide poisoning, but offspring were then produced that exhibited increased sensitivity to low level contamination (Holland, Coppage, Butler, 1966). Studies conducted on young Atlantic salmon (Salmo salar) exposed to 5 to 50 ppb DDT suggested that pesticide residues may interfere with the normal thermal acclimation mechanisms (Ogilvie and Anderson, 1965).

It has also been shown that pesticide residues reduce bird populations by breaking down essential hormones (Peakall, 1967), decreasing egg shell calcium (Peakall, 1970), disabling the reaction to stress situations such as disturbances and food deprivation (Bitman, Cecil, Harris, and Fries, 1969), increasing aggressiveness and restlessness of adult birds (Keith, 1966), and delaying the breeding season (Peakall, 1970).

Although the deleterious effects that have resulted from misused mosquito control techniques are well documented, there have been numerous successful control projects where biting insects were kept to levels not irritating to visitors, while other natural components of the system were unharmed. Marsh modifications coupled with nonpersistent pesticides have been used on Cape Cod to control mosquitoes with minimal damage to the marsh and estuaries (Teal and Teal, 1969). A plan for mosquito control has also been developed for the Delaware marshes, using marsh modifications and potent granular larvicides (Ferrigno, Jobbins, Shinkle, 1967). At Clear Lake, California, gnats have been successfully controlled with a broad spectrum organophosphorus pesticide (Methyl parathion). After seven years, there has been no confirmation of damage to the system (Hazeltine, personal comm.). This pesticide was particularly useful because of its rapid degradation (50% in two days) and its good fish safety factor (Hazeltine, 1962b). Several other organophosphorus insecticides including Baytex, Abate, Malathion, and Dursban have been evaluated and found to have no detectable effects on several species of fish (Ferguson, Gardner, and Lindley, 1966; Von Windeguth and Patterson, 1966; Holland and Lowe, 1966). However, Baytex proved to be toxic to some shrimp and amphipods in tested areas (Von Windeguth and Patterson, 1966).

McDuffie and Weidhaas (1965) have summarized present mosquito control techniques and outlined progress being made on new techniques. "At present, satisfactory mosquito control depends upon methods of source reduction, including water and land management practices and the use of insecticides as larvicides and adulticides. For the future, research is exploring other methods or approaches to mosquito control. These other approaches include biological control, genetic manipulation, attractants, baits and lures, the sterility principle and integrated control."

Biological controls are being investigated and possibilities include larval predators (Lee, 1967), manatees (MacLaren, 1967), mosquito fish (Ferguson, Gardner, and Lindley, 1966), aquatic fungi (Umphlett, 1969), bacteria and protozoa (Kellen, 1960; McDuffie and Weidhaas, 1965). In the case of biological controls, more research is needed in finding ways of establishing the control organism in mosquito breeding environments. Various traps based on smell or visual response to light are being investigated (Fay, 1968). Sterility as a possibility for mosquito control is being investigated. However, the approach needs more work since it has been found that sterile male mosquitoes are sexually less competitive and unable to withstand cold weather conditions (Patterson, Lofgren, and Boston, 1968).

Teal and Teal (1969) identify yet another future control technique as the third generation pesticide; that is, the use of insect hormones to reduce populations. It has been found that if juvenile hormones are applied externally when internal production of the same hormone is ending, the treated animal fails to mature and, of course, cannot reproduce. Because the insecticide is made of specific insect hormones, it has no effect on other forms of life.

Table 1. Effects of organochlorine pesticides on wild animals

(Table from Dustman and Stickel (1966), which contains documentation)

Chemical	Rate	Purpose	Location	Effect
Aldrin	------	Rice seed protection	Texas	Widespread mortality of fulvous tree ducks.
Aldrin	2 lbs/A	Japanese beetle control	Illinois	Nearly complete eliminatio of many species of songbirds. Heavy mortality of gamebirds. Some mortality of mammals.
DDD	50-70 ppm in water	Clear Lake gnat	California	Death of grebes and reduction of breeding populatio
DDT	------	Dutch elm disease control	Maine Michigan Wisconsin New Hampshire	Heavy mortality of robins and songbirds.
DDT	------	Gypsy moth and biting flies	New York	Cessation of reproductive success of trout due to death of fry.
DDT	------	Forest protection	Connecticut	Trout kill due to food depletion.
DDT	------	Agricultural drainage	California	Death of many fish
DDT	1/2 lb/A & 1 lb/A	Spruce budworm and blackheaded budworm	New Brunswick British Columbia	Salmon and trout populations reduced and production curtailed.
DDT	------	Rice pests	California	Some deaths of mallards, pheasants and other birds.
DDT	0.2-1.6 lb/A	Mosquito control	Florida New Jersey	Deaths of fish, crabs, frogs, lizards, and snakes
Dieldrin	2-3 lb/A	White-fringed beetle. Japanese beetle	Virginia Illinois	Heavy mortality of quail, songbirds, waterbirds, rabbits and some other mammals.

Table 1. (Continued)

Chemical	Rate	Purpose	Location	Effect
Dieldrin,DDT, and others	------	Routine Agricultural applications	Calif-ornia	Pheasant production reduced.
Dieldrin	1 lb/A	Sandfly larvae	Florida	Heavy fish mortality.
Endrin	0.8 lb/A	Cutworm	Calif-ornia	Heavy rabbit mortality.
Heptachlor or Dieldrin	2 lbs/A	Imported fire ant	Georgia Alabama	Virtual elimination of birds. Populations of quail remained depressed for at least 3 years (Ga.).
Heptachlor	2 lbs/A	Japanese beetle	Illinois	Heavy songbird mortality.
Cotton insecti-cides	Drift from treated fields	Cotton insect control	Mississ-ippi	Deaths of some rabbits, birds, snakes, fish, and frogs.
Toxaphene	------	Crop protection	Calif-ornia	Heavy mortality of fish-eating birds each year 1960-63.
Cotton insecti-cides	Surface erosion from treated fields.	Cotton insects	Alabama	Heavy fish kills in 15 streams.

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