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HABITAT SUITABILITY INDEX MODELS: AMERICAN EIDER (BREEDING)

Fish and Wildlife Service

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HABITAT SUITABILITY INDEX MODELS: AMERICAN EIDER (BREEDING)

by

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PREFACE

The American eider habitat suitability index (HSI) model is intended for use in the habitat evaluation procedures (HEP) developed by the U.S. Fish and Wildlife Service (1980) for impact assessment and management. The model, developed from a review and synthesis of existing information, is scaled to produce an index of habitat suitability between 0 (unsuitable habitat) and 1 (optimally suitable habitat). Assumptions involved in developing the HSI model and guidelines for model applications, including methods for measuring model variables, are described.

This model is a set of hypothesized species-habitat relationships, not a statement of proven cause and effect. The model has only been partially field-tested. For this reason, the U.S. Fish and Wildlife Service encourages model users to convey comments and suggestions that may help increase the utility and effectiveness of this habitat-based approach to fish and wildlife management. Please send any comments and suggestions you may have on the HSI model to the following address.

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CONTENTS

	Page
PREFACE	iii
TABLES	vi
ACKNOWLEDGMENTS	vii
INTRODUCTION	
Distribution	1
Population	1
Life History Overview	2
HABITAT REQUIREMENTS	2
Cover	4
Food and Foraging Habitat	4
Special Considerations	7
HABITAT SUITABILITY INDEX (HSI) MODEL	8
Model Applicability	11
Model Description	11
Suitability Index (SI) Graphs for Model Variables	12
Component Index Equations and HSI Determination	14
Field Use of the Model	17
Interpreting Model Output	17
Other Sources of Information	17
REFERENCES	19
	21

TABLES

Number		Page
1	Subspecies of the common eider (Somateria mollissima) and distribution in North America	2
2	Occurrence of avian cholera in the American eider of Maine	10
3	Weighting factors for cover types found on eider nesting islands	14
4	Data sources and assumptions for American eider suitability indices	16
5	Model output of the component indices (CI) and habitat suitability indices (HSI) for three hypothetical data sets with their corresponding suitability index (SI) values	18
6	Suggested measurement techniques and definitions for habitat variables used in the American eider HSI models	19

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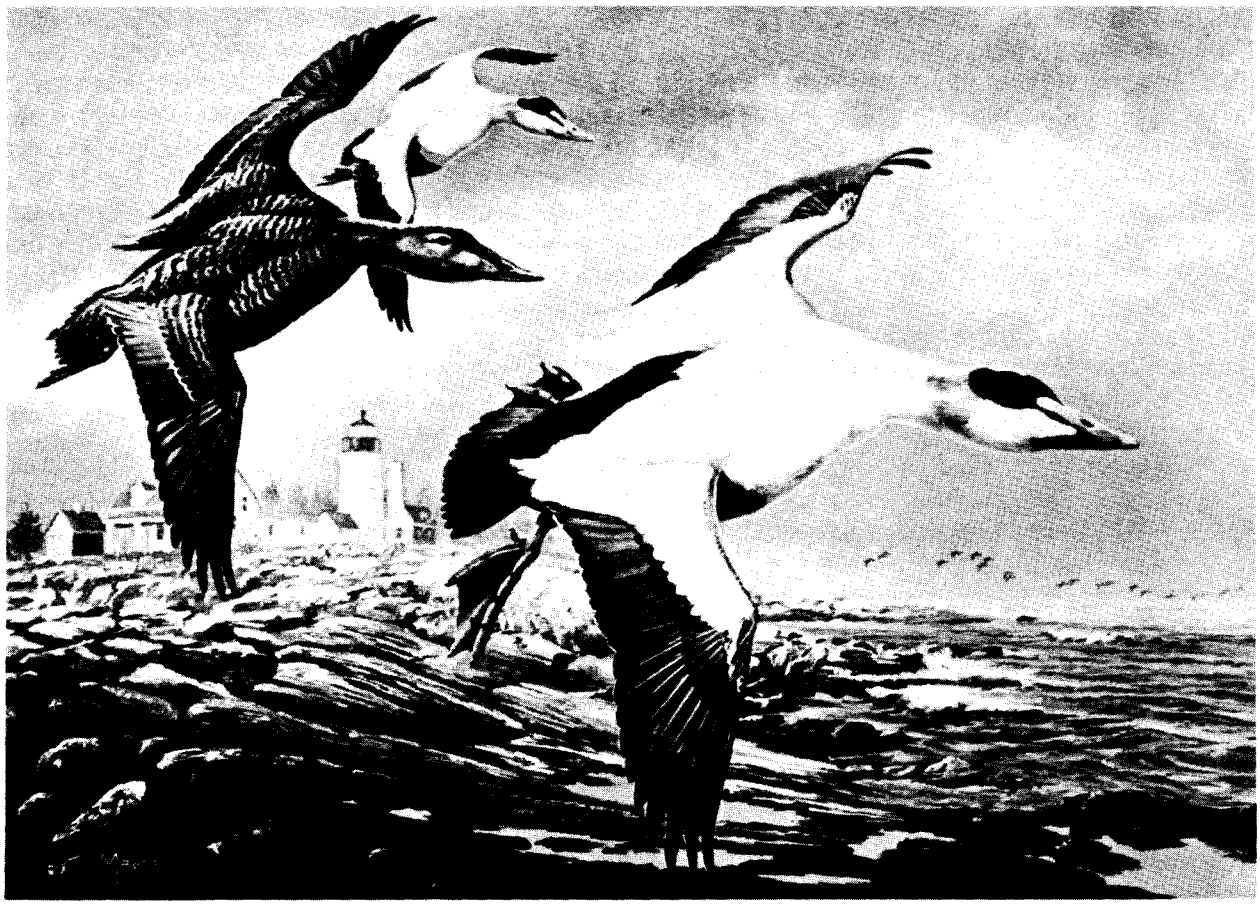


American eider (Somateria mollissima dresseri).

AMERICAN EIDER (Somateria mollissima dresseri)

INTRODUCTION

The common eider (Somateria mollissima) consists of five subspecies; four are found in North America (Palmer 1976). Six management populations of common eiders have recently been defined in eastern Canada and the United States (Reed and Erskine 1986). The American eider (S. mollissima dresseri), of which three populations are recognized (Reed and Erskine 1986), is the southernmost subspecies and the focus of this paper.

The common eider is a member of the order Anseriformes, family Anatidae, and the tribe Mergini. A seabird of the northern latitudes of the world, the common eider is the largest duck of North America, ranging in weight from 1.2 to 2.8 kg and having a total length from 53.3 to 68.6 cm (Bellrose 1980). The American subspecies averages 2.0 kg and 61.0 cm for males, and 1.5 kg and 57.9 cm for females (Bellrose 1980). The drake is distinctly patterned, having a white back and breast and a black belly and sides. The smaller female is brown and heavily barred with dark brown. Both sexes have a leathery extension of the bill which forms a Y-shaped frontal shield that reaches almost to the eyes.

Maine, which supports part of the Atlantic population of common eiders (Reed and Erskine 1986), is the only major eider breeding population in the lower 48 States. American eiders are colonial nesters and use a variety of nesting sites, but they prefer relatively small, uninhabited islands (Mendall 1976). The coastal islands of Maine, which are essential to the eider's life cycle, are increasingly subjected to recreation and development, creating potential disturbances to eider breeding colonies. During recent years, aesthetic and sporting interest in eiders has increased. Sea ducks in Maine are experiencing increased hunting pressure. Compared to hunting seasons and bag limits for inland ducks, sea duck seasons and limits are liberal (Maine Department of Inland Fisheries and Wildlife [MDIFW] 1983).

Distribution

The distribution of the four subspecies of the common eider found in North America is shown in Table 1 (Bellrose 1980; Reed and Erskine 1986).

Most eiders winter near their northern breeding ranges wherever coastal seas are open. The American eider winters from the Gulf of St. Lawrence south along the Atlantic coast to Virginia (Bellrose 1980). Recoveries from Maine bandings indicated that females winter along the coast from Maine to Massachusetts. Wakeley (1973) determined that part of the female eider population in

Table 1. Subspecies of the common eider (Somateria mollissima) and their distribution in North America.

Name	Distribution (breeding range)
American eider (S. m. dresseri)	Central Labrador coast southward along the shores of Newfoundland, eastern Quebec, Nova Scotia, New Brunswick, and Maine.
Pacific eider (S. m. v-nigra)	Victoria Island, Northwest Territories, Canada; West Beaufort Sea and Bering Sea coasts of Alaska and Siberia to the Aleutians.
Northern eider (S. m. borealis)	Coast of Greenland, Baffin Island, Southampton Island, north and central coasts of Labrador.
Hudson Bay eider (S. m. sedentaria)	Confined to islands and coasts of Hudson and James Bays.

Maine was migratory while the rest were resident on or near the breeding area. Too few males have been banded to determine their migratory patterns.

Population

Numbers of eiders along the Maine coast declined during the 1800's as fishermen and farmers increasingly occupied the offshore islands. American eiders reached their lowest numbers on the Maine coast in 1907 (Gross 1944), at which time only two breeding pairs existed on Old Man's Island (Norton 1907). Egg collecting and over-shooting at concentration points contributed to this decline.

With the protection of nesting birds and the regulation of hunting in the early 1900's, the American eider population increased rapidly. Gross (1944) recorded approximately 2,000 pairs nesting on 31 islands in 1943. Mendall (1976), from a 1970 survey, estimated the eider population on the coast of Maine to be at least 20,000 pairs, which were nesting on more than 150 islands. In 1977, Korschgen (1979) estimated a breeding population of 22,385 eider pairs nesting on 240 islands in Maine. Present data suggest that the number of nesting eiders is stabilizing (Figure 1). See Reed (1986) for information on the population status of the American eider in eastern Canada.

Life History Overview

The female common eider is a delayed breeder, generally nesting at 2 to 3 years of age (Choate 1966; Korschgen 1976, 1977; Wakeley and Mendall 1976). The average life expectancy of the adult female is 5 years (Wakeley 1973; Wakeley and Mendall 1976), but reports have documented hens living to at least

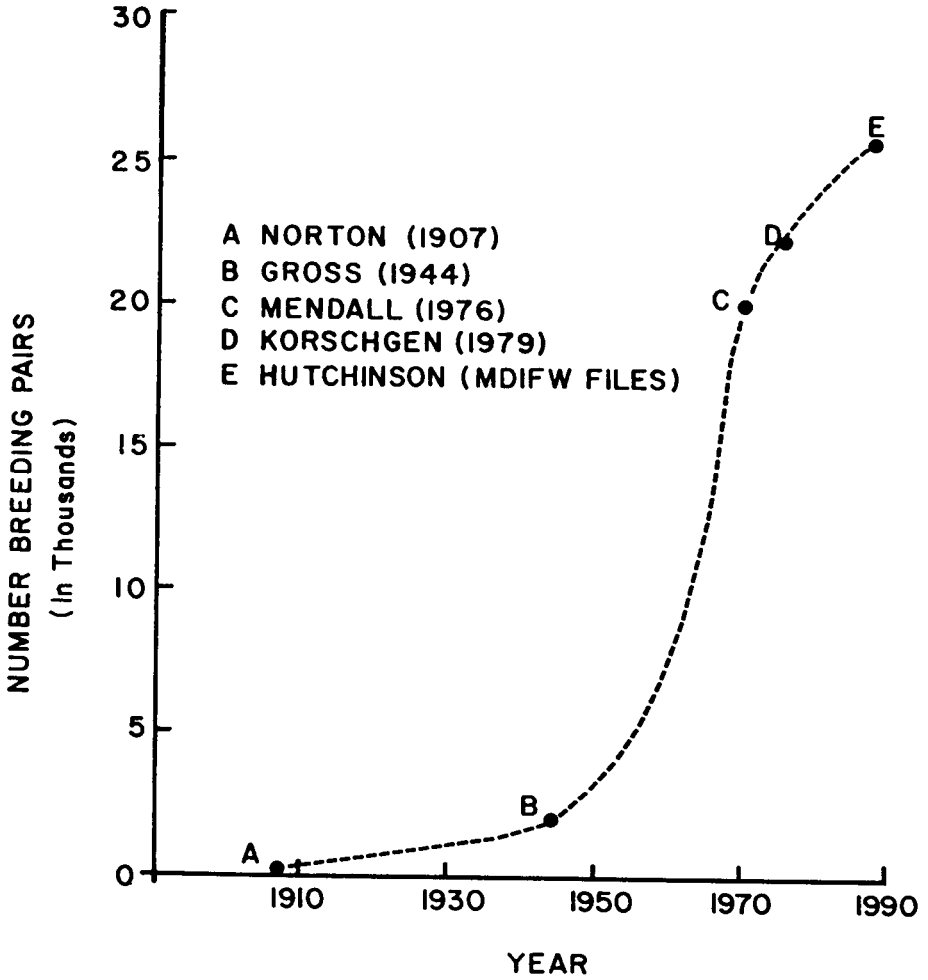


Figure 1. Population estimate of the American eider in Maine.

17 years of age (Baillie and Milne 1982; Coulson 1984). An average annual mortality rate of 25% for females was calculated by Wakeley and Mendall (1976).

In Scotland, Milne (1974) observed common eider drakes guarding an area around their mates during courtship. This prevented intrusion by other males and allowed the female to feed intensively prior to nesting.

Generally a colonial nester, the American eider in Maine is often found in densities up to 80 or more pairs per ha on offshore islands (Mendall 1976), although Minot (1976) recorded 1,000 nests per ha on a portion of Hay Island in the Grand Manan Archipelago, New Brunswick. Studies of nest site selection revealed that the male eider accompanies the female to potential sites and remains for a brief period of time, but has little to do with actual nest site selection and defense (Milne 1974; Schamel 1977). Migrational homing is well developed in adult female eiders (Wakeley 1973; Reed 1975; Wakeley and Mendall

1976), with most hens returning each year to the same locality but not necessarily the same nest site (Milne 1974).

After incubation begins, drakes leave the nesting area and form large flocks. Moving seaward, male eiders undergo their annual molt near offshore ledges and shoals (Mendall 1976; Palmer 1976). Large, traditional staging areas for molting eiders were documented in Maine by Spencer et al. (1982), who located 64 sites with flocks of flightless drakes.

The average clutch size of the American eider is 3.93 eggs (Bellrose 1980). Choate (1966), Korschgen (1976), and Mendall (1976) reported a 26-day incubation period; females began nesting in the region of Penobscot Bay, Maine, in late April with peaks from mid-May to early June (Choate 1966; Clark 1968).

Females feed little or not at all during the incubation period; nutrient reserves, especially the pectoral muscles and fat deposits, provide the incubating hen with a source of energy. Females may lose 50% of their prelaying weight during incubation (Korschgen 1976, 1977).

The precocial young are led to water within 12 to 48 hours after hatching. Broods often enter the water with one female, but in high density areas several females often accompany a group into the water (Minot 1976). Creching in eiders, the combining of several broods accompanied by more than one female, has been cited as a response to several factors: predation by gulls; the need to relieve the female of parental care, thereby allowing her the opportunity to restore nutrients lost during incubation; and the spontaneous clustering of ducklings behind the most stimulating female (McAloney 1973; Milne 1974; Munro and Bedard 1977a, 1977b).

Few studies have examined eider duckling survival rates. In a 13-year study in the Ythan Estuary of Scotland, Mendenhall and Milne (1985) reported that in most years only 10% of the eider hatchlings survived to fledge. The primary cause of mortality was predation by gulls. McAloney (1973) calculated a 76% mortality rate for all observed ducklings in Nova Scotia, and 50% of all juvenile mortality occurred before the ducklings were one week old. McAloney (1973) reported 22% loss on the nesting island, 15% occurring between the island and the mainland, and 39% on coastal fledging areas.

HABITAT REQUIREMENTS

Cover

Nesting. The common eider is found near offshore shoals and islands around the world's northern coasts. Islands with low-lying rocky marine shores are the preferred breeding habitat (Snyder 1957). American eiders in Maine nest primarily on islands less than 20 ha in size, while those islands under 5 ha appear optimal (Figure 2).

Choate (1966), Clark (1968), Bourget (1970), and Korschgen (1976) studied the American eider on several islands in the Penobscot Bay area of Maine. The

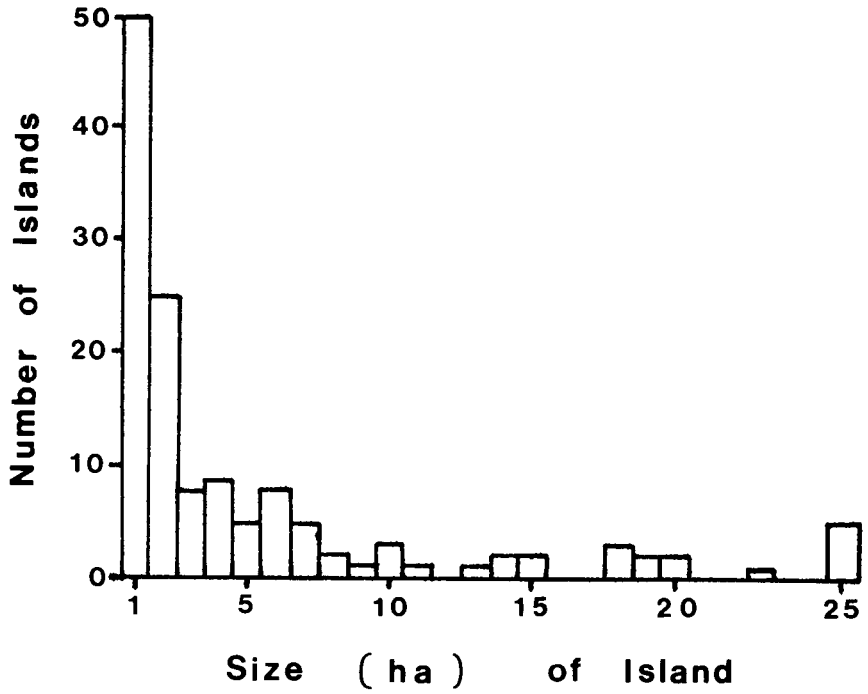


Figure 2. Size of islands used by ≥ 5 nesting pairs of American eiders in Maine (data from Erwin and Korschgen 1979).

islands ranged in size from 0.1 ha to 1.6 ha. Most of the islands studied were long and narrow, steep-sided, and rose abruptly out of the water; the central portions were flatter. They were vegetated with grasses, various herbs, and low shrubs. The vegetative complex on many Maine marine islands includes a herbaceous component comprising meadow foxtail (Alopecurus pratensis), timothy (Phleum pratense), quackgrass (Agropyron repens), wild rye (Elymus virginicus), and numerous forbs including cow parsnip (Heracleum maximum), goldenrod (Solidago canadensis), nightshade (Solanum dulcamara), stinging nettle (Urtica dioica), and ragweed (Amrosia artemisiifolia). The shrub composition includes bayberry (Myrica pensylvanica), raspberry (Rubus ideaus), rose (Rosa virginiana), meadowsweet (Spiraea latifolia), poison ivy (Rhus radicans), and willow (Salix sp.). The trees found on many eider nesting islands are primarily white spruce (Picea glauca), with occasional black spruce (Picea mariana), and red spruce (Picea rubens).

Nest sites may be just above the high tide line or located in the center of an island. Nests, circular hollows on the ground lined with down, have been observed in varying cover types ranging from fully exposed to fully sheltered. The American eider nests in grasslands, shrub, and open forest habitats, and often where different cover types meet (Gross 1944; Choate 1966, 1967; Clark 1968; Boruget 1970; Milne and Reed 1974; Mendall 1976; Minot 1976).

Eider nests are especially vulnerable to avian predation (Choate 1966, 1967; Clark 1968; Bourget 1970, 1973; Milne and Reed 1974; Medall 1976;

Schamel 1977) and are often located in vegetation that provides optimal cover at the time of nest initiation (Choate 1966, 1967; Clark 1968; Mendall 1976). Clark (1968) suggested that shrub cover protected nest sites by restricting the movement of avian predators while herbaceous cover offered a greater degree of concealment. Nesting success has been positively correlated with the amount of overhead cover (Choate 1966; Guignion 1967; Clark 1968; Milne and Reed 1974). Gorman (1974) concluded that nesting eiders selected areas that offered the greatest protection against nest predation. In the St. Lawrence Estuary, Milne and Reed (1974) reported a hatching success of 15% in sparse grass cover, 30% on islands with grass and shrubby vegetation, and 36% on wooded islands providing complete overhead cover. On Ile aux Pommes, also in the St. Lawrence Estuary of Quebec, van Dijk (1986) found hatching success highest in Calamagrostis sp. and shrubs and lowest in Epilobium sp. and on bare rocks.

American eiders in Maine are commonly found nesting in vegetation which develops early in the season, such as cow parsnip or stinging nettle (Choate 1966, 1967; Clark 1968). Choate (1966) observed eiders using sites where cover types met. Nests in forested habitats were found under drooping branches of spruce and beneath woody blowdowns (Mendall 1976; author's pers. obs.). However, Maine eiders nest infrequently on islands that are completely wooded, even though such islands are common along Maine's coast.

Minot (1976) studied the American eider on Kent and Hay Islands of the Grand Manan Archipelago near the mouth of the Bay of Fundy. Spruce was the dominant cover type, with cow parsnip, ragweed (Ambrosia elatior), blue flag (Iris versicolor), grasses (Gramineae), and sedge (Carex sp.) also present. Eiders nested primarily in the wooded section of the islands, especially in areas of blowdown with second growth timber. Herbaceous cover in the more open areas contained fewer nests.

At the Sands of Forvie National Nature Reserve in northeast Scotland, Milne (1974) documented variable nesting cover use by eiders; 23% of the nests were in completely open sites, 36% were found in intermediate cover, and 41% had a complete canopy. There was preference for thick rushes (Juncus sp.) in ditches and for clumps of heather (Culluna vulgaris) and rushes.

Most nesting studies have been conducted on islands so small that the distance to water did not appear to be an important factor in nest site selection. Schmutz et al. (1983) reported that nest site selection of the Hudson Bay eider was related to easy access to water as a means of escape from ground predators.

Brood-rearing habitat generally occurs in sheltered bays or inlets (McAloney 1973; Schamel 1977; Alan Hutchinson, MDIFW; pers. comm.). Minot (1976, 1980) documented the value of rockweed (Fucus sp. and Ascophylum sp.) covered shoreline for brood-rearing habitat and for the post-nesting female. Maximum use occurred if these areas were sheltered and had a wide intertidal zone.

Non-nesting. During the non-nesting season common eiders remain offshore and are almost strictly marine birds. A coastal migrant, the eider takes

advantage of rocks, sandbars, and ice as resting areas (Palmer 1976). Availability of winter foods, as determined by their abundance and water depth, are primary aspects of wintering habitat (Johnsgard 1975). Milne (1974) recorded that eiders in Nova Scotia spend the winter in compact flocks on the water or roosting on the banks of estuaries.

Food and Foraging Habitat

The common eider feeds primarily on marine invertebrates, most often obtaining this food by diving (Mendall 1976; Minot 1976; Palmer 1976). Humphrey (1958) observed eiders foraging at depths of 12 m or more. A distinct feeding rhythm associated with tidal levels during daylight hours was observed where concentrations of eiders fed on mussel beds at low water (Cantin et al. 1974; Milne 1974; Minot 1976, 1980; Palmer 1976).

Korschgen (1976) noted that blue mussels (Mytilus edulis) were the most important food of the American eider in Maine, but eiders also consumed green urchins (Srongylocentrotus roebachiensis), periwinkles (Littorina sp.), green crabs (Carcinus maenus), and other gastropods when available. In the St. Lawrence Estuary adults fed on herring eggs (Clupea harengus) and Nereis virens during the prelaying period (Cantin et al. 1974).

Female eiders establish large nutrient reserves prior to egg laying and enter the nesting cycle with a tremendous quantity of stored fat and protein (Korschgen 1976, 1977; Palmer 1976). Milne (1974) reported that during prelaying the role of the male may be more important than the gross amount of food present since only through his constant attentiveness can the female increase her food intake in preparation for nesting.

Korschgen (1976, 1977) reported that female eiders in Maine attained an average weight of 1.8 kg at the start of incubation and dropped to 1.3 kg when the ducklings hatched. Likewise, in the St. Lawrence Estuary, Cantin et al. (1974) recorded a 45% gross body weight loss during the incubation period. Korschgen (1976, 1977) found relatively few food items in the digestive tract after the first few days of incubation as females rarely leave the nest and do so only for short periods of time. During these infrequent nest absences, females preen and drink at distances up to 200 m from the nest (Mendall 1976; Palmer 1976; Schamel 1977).

The female common eider, when associated with ducklings, often feeds by dabbling or up-ending in the shallow water near the shore instead of diving. Young ducklings have been observed feeding in shallow water on insects by dabbling (Cantin et al. 1974), but as they increased in age, periwinkles became a more important food item. Minot (1976, 1980) reported that broods and adult females in the Grand Mana Archipelago preferred amphipod crustaceans (Gammarus sp.) and periwinkles, with the peak of feeding activity occurring during rising mid-tide. Minot (1976) emphasized the importance of harder-bodied mollusks later in the rearing period. Analysis of eider ducklings in the Liscombe area of Nova Scotia revealed that the birds were not selective feeders, but rather that they ate mainly those food items present in greatest abundance (McAloney 1973). Broods in the St. Lawrence Estuary also eat periwinkles, their most abundant prey (Bedard et al. 1986).

During the fall and winter, Korschgen (1976) found that blue mussels were the most important food item in Maine. Green urchins, periwinkles, and other foods supplemented the late winter diet.

Depredation and mussel aquaculture. Recently, American eiders along the coast of Maine have become a concern for the mussel aquaculture business (Alan Hutchinson; pers. comm.). Both raft and bottom culture methods are subject to depredation by eiders. These mussels are of excellent quality, having a high meat to shell ratio and high carbohydrate levels. Greatest predation takes place during the winter and prenesting period when female eiders experience high nutrient demands. With a growing aquaculture industry and a high eider population, the potential for blue mussel depredation on the coast of Maine is increasing.

Dragging and raking for blue mussels affects benthic communities, potentially reducing and disturbing eider food items and the substrate upon which these organisms live. However, no quantitative data are available regarding the effects of aquaculture.

Special Considerations

Interspecific aspects. The common eider nests on marine coastal islands with large populations of gulls and has often sustained heavy egg and duckling losses by these avian predators (Choate 1966; Clark 1968; Bourget 1970, 1973; Milne and Reed 1974; Mendall 1976; Schamel 1977; Bellrose 1980; van Dijk 1986). Herring gulls (Larus argentatus) and great black-backed gulls (Larus marinus) cause most of the nest failures on the islands of Maine. In some areas, common ravens (Corvus corax), American crows (Corvus brachyrhynchos), and great horned owls (Bubo virginianus) are effective predators.

Bourget (1970) studied four islands in the Islesboro area of Penobscot Bay, Maine, and found predation rates were influenced by island size, topography, vegetative cover, density of the local gull population, and breeding chronology of the eider and the gull species. Choate (1966) and Clark (1968) found that dense cover, such as cow parsnip, provided protection from predation. Greater vulnerability of eider eggs to gull predation in open habitat also was documented by Milne and Reed (1974). Bourget (1970) found that as the density of avian predators increased, nest success rate decreased. In contrast, van Dijk (1986) reported that eider hatching success in Quebec was positively correlated with the density of herring gull nests.

Most predation of eider eggs occurs at the time of laying and during the first week of incubation because of frequent nest absences by the female (Bourget 1970; Schamel 1977). While on the nest, female eiders are effective in defending their eggs against avian predators (Bourget 1970, 1973; Schamel 1977).

Grubb (1974) observed a shift in a nesting population of American eiders on Kent Island in the Bay of Fundy. In 1947 eiders were nesting on the treeless portion of the island; however, on a return visit in 1973 he found that the majority of the eider population was nesting under dense tree cover.

Grubb (1974) suggested that gulls were responsible for the eiders shifting nesting habitat.

Despite the high egg and duckling loss caused by avian predators, eiders in Maine frequently nest on islands colonized by gulls (Alan Hutchinson; pers. comm.; Howard Mendall, U.S. Fish and Wildlife Service [retired]; pers. comm.). In dense, mixed-species colonies, the eider may benefit by nesting in close proximity to a breeding gull. While defending its own nest from intruding avian predators, a gull may reduce predation on nearby eider nests (Choate 1966; Bourget 1970, 1973; Mendall 1976; Schamel 1977). Mendall (1976) reported eiders nesting successfully less than 1 m from incubating gulls. Greater eider nesting success was reported by Clark (1968) when nest placement was within 4.6 m of the gull nest.

Mammalian predators can pose a major threat to colonial nesting birds. Where mammals, such as mink (Mustela vison), raccoon (Procyon lotor), and red fox (Vulpes vulpes) are present, eider productivity on the islands of Maine is severely threatened (Alan Hutchinson; pers. comm.).

Human disturbance. Recreational use and development of Maine's coastal islands has increased greatly during the last 2 decades (Mendall 1968; Wakeley and Mendall 1976; Fefer 1977; Hutchinson 1979). The presence of humans on an eider nesting island causes incubating birds to flush from their nests, thereby increasing the risk of egg destruction by avian predators. Gulls generally return to the island before the eiders and prey on the unguarded eider nests (Choate 1966; Clark 1968; Korschgen 1976; Mendall 1976).

Clark (1968) cited human disturbance as a serious limiting factor to eider nesting success on the islands of Maine. Milne and Reed (1974) also documented extremely high losses of eggs due to human disturbance on islands in the St. Lawrence Estuary. McAloney (1973) observed that the main cause of mortality of eider ducklings and eggs in the Liscombe area of Nova Scotia was gull predation facilitated by human disturbance. Choate (1966) and Clark (1968) reported that nest success declined as the number of visits by humans increased, yet human disturbance infrequently caused nest desertion.

Human disturbance can disrupt the breeding behavior of the bird, increasing the stress on the female at an energetically critical time (Bourget 1970; Korschgen 1976; Fefer 1977; Hutchinson 1979). The recurring impact of human activity on eider nesting colonies in Maine has resulted in the State's restricting recreational use on major breeding islands during the eider nesting season (Wakeley and Mendall 1976; Hutchinson 1979).

Disease. Avian cholera, caused by the bacterium Pasteurella multocida, is an important cause of mortality in Maine eiders (Korschgen 1976; Palmer 1976; Korschgen et al. 1978). The impact of the disease in Maine, however, has varied from year to year and from island to island (Spencer 1980; Table 2). Epidemics were associated with incubating females which were physiologically stressed and nesting in high densities (Korschgen 1976; Korschgen et al. 1978).

Table 2. Occurrence of avian cholera in the American eider of Maine.

Date	Location	Number of deaths
1963	Islesboro area	116 nesting females[a]
1970	Muscle Ridge: Penobscot Bay--1 island	43 (98% females)[b]
1970	Muscongus Bay and offshore islands--8 islands	513[b]
1972	Islesboro area--2 islands	24[b]
1974	Muscle Ridge: Penobscot Bay--3 islands	53 (96% females)[b]
1976	Muscle Ridge	1 female[b]
1980	Blue Hills Bay--14 islands	1,917 (62% females)[c]
1981	Blue Hills Bay--15 islands	300-500[d]
1982	Blue Hill Bay--1 island	100[e]
1984	Muscongus Bay--Franklin Island	1,000-1,500 (60%-70% females)[f]
1984	Muscle Ridge: Penobscot Bay--1 island	11 females[g]
1985	Muscongus Bay Penobscot Bay	<200,[f,h]

[a]Gershman et al. (1964).
[b]Korschgen et al. (1978).
[c]Spencer et al. (1980).
[d]Spencer et al (1981).
[e]Spencer et al. (1982).
[f]Alan Hutchinson (pers. comm.).
[g]Howard Mendall (pers. comm.).
[h]Brad Allen, MDIFW (pers. comm.).

The common eider may contract avian cholera by drinking from contaminated water sources or through the inhalation of infected air. Some birds act as carriers of the bacterium (Spencer 1980). The well-developed poultry industry, adjacent to Penobscot Bay in Maine, may be a major source of P. multocida as domestic chickens are thought to be the initial carriers of avian cholera (Korschgen et al. 1978). Disposal of eider carcasses and disinfection of the habitat are the only two control measures that are practical (Spencer 1980). If the American eider population increases and the number of colonies expands, avian cholera may become an important limiting factor (Korschgen et al. 1978).

The acanthocephalid worm, Polymorphus botulus, may cause considerable physiological stress on eiders, especially on immature birds, which generally are infected with more worms than adult birds (Korschgen 1976). During starvation, associated with the incubation period, adult female eiders eliminate intestinal parasites from the digestive tract. However, Korschgen (1976) reported susceptibility to parasite infections following incubation when the adult female is weakened.

Studies have determined that the green crab is the intermediate host of P. botulus. Korschgen (1976) believes there was a relationship between the frequency of crabs in the diet and the degree of acanthocephalan infection in the eider.

Oil pollution. The common eider is susceptible to oil contamination since it spends a majority of its life on the water (Famous and Ferris 1980; Alan Hutchinson; pers. comm.). Bellrose (1980) viewed oil pollution as a constant threat to waterfowl. Mortality factors such as drowning, exposure, and toxicity may be attributed to oil pollution.

Buoyancy loss from heavy oil-matted feathers may cause the bird to drown. Likewise, oil-coated feathers are no longer able to provide insulation and may result in death due to exposure. Ingestion of oil by the common eider while preening oil-coated features, and drinking or eating oil-contaminated food may cause death, physiological changes, or behavioral changes (Korschgen 1976; Famous and Ferris 1980). Nesting birds can transfer oil from their feathers or feed to eggs while incubating, thus inhibiting embryo respiration (Stickel and Dieter 1970; Famous and Ferris 1980).

The transfer of large volumes of oil at the numerous petroleum ports along the Maine coast inevitably results in oil spills. Although large oil spills may kill thousands of birds and cause great public concern, the large percentage of oil that reaches aquatic environments is released in the course of normal operations (Stickel and Dieter 1970; Hutchinson 1983). From 1976 to 1978, the Maine Department of Environmental Protection reported 950 major spills totaling 175,465 gal of petroleum products in Maine, most of which were in the Portland and Penobscot Bay areas (Fefer and Schettig 1980).

The importance of the quality and quantity of foods consumed by eiders was emphasized by Korschgen (1976). Oil pollution may adversely affect all groups of biota (Fefer and Schettig 1980), resulting in a negative effect on the common eider population (Reed 1975; Korschgen 1976).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area and season. This model was developed to assess the relative habitat quality of Maine coastal islands. Where habitat requirements are similar, the HSI models may also be used to evaluate potential habitat within the entire breeding range of the American eider. The model is based on the habitat requirements of American eiders during the breeding season (late April to mid-July).

Cover types. American eider nest on vegetated islands in marine environments. Nesting cover types include forest (evergreen and deciduous), shrubland (evergreen and deciduous), grassland, forbland, and barren lands.

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous suitable habitat that is required for a species to successfully live and reproduce. Specific information on minimum areas required by American eiders was not found in the literature. If the local information is available to define the minimum habitat area, and less than this amount of area is available, the HSI for the species will be zero.

Verification level. The acceptable model output is an index value between 0.0 and 1.0 that reflects the habitat potential for American eider nesting. A value of 1.0 indicates optimal suitability and 0.0 indicates unsuitability. Hypothetical data sets were used to verify that the model output was reasonable. Review comments by Alan Hutchinson and Patrick Corr, MDIFW, and Howard Mendall, U.S. Fish and Wildlife Service (retired), have been incorporated, but the authors are responsible for the final version of this model.

Krohn and Owen (1987) collected disturbance and vegetation data for 34 coastal Maine islands to test this model's performance as related to (1) total nests per islands and (2) nests per vegetated hectare. Ranking of the model's output was significantly correlated with rankings of the two test criteria ($P < 0.001$), and model output was significantly correlated with both test criteria ($P < 0.02$). Model precision was good at the low (0-9 nests) and high (>100 nests) ranges, but only fair in the mid-range (10-100 nests). Krohn and Owen (1987) noted that the model accurately ranked nesting islands, and discriminated between good ($\geq$10 nests) and poor (<10 nests) islands, but could not be used to predict the actual number of nests expected on any individual island. This model should be applied only after careful consideration of the limitations identified by Krohn and Owen (1987).

Model Description

Overview. Both nesting and brood habitat are important components in assessing the quality of a particular area for the American eider. Unfortunately, few data exist to quantify brood habitat; thus this model deals only with nesting habitat. The suitability of potential nesting sites for American eiders is determined by two factors: cover and disturbance. Though selection of nesting habitat is often influenced by traditional use of a site, American eiders will colonize new sites. The relationships of the habitat variables to the HSI are illustrated in Figure 3.

Consumption of marine invertebrates by the American eider is well-documented. However, distribution of prey species is unknown (Robert Vadas, University of Maine; pers. comm.); likewise, eider influence on benthic community structure has not been studied. As a dynamic resource, marine invertebrates may vary in distribution and abundance from year to year and from place to place. Food resources are crucial prior to egg laying and incubation for the female, during the brood-rearing period, and possibly during the annual molt of males and females. Food abundance and availability

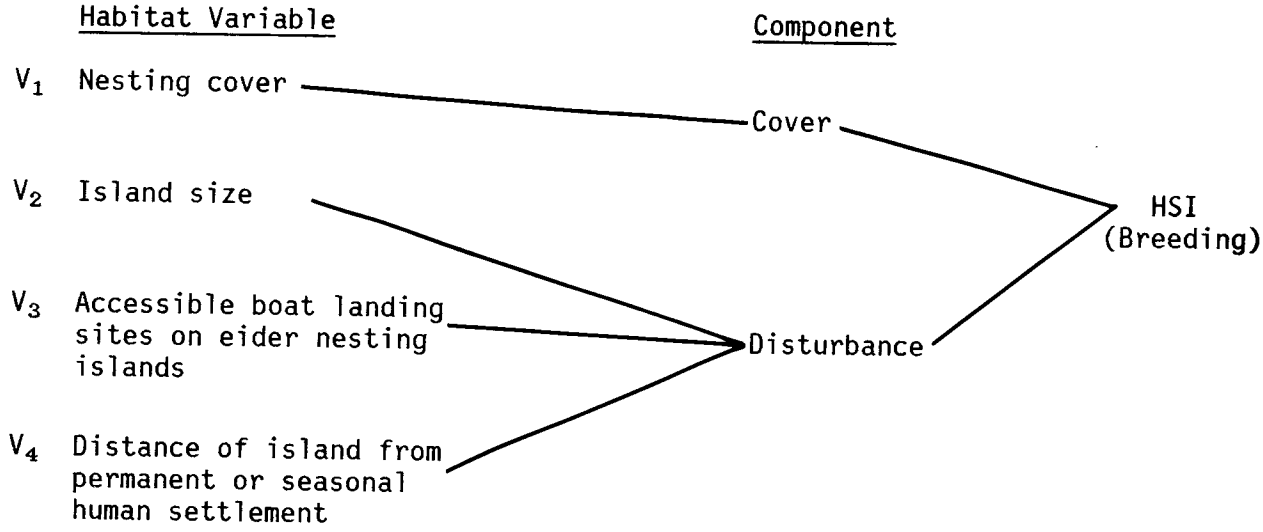


Figure 3. Relationship of habitat variables and components to the HSI model for American eider breeding habitat.

have not been identified as limiting factors during the nesting period and are therefore not included in the model.

Cover-component. Nesting cover (V_1), which reduces avian predation, depends on vegetation characteristics throughout the period of incubation. Both overhead and side cover are important and are a function of the type and structure of the vegetation present on the nesting island. Table 3 provides weighting factors for different cover types.

An index to nesting cover is calculated by multiplying the percentage of cover for each type by the appropriate weighting factor, summing for all cover types and dividing by 5, the maximum weight. We assume that the chances of successful reproduction and female survival are related to cover density; cover indices (CI) of 70 or above are considered optimal (i.e., SI = 1). We also assume that the value of cover to nesting eiders increases slowly at the lower levels (CI = 10 to 24, generally associated with the presence of grasses and rocks), and that cover value increases faster at the mid-range (CI = 25 to 69, generally associated with tall forbs and shrubs).

Disturbance component. During the breeding season American eiders are especially sensitive to disturbance from humans and predators. It is assumed that islands less than 5 ha have the least potential for settlement by humans and mammalian predators (V_2), while islands larger than 20 ha have the greatest potential. Steep and rocky shorelines that prevent boat access to the nesting island also minimize disturbance (V_3). Further, this model assumes that as the distance from permanent human settlements increases, the suitability of a site also increases (V_4). Optimal nesting islands should be at least 2.0 km from a permanent or seasonal human settlement. Islands with human settlement are unsuitable (SI = 0).

Table 3. Weighting factors for cover types found on eider nesting islands.

Vegetative type	Weight[a]
Bare ground and rock	0.5
Grass and low forbs	1.0
Tall forbs[b]	4.0
Shrubs	5.0
Forest	0.5-3[c]

[a] 0.5 = low, 5 = high.
[b] 0.5 m in early May to ≥1 m in early July.
[c] Closed canopy forest with no blowdowns or low branches have little nesting value. Small stands with considerable blowdown, dense shrubs, and branches touching the ground provide moderate cover.

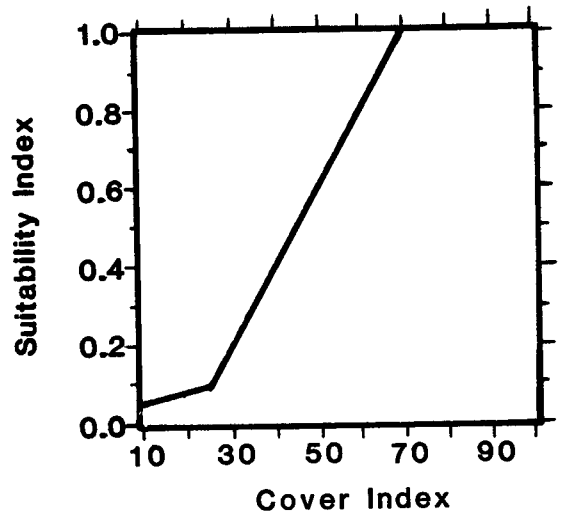
Suitability Index (SI) Graphs for Model Variables

This section contains suitability index (SI) graphs and equations to quantitatively describe the relationships between habitat variables and habitat suitability for American eiders in upland cover types. The SI values are read directly from the graph and range from 0 (unsuitable habitat) to 1 (optimally suitable). Assumptions used in developing the SI graph for each variable are shown in Table 4.

Variable

V_1 Nesting cover.

Suitability Graph

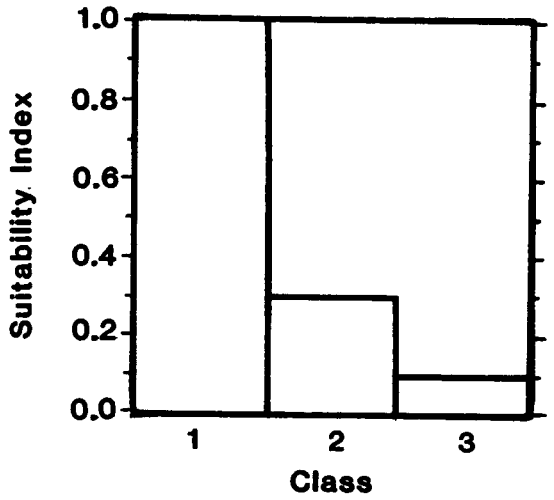


Variable

Suitability Graph

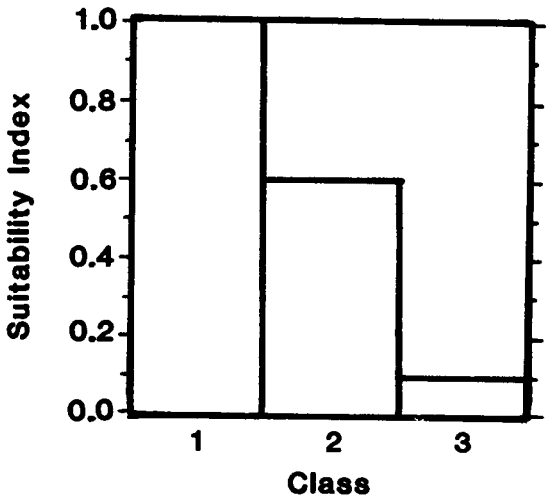
V_2 Surface area of island.

1. <5 ha
2. 5 - 20 ha
3. >20 ha



V_3 Island accessibility.

1. Inaccessible, no landing sites.
2. One accessible site along the shoreline.
3. Sandy beach on lee shore or unlimited accessibility.



V_4 Distance of island from permanent or seasonal (May-Aug.) human settlement.

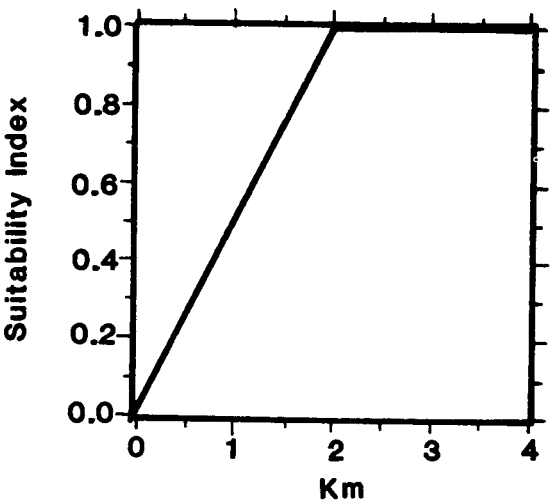


Table 4. Data sources and assumptions for American eider suitability indices.

Variable and source	Assumption
V_1 Choate (1966) Clark (1968) Milne (1974) Milne and Reed (1974) Schamel (1977) Schmutz et al. (1983)	Eider nests, being especially vulnerable to avian predation, are generally located in vegetation types which provide optimum cover conditions throughout the incubation period. Nesting success has been positively correlated with the percentage of overhead cover. Side cover also restricts the movement of avian predators. The thick barrier produced by stems and branches discourages access by gulls.
V_2 Snyder (1957) Mendall (1976) Erwin and Korschgen (1979)	The preferred breeding habitat consists of numerous islands with low-lying rocky marine shores. In Maine, the American eider nests on relatively small, uninhabited islands, which reduces potential mammalian predation and human disturbances.
V_3 Choate (1966) Clark (1968) Mendall (1968) McAloney (1973) Milne and Reed (1974)	The number of people who visit eider nesting islands, the duration of the visits, and the number of visits affect eider nest success. Islands with steep, rocky shores restrict landing of boats and accessibility, while sandy beaches on low-lying islands are more easily accessible.
V_4 Choate (1966) Clark (1968) Mendall (1968) McAloney (1973) Milne and Reed (1974)	The presence of humans on eider nesting islands is a limiting factor to nest success. Secluded islands that limit human interference are most suitable for nesting eiders.

Component Index Equations and HSI Determination

The following equations are suggested for combining individual component index values into the final HSI value.

Cover component (C). The nesting cover component is equal to the suitability index for V_1.

$$C = SI\ V_1$$

Disturbance component (D). A compensatory relationship exists between V_2, V_3, and V_4. It is assumed that the SI's increase with decreasing disturbance on eider nesting islands.

$$D = \frac{SI\ V_2 + SI\ V_3 + SI\ V_4}{3}$$

Nesting HSI. The HSI is determined by using the geometric mean of the two components.

$$HSI = (C \times D)^{\frac{1}{2}}$$

The output of the model is demonstrated by hypothetical data in Table 5. The first data set represents an island with adequate nesting cover but high vulnerability to disturbance. The second data set illustrates an island with poor cover and low vulnerability to disturbance, and the third set represents an ideal situation with excellent cover and low potential for disturbance.

Field Use of the Model

Techniques for measuring and calculating habitat variables included in the American eider HSI models are suggested in Table 6.

Interpreting Model Output

As with other HSI models, the HSI value obtained may have no relationship to actual population numbers. Factors not included directly in this model, such as diseases, predation, or proximity to other nesting islands, may significantly influence species use and abundance. The primary value of an HSI is for ranking coastal islands as to their potential for supporting nesting American eiders.

Although food was not considered in this model, expanding aquaculture, especially involving mussel dredging, could reduce food supplies in the future. Also, additional studies should evaluate brood-rearing habitat, in particular the importance of predation, human disturbance, distance from nesting island to rearing areas, and quality of rearing areas near nesting islands.

Table 5. Model output of the component indices and habitat suitability indices (HSI) for three hypothetical data sets with their corrsponding suitability index (SI) values.

Model component	Data set 1 Data		SI	Data set 2 Data		SI	Data set 3 Data		SI
V_1	Bare ground (0.5)[a] Shrub (5) Forest (0.5) CI[b]	30% 30% 40% 37	0.34[c]	Bare ground (0.5) Grass (1) Forb (4) CI	40% 50% 10% 22	0.09	Bare ground (0.5) Grass (1) Forb (4) Shrub (5) Forest (3) CI	10% 10% 20% 50% 10% 75	1.00
V_2	25 ha		0.10	7 ha		0.30	4 ha		1.00
V_3	Several landing sites		0.10	Inaccessible		1.00	1 landing site		0.60
V_4	1 km		0.50	2 km		1.00	5 km		1.00
C		0.34			0.09			1.00	
D		0.23			0.77			0.86	
HSI		0.28			0.26			0.93	

[a] See Table 3 for nest cover ranks.

[b] Cover Index (CI) = $\frac{(30 \times 0.5) + (30 \times 5) + (40 \times 0.5)}{5} = 37.$

[c] See V_1 Suitability Graph for determining SI value.

Table 6. Suggested measurement techniques and definitions for habitat variables used in the American eider HSI models.

Variable (definition)	Suggested technique
V_1 Nesting Cover	Either cover map directly or use aerial photos to measure the percentage of each island covered by bare ground, grass, medium to tall forbs, shrubs, and forest. Visit island to confirm classification if aerial photos are used. For best results, the data should be collected during the peak nesting period or about mid- to late June.
V_2 Island size (the surface on the island in ha).	Refer to coastal maps or aerial area photos and measure the area with a planimeter or dot grid.
V_3 Accessible boat landing sites on eider-nesting islands	Boat landing areas can be determined by aerial photos, on-the-ground observation, or discussion with biologists familiar with the island.
V_4 Distance of island from permanent or seasonal human settlement (those areas which have access boating facilities).	Refer to coastal maps and measure the straight line distance using a map measurer (Hayes et al. 1981) to the center of the potential nesting to to island.

Other Sources of Information

Current information on common eider populations and band returns is available from unpublished files through the Maine Department of Inland Fisheries and Wildlife, P. O. Box 1298, Bangor, Maine 04401.

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A review and synthesis of existing information was used to develop a model for evaluating the potential suitability of habitat along the coast of Maine for breeding American eider (Somateria mollissima dresseri). The model is scaled to produce an index from 0 (unsuitable habitat) to 1.0 (optimal habitat). Habitat suitability index models are designed for use with the Habitat Evaluation Procedures previously developed by the U.S. Fish and Wildlife Service. Guidelines for model application are provided.

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