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Washington, DC 20460

EPA/600/R-06/132
October 2006
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A Framework for the Assessment of the Wildlife Habitat Value of New England Salt Marshes

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A Framework for the Assessment of the Wildlife Habitat Value of New England Salt Marshes

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Notice

Abstract

Resource managers are frequently asked to make decisions that affect the protection and restoration of wetland habitats. The desire is often to base at least some part of the decision on an assessment of one or more wetland functions, such as wildlife habitat value. While protocols currently exist to evaluate wildlife habitat value in freshwater wetlands, there is a lack of stand-alone methods to assess this function for coastal salt marshes, a class of wetlands that are increasingly under development pressure from urbanization. In this report, we provide a framework for assessing the wildlife habitat value of New England salt marshes by identifying the habitat characteristics that influence the presence and abundance of wildlife species. We identify these characteristics from available information on the habitat requirements of 79 bird, 20 mammal, and 6 reptile and amphibian species that use New England salt marsh habitats. The characteristics are incorporated into wetland and landscape components (*e.g.*, salt marsh size, salt marsh landscape setting) that we feel are important for determining habitat suitability for wildlife species. For each component, we identify several categories that provide a means for ranking habitat value. The wetland and landscape components, along with their associated categories, can be used as the basis of an assessment protocol to estimate salt marsh wildlife habitat value.

Foreword

Since the late 1970's, most wetlands have been considered "waters of the U.S." and regulated under the Clean Water Act (CWA). Under the CWA the U.S. Environmental Protection Agency, States, and Tribes develop programs for protecting the chemical, physical, and biological integrity of the nation's waters, including wetlands. A necessary step towards protecting and restoring the biological integrity of wetlands is to ascertain the relative habitat value of wetlands in a landscape. This manuscript presents a framework for assessing the wildlife habitat value of coastal wetlands by identifying the habitat characteristics that influence the presence and abundance of wildlife species.

The framework is based on relevant life history traits and habitat requirements of (terrestrial) wildlife species that use salt marshes. We identify eight wetland components that we feel would be important to assess wildlife habitat value, such as the presence of habitat types (e.g. marsh -upland border, pools, tidal flats), marsh morphology, size, and extent of anthropogenic modification. We then propose categories within each component that relate to the habitat value of the marsh.

This manuscript is the first phase of developing the assessment protocol, consisting solely of the scientific basis for developing the assessment indicators. In a subsequent manuscript we will present specific ranking and scoring protocols for New England salt marshes. Once established, an assessment protocol can be used to provide information on the habitat value of coastal wetlands to aid in protection, restoration, and mitigation of salt marsh habitats.

This is the Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division contribution number AED-06-054.

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Introduction

Environmental stewards and managers acknowledge the importance of assessing the value of wetlands for the purposes of protection, restoration, and mitigation. These assessments may be particularly important for coastal salt marshes, a class of wetland that by the nature of their location are increasingly under development pressure from urbanization. Wetland assessment protocols typically either add an evaluation of wetland function to existing habitat classification systems or include wetland functional assessments as one component of an overall classification (Bartoldus 1999). Examples of the latter include the hydro geomorphic approach (Brinson 1993), those based on national wetland classification protocols (*e.g.*, Tiner 2003), and stand-alone wetland assessment techniques and protocols (*e.g.*, Adamus *et al.* 1987). These assessments address many wetland functions including water quality improvement, flood control, ground-water recharge, and wildlife habitat value.

Of the wetland functions addressed by assessment protocols, wildlife habitat value has garnered particular attention and led to the development of several regional classification and assessment protocols for freshwater and inland wetlands. These assessments often rely on general vegetative characteristics to estimate habitat value without consideration of the specific habitat requirements of wildlife species known to inhabit the wetlands (*e.g.*, Schroeder 1996). Notable exceptions are the classifications developed by J. S. Larson and coworkers to assess the wildlife habitat value of freshwater wetlands in the northeast U.S. (*e.g.*, Golet and Larson 1976, Whitlock *et al.* 1994). These classifications are based on dominant vegetation, but they also incorporate wildlife habitat requirements.

A number of protocols have been developed to assess the wildlife habitat value of freshwater marshes (Bartoldus 1999). However, to our knowledge there are no species-specific, stand-alone assessment protocols to assess the wildlife habitat value of coastal salt marshes. The objective of this report is to present a framework

Snowy egret *Egretta thula*
(Photo by Ryan Hagerty, US FWS)

for the development of assessment protocols for wildlife habitat value in coastal salt marshes in New England that are based on the presence of marsh habitat types, marsh morphology, and landscape setting and incorporate the specific habitat requirements of resident wildlife species. The report identifies terrestrial wildlife species (birds, mammals, reptiles, and amphibians) known to use salt marshes during some part of their life histories and compiles habitat use data from published life history accounts, unpublished reports, and anecdotal information from wetlands ecologists. Habitat requirements of species are organized into the a series of wetland components that provide a framework for assessing wildlife habitat value for New England salt marshes. For each component, we propose several categories that can be used to classify salt marshes for wildlife habitat value. The different categories within each component range from those that imply that wildlife species would obtain the full benefit or habitat value of the component to those implying that the species would obtain less than full value. However, when utilized in an actual assessment, the weighting and ranking of components will depend upon the target wildlife species under consideration and the overall intent of the assessment.

Great egr*et aldea alba*
(Photo by Lee Karney, US FWS).

In this report we focus on New England salt marshes, defined as those occurring from Maine to New Jersey (Chapman 1940). New England salt marshes are typically small and receive low suspended sediment loads from relatively small drainage basins, resulting in predominately organic peat substrates (Roman *et al.* 2000). Salt marsh morphology in this region reflects the relatively steep slope of New England estuarine coastlines, as well as the influence of development and modification by humans (Kelly 1987, Kelly *et al.* 1988). Traditionally, studies on New England salt marsh habitat value have emphasized marine species that depend on salt marsh habitats during a portion of their life cycle. For example, mummichog *Fundulus* spp. and several shrimp species (*e.g.*, *Paleomontes* spp.) are resident in salt marshes (Cross and Stiven 1999, Halpin 2000), and others use salt marsh habitats for egg laying (Harrington and Harrington 1961, Daiber 1962) and foraging (Vince *et al.* 1976, Daiber 1982), However, in this report we focus on terrestrial wildlife and present a framework for the assessment of salt marsh habitat value solely for these species.

SALT MARSH WILDLIFE HABITAT REQUIREMENTS

We identified 79 bird, 20 mammal, and 6 amphibian and reptile species that use New England salt marshes at some point in their life history (Tables 1 and 2). Wildlife habitat requirements were identified from accounts in the Birds of North America (Poole and Gill 1992), an atlas of New England wildlife (DeGraaf and Yamesaki 2001), literature surveys of salt marsh bird species (*e.g.*, Reinert and Mello 1995, Benoit and Askins 2002, Shriver *et al.* 2004), mammalian species accounts published by the American Society of Mammalogists (*e.g.*, Bekof 1977), unpublished reports, anecdotal information from wetlands ecologists, and personal observations. Salt marsh birds were categorized as breeding (those species that have been observed to nest in salt marshes) or foraging (those which spend at least some portion of their life histories feeding in salt marshes). Foraging species are further divided into year-round, summer-only, migrant, or winter-only foragers. Birds in the latter two foraging categories use salt marshes sporadically and some are rarely encountered in marsh habitats. Mammals are categorized as foragers (*i.e.*, those species that feed on salt marsh vegetation), predator

Table 1. Birds known to inhabit New England salt marshes or use salt marshes as foraging or shelter habitat.

Group	Common Name	Species
Breeders	American oystercatcher	*Haematopus palliatus*
	lapper rail	*Rallus longirostris*
	common tern	*Sterna hirundo*
	killdeer	*Charadrius vociferus*
	laughing gull	*Larus atricilla*
	least bittern	*Ixobrychus exilis*
	mallard	*Anas platyrhynchos*
	marsh wren	*Cistothorus palustris*
	mute swan	*Cygnus olor*
	red-winged blackbird	*Agelaius phoeniceus*
	salt marsh sharp-tailed sparrow	*Ammodramus caudacutus*
	seaside sparrow	*Ammodramus maritimus*
	swamp sparrow	*Melospiza georgiana*
	Virginia rail	*Rallus limicola*
	willet	*Catoptrophorus semipalmatus*
Foragers - year round	American crow	*Corvus brachyrhynchos*
	American robin	*Turdus migratorius*
	bald eagle	*Haliaeetus leucocephalus*
	belted kingfisher	*Ceryle alcyon*
	black-bellied plover	*Pluvialis squatarola*
	Bonaparte’s gull	*Larus philadelphia*
	cedar waxwing	*Bombycilla cedrorum*
	common grackle	*Quiscalus quiscula*
	double-crested cormorant	*Phalacrocorax auritus*
	European starling	*Sturnus vulgaris*
	fish crow	*Corvus ossifragus*
	gray catbird	*Dumetella carolinensis*
	great black-backed gull	*Larus marinus*
	great horned owl	*Bubo virginianus*
	herring gull	*Larus argentatus*
	house sparrow	*Passer domesticus*
	mourning dove	*Zenaida macroura*
	northern cardinal	*Cardinalis cardinalis*
	northern flicker	*Colaptes auratus*
	northern mockingbird	*Mimus polyglottos*
	red-shouldered hawk	*Buteo lineatus*
	red-tailed hawk	*Buteo jamaicensis*
	rough-legged hawk	*Buteo lagopus*
	ring-billed gull	*Larus delawarensis*
	ring-necked pheasant	*Phasianus colchicus*
	semipalmated sandpiper	*Calidris pusilla*
	short-eared owl	*Asio flammeus*
	song sparrow	*Melospica melodia*

Foragers - summer	American goldfinch	*Carduelis tristis*
	bank swallow	*Riparia riparia*
	barn swallow	*Hirundo rustica*
	black-crowned night heron	*Nycticorax nycticorax*
	chimney swift	*Chaetura pelagica*
	common yellowthroat	*Geothlypis trichas*
	eastern kingbird	*Tyrannus tyrannus*
	glossy ibis	*Plegadis falcinellus*
	great blue heron	*Aldea herodias*
	great egret	*Aldea alba*
	greater yellowlegs	*Tringa melanoleuca*
	green heron	*Butorides virescens*
	least tern	*Sterna antillarum*
	lesser yellowlegs	*Tringa flavipes*
	little blue heron	*Egretta caerulea*
	osprey	*Pandion haliaetus*
	snowy egret	*Egretta thula*
	spotted sandpiper	*Actitus macularia*
	tree swallow	*Tachycineta bicolor*
	yellow-crowned night heron	*Nyctanassa violacea*
Foragers - migration	cattle egret	*Bubulcus ibis*
	least sandpiper	*Calidris minutilla*
	semipalmated plover	*Charadrius semipalmatus*
	semipalmated sandpiper	*Calidris pusilla*
	sora	*Porzana Carolina*
Foragers - winter	American black duck	*Anas rubripes*
	American coot	*Fulica americana*
	American wigeon	*Anas americanus*
	blue-winged teal	*Anas discors*
	brant	*Branta bernicla*
	Canada goose	*Branta canadensis*
	dunlin	*Calidris alpina*
	green-winged teal	*Anas crecca*
	northern harrier	*Circus cyaneus*
	northern pintail	*Anas acuta*
	ring-necked duck	*Aythya collaris*
	sanderling	*Calidris alba*
	snowy owl	*Nyctea scandiaca*

Table 2. Mammals, amphibians, and reptiles known to inhabit New England salt marshes or use salt marshes as foraging habitat.

Group[1]	Common Name	Species
Mammals		
Foragers	black-tailed jackrabbit	*Lepus californicus*
	eastern cottontail	*Sylvilagus florianus*
	least shrew	*Cryptotis parva*
	masked shrew	*Sorex cinereus*
	raccoon	*Procyon lotor*
	Virginia opossum	*Didelphis virginiana*
	white-tailed deer	Odocoileus virginianus
Predators	coyote	*Canis latrans*
	fisher	*Martes pennanti*
	long-tailed weasel	*Mustela frenata*
	mink	*Mustela vison*
	red fox	*Vulpes vulpes*
	river otter	*Lontra canadensis*
	striped skunk	*Mephitis mephitis*
Breeders	meadow jumping mouse	*Zapus hudsonius*
	meadow vole	*Microtus pennsylvanicus*
	muskrat	*Ondatra zibethicus*
	New England cottontail	*Sylvilagus transitionalis*
	Norway rat	*Rattus norvegicus*
	woodland vole	*Microtus pinetorum*
Amphibians / reptiles	common snapping turtle	*Chelydra serpentina serpentina*
	eastern painted turtle	*Chrysemys picta picta*
	green frog	*Rana clamitans melanota*
	northern diamondback terrapin	*Malaclemys terrapin terrapin*
	northern water snake	*Nerodra sipedon sipedon*
	spotted turtle	*Clemmys guttata*

[1]Foragers are those who consume indigenous salt marsh flora or fauna; *e.g.*, marsh grasses or resident invertebrates such as bivalves. Predators will take advantage of prey when present; *e.g.*, small mammals, birds and eggs. Breeders are those that will potentially nest in some part of the marsh.

(*i.e.*, those who will venture onto a salt marsh to take advantage of prey when present), and breeders (*i.e.*, those that will potentially nest in some part of the marsh).

While our framework as a whole uses maximum wildlife species diversity and abundance as a standard by which to assess salt marsh habitat value, categorization of bird and mammal species allows for flexibility in its application. For example, to assess habitat value for salt marsh foraging birds, one would first identify the relevant species from Table 1, then refer to Appendix 1 and the appropriate passages in the text for specific habitat types and component categories that are important for these species. These categories could then be emphasized in an assessment by weighting their values appropriately.

We identified common habitat types associated with New England salt marshes, or those that were reported as being used by at least 3 bird or mammal species in published life history accounts, unpublished reports, and anecdotal information from local wetlands ecologists (Table 3). The most commonly reported habitat types, edge habitats, or adjoining habitats for each bird and mammal category, based on the published literature including species life history accounts in the Birds of North America (Poole and Gill 1992) and Mammalian Species reports (*e.g.*, Bekof 1977), are summarized in Tables 4 and 5. These habitat types, as well as the habitat requirements of salt marsh fauna, form the basis of the salt marsh assessment components described in this report.

WETLAND AND LANDSCAPE ASSESSMENT COMPONENTS

Below we describe eight wetland and landscape assessment components of New England salt marshes (Table 6). Several of the components, such as Salt Marsh Habitat Type, Salt Marsh Vegetation, Salt Marsh Vegetative Heterogeneity, and Connectivity and Associated Habitat are directly based on or composed of the different habitat types on the salt marsh landscape or ecosystems that are linked to the salt marsh. Other components, such as Degree of Anthropogenic Modification, and Surrounding Land Cover and Land Use reflect the alteration of these habitats. The remaining

Table 3. Habitat types, edge habitats, and adjoining habitats of value to salt marsh wildlife.

Habitat types	Edge habitats	Associated habitats
Open water (< 60 cm)[1]	Marsh-water edge	Sand or cobble beach
Tidal flat	Tidal creek edge	Coastal dunes or overwash
Low marsh[2]	Marsh-pool edge	Other salt marsh wetland
High marsh[3]	Marsh-upland edge	Brackish wetland or pond
Pools		Freshwater wetland or pond
Pannes		Upland meadow
Trees overhanging water		Upland forest
Wooded islands		
Marsh-upland border		
Phragmites		

[1]Shallow open water less than 60 cm in depth
[2]Smooth cordgrass (*Spartina alterniflora*)–dominated low marsh
[3]Salt meadow often dominated by *Spartina patens* and forbs

Table 4. Most commonly reported[1] habitat types, edge habitats, and associated habitats used by salt marsh breeding and foraging birds.

All birds	Breeders	Foragers - year round
1) High marsh	1) High marsh	1) High marsh
2) Low marsh	2) Marsh-upland edge	2) Marsh-upland border
3) Tidal flats	3) Low marsh	3) Low marsh
4) Shallow open water	4) Tidal flats	4) Upland forest
5) Upland forest	5) Shallow open water	5) Sand or cobble beach

Foragers - summer	Foragers - migration	Foragers - winter
1) High marsh	1) Low marsh	1) Shallow open water
2) Shallow open water	2) Tidal flats	2) Marsh-upland edge
3) Low marsh	3) Shallow open water	3) Low marsh
4) Marsh-upland edge	4) Sand or cobble beach	4) Tidal flats
5) Marsh-water edge	5) Marsh-upland edge	5) Upland meadow

[1]Sources for avian wildlife habitat information include Birds of North America (Poole and Gill 1992), DeGraaf and Yamesaki 2001, and literature cited in Appendix 1.

Table 5a. Most commonly reported[1] habitat types, edge habitats, and associated habitats used by grazing, predator, and breeding salt marsh mammals, as well as all mammals that use salt marshes.

All mammals	Grazers	Predators	Breeders
1) High marsh	1) High marsh	1) Low marsh	1) High marsh
2) Marsh-upland border	2) Marsh-upland border	2) Freshwater wetland	2) Marsh-upland border
3) Low marsh	3) Low marsh	3) High marsh	3) Upland meadow
4) Upland meadow	4) Upland meadow	4) Upland meadow	4) Upland forest
5) Freshwater wetland	5) Upland forest	5) Tidal flats	5) Low marsh

[1]Sources for mammalian wildlife habitat information include mammalian species accounts published by the American Society of Mammalogists, DeGraaf and Yamesaki 2001, and literature cited in Appendix 2.

Table 5b. Most commonly reported[1] salt marsh habitat types, edge habitats, and associated habitats used by amphibians and reptiles.

All amphibians and reptiles
1) Freshwater wetland or pond
2) Brackish wetland or pond
3) Marsh-upland border
4) Marsh-water edge
5) Tidal flat

[1]Sources for amphibian wildlife habitat are given in Appendix 2.

components (Salt Marsh Size, Salt Marsh Morphology) take into account the size, morphology, and landscape position of the marsh, which may be important to territorial species and those that require adjacent upland habitats. Salt marsh size and morphology may also be useful in pre-classifying marshes prior to assessment.

Together these eight wetland and landscape assessment components comprise a framework that can be used to assess and evaluate salt marsh wildlife habitat value.

I. Salt Marsh Size Class

Salt marshes along the New England coast include narrow, discrete fringe marshes less than 10 ha in area and salt meadow complexes of up to 2000 ha. Mean salt marsh size ranges from 40.2 ha for marshes in southern New England to 174.8 ha for marshes in the Gulf of Maine (Shriver *et al.* 2004). In general, large wetlands are considered to be of greater value to wildlife as habitat, although smaller marshes may in some cases provide important habitat for endemic species or those with specific habitat requirements. Several studies have reported a positive relationship between the number of bird species and wetland area (Brown and Dinsmore 1986, Craig and Beal 1992), and others have documented area dependence for species richness of salt marsh breeding birds, particularly those that are short

Table 6. Wetland and landscape assessment components of New England salt marshes and their associated categories. The categories represent habitat, morphological, vegetation or land use types, or classes that represent a marsh characteristic (size class, degree of anthropogenic modification, level of heterogeneity). Criteria are those parameters that may be used in an assessment protocol to rank marshes, *e.g.*, a marsh with a greater number of salt marsh habitat types may rank above a marsh with fewer types, depending on goal of the assessment protocol.

Component	Categories	Criteria
I. Salt Marsh Size Class	Very small (under 5 ha)	Marsh area
	Small (5 – 25 ha)	
	Medium-sized (26 – 125 ha)	
	Large (126 – 200 ha)	
	Very large (over 200 ha)	
II. Salt Marsh Morphology	Salt meadow marsh	Marsh morphology
	Meadow / fringe marsh	
	Wide fringe marsh	
	Narrow fringe marsh	
	Marine fringe marsh	
III. Salt Marsh Habitat Types	Shallow open water	Presence or abundance
	Tidal flats	
	Low marsh	
	Trees overhanging water	
	High marsh	
	Pools	

Component	Categories	Criteria
	Pannes	
	Wooded islands	
	Marsh-upland border	
	Phragmites	
IV. Extent of Modification	Little to no ditching	Degree of modification
	Moderate ditching	
	Severe ditching	
	Little to no tidal restriction	
	Moderate tidal restriction	
	Severe tidal restriction	
V. Salt Marsh Vegetation	Aquatic plants	Presence or abundance
	Emergents	
	Shrubs	
	Trees	
	Vines	
VI. Vegetative Heterogeneity	High heterogeneity	Number of habitat edges
	Moderate heterogeneity	
	Low heterogeneity	
VII. Surrounding Land Cover	Open water	Presence or area
	Natural land	
	Maintained open land	
	Developed land	
VIII. Connectivity	Sand or cobble beach	Presence or area
	Coastal dunes or overwash	
	Other salt marsh wetland	
	Brackish wetland or pond	
	Freshwater wetland or pond	
	Upland meadow	
	Upland forest	

grass meadow specialists (Benoit and Askins 1992, Shriver *et al.* 2004). These findings imply that larger salt marshes may provide greater relative habitat value for some species of breeding birds. They also point to the importance of habitat fragmentation in determining species richness. The negative effects of habitat fragmentation on bird species richness has been demonstrated for forest and grassland birds, where it has been reported that area sensitive species tend to have lower densities in small habitat patches versus larger blocks of continuous habitat (Askins *et al.* 1990, Vickery *et al.* 1994). Fragmentation has been shown to influence bird distribution in New England salt marshes, with larger habitat patches generally supporting more species (Clarke *et al.* 1984, Benoit and Askins 1999, 2002). Larger and less fragmented marshes may provide greater habitat value to wildlife that are sensitive to human activities, since peripheral disturbances will have less of an effect on the inner part of the marsh (Golet and Larson 1974). Larger marshes will also have less relative edge habitat per marsh area, which may mitigate processes such as nest predation that may be correlated with marsh edge (Johnson and Temple 1990). Large, contiguous blocks of wetland will tend to contain a greater diversity of habitat types, and are therefore more likely to meet all species' habitat requirements (Burke and Nol 1998). However, even small or fringe salt marshes have habitat value, particularly for foraging species. For example, a study of salt marsh habitat use in Narragansett Bay, RI showed consistent densities of foraging herons and egrets at sites ranging from 2 – 70 ha (Trocki 2003).

Benoit and Askins (2002) reported minimum area requirements for six bird species that breed in Connecticut salt marshes. They found that when they considered salt marsh fragments to be defined as those separated by broad barriers (>500 m of open water, or >50 m of upland habitat), minimum area requirements ranged from 8 to 138 ha (Benoit and Askins 2002). Seaside sparrow territories of <1 ha were reported in ditched marshes in Massachusetts (Marshall and Reinert 1990), but nonetheless these species were absent in marshes of less than 67 ha in the Connecticut study. Similarly, sharp-tailed sparrows have reported home-ranges of 1.2 – 5.7 ha (Wolfenden 1956, Greenlaw and Rising 1994), but were not reported in Connecticut marshes less than 10 ha. Willet *Catoptrophorus semipalmatus* were the most area sensitive, absent in marshes of less than 138 ha, but this may have been confounded by recent recolonization of salt marshes after extirpation from hunting and egg collection (Bevier 1994).

Mammals that utilize salt marshes exhibit a wide range of home range sizes, depending upon

B1ack-crowned night heron *Nycticorax nycticoras* (Photo by Lee Karney, US FWS).

whether they forage near nests and burrows or follow and chase mobile prey across larger areas. For example, meadow jumping mouse *Zapus hudsonius* and meadow vole *Microtus pennsylvanicus* have home ranges of less than 1 ha, while home ranges of the wide ranging coyote *Canis latrans*, red fox *Vulpes* vulpes, and mink can extend for thousands of hectares (Whitaker 1972, Harrison *et al.* 1989, Reich 1996, Lariviere 1999).

We adopted the mean of the minimum area requirements for salt marsh breeding birds (about 60 ha) reported by Benoit and Askins (2002) as the mid-point of our middle salt marsh size category. We then divided the range of areas between 5 and 200 ha among three size classes to derive the following salt marsh size categories:

1. **Very small**:	under 5 ha.
2. **Small**:	5 - 25 ha.
3. **Medium-sized**:	26 - 125 ha.
4. **Large**:	126 - 200 ha.
5. **Very large**:	over 200 ha.

Use of this component in a wildlife habitat assessment

Based on the available information about species habitat requirements, an assessment of salt marsh wildlife habitat value should include a consideration of marsh size. Since for a majority of species habitat value increases with marsh size, a ranking scheme should value larger over smaller marshes. The five categories presented above could be used to rank salt marshes by assigning increasing value to the ranking as size class increases. However, we reiterate that even small or fringe salt marshes may have significant habitat value for wildlife species. For example, a given salt marsh regardless of size may provide important habitat for an endemic or endangered species. Smaller marshes have also been shown to support significant numbers of foraging herons and egrets (Trocki 2003); quite possibly these marshes may be appealing to these species because their small size discourages use by potential avian and mammalian predators. Situations of this sort can be mitigated to some extent by including this assessment framework as one component in a multivariate decision-making model such as that proposed by Larson (1976) for fresh-water wetlands. Models of this sort will first determine whether a wetland possesses out-standing or unique attributes (*e.g.*, uncommon geomorphological features, archaeological value). This approach can identify marshes that may rank low in an overall assessment of wildlife species diversity but nonetheless may have important intrinsic value.

II. Salt Marsh Morphology

In addition to its size, the morphology of a salt marsh may affect habitat value. For example, a fringing salt marsh is by definition narrow, but may cover a long extent of a shoreline and hence have a large area. However, because it provides little buffer from peripheral human disturbance and is often dominated by low marsh with few additional marsh habitat types, it may be of limited value to wildlife. Conversely, a meadow marsh of equal area may buffer wildlife in its interior from peripheral disturbance, and is also more likely to consist of several salt marsh habitat types. It is therefore important to consider salt marsh morphology along with the area of the marsh when determining wildlife habitat value.

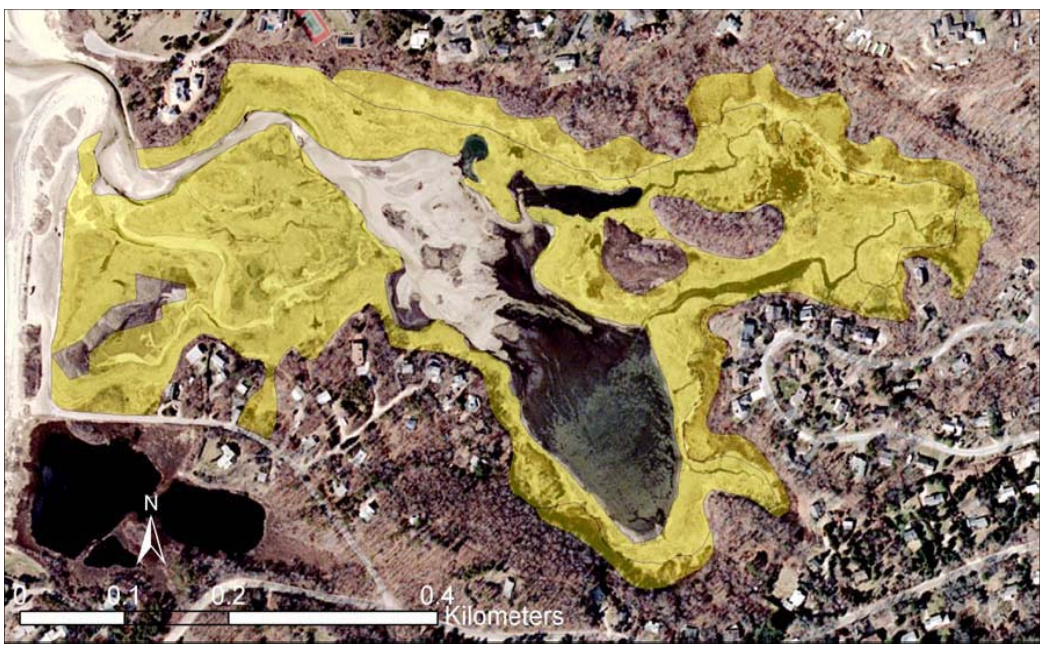
The Salt Marsh Morphology component is derived from the concept of wetland cover type first introduced by Stewart and Kantrud (1971) for prairie pothole wetlands and adapted by Golet and Larson (1974) for freshwater wetlands in the northeast. Cover type acknowledges the importance of the proportion of vegetative cover and open water to wetland wildlife, with the most important factor being the length of edge between cover and water per unit area of wetland. This element is particularly important for species that utilize open water for foraging but need the presence of nearby vegetative cover for shelter. In freshwater wetlands, cover type is important for breeding waterfowl because the edge between vegetative cover and water provides isolation of breeding pairs, protection from exposure to strong winds, and greater production and diversity of food organisms (Baldassare and Bolen 1994). The marsh-water edge may provide similar functions for wintering waterfowl in New England salt marshes. In addition, the marsh-water edge may be important for species that forage in shallow water and occasionally use nearby vegetated areas for protection. For example, plovers and sandpipers feed on exposed tidal flats at the marsh border and dart in and out of sparse *Spartina alterniflora* for protection or to pursue prey organisms (Recher 1966, Johnsgaard 1981). Other species, including willet and killdeer *Charadrius vociferus*, may take advantage of the increased prey abundance and diversity at the marsh-water edge (Danufsky and Colwell 2003, Maimone-Celorio and Mellink 2003). Wading birds may occasionally forage at the marsh-water edge when it is flooded to take advantage of the camouflaging effect of vegetation (Hancock and Kushlan 1984).

Marsh cover type as defined for freshwater wetlands may not be an appropriate metric for evaluating the wildlife habitat value of salt marshes. While the impact of marsh-water edge may be similar for salt marsh species, cover type is confounded somewhat by tidal inundation and marsh geomorphology. Salt marshes are by definition bordered by estuarine or marine open water; defining what proportion of the adjoining open water is to be considered when determining cover type by estimating percent vegetative cover (*i.e.*, what percentage of the wetland area is occupied by open water) can be problematic. We therefore propose an alternate classification based on the geomorphology of salt marshes along the New England coast. Classes of salt marsh morphology will represent varying amounts of marsh-water edge and marsh-upland edge in relation to wetland area. This classification acknowledges that edge habitat, which may be beneficial to some species, needs to be balanced by sufficient interior area to buffer wildlife from unfavorable edge processes (*e.g.*, increased predation risk, human disturbance). Five classes of salt marsh morphology are shown in Figure 1 and described below:

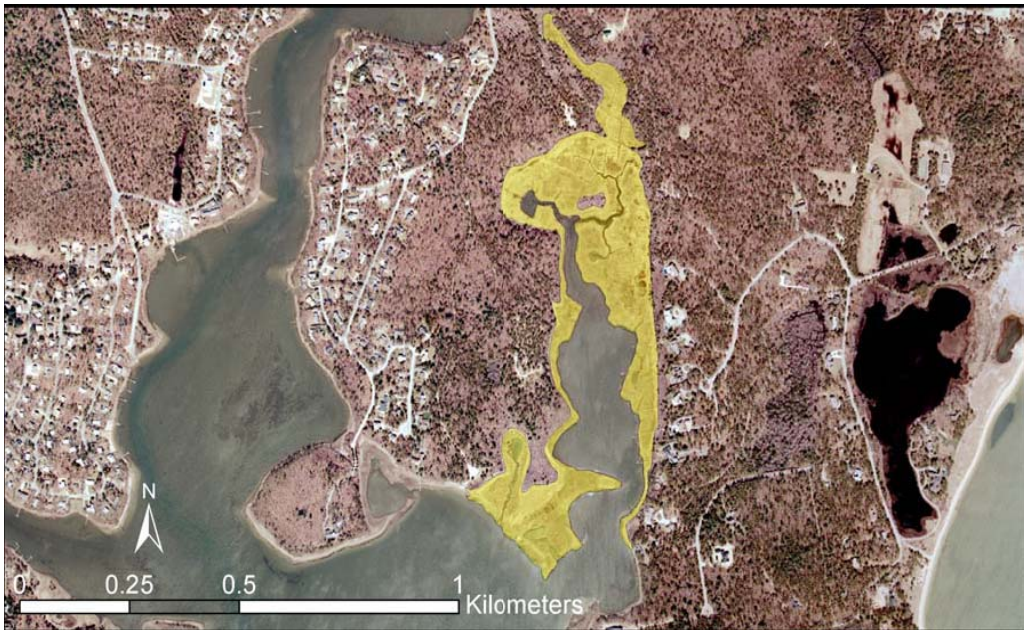
1.) Salt-meadow marsh: The salt meadow marsh is generally a back-barrier or basin marsh with extensive systems of wide and narrow creeks interspersed with large expanses of salt meadow marsh interior. Wide, basin-like marshes typically have a distinct bank between open water and marsh and support a greater diversity of habitat types and features, including high marsh and border plant communities, marsh pannes and pools, and inter- and sub-tidal creeks. Salt meadow marshes may be ditched or un-ditched (Figure 1a). This salt marsh type is generally of the greatest value to wildlife species, because of the potential for the existence of a number of habitat types, and the degree of protection and buffering afforded from the surrounding landscape.

Figure 1. Salt marsh morphology categories of New England marshes.

a) **Salt-meadow marsh.** Back-barrier or basin marsh with extensive creek systems interspersed with salt meadow marsh interior. May be ditched or un-ditched.



b) **Meadow / fringe marsh**. Typically consists of areas of salt meadow marsh interspersed with narrow or wide fringe marsh.



c) **Wide fringe marsh.** Typically dominated by low marsh but can contain some patches of high marsh vegetation, with a small number of narrow creeks (Figure 1c). Marsh width ranges from 10-50 m in width from seaward to landward marsh edge.

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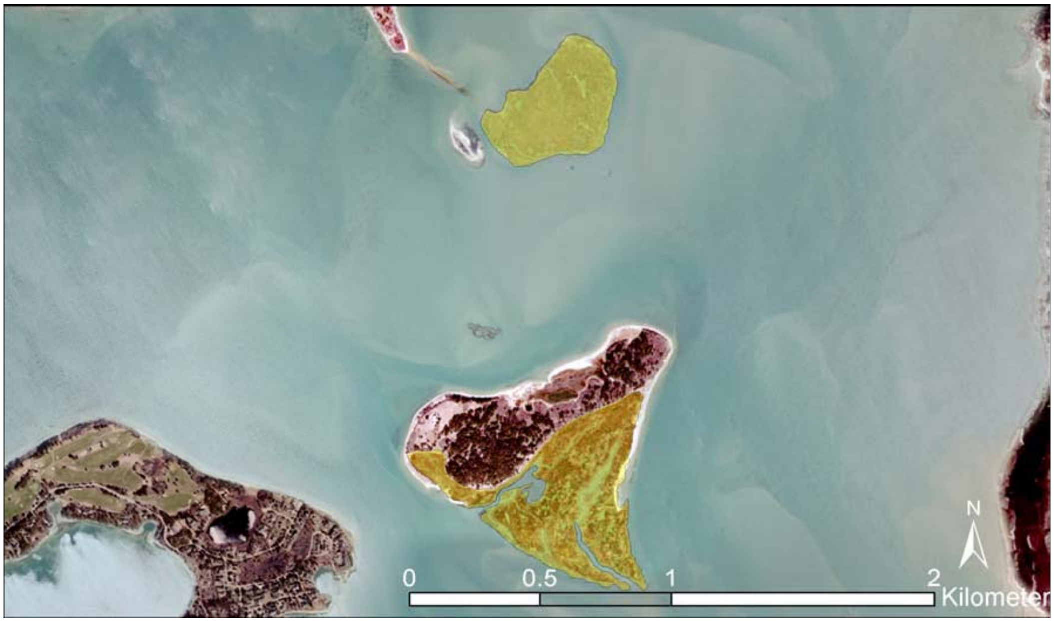
d) **Narrow fringe marsh**. Consists of a narrow belt of vegetation dominated primarily by the low marsh *Spartina alterniflora* with few creeks. Generally less than 10 m in width from seaward to landward marsh edge.



e) **Marine fringe marsh.** A narrow fringe marsh that is bordered on the seaward edge by unprotected open water; *i.e.*, not located within a cove or embayment. Typically have significant edge exposed to open water and high exposure to waves and prevailing winds.

2.) Meadow / fringe marsh: This marsh type consists of areas of salt meadow marsh interspersed with fringe marsh. Fringe marsh may be narrow or wide, and predominantly consists of low marsh. These marshes may be ditched or un-ditched (Figure 1b). Because meadow / fringe marshes can contain a number habitat types, they can provide significant wildlife value to most bird and mammal species.

3.) Wide fringe marsh: Fringe marshes form in bands along shorelines where there is some protection from wave and wind but slope limits the landward extent of the marsh. Wide fringe marshes are often dominated by low marsh but can contain some patches of high marsh vegetation, typically grade from open water to upland, and have a small number of narrow creeks (Figure 1c). Generally, these marshes range from 10 – 50 m in width from seaward to landward marsh edge. This salt marsh type has less habitat value to most species, although a wide fringe marsh may provide important foraging habitat for low marsh foraging and breeding birds and mammals.

4.) Narrow fringe marsh: This marsh type consists of a narrow belt of vegetation dominated primarily by the low marsh *Spartina alterniflora* with few creeks. Narrow fringe marshes are characterized by high amounts of both marsh-water and marsh-upland edge per wetland area. These marshes are generally less than 10 m in width from seaward to landward marsh edge. This marsh type is characteristic of areas impacted by urbanization where a marsh has been filled to accommodate adjacent development (Figure 1d), but can also be found in undisturbed areas. Narrow fringe marshes provide the least value to wildlife species, because they are generally composed of only a few habitat types, and offers little protection and buffering from the surrounding landscape.

5.) Marine fringe marsh: narrow fringe marsh that is bordered on the seaward edge by unprotected open water; *i.e.*, not located within a cove or embayment. These marshes have significant edge exposed to open water and gain little to no protection from upland environments. Marine fringe marshes have high exposure to waves and prevailing winds, and hence their habitat value to wildlife may be limited (Figure 1e).

Use of this component in a wildlife habitat assessment

In an assessment of salt marsh wildlife habitat value, salt marsh morphology and size class may be used to stratify salt marshes under consideration (*i.e.*, pre-classify a set of marshes into categories) such that, for example, salt meadow marshes are compared and ranked relative to other salt meadow marshes and separate from wide fringe marshes. Alternatively, since we can assign relative habitat value to the salt marsh morphology categories, these could be used in an assessment by weighting the categories with salt meadows marshes having the most and narrow fringe marshes the least habitat value.

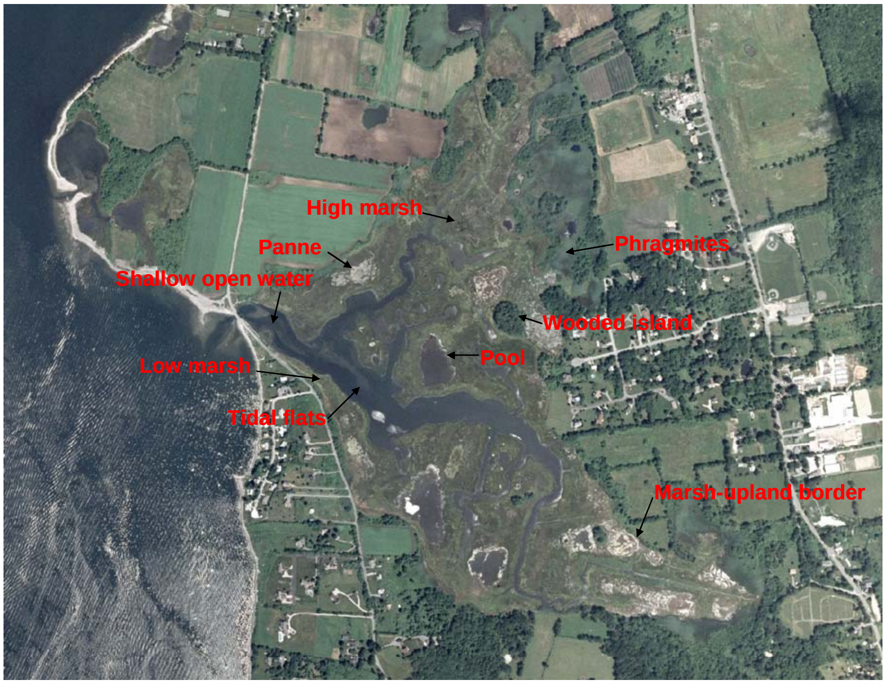
III. Salt Marsh Habitat Type

Interaction of tidal inundation with the geomorphology of salt marshes results in belts of halophytic vegetation from the seaward edge of the marsh toward the upland (Miller and Egler 1950, Redfield 1972, Nixon 1980). Chapman (1940) first described this general pattern of zonation in New England salt Marshes as one consisting of: i) submergent sub-tidal vegetation, *e.g.*, *Zostera marina*, ii) tidal flats; iii) low marsh dominated by smooth cordgrass *Spartina alterniflora*, iv) high marsh dominated by salt meadow cordgrass *Spartina patens*, and v) marsh-upland border dominated by *Juncus* spp. We retain these five zones as distinct micro-habitat types in New England salt marshes, replacing "submergent sub-tidal vegetation" with a shallow open water habitat that may or may not be vegetated. We also identify five microhabitat types that arise from differences in the geomorphology, tidal inundation, and the composition and complexity of salt marsh vegetation: pannes, marsh pools, trees overhanging water, wooded islands, and *Phragmites australis* (Figure 2). Below we describe wildlife use of these habitat types in their order of occurrence from the seaward to the landward edge on the salt marsh.

Shallow open water (<60cm depth)

Shallow open water consists of estuarine water seaward of the low marsh edge or tidal waters that are part of large creeks within the marsh itself. This habitat is used by foraging herons and egrets during the breeding season (Willard 1977, Ramo and Busto 1993). Additionally, migrating herons and egrets rely heavily on these foraging habitats as stopover sites during spring and summer migration (Chavez-Ramirez and Slack 1995). Water height is particularly important to these species. Based on Birds of North America species accounts and other studies a maximum water depth of 60 cm for is suggested for herons and egrets foraging in New England salt marshes (Custer and Osborn 1978, DuBowy 1996, Matsunaga 2000; Table 7). Shallow open water is also important for wintering waterfowl, particularly dabbling ducks that use these areas for foraging on submerged macroalgae or submergent vegetation (Erwin *et al.* 1994, Mowbray 1999, Longcore *et al.* 2000, Drilling *et al.* 2002). Maximum foraging depths may differ for these species. Several species of diving ducks

Figure 2. Salt marsh habitat types and the occurrence within a typical New England salt marsh. Not shown trees overhanging water.



(including bufflehead *Bucephala albeola* and scaup *Aythya* spp.) may also use shallow sub-tidal areas to forage for benthic macro-invertebrates (Gauthier 1993). Mammals including mink *Mustela vison* and fisher *Martes pennanti* utilize this habitat as well as the adjacent tidal flats when feeding on fish and birds (Powell 1984, Lariviere 1999).

Tidal flats

Tidal flats are areas of mud or sand on the seaward edge of a marsh or creek that are exposed at low tide. Tidal flats are important foraging areas for a number of salt marsh bird species, including foraging, breeding and wintering species (Appendix 1). In our review of the published literature, tidal flats are used by 17 of the 79 bird species. Tidal flat substrate includes both mud and fine sediments and sandy areas of course grain sediments. Each substrate has a unique assemblage of benthic fauna, consisting primarily of invertebrates that reside in or on the sediment. Although there is some overlap in benthic species between the two substrates, each provides a unique foraging habitat for different assemblages of marsh bird species (Appendix 1). For example, yellowlegs *Tringa* spp. feed almost exclusively on exposed mud flats on a diet that includes amphipods and other small crustaceans (Elphick and Tibbitts 1998, Tibbitts and Moskoff 1999). Other birds using mud flats include rails, sparrows, several duck species, willets *Catoptrophorus semipalmatus*, and occasionally herons and egrets. Sandpipers and plovers will preferentially forage on more sandy sediments, feeding on polychaetes, gastropods, and small bivalves. Oystercatchers *Haematopus palliatus* also forage on tidal flats that contain sufficient densities of bivalves (Nol and Humphrey 1994). As a foraging strategy, common snapping turtles *Chelydra serpentina serpentina* will burrow in salt marsh tidal flats and wait for prey to pass near (Babcock 1971).

Low marsh

The low marsh in New England salt marshes is described as the belt of emergent vegetation at the seaward edge of the marsh that is typically dominated by *Spartina alterniflora* (Miller and Egler 1950, Niering and Warren 1980, Nixon 1980). The landward edge of the low marsh is often defined by the extent to which the marsh is consistently flooded by tides, *i.e.*, mean high water (Redfield 1972). Low marsh habitat is used for nesting or foraging by 43 of the 79 bird species (Appendix 1), and is the second most frequently used of all salt marsh habitats (Table 4). Low marsh vegetation is important breeding habitat for seaside sparrow *Ammodramus maritimus*, willet *Catoptrophorus semipalmatus*, and on occasion salt marsh sharp-tailed sparrow *Ammodramus caudacutus*. The relatively low stem density of stands of *Spartina alterniflora*, combined with its wide, tall leaves, provide an ideal microhabitat for nests of these species: sturdy stems are used to support nests above the substrate and also to dissipate winds and maintain high temperatures and humidity. Seaside sparrows require relatively large (> 0.5 ha) expanses of tall form *Spartina alterniflora*, and build their nests several centimeters above the substrate in an attempt to avoid flooding Greenlaw and Rising 1994). The low stem density of *Spartina alterniflora*, along with the scouring action of daily tides, helps to keep the underlying sediments clear of debris. This gives smaller species that forage in the low marsh access to the bare sediment (and resident benthic invertebrates) between stems, while still providing protective cover. When flooded, the low marsh is also occasionally used as forging habitat by larger birds such as herons and egrets (Appendix 1).

Trees overhanging water

Although more common in marshes in the southeastern U.S., trees can occasionally be located sufficiently close to the marsh-water edge such that tree limbs will overhang open water. This provides a preferred foraging habitat for cattle egrets *Bubulcus ibis*, green herons *Butorides virescens*, black-crowned night herons *Nycticorax nycticora*, and belted kingfishers *Ceryle alcyon* (Davis and Kushlan 1994; Hamas 1994; Appendix 1).

High marsh

In contrast to low marsh vegetation, *Spartina patens*, which dominates the high marsh in New England salt marshes, is a short fine grass with high stem density. The high marsh may also be populated with several other salt marsh grasses and several species of forbs. The combination of dense vegetation, vegetative diversity and infrequent flooding results in a habitat that supports a greater diversity and abundance of invertebrates, particularly insects. This vegetative heterogeneity also results in a favorable habitat for foraging bird species, particularly those that feed on flying insects (Appendix 1). Swallows, red-winged blackbirds *Agelaius phoeniceus*, and sparrows, as well as other occasional passerines, utilize high marsh habitats for foraging. Furthermore, the dense vegetation characteristic of the high marsh, along with less frequent flooding, provides nesting habitat for sharp-tailed sparrows, waterfowl and least bittern *Ixobrychus exilis*. Sharp-tailed sparrows reportedly will locate nests where they will only be flooded by extreme spring tides, and often successfully

Table 7. Body mass, optimal foraging water depth, and tarsus length of wading birds in the family Ardeidae that utilize New England salt marshes.

Common Name	Species	Body mass[1]	Optimal Water Depth	Tarsus length[2]	Reference[4]
Black-crowned night heron	*Nycticorax nycticorax*	913±115 g / 827±69 g	--	18.3±0.5 mm / 17.7±0.3 mm	D
Cattle egret	*Bubulcus ibis*	371.8 g / 359.8 g	--	78.6 mm / 80.4 mm	C
Great egret	*Egretta alba*	935±134 g / 812 g	20 – 40 cm	167 mm / 137±14 mm	A,B
Great blue heron	*Aldea herodias*	2230±760 g[3]	25 – 60 cm	179±12 mm / 171±12 mm	E
Green heron	*Butorides virescens*	241 g[3]	<5 cm	53.0 mm / 51.2 mm	F
Little blue heron	*Egretta caerulea*	364±47 g / 315 g	5 - 15 cm	96.2 mm / 88.1 mm	B,G
Snowy egret	*Egretta thula*	369 g[3]	8 cm	97.1 mm / 89.6 mm	B
Yellow-crowned night heron	*Nyctanassa violacea*	716±18 g / 649±16 g	15 – 25 cm	99 mm / 97 mm	H,I

[1]Average male ± SD (when reported) / Average female ± SD (when reported).

[2]Tarsus = lowest segment of leg, before toes; average male ± SD (when reported) / Average female ± SD (when reported).

[3]Average adult mass.

[4]References

A) Dunning 1993.
B) Palmer 1962.
C) Browder 1973.
D) Gross 1923.
E) Quinney and Smith 1979.
F) Niethammer and Kaiser 1983.
G) Rodgers and Smith 1995.
H) Blake 1977.
I) Hartman 1955.

re-nest immediately after the first flooding, allowing young to fledge before the next spring tide (Post and Greenlaw 1982, DeRagon 1988). Several species (*e.g.*, black-bellied plover *Pluvialis squatarola*) use the high marsh for roosting during high tide when feeding grounds are covered (Paulson 1995). Overall, 47 of the 79 bird species use the high marsh, and it is the most frequently used of all salt marsh habitats by birds (Table 4).

Coyote *Canis latrans*
(Photo by R.H. Barrett, US FWS).

A number of mammal species, including black-tailed jackrabbit *Lepus californicus*, eastern cottontail *Sylvilagus florianus*, and meadow jumping mouse *Zapus hudsonius* feed on forbs that are found in the high marsh (Currie and Goodwin 1966, Chapman *et al.* 1980, Whitaker 1972; Appendix 2). Glossy ibis *Plegadis falcinellus* often forage extensively on the high marsh, particularly in marshes that are adjacent to or near agricultural fields (Trocki 2003). Herons and egrets have also been observed to forage in high marsh vegetation at high tide (Hancock and Kushlan 1984, Custer and Osborn 1978). All told, this diverse habitat type is reportedly used for nesting and foraging by 17 of the 79 marsh bird species, and 14 of the 20 mammal species (Tables 7 & 8).

Pools

Marsh pools are a common feature in New England salt marshes, although their abundance in the marsh landscape may be tied to the extent to which the marsh has been subjected to mosquito ditching (Adamowicz and Roman 2005). Miller and Egler (1950) describe pools as shallow (seldom deeper than 30 cm), typically containing submergent vegetation (*Rupia maritime*), and inhabited by a variety of nekton species. Pools will generally form in depressions in the marsh surface that can retain tidal waters, and would therefore be expected to contain many of the same prey species as are found in the surrounding open water habitat (Raposa and Roman 2001). However, varying water depths and different pool water salinities may alter community composition. For example, pools that are located some distance from tidal waters and therefore experience only infrequent flooding may take on the characteristics and of brackish/freshwater ponds. Pools in the salt marsh landscape are therefore a diverse habitat type that seemingly could provide foraging habitat for a number of bird species. Interestingly, only 3 species have been specifically identified in life history accounts as using marsh pools (glossy ibis, lesser yellowlegs *Tringa flavipes*, and snowy egrets *Egretta thula*), although we have observed on numerous occasions many of the same heron and egret species that feed in shallow water foraging in salt marsh pools. A study of bird use of ditched versus unditched marshes in Narragansett Bay showed greater bird use in unditched marshes, which may have been related to the greater density of marsh pools (Reinert *et al.* 1981). However, an important consideration may be the amount of available foraging habitat within a pool (*i.e.*, water depth <60 cm). Depending on marsh geomorphology, pools may have steep, erosional edges and depths that are too great for use by wading birds. Several marshes during a recent survey of salt marshes in Narragansett Bay were found to have average depths of greater than 60 cm in many of their pools, and foraging by herons and egrets was not observed in the deeper pools (K. Raposa and T. Kutcher, personal communication). Therefore, available foraging habitat should be considered in addition to the presence of pools when determining wildlife habitat value.

Pannes

Particularly in the high marsh, slight depressions in the salt marsh surface may retain water that subsequently becomes highly saline as a result of evaporation. These areas may develop into pannes, or bare, exposed depressions in the marsh that can at times be filled with shallow water (Wiegert and Freeman 1990). The habitat value of pannes results from their being devoid of vegetation and therefore providing foraging areas for species that prefer low-lying, un-vegetated substrates. However, pannes are physically harsh habitats characterized by high soil salinities and frequent flooding and drying, and little is known of their benthic communities. Additionally, mid-elevation pannes in northern New England salt marshes are typically colonized by a number of stress-tolerant forbs, owing to differences in climate (less solar radiation and cooler temperatures results in less potential for high soil salinities) and a lesser extent of ditching and draining (Ewanchuk and Bertness 2004a,b). Forb pannes in northern New England marshes may not provide the same wildlife habitat value as un-vegetated southern marsh pannes. Species known to forage in un-vegetated or low-lying areas include snowy egret, lesser yellowlegs, glossy ibis, sharp-tailed sparrow, and seaside sparrow. Additionally, species that forage on tidal flats or exposed mud may utilize pannes (Appendix 1).

Wooded islands

Wooded islands are elevated areas within the high marsh dominated by trees. Species may include red maple *Acer rubrum*, black cherry *Prunus seratina*, black oak *Quercus velutina*, pitch pine *Pinus rigida*, black gum *Nyssa sylvatica*, willow *Salix* spp., and alder *Alnus* spp. Although small in area, wooded islands function as habitat for several species, particularly as roost sites for great egrets *Aldea alba*, great blue herons *Aldea herodias*, and black-crowned night herons *Nycticorax nycticorax* (Appendix 1). These areas have the potential to provide breeding habitat for herons and egrets, although it is unclear whether they would be of sufficient area to provide this function, particularly for colonial breeders (Butler 1992, McCrimmon *et al.* 2001).

Marsh-upland border

In New England salt marshes, the habitat located at the upland margin of the marsh is dominated by salt marsh shrubs *Iva fructescens* and sea myrtle *Baccharis halimifolia*, as well as brackish / upland sedges (*Carex* spp., *Scirpus* spp.), rushes (*Juncus* spp.), and forbs (*e.g.*, marsh mallow *Althaea officinalis*, salt marsh aster *Aster* spp.). The marsh-upland border can be rather broad depending on marsh topography, and is of value to a number of species for foraging and nesting. Least bittern, clapper rail *Rallus longirostris*, and Virginia rail *Rallus limicola* are known to use marsh shrubs as breeding habitat (Gibbs *et al.* 1992, Conway 1995, Eddleman and

Conway 1998). Several passerine species utilize this habitat type for foraging, including gray catbird *Dumetella carolinensis*, willow flycatcher *Empidorax traillii*, and eastern kingbird *Tyrannus tyrannus*. Waterfowl, including American black duck, mallard, and Canada geese *Branta canadensis*, may also use this habitat type for roosting. The presence of waterfowl and marsh bird nests make this habitat attractive to mammals and reptiles (*e.g.*, northern water snake *Nerodra sipedon sipedon*) that feed on breeding birds and their eggs (Appendix 2). For example, coyote *Canis latrans*, red fox *Vulpes vulpes*, and striped skunk *Mephitis mephitis* have been known to feed on waterfowl and their eggs (Verts 1967, Bekoff 1977, Lariviere and Pasitschniak-Arts 1996).

Mink *Mustela vison*

Phragmites

Dense stands of common reed *Phragmites australis* at the upland edge of salt marshes are a widespread feature of southern New England marshes, particularly in areas subject to high nutrient inputs. This tall, erect perennial was long thought to have little or no wildlife habitat value, however recent studies have shown that some bird species will nest in *Phragmites* stands (*e.g.*, Benoit and Askins 1999). This may be a result of adaptation: for example the marsh wren *Cistothorus palustris* and swamp sparrow *Melospiza georgiana* are both marsh specialist that nest in tall, reedy vegetation, preferably cattail *Typha angustifolia*, but have been found to nest in *Phragmites* stands that have replaced cattails (Mowbray 1997, Benoit and Askins 1999). All told, we identified 10 species that use *Phragmites* for nesting or foraging habitat. In addition to marsh wren and swamp sparrows, little blue heron *Egretta caerulea*, least bittern, and mallard have been documented to nest in *Phragmites* (Gibbs *et al.* 1992, Rodgers and Smith 1995, Drilling *et al.* 2002). Recently, tree swallows have been observed foraging for insects over *Phragmites* stands on Cape Cod salt marshes (J. Portnoy, personal communication).

Use of this component in a wildlife habitat assessment

Salt marsh habitat type can be included in an assessment of wildlife habitat value of New England salt marshes by assigning a relative value to the presence of each habitat type, or assigning a value to a marsh based on the number of habitat types present. How these components are ranked or scored would depend on the goal of the assessment. For example, if the goal is to assess salt marsh habitat for maximum species diversity, the presence of many habitat types in a wetland would be emphasized. Alternatively, if habitat value was assessed for a guild of species, presence of suitable habitat for the species under consideration would be given more weight in an overall assessment.

IV. Extent of Anthropogenic Modification

A majority of the salt marshes in New England have been subject to some degree of human modification (Adamovicz and Roman 2005). Human impacts at the local scale include those that directly modify or destroy salt marsh habitat such as dredging, diking, spoil dumping, grid ditching, canal cutting, and salt hay farming (Kennish 2001). Salt marshes in New England have been extensively ditched, and by 1938 an estimated 90% of the salt marshes from Maine to Virginia had been ditched in order to reduce breeding habitat for the marsh mosquito *Ochlerotatus sollicitans* (Bourn and Cottam 1950). Ditching typically leads to lowered water table levels and draining of the marsh surface, which in turn alters marsh habitat. In addition to ditching, restriction of tidal flow to the marsh caused by under-sized culverts or bridges, causeways, manmade dikes, naturally occurring berms or shelves can lead to large-scale changes in marsh topography and vegetation patterns (Esselink *et al.* 1998, Sturdevant *et al.* 2002). Ditching and tidal restriction may lead to a reduced density of pools in ditched salt marshes (Adamowicz and Roman 2005), decreases in low marsh vegetation (Sun *et al.* 2003), and increases in the number of un-vegetated pannes and in the extent of *Phragmites australis* (Ewanchuk and Bertness 2004b). These changes in the topography and vegetative structure of the marsh may in turn influence patterns of utilization by wildlife, and hence affect salt marsh wildlife habitat value (Wolfe 1996).

Ditching and tidal restriction may differ in the degree to which they influence salt marsh wildlife habitat value. As described, most ditching diminishes wildlife habitat value, particularly for those species which rely on marsh pools. However, ditching may in some cases increase the occurrence of un-vegetated pannes, and therefore increase foraging opportunities for species that utilize panne habitats. Tidal restriction can cause a decrease in vegetative heterogeneity, but can also lead to the formation of new marsh habitats such as semi-permanent brackish ponds favored by several species. We therefore classify ditching and tidal restriction from least impact to highest in the following categories.

Degree of ditching

1.) **Little to no ditching**. Marsh supports as intact and natural system of wide and narrow creeks, and generally have a density of marsh pools (Figure 3a).

2.) **Moderate ditching**. Ditches are present and may be numerous, but natural creeks still intact and present. Marshes have a moderate density of marsh pools (Figure 3b).

3.) **Severe ditching**. Marshes show extensive regular pattern of man-made ditches, contain few or no natural creeks, and are characterized by low density of marsh pools (Figure 3c).

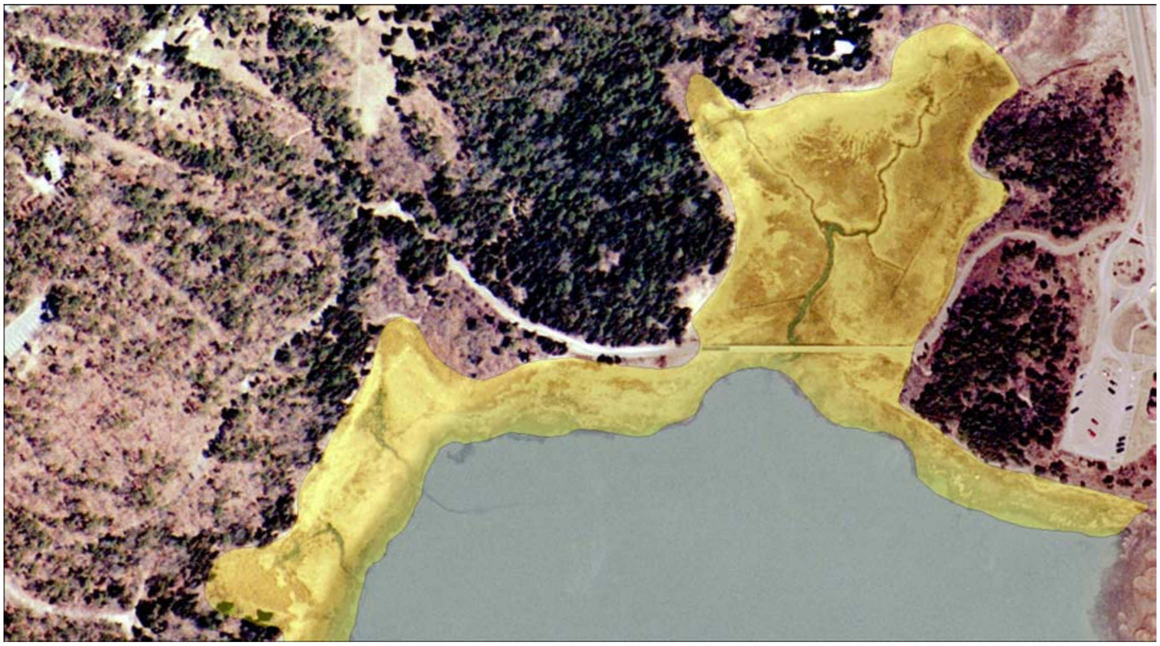
Degree of tidal restriction

1.) **Little to no tidal restriction**. Salt marsh has significant contact with marine waters (Figure 4a).

2.) **Moderate tidal restriction**. Moderate contact with marine waters, though configuration (channels not notably wide or deep, not open to embayment, some drainage creeks and ditches) or man-made restrictions may present some obstacle to flushing (Figure 4b).

3.) Severe tidal restriction. Little contact with tidal waters as a result of man-made restrictions. Noticeable changes in topography and vegetative structure (Figure 4c)

Figure 3. Example of a New England salt marshes.



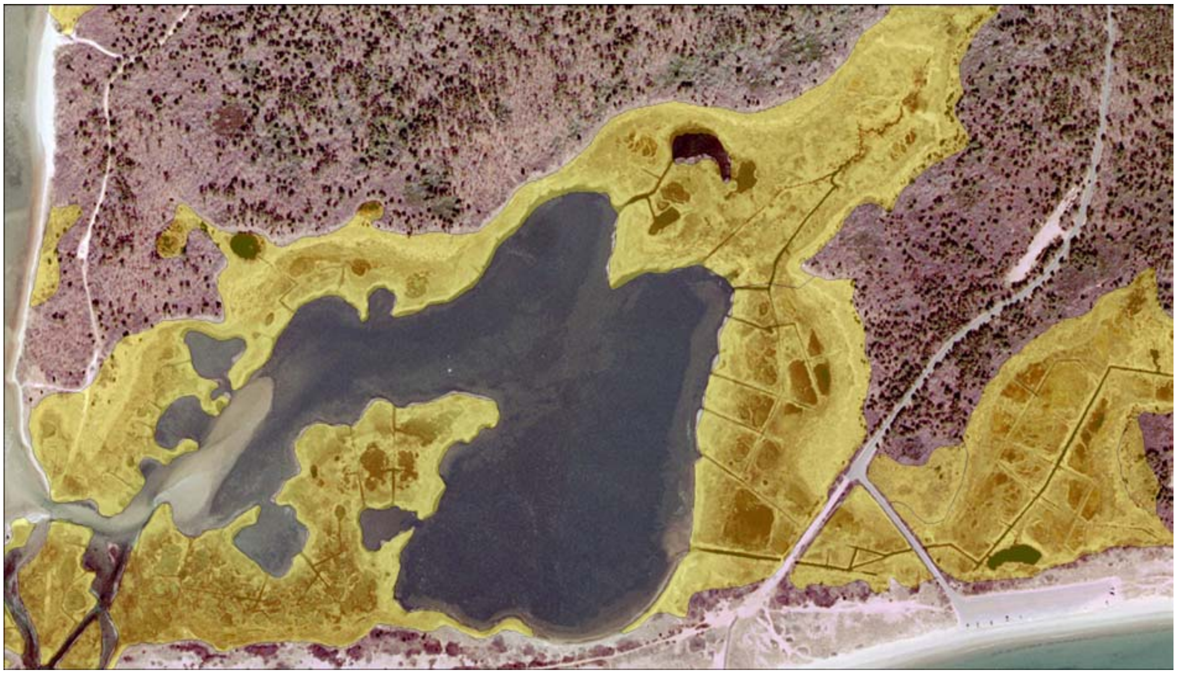
a) **Little or no ditching.** Most un-ditched marshes are characterized by an intact and natural system of wide and narrow creeks and a high density of marsh pools.

b) **Moderate ditching.** Ditches are present and may be numerous, but natural creeks are still intact and present. There is generally a moderate density of marsh pools.

c) **Severe ditching.** Note the extensive regular pattern of man-made ditches with few or no natural creeks. The marsh also has a low density of marsh pools.

Figure 4. Extent of tidal restriction in New England salt marshes.

a) **No to low tidal restriction.** The marsh has significant contact with marine waters.



b) **Moderate tidal restriction.** The marsh has moderate contact with marine waters, though configuration or man-made restrictions may present some obstacle to flushing.

c) **Severe tidal restriction.** There is little contact with tidal waters as a result of man-made restrictions.

Use of this component in a wildlife habitat assessment

The degree of ditching is primarily related to the extent of surface water on the marsh (Reinert *et al.* 1981, Adamovicz and Roman 2005). In general, salt marshes with lesser degrees of ditching or extent of tidal restriction would be expected to have greater habitat value. This could be captured in a quantitative assessment by weighting the categories with the "little to no" categories having the greatest value and "severe" categories the least value. While it is difficult to directly relate the extent of tidal restriction to habitat value, tidally restricted marshes may offer fewer resources to wildlife species (*e.g.*, Raposa and Roman 2001). This component could therefore be included in an assessment in a manner similar to that of the degree of ditching (*i.e.*, the "little to no" categories to "moderate" categories having the greatest habitat value and "severe" categories the least value).

V. Salt Marsh Vegetation

While vegetation has been proposed as the most important component of wildlife habitat in freshwater marshes (Golet and Larson 1974), New England salt marshes contain fewer species of plants, trees, and shrubs than freshwater wetlands because of their harsh physical regimes determined in part by salt water inundation, high soil salinities, and nutrient limitation. Tiner (1987) describes five life forms of New England tidal marshes (including tidal fresh marshes): aquatic plants, emergents, shrubs, trees, and vines. However, not all life forms may be present in estuarine and coastal salt marshes. For example, aquatic plants include three sub-forms (submergents, free-floating plants, and plants with floating leaves), but only submergents are regularly found in salt marshes. Trees, while generally not capable of growing in hyper-saline soils, may be found occasionally in isolated patches within the salt marsh of sufficient elevation to avoid regular tidal inundation (wooded islands). Vines are limited to one species: common dodder *Cuscuta gronovii* that is only occasionally found in salt marshes, usually parasitizing marsh elder *Iva frutescens*. While vegetative life forms and sub-forms still have important wildlife habitat value, the lack of vegetative heterogeneity may decrease the relative importance of this category to the overall habitat value of a salt marsh.

Below we list five life forms and nine sub-forms of vegetation found in salt marshes and important to wildlife. Sub-form categories are derived from Golet and Larson (1974). Latin names are taken from Tiner (1987).

Aquatic plants

Found in permanently flooded pools or sub-tidal waters. In salt marshes, consist of rooted submerged plants.

Sub-form:

1. Rooted submergent
   - Widgeon grass *Ruppia maratima*
   - Eelgrass *Zostera marina*
   - Pondweeds *Potamogeton* spp.

Emergents

Rooted, erect herbaceous plants that have all or part of their growth above water, or that grow in regularly flooded inter-tidal areas.

Sub-forms:

1. Robust emergents (Erect emergents up to 4 m tall)
   - Common reed *Phragmites australis*
   - Cattail *Typha* spp.
   - Fireweed *Erechtites hieracifolia*

2. Short meadow emergents (Sedge-like emergents, less than 1.5 m tall)
   - Sedges *Scirpus* spp.; *Carex* spp.
   - Spike-rush *Eleocharis* spp.
   - Black grass *Juncus gerardii*
   - Baltic rush *Juncus balticus*
3. Narrow-leaved emergents (Narrow-leaved graminoids less than 2 m tall)
   - Smooth cordgrass *Spartina alterniflora* (tall form up to 2.5 m tall)
   - Salt meadow grass *Spartina patens*
   - Spike grass *Distichlis spicata*
   - Switchgrass *Panicum virgatum*
   - Red fescue *Festuca rubra*
   - Goose grass *Puccinellia maritime*
4. Forbs (herbaceous plants other than grasses having little or no woody material)
   - Seaside goldenrod *Solidago sempervirens*
   - Salt marsh asters *Aster* spp.
   - Seaside plantain *Plantago maritime*
   - Sea lavender *Limonium nashii*
   - Sea milkwort *Glaux maritime*
   - Rose mallow *Habiscus moscheutos*
   - Marsh mallow *Althaea officinalis*
   - Sea rocket *Cakile edentula*
   - Sea blite S*uaeda linearis*
   - Glasswort *Salicornia* spp.
   - Marsh orach *Atriplex patula*
   - Silverweed *Potentilla anserine*
   - Marsh pink *Sabatia* spp.
   - Seaside gerardia *Agalinis maritime*
   - Annual salt marsh fleabane *Pluchea purpurascens*
   - Seaside arrow grass *Triglochin maritimum*
   - Saltwort *Salsola kali*
   - Marsh fleabane *Pluchea odorata*

Shrubs

Woody vegetation less than 7 m in height usually with multiple stems.

Sub-forms:

1. Low compact shrubs (generally less than 1.5 m tall, with dense foliage
   - Marsh elder *Iva frutescens*
   - Sea myrtle *Baccharis halimifolia*
   - Sweet gale *Myrica gale*

Trees

Woody plants 7 m or greater in height having a single main stem.

Sub-forms:

1. Deciduous trees:
   - Black willow *salix nigra*
   - Alder *Alnus* spp.
   - Red maple *Acer rubrum*
   - Black gum *Nyssa sylvatica*
   - Trembling aspen *Populus tremuloides*
   - Black oak *Quercus velutina*
   - Black cherry *Prunus serotina*
2. Coniferous trees:
   - American white cedar *Chamaecyparis thyoides*
   - Pitch pine *Pinus rigida*
   - Eastern red cedar *Juniperus virginiana* Vines

Woody plants or herbaceous plants that intertwine around stems of other plants.

Sub-form:

1. Vines
   - Common dodder *Cuscuta gronovii*

Use of this component in a wildlife habitat assessment

The presence of these salt marsh vegetation forms and sub-forms may have most utility when assessing habitat value for a particular wildlife species for which specific vegetative habitat requirements are known. In this case, the optimal vegetation type for that species would be given more weight in the overall assessment. Alternatively, greater relative value could be placed on the presence of a number of vegetative life forms and sub-forms when assessing habitat value for overall wildlife species diversity.

VI. Salt Marsh Vegetative Heterogeneity

New England salt marshes are typified by regular zonation among bands of differing species of emergent vegetation (Miller and Egler 1950, Neiring and Warren 1980). Much of the vegetative heterogeneity in salt marshes arises from the interspersion of different sub-forms of emergent vegetation. However, to a lesser degree emergent vegetation is interspersed with other forms of vegetation, for example shrubs on the marsh-upland edge, and with water, as at the edge of tidal creeks and pools. In this sense, vegetative heterogeneity in salt marshes can be represented by the abundance and diversity of vegetative edge habitats (Table 3). We define salt marsh vegetative edge habitat as the interface between two adjacent vegetative life forms, or between a vegetative life form and a marsh habitat type.

A currently held paradigm in conservation biology is that wildlife species diversity increases with increasing number of types of edge habitat, inasmuch as increases in edge habitat represent an increase in habitat heterogeneity (Ries and Sisk 2004, Ries *et al.* 2004, Cramer and Willig 2005). Edge habitat may also be beneficial to some species by providing increased prey abundance and diversity (Whaley and Minello 2002, Albrecht 2004, Horn *et al.* 2005). However, some studies have shown that habitat edge may be detrimental, for example to breeding birds by exposing nests to predation and parasitism (Batary and Baldi 2004, Wolf and Batzli 2004, Fletcher 2005).

Several species of breeding birds, including waterfowl, marsh wren, and clapper rail will utilize the marsh/upland edge, possibly to take advantage of increased foraging opportunities (Gibbs *et al.* 1992, Eddleman and Conway 1998, Drilling *et al.* 2002). Foraging species may use marsh/water edge habitat, and this edge may also be of value as protection from exposure for wintering waterfowl. Tidal creek edge may be important for sharp-tailed sparrows and clapper rails (DeRagon 1988, Eddleman and Conway 1998).

While a majority of the vegetative heterogeneity in salt marshes arises from the interspersion of different sub-forms of emergent vegetation, we have seen little evidence either in the literature or anecdotally of use of this edge by wildlife species. Emergent plants species are often interspersed in New England marshes, and when present in monotypic stands the borders between species can be irregular and indistinct. This along with the similar physical structure of the plants in different emergent zones may diminish habitat value. We therefore omit emergent/emergent edge from consideration, and propose three life form edges (**emergent/shrub, emergent/tree, and shrub/tree**) as possibly enhancing salt marsh wildlife habitat value. The emergent/shrub and shrub/ tree edges will typify the marsh/upland edge in New England salt marshes, and may provide habitat value for some avian species when present. We also add two life form / habitat type edges (**emergent/open water, emergent/tidal flat**) that were identified as being important for foraging birds (Table 3). Three categories of salt marsh vegetative heterogeneity are derived from the presence of these 5 types of habitat edge (Figure 5):

1.) **High heterogeneity**: 5 habitat edges present (Figure 5a)

2.) **Moderate heterogeneity**: 3 or 4 habitat edges present (Figure 5b)

3.) **Low heterogeneity**: 1 or 2 habitat edges present (Figure 5c)

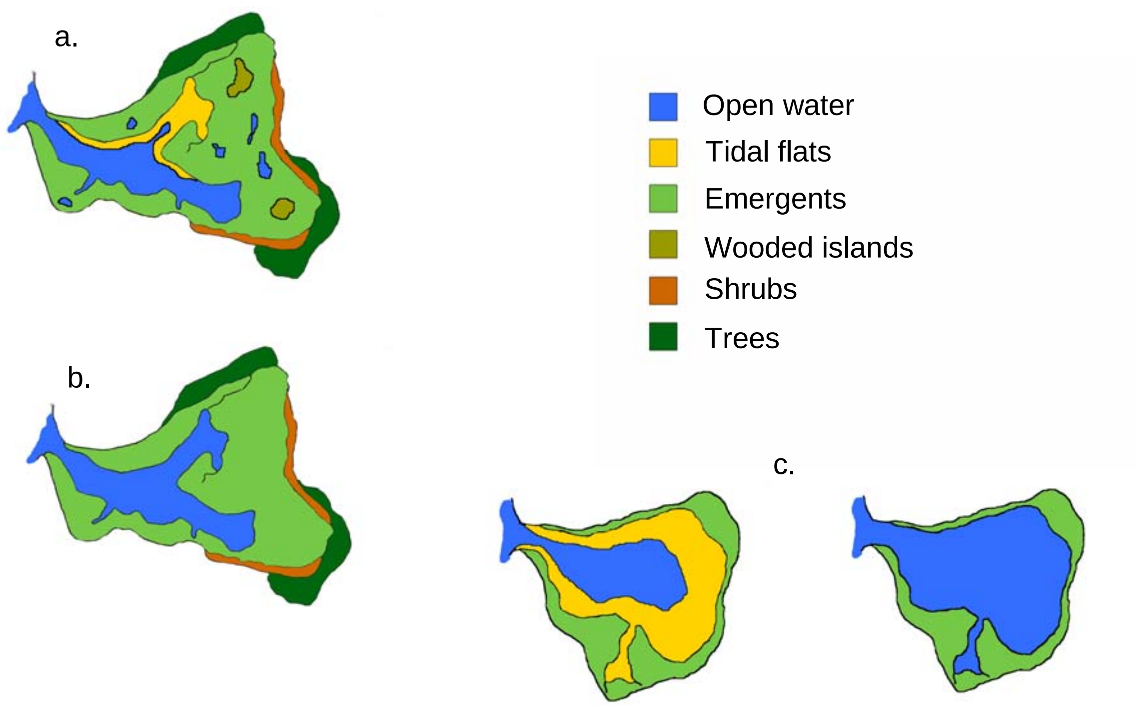
Use of this component in a wildlife habitat assessment

New England salt marshes with greater vegetative heterogeneity would be expected to have greater wildlife habitat value. In an assessment of habitat value, this could be reflected in a weighting of the categories with high heterogeneity having the greatest value and low heterogeneity the least value. However, we caution when assessing habitat value for a single species or guild of species, habitat heterogeneity may not be as important as the presence of one or more favorable habitat types for the species of concern.

VII. Surrounding Land Cover and Land Use

The importance of surrounding habitat type to wetland wildlife value has been hypothesized for many years. Early work demonstrated the importance of adjacent natural habitat for a number of species that

Figure 5. Occurrence of varying degrees of vegetative heterogeneity in New England salt marshes



. **a)** High habitat heterogeneity: 5 habitat edges present, **b)** moderate habitat heterogeneity: 3 or 4 habitat edges present; **c)** low habitat heterogeneity: 1 or 2 habitat edges present.

prefer upland foraging and nesting sites. For example, waterfowl often depend on the presence of suitable upland habitat adjacent to wetlands for nest sites and for roosting (Baldassarre and Bolen 1994). Great blue herons and great egrets will preferentially use large canopy hardwood trees adjacent to salt marsh foraging habitat for roosting and occasionally nesting (Hancock and Kushlan 1984, Butler 1992). Several species, including glossy ibis *Plegadis falcinellus* and red-winged blackbirds will preferentially use salt marshes that are adjacent to agricultural land because of increased availability of food (Davis and Kricher 2000, Trocki 2003).

Recent studies in the landscape ecology of wetlands have demonstrated the importance of the complexity and degree of disturbance of surrounding habitat (Freemark *et al.* 1995, Riffell *et al.* 2003). The negative effects of urbanization and alteration of adjacent uplands on wildlife has been demonstrated for both inland and coastal marshes (DeLuca *et al.* 2004, Shriver *et al.* 2004, Traut and Hostetler 2004). In urban settings, natural lands bordering salt marshes may have a buffering effect and may be important in mitigating the effects of human disturbance.

Information about the proportion of land-use types in a buffer around a salt marsh can be used to classify the landscape setting of the marsh. The size of the buffer will depend both on the scale of the intended assessment (*e.g.*, regional comparisons over large geographic areas versus local studies) and the species under consideration. For a study at the scale of a typical bay or estuary, we suggest quantifying the proportion of land-use types in a 150 m buffer around the marsh (Carslisle *et al* 2004, McKinney *et al.* 2006). We propose nine land use types aggregated into 4 broad categories for the assessment. These land use types include generally accepted land cover categories that have been identified by or included in previous classifications (*e.g.*, Anderson 1976). In assessing the value of landscape setting, we recognize that 1) salt marshes bordered by forested, open or other wetlands are more valuable to wildlife; 2) depending on the species, agricultural or certain maintained open lands may be of wildlife habitat value; and 3) salt marshes bordered by developed lands will be less valuable as wildlife habitat.

Northern Water snake *Nerodra sipedon sipedon*
(Photo by Gary Stoltz, US FWS).

The nine land-use types are:

Open water
Land-use type:
1)Water: marine sub-tidal habitat

Natural land
Land-use types:
2) Forest: deciduous forest, coniferous forest, brushland
3) Wetland
4) Barren land: beaches, sandy areas, rock outcrops

Maintained open land

Land-use types:

5) Urban or built-up land: power lines developed recreation, cemeteries, vacant land
6) Agricultural land: row crops, pasture, orchards, cranberry bogs, confined feeding operations, idle agriculture
7) Maintained open land: strip mines, quarries, gravel pits, power lines

Developed land

Land-use types:

8) Disturbed open land: commercial and industrial land, airports, rail line, roads and highways, railroads, freight, storage, stadiums, water and sewage treatment, waste disposal facilities, marinas
9) Residential land: single or multi-family homes, areas of high population density characterized by multi-dwelling apartment buildings

Use of this component in a wildlife habitat assessment

In an assessment of wildlife habitat value, landscape setting, or an assessment of surrounding land use, could influence salt marsh habitat quality with urbanization and human alteration of adjacent uplands thought to have a negative effect and surrounding natural lands a mitigating or positive influence on habitat quality. This could be reflected in an assessment by calculating the proportion of developed versus natural lands and open water and assigning a rank or score to a marsh accordingly, with for example marshes with a higher proportion of natural land being ranked above those with a greater proportion of developed land. The "maintained open lands" category would be assessed relative to the species under consideration, but in general this category would be expected to have a relative value between that of developed and natural lands.

VIII. Connectivity and Associated Habitat

During the past decade, wildlife–habitat studies have begun to encompass larger spatial and temporal scales (Edwards *et al.* 1994, Morrisey 1996). Ecologists continue to formalize the importance of both landscape structure (the patterns of habitat density, distribution, shape and size) and landscape connectivity, or the functional relationship between adjacent habitats arising from their spatial distribution and the movement of organisms (With *et al.* 1997). This emphasis and resulting studies serve to reinforce the long-held hypothesis that a wetland's value as wildlife habitat is greater if it is located near other wetlands, and that its value increases with the degree of connectivity to and complexity of associated wetlands. There are many examples of connectivity and the availability of associated natural habitats enhancing a wetland's habitat value, particularly for avian species. Specific examples for salt marsh fauna include use of adjacent foraging areas away from nest sites (Ramo and Busto 1993, Bryan *et al.* 1995, Smith 1995), post-breeding movements (Rotella and Ratti 1992, Mauser *et al.* 1994), and movements within migration and winter sites (Goss-Custard and Durell 1990, Rehfisch *et al.* 1996, Farmer and Parent 1997).

The following categories of associated habitat are of potential value to salt marsh wildlife (Table 3):

1) Sand or cobble beach
2) Coastal dunes or overwash
3) Other salt marsh wetland
4) Brackish wetland or pond
5) Freshwater wetland or pond
6) Upland meadow
7) Upland forest

The presence of these habitat types in close proximity (*e.g.*, within a 150 m buffer) to a salt marsh will enhance connectivity and facilitate movements between salt marsh and associated habitats (Haig *et al.* 1998).

Use of this component in a wildlife habitat assessment

As with landscape setting of a marsh, the presence of associated habitat types could influence salt marsh habitat quality. In a general sense, the presence of associated habitats (*i.e.*, greater landscape heterogeneity) is thought to have a positive influence on habitat quality and hence would increase wildlife habitat value. To include salt marsh habitat type in an assessment of wildlife habitat value of New England salt marshes, one could assign a relative value to the presence of each associated habitat, or assign a value to a marsh based on the number of associated habitats. How these components are ranked or scored could depend on the goal of the assessment and the specific habitat requirements of the species under consideration. Alternatively, if the goal is to assess salt marsh habitat for maximum species diversity, the presence of many associated habitats within a 150 m buffer surrounding the marsh would be emphasized.

Conclusions

This report provides a summary of wildlife (*i.e.*, birds, mammals, amphibians, and reptiles) found in New England salt marshes and some of their respective habitat requirements. The wetland and landscape components in the report describe some aspects coastal wetlands and their associated habitats, and form the basis of a framework to assess wildlife habitat value of New England salt marshes.

An assessment of salt marsh wildlife habitat function will require data on the extent of the various components listed in this report. While much of this data can be gleaned from the analysis of remote sensing data such as aerial photos, some level of field work will be required to determine the occurrence of salt marsh

Great blue heron *Aldea herodias*
(Photo by Lee Karney, US FWS).

habitat types and the extent of vegetative heterogeneity. Alternatively, this data can come from existing salt marsh assessment protocols (*e.g.*, Carlisle *et al.* 2004) that have a field component.

In any assessment, the actual weighting of the various components and a component's relative contribution will depend upon the species and habitat under consideration and the stakeholder intent. For example, distinct requirements of species under consideration should be reflected in the assessment by emphasizing the wetland and landscape components that encompass those requirements. Special weighting for rare species or those of local, regional, or national interest, and rare habitats (those that are not commonly found in a region) should also be considered. Once completed, a salt marsh wildlife habitat assessment could be used as a guide for protective, restorative, and mitigation efforts for New England salt marshes.

The overall value of a wetland is dependent not only upon wildlife use and support but also on the provision of many other ecosystem services (*e.g.*, water quality maintenance, erosion control and flood abatement, recreation and aesthetics). Other socioeconomic and ecological factors that are not covered in this report may also be important and enhance ecosystem services provided by New England salt marshes. In addition to wildlife habitat value, consideration of special or needed services (*e.g.*, educational or recreational resources; water quality maintenance; flood abatement) will be an important part of developing an overall salt marsh evaluation model.

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Appendix 1. Habitat use, occurrence, and primary prey of birds that utilize New England salt marshes.

Common Name	Species	Habitat Type[1]	Occurrence[2]	Prey[3]	Reference[4]
Breeders					
American oystercatcher	*Haematopus palliates*	TF, HM, MB	O, S	Invertebrates (seeds)	AT,AU
Clapper rail	*Rallus longirostris*	TF, LM, HM	O, S	Crustaceans (fish)	T
Common tern	*Sterna hirundo*	SW, TF, HM, MB	O, S	Fish (crustaceans)	BF,BG
Killdeer	*Charadrius vociferous*	TF, LM, PL, PN	O, S	Invertebrates (seeds)	U
Laughing gull	*Larus atricilla*	SW, TF, HM, MB	O, S	Invertebrates (fish)	BO,BP,BQ,BR
Least bittern	*Ixobrychus exilis*	SW, TF, HM, MB, PH	O, S	Fish (insects)	V
Mallard	*Anas platyrhynchos*	SW, LM, HM, PL	F, Y	Vegetation	W,X,Y,Z,AA
Marsh wren	*Cistothorus palustris*	TF, HM, MB, PH	O, S	Invertebrates	AB
Mute swan	*Cygnus olor*	SW, LM, HM, MB, PH	F, Y	Vegetation	AC,AD,AE
Red-winged blackbird	*Agelaius phoeniceus*	LM, HM, WI, MB, PH	F, S	Insects	AF
Salt marsh sharp-tailed sparrow	*Ammodramus caudacutus*	LM, HM	F, S	Insects (seeds)	AG,AH
Seaside sparrow	*Ammodramus maritimus*	LM, HM	O, S	Insects (seeds)	AG,AI
Swamp sparrow	*Melospiza georgiana*	LM, HM, MB	O, S	Seeds (invertebrates)	AJ,AK
Virginia rail	*Rallus limicola*	TF, LM, HM	O, S	Invertebrates (seeds)	AL,AM
Willet Catoptrophoru	*semipalmatus*	TF, LM, HM, PL, PN	O, S	Crustaceans (insects)	AN,AO
Foragers					
American black duck	*Anas rubripes*	SW, LM, PL	F, W	Vegetation	R, S
American coot	*Fulica Americana*	SW	O, W	Vegetation (seeds)	AP,AQ
American crow	*Corvus brachyrhynchos*	LM, HM	O, Y	Invertebrates (seeds)	AR
American goldfinch	*Carduelis tristis*	HM, MB, PH	O, S	Seeds (insects)	AS
American robin	*Turdus migratorius*	HM, MB	O, Y	Invertebrates (seeds)	AV
American wigeon	*Anas americanus*	SW, LM	O, W	Vegetation (seeds)	DD
Bald eagle	*Haliaeetus leucocephalus*	LM, HM, MB	O, Y	Fish (birds, mammals)	AW
Bank swallow	*Riparia riparia*	LM, HM, MB, PH	O, S	Insects	CF
Barn swallow	*Hirundo rustica*	LM, HM, MB, PH	O, S	Insects	CG
Belted kingfisher	*ceryle alcyon*	SW, LM, HM, MB	O, Y	Fish (invertebrates)	AX,AY,AZ
Black-bellied plover	*Pluvialis squatarola*	TF, LM	O, Y	Invertebrates (bivalves)	BA,BB
Black-crowned night heron	*Nycticorax nycticorax*	SW, TF, LM, HM, PL, WI	F, S	Fish (crustaceans)	C,D,K,N
Blue-winged teal	*Anas discors*	SW, TF, LM	O, W	Invertebrates (seeds)	DE

Appendix 1. Habitat use, occurrence, and primary prey of birds that utilize New England salt marshes (Cont'd).

Common Name	Species	Habitat Type[1]	Occurrence[2]	Prey[3]	Reference[4]
Bonaparte's gull	*Larus philadelphi*	SW, TF	O, Y	Fish (invertebrates)	BC
Brant	*Branta bernicla*	SW, TF, LM	O, W	Vegetation	DJ
Canada goose	*Branta canadensis*	SW, LM, HM	O, Y	Vegetation	DG
Cattle egret	*Bubulcus ibis*	SW, TF, LM, HM, PL	O, M	Fish (invertebrates)	BD
Cedar waxwing	*Bombycilla cedrorum*	MB	O, Y	Fruit (insects)	CH
Chimney swift	*Chaetura pelagica*	HM, MB	O, S	Insects	CI
Common grackle	*Quiscalus quiscula*	LM, HM, MB, PH	O, Y	Insects (seeds)	BE
Common yellowthroat	*Geothylpis trichas*	MB	O, S	Insects	BH
Double-crested cormorant	*Phalacrocorax auritus*	SW	O, Y	Fish	BI
Dunlin	*Calidris alpina*	SW, TF	O, W	Invertebrates	CL,CM,CN
Eastern kingbird	*Tyrannus tyrannus*	HM, MB	O, S	Insects (fruit)	CJ
European starling	*Sturnus vulgaris*	LM, HM, MB, PH	O, Y	Invertebrates (insects)	BJ
Fish crow	*Corvus ossifragus*	LM, HM	O, Y	Invertebrates (seeds)	BK
Glossy ibis	*Plegadis falcinellus*	SW, HM, PL	F, S	Invertebrates	E
Gray catbird	*Dumetella carolinensis*	MB	O, Y	Insects (fruit)	BL
Great black-backed gull	*Larus marinus*	SW, TF	O, Y	Fish (invertebrates)	BM
Great blue heron	*Aldea herodias*	SW, TF, LM, WI	F, S	Fish	A,B,G,K,N,Q
Great egret	*Egretta alba*	SW, TF, LM, HM, PL	F, S	Fish (crustaceans)	B,C,G,K,L,Q
Great horned owl	*Bubo virginianus*	LM, HM, MB	O, Y	Mammals (birds)	CT
Greater yellowlegs	*Tringa melanoleuca*	SW, TF, LM, PL	F, S	Invertebrates (Small fish)	H,P
Green heron	*Butorides virescens*	SW, TR, PL	F, S	Fish	F,N
Green-winged teal	*Anas crecca*	SW, TF, LM	O, W	Invertebrates (seeds)	DF
Herring gull	*Larus argentatus*	SW, TF	O, Y	Fish (invertebrates)	BN
House sparrow	*Passer domesticus*	LM, HM, MB, PH	O, Y	Fish (invertebrates)	BS
Least sandpiper	*Calidris minutilla*	TF, LM	O, M	Invertebrates	CO,CP
Least tern	*Sterna antillarum*	SW, TF	O, S	Fish (invertebrates)	BT
Lesser yellowlegs	*Tringa* spp.	SW, TF, LM, PL	F, S	Invertebrates (Small fish)	H,P
Little blue heron	*Egretta caerulea*	SW, TF, PL	O, S	Fish (crustaceans)	G,I,K,N,O,Q
Mourning dove	*Zenaida macroura*	LM, HM, MB	O, Y	Seeds	BU
Northern cardinal	*Cardinalis cardinalis*	HM, MB, PH	O, Y	Seeds (insects)	BV
Northern flicker	*Colaptes auratus*	MB	O, Y	Insects (seeds)	BW
Northern harrier	*Circus cyaneus*	LM, HM, MB	O, W	Mammals (birds)	CU,CV

Northern mockingbird	*Mimus polyglottos*	HM, PN, MB	O, Y	Insects (seeds)	BX,BY
Northern pintail	*Anas acuta*	SW, LM	O, W	Vegetation (Invertebrates)	DH
Osprey	*Pandion haliateus*	SW	O, S	Fish	CW
Red-shouldered hawk	*Buteo lineatus*	HM, MB	O, Y	Mammals (birds)	CX
Red-tailed hawk	*Buteo jamaicensis*	HM, MB	O, Y	Mammals (birds)	CY
Rough-legged hawk	*Buteo laopus*	HM, MB	O, Y	Mammals (birds)	CZ,DA
Ring-necked duck	*Anas collaris*	SW	O, W	Seeds (invertebrates)	DI
Ring-necked pheasant	*Phasianus colchicus*	HM, MB	O, Y	Seeds (vegetation)	CA
Sanderling	*Calidris alba*	SW, TF	O, W	Invertebrates (bivalves)	CR
Semipalmated plover	*Calidris semipalmatus*	TF	O, M	Invertebrates	CB
Semipalmated sandpiper	*Calidris pusilla*	TF, LM	O, M	Invertebrates	CQ
Short-eared owl	*Asio flammeus*	LM, HM, MB	O, Y	Mammals (birds)	DB
Snowy egret	*Egretta thula*	SW, TF, LM, HM, PL	F, S	Fish (crustaceans)	B,C,G,K,M,Q
Snowy owl	*Nyctea scandiaca*	LM, HM, MB	O, W	Mammals (birds)	DC
Song sparrow	*Melospiza melodia*	LM, HM, MB	O, Y	Seeds (insects)	CC
Sora	*Porzana carolina*	LM, HM	O, M	Seeds (invertebrates)	CS
Spotted sandpiper	*Actitus macularia*	SW, TF	O, S	Invertebrates (fish)	CD
Tree swallow	*Tachycineta bicolor*	LM, HM, MB, PH	O, S	Insects	CK
Yellow-crowned night heron	*Nyctanassa violacea*	SW, TF, LM, HM, PL, WI	F, S	Crustaceans	C,K,N,R,CE

[1]SW = shallow water; TF = tidal flats; LM = low marsh; TR = trees overhanging water; HM = high marsh; PL = marsh pools; PN = pannes; WI = wooded islands; MB = marsh-upland border; PH = phragmites.

[2]F = frequent; O = occasional; S = summer (breeding); W = winter (non-breeding); M = fall/spring migration; Y = year-round

[3]Primary prey (secondary prey in parentheses).

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Appendix 2. Habitat use, home range, and primary prey of mammals, amphibians, and reptiles that utilize New England salt marshes.

Common Name	Species	Habitat Type[1]	Home Range	Prey[2]	Reference[3]
Black-tailed jackrabbit	*Lepus californicus*	HM, WI, MU	20 – 140 ha	Forbs, succulents	B,G
Eastern cottontail	*Sylvilagus florianus*	HM, MU	0.9 – 2.8 ha	Forbs (grasses)	F
Least shrew	*Cryptotis parva*	HM, MU	170 – 280 ha	Insects (crustaceans)	AE
Masked shrew	*Sorex cinereus*	HM, MU	--	Insects	--
Raccoon	*Procyon lotor*	LM, HM, PL, MU	49 ha	Invertebrates	Q,Z
Virginia opossum	*Didelphis virginiana*	HM, MU	4.65 – 23.5 ha	Insects (carrion)	I,P,S
White-tailed deer	*Odocoileus virginianus*	HM, WI, MU, PG	59 – 520 ha	Grasses (forbs)	R,X
Coyote	*Canis latrans*	LM, HM, WI, MU, PG	1000 – 4900 ha	Small mammals (crustaceans)	A
Fisher	*Martes pennanti*	SW, TF, LM, HM	900 – 1300 ha	Small mammals (birds)	T
Long-tailed weasel	*Mustela frenata*	LM, HM, WI, MU	16 – 160 ha	Small mammals (birds)	W
Mink	*Mustela vison*	SW, TF, LM, HM	600 – 5600 ha	Fish (small mammals)	J,L
Red fox	*Vulpes vulpes*	LM, HM, WI, MU, PG	1450 – 2000 ha	Birds (fish)	K,M
River otter	*Lontra canadensis*	SW, TF, LM	--	Fish (crustaceans)	N,O
Striped skunk	*Mephitis mephitis*	HM, MU	200 ha	Insects (small mammals)	AB,AC
Meadow jumping mouse	*Zapus hudsonius*	LM, HM, PL, MU, PG	0.1 – 0.4 ha	Forbs (insects)	AD
Meadow vole	*Microtus pennsylvanicus*	HM, MU	0.01 – 0.4 ha	Grasses (forbs)	U,V
Muskrat	*Ondatra zibethicus*	SW, TF, LM	50 – 200 ha	Aquatic plants (fish)	AF
New England cottontail	*Sylvilagus transitionalis*	HM, MU	50 – 200 ha	Aquatic plants (fish)	E,H
Norway rat	*Rattus norvegicus*	HM, MU	7.8 ha	Forbs (small mammals)	C
Woodland vole	*Microtus pinetorum*	HM, MU	1.1 ha	Grasses (forbs)	D,Y
Common snapping turtle	*Chelydra s. serpentine*	TF, LM	--	Insects (crustaceans)	AG
Diamondback terrapin	*Malaclemys t. terrapin*	LM, HM	--	Crustaceans (insects)	AH
Green frog	*Rana clamitans melanota*	SW, TF	0.01 ha	Insects (crustaceans)	AI
Northern water snake	*Nerodra s. sipedon*	SW, TF, LM, MU, PG	--	Amphibians (fish)	AH
Painted turtle	*Chrysemys picta*	HM, WI, MU	--	Insects (crustaceans)	AG
Spotted turtle	*Clemmys guttata*	SW, HM, MU	--	Gastropods (insects)	AG

[1] SW = shallow open water; TF = tidal flats; LM = low marsh; TR = trees overhanging water; HM = high marsh; PL = marsh pools; PA = pannes; WI =wooded islands; MU = marsh-upland border; PG = phragmites.

[2] Primary prey (secondary prey in parentheses).

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