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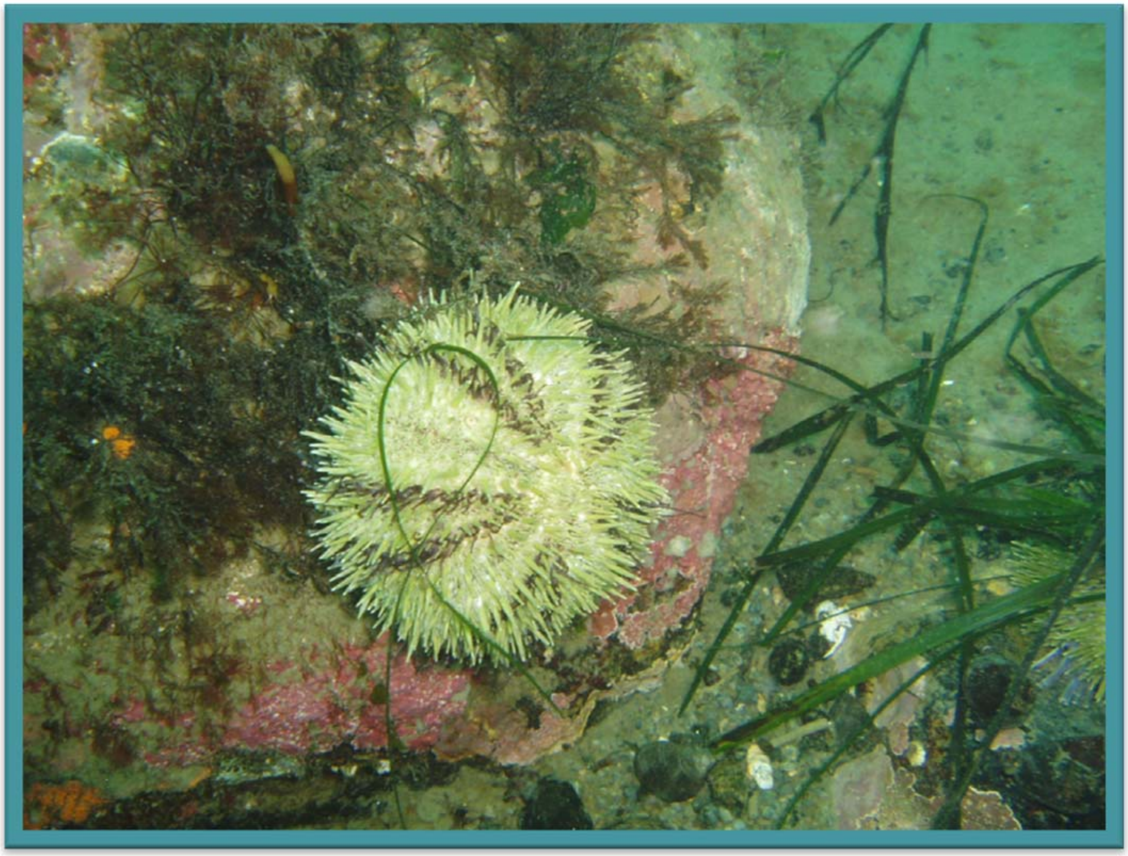

Shallow Water Benthic Habitats in the Gulf of Maine:
A Summary of Habitat Use by Common Fish and Shellfish Species in the Gulf of Maine

David K. Stevenson
Susan Tuxbury
Michael R. Johnson
Christopher Boelke

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Abstract

Shallow-water estuarine and coastal marine habitats in the Gulf of Maine comprise some of the most productive habitats in the northeastern United States and have been identified as Essential Fish Habitat (EFH)[1] for many species of importance to commercial and recreational fisheries. However, these near-shore habitats are also the most vulnerable to human disturbances due to their proximity to coastal population centers. The purpose of this report is to describe the importance of shallow-water habitats (0-10 meters) for spawning, feeding, and growth to maturity for 16 fish and invertebrate species in the Gulf of Maine based on a literature review. The species include a mix of federally managed fishery species, state-managed fishery species and other species that are important members of the shallow-water marine ecosystem. Habitat use was assessed for individual life history stages of each species in eight shallow-water benthic habitats: mud, sand, gravel/cobble, boulder, eelgrass, macroalgae, salt marsh channels, and shellfish beds. Habitat use scores (0 = absent, 1 = present, and 2 = common or abundant) were assigned to each benthic life stage of each species known to occur in depths less than 10 meters. Scores were then summarized for all species in each habitat type. According to this evaluation, shallow-water habitats in the Gulf of Maine are used by young-of-the-year juveniles of all 16 species. Additionally, older juveniles of 12 species and adults of 11 species also rely on these habitats. Nine of the sixteen species spawn in one or more of these habitats. Further analysis shows that sand and gravel/cobble habitats are used by the most species and life stages, followed by mud, eelgrass, macroalgae, boulder, salt marsh channels, and shell (mussel) beds. Shallow-water habitats in the Gulf of Maine provide valuable ecological services for a variety of species. Mud, sand, gravel/cobble, and vegetated habitats are particularly important as juvenile nursery grounds for species such as Atlantic cod, Atlantic tomcod, American lobsters, winter flounder, soft-shell clams, and blue mussels.

[1] As defined under the Magnuson-Stevens Act §3(10)

Introduction

Shallow-water coastal, marine, and estuarine habitats are extremely important for a variety of fish and invertebrate species in the Gulf of Maine (GOM). Because of their shallow depths, seasonally warm water temperatures, and proximity to nutrients derived from river runoff, these habitats are highly productive. They also serve as nursery grounds for juvenile life stages of many valuable commercial and recreational species. In some cases, these habitats also provide suitable conditions for reproduction. The growth and survival of fish in these shallow-water habitats is enhanced if they have access to shelter and refuge from predators and a plentiful food supply, such as smaller fish or invertebrates (Diaz *et al.* 2003, Scharf *et al.* 2006). Because of their proximity to the coast, these shallow-water habitats are more vulnerable to degradation and loss resulting from a variety of human activities than deep water marine habitats.

The 1996 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act, also known as the Sustainable Fisheries Act (SFA), changed the focus of the law by emphasizing the importance of habitat protection to healthy fisheries and by strengthening the ability of the National Marine Fisheries Service (NMFS) and the regional fishery management councils to protect and conserve the essential fish habitat (EFH) of marine, estuarine, and anadromous finfish, mollusks, and crustaceans from the adverse effects of fishing. The SFA also requires federal agencies to consult with NMFS on any activity proposed, authorized, funded, or undertaken that may adversely affect EFH. NMFS is required to provide recommendations on ways to avoid, minimize, or mitigate those adverse effects. EFH is broadly defined to include "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

The purpose of this report is to identify GOM species and life stages that use shallow-water marine and estuarine habitats threatened by human impacts, and to evaluate the importance of these habitats for those species. This information is intended to enhance the permit application and review process for activities that could adversely affect the quality and quantity of inshore habitats that support productive marine fishery resources. The Habitat Conservation Division at NOAA's Greater Atlantic Regional Fisheries Office (formerly Northeast Regional Office) relies on the type of information in this report to assess the potential impacts of proposed projects and to provide advice on measures that would avoid or minimize such impacts. This report is particularly valuable because it provides information on habitat use by young-of-the-year juvenile fish that is not readily available elsewhere.[2]

Methods

The emphasis of this report is on habitat used by commercially important species and some of their common prey species in the GOM. The geographical region considered is this report is the GOM inclusive of all coastal waters from Cape Cod Bay, Massachusetts to the U.S.-Canada boundary in the Bay of Fundy. Anadromous species (e.g., river herring, rainbow smelt) and pelagic species (e.g., bluefish) were not included because they are much less dependent on

[2] The current EFH descriptions in the Greater Atlantic region define juveniles as individuals that have not yet reached sexual maturity. For many species, the disparity in size and habitat use between young-of-the-year and older juveniles is quite large. Cod, for example, reach about 10-15 cm in length by the time they are one year old and do not mature until age 2 or 3, when they are approximately 40-45 cm in size and have migrated to deeper, offshore water.

the availability of suitable benthic habitat. Sixteen species known to inhabit shallow-water habitats at some point during their life history were selected. All the selected species (Table 1) have at least one benthic life history stage. Six species are managed federally by the New England Fisheries Management Council (NEFMC), four by the Atlantic States Marine Fisheries Commission (ASMFC), and one jointly by the NEFMC and the ASMFC. Additionally, five other species were included because they are important prey species (e.g., sand lance) or provide habitat for other managed species (e.g., mussels). We limited our analysis to these 16 species because they are representative of other species that use the same habitats. Management measures designed to conserve habitats used by these species will benefit other species as well.

Table 1. List of species included in this evaluation with corresponding management authorities

Species	Scientific name	Federal Management Authority (NEFMC)	State Management Authority (ASMFC)	Non-managed (e.g., prey) species
American eel	*Anguilla rostrata*		√	
American lobster	*Homarus americanus*		√	
Atlantic cod	*Gadus morhua*	√		
Atlantic tomcod	*Microgadus tomcod*			√
Blue mussels	*Mytilus edulis*			√
Cunner	*Tautogolabrus adspersus*			√
Little skate	*Leucoraja erinacea*	√		
Pollock	*Pollachius virens*	√		
Red hake	*Urophycis chuss*	√		
Sand lance	*Ammodytes americanus*			√
Smooth flounder	*Pleuronectes putnami*			√
Soft-shell clam	*Mya arenaria*		√	
Tautog	*Tautoga onitis*		√	
White hake	*Urophycis tenuis*	√		
Windowpane	*Scophthalmus aquosus*	√		
Winter flounder	*Pseudopleuronectes americanus*	√	√	

We selected 10 meters as the maximum depth of the study area in order to limit the evaluation to the upper sub-tidal zone. At this depth, light penetration is equal to about 20% of the incident light at the sea surface and plant growth is still possible. Strictly speaking, the outer depth limit is relative to mean low water, so when the tide is high, the study area includes depths exceeding 10 meters. Tides along the GOM coast vary from three to seven meters, and are progressively higher from south to north.

The benthic habitat types included in this report are defined by substrate or sediment type, or according to the dominant types of flora or fauna present (biogenic habitats). They correspond to the broad GOM coastal habitat categories described in other publications (see, for example, Tyrell 2005). Benthic habitats examined here consist of featureless mud and sand, gravel/cobble, boulder, eelgrass, macroalgae, and shellfish beds. These benthic habitats are susceptible to alteration and degradation from activities such as dredging, fishing, cable or pipeline laying, pier, jetty, and bridge construction, sand and gravel removal for beach nourishment, etc. More specific information on the characteristics of each habitat type, as defined in this report, is as follows:

Mud – Unvegetated mud bottom in the inter-tidal and upper sub-tidal zones (MHW to -10 m at MLW)

Sand - Unvegetated sand bottom in the inter-tidal and upper sub-tidal zones (MHW to -10 m at MLW)

Gravel/Cobble – Unconsolidated gravel and rocky bottom from MHW to -10 m at MLW, including granules, pebbles, and cobbles with diameters greater than 2 mm to 256 mm (0.08 to 10.1 inches) and associated epifauna and ephemeral algal species such as *Ulva lactuca* and *Porphyra* spp. Larger macroalgae that attach to hard bottom were treated as a separate habitat type.

Boulders – Rocks larger than 256 mm in diameter in the inter- and sub-tidal zones (<10 m at MLW), including boulder reefs and solid rock outcrops (ledge). Associated macroalgae were treated as a separate biogenic habitat.

Eelgrass – Bottom habitats in the lower intertidal and sub-tidal zones with *Zostera marina*, the common species of eelgrass in the GOM. Eelgrass takes root in substrates from coarse sand to mud and even thrives among cobbles and boulders, in small patches of soft sediment, and does not survive in low light conditions.

Macroalgae – Hard bottom macroalgal habitats composed of smaller brown algae such as *Fucus* spp. and *Ascophyllum nodosum* and red algae such as *Phyllophora* spp. in the intertidal and sub-tidal zones, and kelp beds composed of any of three species of brown algae, *Laminaria saccharina*, *Alaria esculenta*, and *Agarum clathratum*.

Salt Marsh Channels – Salt marshes are highly productive, grass-dominated habitats that extend from the lower intertidal zone to the highest high tides with a wide range of salinity. Fringing marshes form narrow bands along protected shorelines and can grow in areas of muddy, sandy, or rocky substrates and are dominated by the tall form of cordgrass (*Spartina alterniflora)*. Salt marsh meadows are broad expanses of vegetation that form in calm areas along the coast, such as behind barrier beaches. They typically have a greater variety of topography and ecological communities than fringing marshes and are incised by channels which allow fish to enter and leave the marsh with the tides. This report evaluates habitat use by fish and shellfish in the tidal creeks and channels, not on the marsh surface itself.

Shellfish Beds – Dense aggregations of the blue mussel *Mytilus edulis*, usually on hard substrates, but also common on mud and sand where they attach initially to small patches of hard substrate and then to each other with byssal threads. Mussel beds are found in the intertidal and upper sub-tidal zone. Oysters also attach to hard substrates in shallow water, but are not very common in the GOM, and scallops are found primarily in depths greater than 10 m.

Rankings of benthic habitat use for the 16 species evaluated in this report were based on a literature review. In some cases, there was no available information and best professional judgment was used to determine a habitat use ranking based on information available on other life stages of the same species and on ecological characteristics. Information for the following five life stages was compiled: 1) eggs; 2) young-of-the-year (YOY) juveniles; 3) older juveniles; 4) adults; and 5) spawning adults. Larvae were not included because they are pelagic. Neither were benthic life stages that do not occupy depths less than 10 meters in the GOM. Of the remaining 80 possible species and life stage (S/LS) combinations (16 species and five life stages per species), 27 were excluded from analysis because they were either pelagic (eggs for eleven species) or benthic life stages (16) that are not found at depths less than 10 meters in the GOM. In the following tables, cells for these 27 S/LS were left blank. Results are presented for the remaining 53 S/LS that could potentially occupy any given benthic habitat type in the GOM at depths less than 10 meters at any time of year.[3]

The following three rankings were used, with a question mark indicating uncertainty in ranking:

0 = benthic life stage does not occur
1 = benthic life stage is present, but not common
2 = benthic life stage is common or abundant

Rankings based on information obtained from literature reviews or otherwise determined with high confidence were differentiated from less certain rankings. In the habitat tables (see Results), the shaded cells indicate uncertain rankings. The results are summarized by habitat type.[4],[5]

The following metrics were used to describe the results for each habitat type:

1. The sum of the scores (0, 1, 2) for all the species and life stages (S/LS) present
2. The number and percentage of S/LS present (scores = 1 or 2)
3. The number and percentage of S/LS absent (score = 0)
4. The number and percentage of S/LS that are common or abundant (score = 2)
5. The number and percentage of S/LS with uncertain scores

In order to relate the results of this assessment to the statutory EFH definition, habitat use was also evaluated in terms of three functional habitat values: survival, growth to maturity, and reproduction (spawning) (Tables 10-12).

[3] The percentages of species present or absent in each habitat were calculated across all benthic life stages in Tables 2-9 as fractions of these 53 S/LS.
[4] The detailed results are appended to the report in text (with literature citations) and summary tables for each species, along with a master list of references.
[5] All rankings and certainty decisions were made by the principal author to provide as much consistency as possible.

Results

For the 16 species evaluated in this report, YOY juveniles are the most commonly occurring life stage in the eight shallow-water habitats included in this report. YOY juveniles for all 16 species are found in at least one of these habitats and many of them occur in multiple habitats. YOY Atlantic cod, for example, are present in all eight habitats, winter flounder in six, and windowpane flounder in five. Other life stages, in decreasing order of occurrence, are older juveniles (12 species), adults (11), spawning adults (9), and eggs (5).

Figures 1 through 4 offer an overall comparison of the use of shallow-water coastal habitats in the Gulf of Maine. Detailed discussion on each habitat type follows.

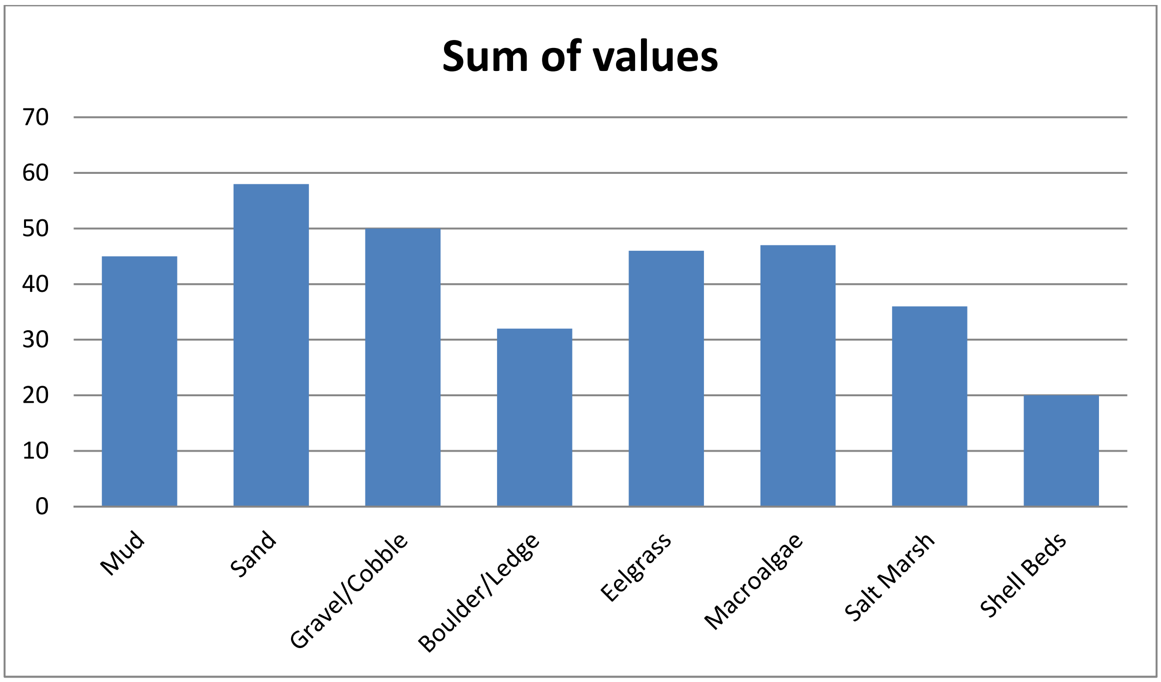

Figure 1. Sum of scores (scores = 0,1,2) for benthic life stages of species inhabiting shallow-water coastal habitats in the Gulf of Maine

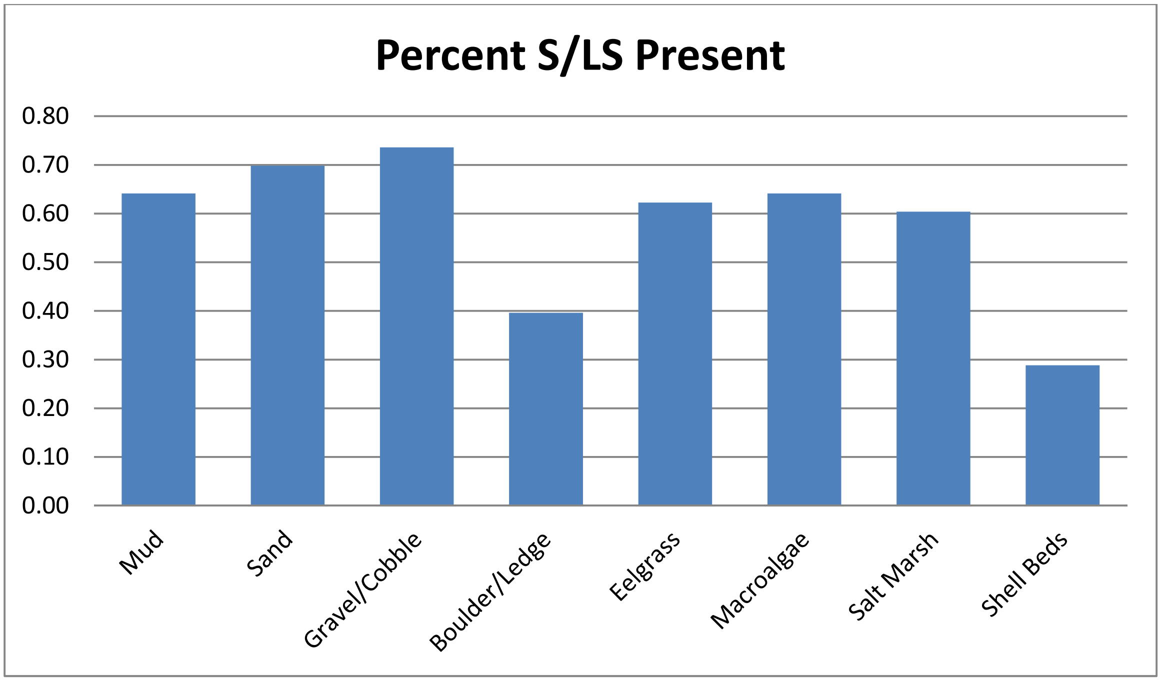

Figure 2. Percentage of species and life stages present (scores = 1 and 2) in shallow-water coastal habitats in the Gulf of Maine

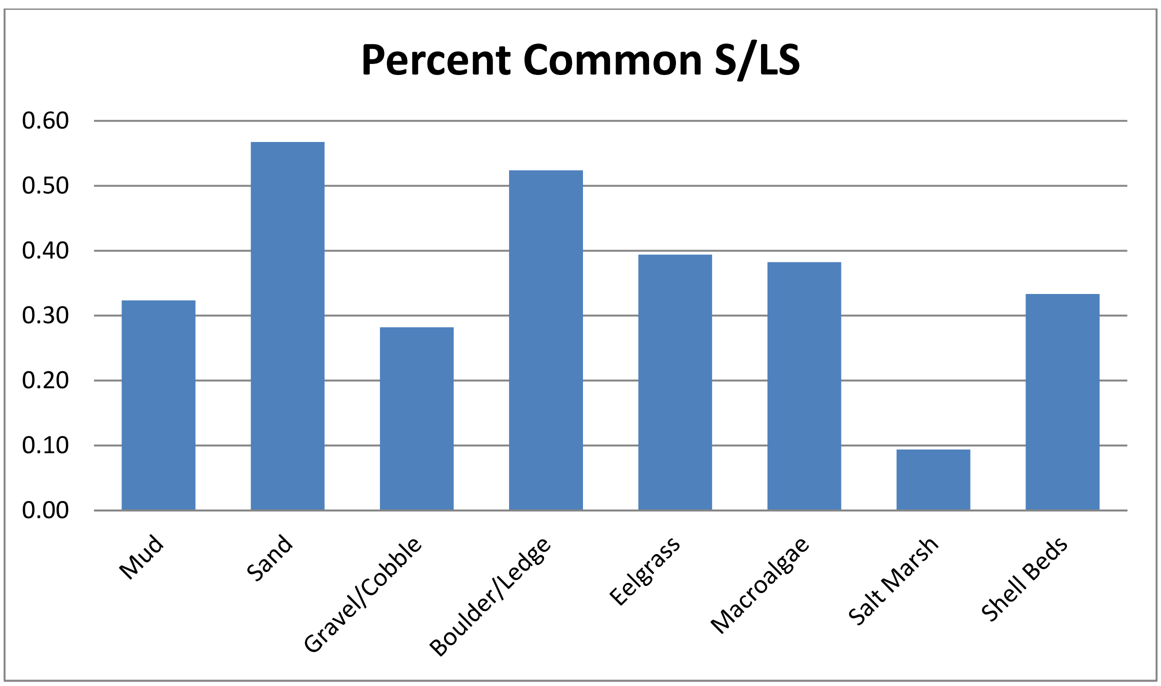

Figure 3. Percentage of common species and life stages present (score = 2) in shallow-water coastal habitats in the Gulf of Maine

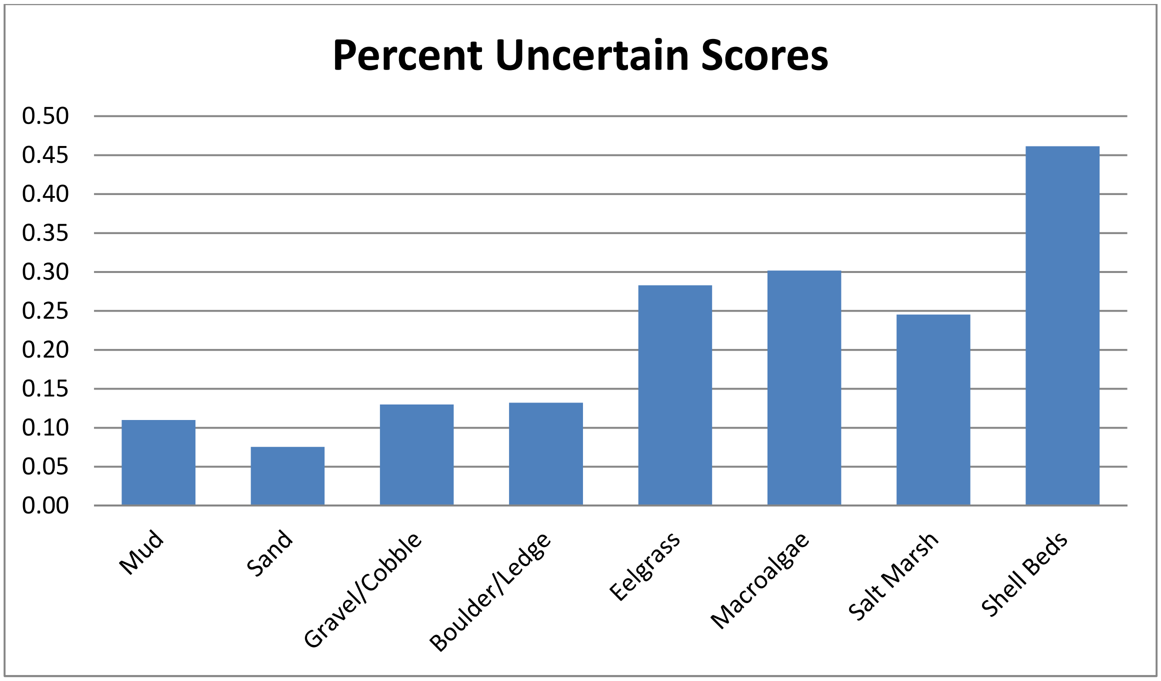

Figure 4. Percentage of uncertain scores for species and life stages (scores = 0, 1 and 2) in shallow-water coastal habitats in the Gulf of Maine

Mud Bottom Habitats

The sum of values for the S/LS that occupy mud bottom habitats was high (45), greater than boulder, salt marsh, and shell beds, but not quite as high as sand or gravel (Fig. 1). Similar results were obtained for the percentage of S/LS present in this habitat type (>60%, Fig. 2). Of those S/LS present, >30% of them were common/abundant (Fig. 3). Very few (11%) of the scores were uncertain (Fig. 4). Across all life stages, smooth flounders and soft-shell clams were the most common species in this habitat, but winter flounders also scored fairly high (Table 2). All three of these species were common as YOY and older juveniles, with smooth flounders and clams also common as adults and spawning adults. Ten other species were present, but not common, in this habitat type as either YOY or older juveniles. The prevalence of infaunal and epifaunal prey species indicates that mud bottom habitats provide food for a variety of species. Given the absence of bottom structure, species that thrive in this habitat either burrow into the bottom (eels, clams) or avoid predators by partially burying themselves (flounders).

Three species were common in unvegetated mud habitat: smooth flounder, winter flounder, and soft-shell clams. All three were common as YOY and older juveniles; smooth flounders and soft-shell clams were also common as adults. Soft-shell clam spawn in this habitat, and it is likely that smooth flounder also spawn in this habitat.

Smooth flounder are restricted to shallow, muddy, inshore habitats and produce demersal eggs. Given their small size and common occurrence in shallow, coastal waters, they are probably an important prey species for many larger fish. Soft-shell clams burrow into sandy mud, but sediments that are too soft are not favorable for settlement and survival (see ***Sand Bottom Habitats***). Intertidal mud flats provide a primary habitat for reproduction and growth of this species, with larvae from one location "seeding" inshore habitats in other locations. Older juvenile and adult lobsters escape predation by burrowing into the mud and, in certain environments, use of these burrows can be extensive.

Shallow, unvegetated mud habitats also are important nursery grounds for juvenile winter flounder. The pelagic larvae are concentrated by currents in low velocity depositional areas with fine sediments (mud and sand), where they settle to the bottom as juveniles. Young-of-the-year juveniles prefer fine-grained sediments for burial in order to escape from predators. In Connecticut estuaries, YOY were more abundant on muddy sediments with debris (shells, wood, and leaves) than on sand. Juvenile winter flounder feed primarily on polychaetes and amphipods that live in soft sediments. Shallow, inshore mud and sand habitats also are used for spawning; the eggs are demersal and adhesive, sticking to a variety of substrates, and are often found on sand, muddy sand, vegetation, and bottom debris, but rarely on open, unvegetated mud bottom. Small winter flounder are also an important prey item for many other species of fish.

Table 2. Occurrence of benthic species and life stages in shallow unvegetated mud habitat in Gulf of Maine coastal waters

	Species	Eggs	YOY Juveniles	Juveniles	Adults	Spawning Adults	All
	American eel		1	1	1		3
	Atlantic cod		1	1			2
	American lobster		0	1			1
	Atlantic tomcod	0	1		1	0	2
	Blue mussels		0	0	0	0	0
	Cunner		0	0	0	0	0
	Little skate	0	1	1	1	0	3
	Pollock		1				1
	Red hake		1				1
	Sand lance	0	1	1	1	0	3
	Smooth flounder	2	2	2	2	2	10
	Soft-shell clam		2	2	2	2	8
	Tautog		0	0	0	0	0
	White hake		1				1
	Windowpane		1	1	1		3
	Winter flounder	1	2	2	1	1	7
A	Sum of values	3	15	12	10	5	45
B	Species present	2	12	9	8	3	34
C	Species absent	3	4	3	3	6	19
D	Common species	1	3	3	2	2	11
E	Uncertain scores	1	3	1	0	1	6
F	Percent species present	0.40	0.75	0.75	0.73	0.33	0.64
G	Percent species absent	0.60	0.25	0.25	0.27	0.67	0.36
H	Percent common species	0.50	0.25	0.33	0.25	0.67	0.32
I	Percent uncertain scores	0.20	0.19	0.08	0.00	0.22	0.11

Blank = not present in shallow water (<10 m) OR life stage is pelagic
0 = present in shallow water (<10 m), but not in this habitat
1 = present, but not common or abundant
2 = common or abundant
Shaded = uncertain score
A = Sum of values in all cells
B = Number of boxes with values >0
C = Number of boxes with value = 0
D = Number of boxes with values of 2
E = Number of shaded values
F = Species present/Species present + species absent
G = Species absent/Species present + species absent
H = Common species/Species present + species absent
I = Number of shaded boxes/Species present + species absent

Sand Bottom Habitats

The sum of values for the S/LS that occupy unvegetated sandy bottom habitats was the highest (58) of all eight of the habitat types evaluated (Fig. 1). The percentage of S/LS present in this habitat type was also high (70%, Fig. 2). Of those S/LS present, almost 60% of them were common or abundant (Fig. 3), ranking sand along with boulder/ledge habitat as having the highest percentage of common or abundant S/LS among all habitat types. Very few (<10%) of the scores were uncertain (Fig. 4). Across all life stages, little skate and sand lance were common at all five life stages, followed closely by soft-shell clams and winter flounder, which were common at four life stages (Table 3). Among all species, YOY juveniles were the most frequently represented life stage. The presence of 12 species as YOY juveniles, with five of them ranked as common or abundant, indicates that this is important nursery habitat. The fact that four species are also common as spawning adults, and that demersal eggs for winter flounder, sand lance, and little skate are commonly found in sand, indicates that shallow, unvegetated, sandy habitats are also used for spawning.

Little skate, sand lance, soft-shell clams, windowpane flounder, and winter flounder were common as YOY juveniles, older juveniles, and adults in featureless sand habitat. All except windowpane flounder spawn in this habitat.[6]

In the GOM, juvenile and adult windowpane flounder are common in shallow-water habitats and prefer sand over mud. Shallow sandy-bottom habitats provide an ideal substrate for soft-shell clams (also see ***Mud Bottom Habitats***), providing favorable conditions for reproduction, survival, and growth. American sand lance – an important prey species for many finfish and marine mammals – burrow in sand to escape predators or rest and lay demersal, adhesive eggs in very shallow (<2 meters) sandy bottom habitats. Little skate also deposit eggs in capsules that stick to sand. In the absence of predators, juvenile Atlantic cod are found over unvegetated fine-grained sediments and feed over sandy bottom at night, but seek shelter from predators during the day in more structured bottom habitats.

GOM shallow-water sandy habitats are primary nursery grounds for juvenile winter flounder. Recently settled juveniles are more likely to occupy medium to coarse-grained sand (mean diameter 0.5 mm) while slightly larger YOY juveniles (>40 mm SL) were more common on coarse sand (up to 1 mm diameter). Juvenile winter flounder feed primarily on polychaetes and amphipods that live in soft sediments. Shallow, unvegetated sand and mud habitats in GOM coastal waters function as important nursery areas for winter flounder, providing shelter from predators (burial) and prey (also see eelgrass). In southern New England and the Mid-Atlantic states, sand appears to be the most common substrate for egg deposition. However, winter flounder in the GOM are reported to spawn primarily in deeper water, not in inshore estuaries.

[6] Windowpane flounder reportedly do not spawn in the Gulf of Maine

Table 3. Occurrence of benthic species and life stages in shallow unvegetated sand habitat in Gulf of Maine coastal waters

	Species	Eggs	YOY Juveniles	Juveniles	Adults	Spawning Adults	All
	American eel		1	1	1		3
	Atlantic cod		1	1			2
	Atlantic tomcod	1	1		1	1	4
	American lobster		0	1			1
	Blue mussels		0	0	0	0	0
	Cunner		0	0	0	0	0
	Little skate	2	2	2	2	2	10
	Pollock		1				1
	Red hake		1				1
	Sand lance	2	2	2	2	2	10
	Smooth flounder	0	0	0	0	0	0
	Soft-shell clam		2	2	2	2	8
	Tautog		1	0	1	0	2
	White hake		1				1
	Windowpane		2	2	2		6
	Winter flounder	2	2	2	1	2	9
A	Sum of values	7	17	13	12	9	58
B	Species present	4	12	8	8	5	37
C	Species absent	1	4	4	3	4	16
D	Common species	3	5	5	4	4	21
E	Uncertain scores	1	1	0	0	2	4
F	Percent species present	0.80	0.75	0.67	0.73	0.56	0.70
G	Percent species absent	0.20	0.25	0.33	0.27	0.44	0.30
H	Percent common species	0.75	0.42	0.63	0.50	0.80	0.57
I	Percent uncertain scores	0.20	0.06	0.00	0.00	0.22	0.08

Blank = not present in shallow water (<10 m) OR life stage is pelagic
0 = present in shallow water (<10 m), but not in this habitat
1 = present, but not common or abundant
2 = common or abundant
Shaded = uncertain score
A = Sum of values in all cells
B = Number of boxes with values >0
C = Number of boxes with value = 0
D = Number of boxes with values of 2
E = Number of shaded values
F = Species present/Species present + species absent
G = Species absent/Species present + species absent
H = Common species/Species present + species absent
I = Number of shaded boxes/Species present + species absent

Gravel/Cobble Bottom Habitats

The sum of values for this habitat type (50) ranked high, in between mud and sand, making gravel/cobble the second highest scoring habitat (Fig. 1). Also, the percentage of S/LS present was higher (>70%) than any of the other habitats, but the percentage of those that were common/abundant was lower than all other habitats except salt marsh (Figs. 2 and 3). Few (<15%) of the scores were uncertain (Fig. 4). Across life stages, blue mussels ranked highest, followed by sand lance and little skate (Table 4). Sand lance were present at all five life stages and blue mussels, tomcod, cunner, tautog, and soft-shell clams were present at four life stages. As was the case for all eight habitat types, YOY juveniles were the most frequently represented life stage, but their presence in gravel/cobble did not exceed the occurrence of other life stages to the same degree as in mud, sand, eelgrass, or macroalgae habitats. Species that use unvegetated, shallow-water gravel/cobble habitat as juvenile nursery habitat are cod, lobsters, and mussels; seven other species are present, but not common, as YOY juveniles.

Atlantic cod, American lobsters, blue mussels, little skate, and sand lance are common in gravel/cobble habitat. The common life stages of cod and lobster are YOY juveniles, and little skate and blue mussels as juveniles and adults. Sand lance are not common as juveniles or adults in gravel and cobble habitats, but their eggs have been collected on gravel.

Recently settled Atlantic cod juveniles and early benthic phase American lobsters seek shelter from predators in shallow cobble bottom habitats. This has been demonstrated for cod in a number of field and laboratory studies. With predators present, small juvenile cod seek shelter in cobble habitats; in the absence of predators, larger juveniles return to finer grained sediments, but the smaller ones remain in cobble. Increased habitat complexity decreases predator success and – compared to flat sand – increases the survival of YOY juveniles. Cobble and rock-reef habitats provide better protection from predation than sand or eelgrass. Recently settled juvenile lobsters actively select suitable habitat and are primarily confined to shallow-water cobble beds or other shelter-providing habitats, such as rock substratum with kelp and mussels that offer protection from predation. Such habitats may be used for the first four to five years of their life, although older juveniles and adults inhabit a broader range of habitats. Rocky bottom habitats are also the primary habitat for blue mussels, which attach to all kinds of hard substrates, including small stones, shells, and other mussels, and form dense mussel beds in wave-exposed areas. Mussel beds provide important habitats for many species of fish and other invertebrates (see Shellfish Beds).

Table 4. Occurrence of benthic species and life stages in shallow gravel and cobble habitat in Gulf of Maine coastal waters

	Species	Eggs	YOY Juveniles	Juveniles	Adults	Spawning Adults	All
	American eel		no	1	1		2
	Atlantic cod		2	1			3
	Atlantic tomcod	1	1		1	1	4
	American lobster		2	1			3
	Blue mussels		2	2	2	2	8
	Cunner		1	1	1	1	4
	Little skate	0	2	2	2	0	6
	Pollock		1				1
	Red hake		1				1
	Sand lance	2	1	1	1	2	7
	Smooth flounder	0	0	0	0	0	0
	Soft-shell clam		1	1	1	1	4
	Tautog		1	1	1	1	4
	White hake		0				0
	Windowpane		0	0	0		0
	Winter flounder	1	0	0	1	1	3
A	Sum of values	4	15	11	11	9	50
B	Species present	3	11	9	9	7	39
C	Species absent	2	5	3	2	2	14
D	Common species	1	4	2	2	2	11
E	Uncertain scores	1	3	0	1	2	7
F	Percent species present	0.60	0.69	0.75	0.82	0.78	0.74
G	Percent species absent	0.40	0.31	0.25	0.18	0.22	0.26
H	Percent common species	0.33	0.36	0.22	0.22	0.29	0.28
I	Percent uncertain scores	0.20	0.19	0.00	0.09	0.22	0.13

Blank = not present in shallow water (<10 m) OR life stage is pelagic
0 = present in shallow water (<10 m), but not in this habitat
1 = present, but not common or abundant
2 = common or abundant
Shaded = uncertain score
A = Sum of values in all cells
B = Number of boxes with values >0
C = Number of boxes with value = 0
D = Number of boxes with values of 2
E = Number of shaded values
F = Species present/Species present + species absent
G = Species absent/Species present + species absent
H = Common species/Species present + species absent
I = Number of shaded boxes/Species present + species absent

Boulder/Ledge Habitats

The sum of values for this habitat type was intermediate (32) and slightly lower than salt marsh (Fig. 1). The percentage of S/LS present (40%) was low, but half of them were common/abundant (Figs. 2 and 3). Uncertainty was low (<15%). Most of the common or abundant species (cod, lobsters, blue mussels, cunner, and tautog) were present as older juveniles (Table 5). Across all life stages, mussels, cunner, and tautog scored much higher than any of the other species, being present or common in four life stages. Unvegetated boulder and ledge habitat does not appear to be as important for YOY juveniles as other inshore habitats.

Six of the 16 species are common in this habitat: YOY juvenile pollock, YOY and older juvenile tautog, older juvenile cod and lobsters, and juvenile and adult blue mussels and cunner. Cunner and blue mussels also spawn in boulder and ledge habitats.

Juvenile and adult cunner and tautog use complex structured habitats, like boulders, that provide shelter from predators or in order to reduce energy expenditures. The number of cunner declines rapidly a short distance from cover. Shelter availability may be a factor limiting population size. Cunner are an important prey species for a number of other fish species. Tautog are strictly coastal and have extremely local distributions in the GOM. Small juveniles are often found in macroalgal habitats (see ***Macroalgae***), but move into rocky habitats as they grow. YOY juveniles are also found in rocky habitats and may prefer small boulders over cobble habitat. Adults occupy a variety of sheltering habitats including rocks. Older immature lobsters in the GOM are most abundant in boulder fields, but are not as vulnerable to predation as the smaller juveniles. The use of shelters in rocky habitats is critical for successful mating behavior. Juvenile Atlantic cod (age 2 and 3) are common in boulder and kelp habitats. Blue mussels attach to boulders as well as other types of hard substrate.

Table 5. Occurrence of benthic species and life stages in shallow boulder and ledge habitat in Gulf of Maine coastal waters

	Species	Eggs	YOY Juveniles	Juveniles	Adults	Spawning Adults	All
	American eel		0	0	0		0
	Atlantic cod		1	2			3
	Atlantic tomcod	1	1		1	1	4
	American lobster		0	2			2
	Blue mussels		2	2	2	2	8
	Cunner		1	2	2	2	7
	Little skate	0	0	0	0	0	0
	Pollock		1				1
	Red hake		0				0
	Sand lance	0	0	0	0	0	0
	Smooth flounder	0	0	0	0	0	0
	Soft-shell clam		0	0	0	0	0
	Tautog		2	2	1	1	6
	White hake		0				0
	Windowpane		0	0	0		0
	Winter flounder	0	0	0	1	0	1
A	Sum of values	1	8	10	7	6	32
B	Species present	1	6	5	5	4	21
C	Species absent	4	10	7	6	5	32
D	Common species	0	2	5	2	2	11
E	Uncertain scores	1	4	0	1	1	7
F	Percent species present	0.20	0.38	0.42	0.45	0.44	0.40
G	Percent species absent	0.80	0.63	0.58	0.55	0.56	0.60
H	Percent common species	0.00	0.33	1.00	0.40	0.50	0.52
I	Percent uncertain scores	0.20	0.25	0.00	0.09	0.11	0.13

Blank = not present in shallow water (<10 m) OR life stage is pelagic
0 = present in shallow water (<10 m), but not in this habitat
1 = present, but not common or abundant
2 = common or abundant
Shaded = uncertain score
A = Sum of values in all cells
B = Number of boxes with values >0
C = Number of boxes with value = 0
D = Number of boxes with values of 2
E = Number of shaded values
F = Species present/Species present + species absent
G = Species absent/Species present + species absent
H = Common species/Species present + species absent
I = Number of shaded boxes/Species present + species absent

Eelgrass Habitats

The sum of values for eelgrass habitat was relatively high (46), comparable to macroalgae and mud, but not as high as sand or gravel (Fig. 1). The percentage of S/LS present (>60%) was also high (Fig. 2), but the percentage of those S/LS that were common or abundant (<40%) was considerably lower than in sand and boulder habitats (Fig. 3). The percentage of uncertain scores (>25%) was higher in eelgrass than in any of the previously mentioned habitats (Fig. 4). Across all life stages, tautog and winter flounder were common or abundant in four life stages (Table 6). Other well-represented species are sand lance, tomcod, and cunner. Eelgrass is particularly important for YOY juveniles because it provides shelter from predators; the sum of values for this life stage was higher in eelgrass than in any of the other seven habitat types. Species that commonly use eelgrass as a nursery habitat are cod, pollock, red hake, tautog, tomcod, white hake, and winter flounder, with five other species ranked as present (Table 6).

Seven species were ranked as common in eelgrass for at least one life stage: cod, pollock, red hake, tautog, tomcod, white hake, and winter flounder. This habitat serves as juvenile nursery ground for these species as well as for older tautog and winter flounder juveniles. Tautog was the only species ranked as common in the adult stage and may spawn in eelgrass as well. Non-spawning winter flounder are not common in eelgrass, but probably move into shallow eelgrass habitat to spawn in the spring.

After settlement, juvenile Atlantic cod display a preference for eelgrass beds over unvegetated habitats. Predation on juvenile cod is higher in unvegetated than in vegetated habitats. The presence of YOY juvenile pollock, Atlantic cod, Atlantic tomcod, white hake, and red hake has been significantly related to eelgrass in a five-year survey of shallow-water habitats along the Maine coast (Lazzari and Stone 2006). During four years of this survey, YOY juvenile winter flounder were more abundant in eelgrass than in kelp, drift algae, and unvegetated sand/mud habitats, but in the fifth year, when overall catch rates were much higher, they were distributed much more uniformly across all four habitat types. These results suggest that in years when YOY juveniles are more abundant, they disperse from eelgrass beds into less preferred habitats. Juvenile and adult tautog are also found more often in vegetated habitats like eelgrass. The availability of shallow-water vegetated habitats may be a limiting factor for juveniles less than two years old. Winter flounder also spawn in shallow, sandy, eelgrass beds in southern New England and the Mid-Atlantic, but the primary GOM spawning grounds may be in deeper, unvegetated benthic habitats.

Table 6. Occurrence of benthic species and life stages in shallow eelgrass habitat in Gulf of Maine coastal waters

	Species	Eggs	YOY Juveniles	Juveniles	Adults	Spawning Adults	All
	American eel		1	0	0		1
	Atlantic cod		2	0			2
	Atlantic tomcod	1	2		1	1	5
	American lobster		0	1			1
	Blue mussels		1	1	0	0	2
	Cunner		1	1	1	1	4
	Little skate	0	0	0	0	0	0
	Pollock		2				2
	Red hake		2				2
	Sand lance	1	1	1	1	1	5
	Smooth flounder	0	0	0	0	0	0
	Soft-shell clam		0	0	0	0	0
	Tautog		2	2	2	2	8
	White hake		2				2
	Windowpane		1	1	1		3
	Winter flounder	2	2	2	1	2	9
A	Sum of values	4	19	9	7	7	46
B	Species present	3	12	7	6	5	33
C	Species absent	2	4	5	5	4	20
D	Common species	1	7	2	1	2	13
E	Uncertain scores	3	3	3	2	4	15
F	Percent species present	0.60	0.75	0.58	0.55	0.56	0.62
G	Percent species absent	0.40	0.25	0.42	0.45	0.44	0.38
H	Percent common species	0.33	0.58	0.29	0.17	0.40	0.39
I	Percent uncertain scores	0.60	0.19	0.25	0.18	0.44	0.28

Blank = not present in shallow water (<10 m) OR life stage is pelagic
0 = present in shallow water (<10 m), but not in this habitat
1 = present, but not common or abundant
2 = common or abundant
Shaded = uncertain score
A = Sum of values in all cells
B = Number of boxes with values >0
C = Number of boxes with value = 0
D = Number of boxes with values of 2
E = Number of shaded values
F = Species present/Species present + species absent
G = Species absent/Species present + species absent
H = Common species/Species present + species absent
I = Number of shaded boxes/Species present + species absent

Macroalgae

The overall results for this habitat type were nearly identical to those for eelgrass, even though it included macroalgae growing on soft sediments as well as on rocky substrates on deeper, more exposed shorelines (Figs. 1-3). There were some differences, however, in the species and life stages that occupy the two habitats. The two most common species in macroalgal habitats, across all life stages, were cunner and tautog (Table 7). YOY juveniles utilize this habitat extensively: twelve species were present and six of them were considered to be common or abundant – cunner, lobsters, pollock, red hake, tautog, and white hake.

Seven of the 16 species that were evaluated – cod, lobsters, cunner, pollock, red hake, tautog, and white hake – are common in this habitat. All seven species are common as juveniles: cod, and lobster as older juveniles, cunner and tautog as YOY and older juveniles, and the other three species only as YOY juveniles. Cunner and tautog are also common as adults and during spawning, although that is less certain for tautog.

Shallow macroalgal habitats in the GOM provide important nursery grounds for juvenile lobsters, cunner, pollock, tautog, red hake, and white hake. The presence of these four species has been significantly related to kelp and/or other macroalgal habitats in shallow-water habitats along the Maine coast. YOY pollock have been observed moving into the intertidal zone in large schools on rising tides, then dispersing in small schools or as solitary fish into algal habitats where they preferred dense algal habitat (>50% algal cover) over sparse algal habitat (<50% cover). These results support the hypothesis that pollock use both refuging and schooling anti-predator tactics during intertidal zone migrations. Structure also appears to be critical for the survival of juvenile red hake, which are often found inside live mollusks or under shells (but not mussels, see Shellfish Beds). YOY juvenile cunner settle preferentially in algal macrophytes attached to rocky substrates that provide cover from predators.

Older juvenile cod are strongly associated with macroalgal habitats. Age 2 and 3 Atlantic cod in Newfoundland were observed to occupy kelp and boulder habitats significantly more than would be expected given the availability of these habitats in the study area, and juvenile cod were more abundant in shallow (<10 m) macroalgal habitat than in adjacent rocky "barrens." In addition to providing shelter from predators, macroalgal habitats provide food for age 1+ juvenile cod that feed on benthic epifauna. Early benthic phase lobsters are common in rocky substratum with kelp because it provides shelter from predators, but older juveniles are less vulnerable to predation and use a broader range of habitats. Small juvenile tautog use sea lettuce (*Ulva lactuca*) and other macroalgae for cover and are often found in vegetated areas or macroalgal mats. Adult tautog (and, presumably, older juveniles) also prefer vegetated habitats.

Table 7. Occurrence of benthic species and life stages in shallow macroalgae habitat in Gulf of Maine coastal waters

	Species	Eggs	YOY Juveniles	Juveniles	Adults	Spawning Adults	All
	American eel		0	0	0		0
	Atlantic cod		1	2			3
	Atlantic tomcod	1	1		1	1	4
	American lobster		2	1			3
	Blue mussels		1	1	0	0	2
	Cunner		2	2	2	2	8
	Little skate	0	0	0	0	0	0
	Pollock		2				2
	Red hake		2				2
	Sand lance	1	1	1	1	1	5
	Smooth flounder	0	0	0	0	0	0
	Soft-shell clam		0	0	0	0	0
	Tautog		2	2	2	2	8
	White hake		2				2
	Windowpane		1	1	1		3
	Winter flounder	1	1	1	1	1	4
A	Sum of values	3	18	11	8	7	47
B	Species present	3	12	8	6	5	34
C	Species absent	2	4	4	5	4	19
D	Common species	0	6	3	2	2	13
E	Uncertain scores	2	4	4	3	3	16
F	Percent species present	0.60	0.75	0.67	0.55	0.56	0.64
G	Percent species absent	0.40	0.25	0.33	0.45	0.44	0.36
H	Percent common species	0.00	0.42	0.50	0.33	0.40	0.38
I	Percent uncertain scores	0.40	0.25	0.33	0.27	0.33	0.30

Blank = not present in shallow water (<10 m) OR life stage is pelagic
0 = present in shallow water (<10 m), but not in this habitat
1 = present, but not common or abundant
2 = common or abundant
Shaded = uncertain score
A = Sum of values in all cells
B = Number of boxes with values >0
C = Number of boxes with value = 0
D = Number of boxes with values of 2
E = Number of shaded values
F = Species present/Species present + species absent
G = Species absent/Species present + species absent
H = Common species/Species present + species absent
I = Number of shaded boxes/Species present + species absent

Salt Marsh Channels

The sum of values in salt marsh channels and creeks was not very high (35), ranking a little higher than boulder and ledge and below five other habitat types, but a fairly high percentage (60%) of the benthic S/LS that are found in depths <10 m were present in this habitat (Figs. 1 and 2). This is because a number of species are transients, moving in and out of salt marsh creeks with the tide, and do not rely on benthic habitats. Only three S/LS were abundant in this habitat: YOY juvenile white hake, and older juvenile eel and winter flounder (Table 8). YOY juveniles of nine other species are present in salt marsh creeks. Four of the 16 species that were evaluated – American eel (juveniles), tomcod (adults), white hake (YOY juveniles), and winter flounder (juveniles) – had at least one life stage that was ranked as common in this habitat, although the information for white hake and winter flounder was uncertain.

Salt marsh creeks and channels serve primarily as pathways for fish that move in and out of marsh systems with the tide and are not associated with benthic habitats. Of the species evaluated in this report, one exception may be juvenile American eels; they are very common in salt marshes and usually lie buried in the mud during the day. They can also survive long periods of exposure to the air and, therefore, are able to remain in marsh creeks at low tide. The edges and smaller branches of marsh creeks probably provide ideal shelter and food for eels.

Table 8. Occurrence of benthic species and life stages in salt marsh channels in Gulf of Maine coastal waters

	Species	Eggs	YOY Juveniles	Juveniles	Adults	Spawning Adults	All
	American eel		0	2	1		3
	Atlantic cod		1	1			2
	Atlantic tomcod	1	1		1	1	4
	American lobster		1	0			1
	Blue mussels		1	1	1	1	4
	Cunner		0	1	1	1	3
	Little skate	0	0	0	0	0	0
	Pollock		1				1
	Red hake		1				1
	Sand lance	1	1	1	1	1	5
	Smooth flounder	0	0	0	0	0	0
	Soft-shell clam		0	0	0	0	0
	Tautog		0	0	0	0	0
	White hake		2				2
	Windowpane		1	1	1		3
	Winter flounder	1	1	2	1	1	6
A	Sum of values	3	11	9	7	5	35
B	Species present	3	10	7	7	5	32
C	Species absent	2	6	5	4	4	21
D	Common species	0	1	2	0	0	3
E	Uncertain scores	2	5	3	1	2	13
F	Percent species present	0.60	0.63	0.58	0.64	0.56	0.60
G	Percent species absent	0.40	0.38	0.42	0.36	0.44	0.40
H	Percent common species	0.00	0.10	0.29	0.00	0.00	0.09
I	Percent uncertain scores	0.40	0.31	0.25	0.09	0.22	0.25

Blank = not present in shallow water (<10 m) OR life stage is pelagic
0 = present in shallow water (<10 m), but not in this habitat
1 = present, but not common or abundant
2 = common or abundant
Shaded = uncertain score
A = Sum of values in all cells
B = Number of boxes with values >0
C = Number of boxes with value = 0
D = Number of boxes with values of 2
E = Number of shaded values
F = Species present/Species present + species absent
G = Species absent/Species present + species absent
H = Common species/Species present + species absent
I = Number of shaded boxes/Species present + species absent

Shellfish Beds

Mussel beds scored lower than all the other habitats in terms of summed values and the percentage of S/LS present (Figs. 1 and 2). A third of the S/LS present were common or abundant (Fig. 3). The proportion of uncertain scores was much higher (almost 50%) than in any other habitat (Fig. 4), making the results highly speculative. Given the propensity of mussels to settle and grow in association with other mussels, this species scored high for all four of its benthic life stages (Table 9). Lobsters, tautog, and winter flounder (and perhaps cod and cunner) are present as YOY juveniles, and tautog are common as older juveniles. Tautog are strongly associated with shallow, sheltered habitats and the juveniles may use mussel beds to escape from predators. Blue mussels also provide food for lobsters, tautog, and cunner, as well as a substrate for macroalgae, which, in turn, provides additional shelter for fish and invertebrates. Of the 16 species included in this report, the tautog (juveniles) was the only species of finfish that was strongly associated with mussel beds.

Table 9. Occurrence of benthic species and life stages in Shellfish Beds in Gulf of Maine coastal waters

	Species	Eggs	YOY Juveniles	Juveniles	Adults	Spawning Adults	All
	American eel		0	0	0		0
	Atlantic cod		1	0			1
	Atlantic tomcod	0	0		0	0	0
	American lobster		1	0			1
	Blue mussels		2	2	2	2	8
	Cunner		1	1	1	1	4
	Little skate	0	0	0	0	0	0
	Pollock		0				0
	Red hake		0				0
	Sand lance	0	0	0	0	0	0
	Smooth flounder	0	0	0	0	0	0
	Soft-shell clam		0	0	0	0	0
	Tautog		1	2	1	1	5
	White hake		0				0
	Windowpane		0	0	0		0
	Winter flounder	0	1	0	0		1
A	Sum of values	0	7	5	4	4	20
B	Species present	0	6	3	3	3	15
C	Species absent	5	10	9	8	5	37
D	Common species	0	1	2	1	1	5
E	Uncertain scores	3	8	5	4	4	24
F	Percent species present	0.00	0.38	0.25	0.27	0.38	0.29
G	Percent species absent	1.00	0.63	0.75	0.73	0.63	0.71
H	Percent common species		0.17	0.67	0.33	0.33	0.33
I	Percent uncertain scores	0.60	0.50	0.42	0.36	0.50	0.46

Blank = not present in shallow water (<10 m) OR life stage is pelagic
0 = present in shallow water (<10 m), but not in this habitat
1 = present, but not common or abundant
2 = common or abundant
Shaded = uncertain score
A = Sum of values in all cells
B = Number of boxes with values >0
C = Number of boxes with value = 0
D = Number of boxes with values of 2
E = Number of shaded values
F = Species present/Species present + species absent
G = Species absent/Species present + species absent
H = Common species/Species present + species absent
I = Number of shaded boxes/Species present + species absent

Functional Value of Habitat

The SFA defines essential fish habitat as "those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity." The functional values of the eight shallow-water marine and estuarine habitats included in this report were derived from the results of the species-specific assessments (Tables 2-9) by applying the following decision criteria:

> **Spawning** – any habitat type where a species is either present, common, or abundant as a spawning adult, with a higher functional value for those species that are common or abundant (score = 2).
> **Breeding** – assumed to be the same as spawning.
> **Growth to Maturity** – any habitat type where a species is present or common as an adult, with a higher functional value for those species that are common or abundant (score = 2); species that occupy shallow inshore habitats as juveniles, but only rarely or not at all as adults (e.g., cod) migrate into deeper water as they get older.
> **Feeding** – the other element in the EFH definition – cannot be assessed from the information that is summarized in this report because we did not review any information regarding feeding habits. However, it can be asserted that all the species that are present in a particular habitat type use that habitat for feeding, whether they feed primarily on benthic or pelagic prey organisms. Therefore, food value by habitat is not evaluated in this report.

The scores at the bottom of each table indicate how many species use each habitat for survival, growth to maturity, and spawning, and how each habitat ranks in terms of the abundance of those species relative to the other habitats. The results of this ranking scheme are summarized in Tables 10-12.

An additional and very important function of shallow-water habitats is survival. We interpreted this to apply to juveniles and their use of benthic habitat features for shelter from predators. Because recently settled and very small juveniles are particularly prone to predation and, therefore, more dependent on shelter for survival than older fish, we assumed that species present as YOY stage juveniles would rely to a greater extent on the survival value of their habitat. Also, when applying the results summarized in the tables, we assumed that any species that was common or abundant in the juvenile YOY life stage (score = 2) would benefit to a greater degree than a species that was simply present (score = 1) as a YOY juvenile.

Shallow-water GOM habitats provide important nursery grounds for a variety of species. Juvenile fish and invertebrates rely for survival on shallow-water mud, sand, gravel/cobble, and vegetated habitats more than they do on boulder, salt marsh channels, and shell (mussel) bed habitats (Table 10). Recently settled smooth flounder are common in intertidal and shallow sub-tidal mud bottom habitats, as are juvenile windowpane and sand lance on sand. Winter flounder settle to the bottom in shallow mud and sand-dominated habitats and remain there for most of their first year of life. Soft-shell clam larvae also settle to the bottom in inshore mud and sand habitats. The survival value of gravel/cobble habitats is high for juvenile Atlantic cod, American lobsters, and blue mussels. Eelgrass and macroalgal habitats provide refuge for juvenile cod, lobsters, cunner, pollock, red hake, tautog, white hake, and winter flounder. Boulders provide important nursery habitat for tautog and mussels. YOY Atlantic cod were associated with all eight habitat types, although their presence in boulders and mussel beds is uncertain. YOY Atlantic tomcod were associated with seven habitats, and winter flounder and blue mussels with six.

The species that were evaluated in this report rely less heavily on shallow-water GOM habitats for growth to maturity and spawning than they do for survival. Juveniles of more species grow to maturity in mud, sand, and gravel/cobble habitats than in the other five habitats (Table 11). Mud habitats are especially important for the growth of smooth flounder and soft-shell clams, sand habitats for little skates and clams, and gravel/cobble habitats for mussels and little skates. Cunner are common and grow to maturity in boulder and macroalgal habitats, as was also true for tautog in eelgrass and macroalgal habitats.

Some species that grow to maturity in shallow-water habitats also spawn there. This was less evident in mud and sand where five and three species, respectively, grow to maturity but spawn in deeper water (Tables 11 and 12). Species ranked common as spawning adults were smooth flounder and soft-shell clams in mud, little skate, sand lance, clams, and winter flounder in sand, and mussels and sand lance in gravel/cobble. Spawning blue mussels are also common in boulders and – not surprisingly – in mussel beds, while cunner are common and spawn in boulders and macroalgal habitats. Both types of vegetated habitats appear to be important spawning habitats for tautog, at least in the southwestern GOM where they occur. Winter flounder appear to spawn in all but two of the eight habitats.

Table 10. Functional value assessment by habitat type: juvenile survival[7]

Mud	Sand	Gravel/Cobble	Boulder	Eelgrass	Macroalgae	Salt Marsh	Shellfish beds
American eel (1)	American eel (1)	Atlantic cod (2)	Atlantic cod (1?)	American eel (1)	Atlantic cod (1)	Atlantic cod (1)	Atlantic cod (1?)
Atlantic cod (1)	Atlantic cod (1)	Atlantic tomcod (1)	Atlantic tomcod (1)	Atlantic cod (2)	Atlantic tomcod (1)	Atlantic tomcod (1)	American lobster (1)
Atlantic tomcod (1)	Atlantic tomcod (1)	American lobster (2)	Blue mussels (2)	Atlantic tomcod (2)	American lobster (2)	American lobster (1?)	Blue mussels (2)
Little skate (1?)	Little skate (2?)	Blue mussels (2)	Cunner (1)	Blue mussels (1)	Blue mussels (1)	Blue mussels (1?)	Cunner (1?)
Pollock (1?)	Pollock (1)	Cunner (1)	Pollock (1)	Cunner (1?)	Cunner (2)	Pollock (1)	Tautog (1)
Red hake (1)	Red hake (1)	Little skate (2?)	Tautog (2)	Pollock (2)	Pollock (2)	Red hake (1)	Winter flounder (1)
Sand lance (1?)	Sand lance (2)	Pollock (1)		Red hake (2)	Red hake (2)	Sand lance (1)	
Smooth flounder (2)	Soft-shell clams (2)	Red hake (1?)		Sand lance (1?)	Sand lance (1?)	White hake (2?)	
Soft-shell clams (2)	Tautog (1)	Sand lance (1)		Tautog (2)	Tautog (2)	Windowpane (1)	
White hake (1)	White hake (1)	Soft-shell clams (1)		White hake (2)	White hake (2)	Winter flounder (1)	
Windowpane (1)	Windowpane (2)	Tautog (1)		Windowpane (1)	Windowpane (1)		
Winter flounder (2)	Winter flounder (2)			Winter flounder (2)	Winter flounder (1)		
Species = 12	12	11	6	12	12	10	6
Score = 15	17	15	8	19	18	11	7

[7] Numbers after each species name indicate scores for presence (=1) or common/abundant (=2), see Tables 2-9. Totals in the last two rows are counts of species present and the sums of their scores, by habitat type. Question marks indicate uncertain scores.

Table 11. Functional value assessment by habitat type: growth to maturity[8]

Mud	Sand	Gravel/Cobble	Boulder	Eelgrass	Macroalgae	Salt Marsh	Shellfish beds
American eel (1)	American eel (1)	American eel (1)	Atlantic tomcod (1)	Atlantic tomcod (1)	Atlantic tomcod (1?)	American eel (1)	Blue mussels (2)
Atlantic tomcod (1)	Atlantic tomcod (1)	Atlantic tomcod (1?)	Blue mussels (2)	Cunner (1)	Cunner (2)	Atlantic tomcod (1)	Cunner (1?)
Little skate (1)	Little skate (2)	Blue mussels (2)	Cunner (2)	Sand lance (1)	Sand lance (1)	Blue mussels (1)	Tautog (1)
Sand lance (1)	Sand lance (2)	Cunner (1)	Tautog (1)	Tautog (2)	Tautog (2)	Cunner (1)	
Smooth flounder (2)	Soft-shell clams (2)	Little skate (2)	Winter flounder (1)	Windowpane (1)	Windowpane (1)	Sand lance (1)	
Soft-shell clams (2)	Tautog (1)	Sand lance (1)		Winter flounder (1?)	Winter flounder (1?)	Windowpane (1)	
Windowpane (1)	Windowpane (1)	Soft-shell clams (1)				Winter flounder (1?)	
Winter flounder (1)	Winter flounder (1)	Tautog (1)					
		Winter flounder (1)					
Species = 8	8	9	5	6	6	7	3
Score = 10	12	11	7	7	8	7	4

[8] Numbers after each species name indicate scores for presence (=1) or common/abundant (=2), see Tables 2-9. Totals in the last two rows are counts of species present and the sums of their scores, by habitat type. Question marks indicate uncertain scores.

Table 12. Functional value assessment by habitat type: spawning[9]

Mud	Sand	Gravel/Cobble	Boulder	Eelgrass	Macroalgae	Salt Marsh	Shellfish beds
Smooth flounder (2?)	Atlantic tomcod (1)	Atlantic tomcod (1)	Atlantic tomcod (1)	Atlantic tomcod (1)	Atlantic tomcod (1)	Atlantic tomcod (1)	Blue mussels (2)
Soft-shell clams (2)	Little skate (2)	Blue mussels (2)	Blue mussels (2)	Cunner (1)	Cunner (2)	Blue mussels (1)	Cunner (1?)
Winter flounder (1)	Sand lance (2)	Cunner (1)	Cunner (2)	Sand lance (1?)	Sand lance (1?)	Cunner (1)	Tautog (1?)
	Soft-shell clam (2)	Sand lance (2)	Tautog (1)	Tautog (2?)	Tautog (2?)	Sand lance (1)	
	Winter flounder (2)	Soft-shell clam (1)		Winter flounder (2?)	Winter flounder (1)	Winter flounder (1?)	
		Tautog (1?)					
		Winter flounder (1)					
Species = 3	5	7	4	5	5	5	3
Score = 5	9	9	6	7	6	5	4

[9] Numbers after each species name indicate scores for presence (=1) or common/abundant (=2), see Tables 2-9. Totals in the last two rows are counts of species present and the sums of their scores, by habitat type. Question marks indicate uncertain scores.

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APPENDIX

Summaries of species-specific information from literature reviews
with tables showing rankings of benthic habitat use by life stage

American Eel (*Anguilla rostrata*)

American eel are catadromous, spending 5-20 years as juveniles in fresh or coastal waters feeding and growing. After maturing, they migrate to the Atlantic Ocean to spawn in deep water in the Sargasso Sea. Eels are common inhabitants of freshwater streams, rivers, lakes, tidal marshes, creeks, and estuaries around the entire periphery of the GOM. They usually bury in the mud during the day, but appear to use a variety of substrate and habitat types, including rocky bottom near the mouths of embayments on the south shore of Massachusetts, and sandy, swift-flowing trout streams on Cape Cod (Smith and Tighe 2002). American eel are very common inhabitants of tidal creeks and channels in salt marshes in the GOM (Dionne *et al*. 1999).

Unpigmented, post larval (“glass”) eels enter estuaries by drifting upstream on flooding tides and holding position near the bottom on ebb tides. They also actively swim along shore in estuaries above tidal influence (Pacheco and Grant 1973, McCleave and Kleckner 1982, McCleave and Wippelhauser 1986, Barbin and Krueger 1994). Post-larval eels tend to be bottom dwellers and hide in burrows, tubes, snags, plant masses, other types of shelter, or the substrate itself (Fahay 1978). This behavior is reflected in their food habits and protects them from predators. Cruetzberg (1961) reported that at night, unpigmented eels in coastal waters are found in a variety of depths throughout the water column during incoming tides. Glass eels change into pigmented elvers once they enter freshwater. Elvers are active at night. During the day move to the bottom and bury themselves in the substrate (Deelder 1958). A study by Edel (1979) demonstrated that American eel are less active when there is shelter present.

Not much is known about the substrate preference of elvers. Migrating elvers make use of soft undisturbed bottom sediments as shelter (Facey and Van den Avyle (1987). Geer (2003) reported the habitat preference for elvers in the Chesapeake Bay as detritus, hydroids, and shell bottoms; most were caught in depths of 4-10 meters. Elvers are also found in eelgrass beds along the open coast (Smith and Tighe 2002). MacDonald *et al.* (1984) collected American eels in shallow (1.5 m) eelgrass beds in the upper Passamaquoddy Bay estuary (lower Bay of Fundy).

American Eel (*Anguilla rostrata*)										
		Habitat Type								
Life History Stage	**Depth <10m?**	**Mud**	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	**Comments**
Eggs	No	Not applicable								Eggs and larvae are pelagic and remain in the open sea
Larvae	No	Not applicable								See above
YOY juveniles (elvers)	Yes	1	1	No	No	1	0	0	0	Post-larval glass eels enter coastal estuaries and rivers and metamorphose into elvers as they enter freshwater; elvers occupy bottom habitats during the day, seeking shelter (often by burrowing) in soft sediments; they are also found in eelgrass beds along the coast
Older juveniles (yellow eels)	Yes	1	1	1	No	0	0	2	0	American eels spend 5-20 years as juveniles in freshwater and estuarine habitats; they use a variety of bottom types, including sandy and rocky habitats, but presumably do not require shelter as much as the elvers or glass eels
Adults (silver eels)	Yes	1	1	1	No	0	0	1	0	Eels migrate downstream to the ocean after maturing and are assumed to use the same bottom habitats as the older juveniles as long as they are in the rivers, estuaries, and nearshore coastal waters
Spawning adults	No									American eels spawn in the open sea

0 = life stage does not occur in this habitat type
1 = life stage is present in this habitat type, but is not common
2 = life stage is common or abundant in this habitat type

Unshaded cells indicate rankings that were based on literature review or inferred from published information for other life stages. Shaded cells indicate uncertain rankings that were based solely on best professional judgment.

American Lobster (*Homarus americanus*)

Depth

American lobsters range from intertidal areas to depths as high as 700 m (Aiken and Waddy 1986). Shallow-water habitats are largely inhabited by juveniles (Lincoln 1998, Cowan 1999). Mature adult lobsters (>90 mm CL) are reported to be rare in all coastal shallow-water habitats in the GOM (Steneck *et al.* 1991). However, south of Cape Cod, sub-adult and adult lobsters have been shown to use a shallow-water cove for long-term residency, overwintering, and as refuge when injured or molting (Karnofsky *et al.* 1989). Shallow-water areas are particularly important for lobster settlement and early benthic phases (Lincoln 1998; Wahle and Steneck 1991; Incze *et al.* 2006). Early benthic phase (EBP) and older juveniles are found intertidally, with most nursery areas extending from lower intertidal to shallow depths (Cowan 1999, Cowan 2001). Settlement of post-larvae occur in coastal shallow water, typically less than 25 m (Incze *et al.* 2006), but studies have also found settlement largely limited to water shallower than 0.5 m (Lincoln 1998). settlement in shallow water may optimize growth rates due to the abundance for food supplies and elevated temperatures (Cowan 1999).

Substrate

Soft Sediments

Studies have found settling juvenile lobsters prefer shelter-providing habitats. When encountering sandy or muddy substrate, recently settled juveniles continue swimming, delaying settlement when no suitable substrate is provided (Cobb *et al.* 1983). During the first year or two after settlement, juvenile lobsters continue to avoid featureless sand and mud habitats, strongly preferring shelter-providing habitats (Wahle and Steneck 1991). As they get older and less vulnerable to predation, they occupy a wider variety of exposed and protected benthic habitats. Juvenile and adult lobsters burrow in the mud (Cooper and Uzmann 1980). No early benthic phase (EBP) juveniles or burrows were observed on mud bottom in Portland, ME or Gloucester, MA harbors (Heinig and Tarbox 2000, Normandeau Associates 1999). On Cape Cod, small juveniles were also found to use peat reefs from vegetated marshes (Able *et al*.1988); this habitat type is less prevalent in the northern part of the GOM. Lobsters may move farther and faster on featureless sediment, which may be more often occupied by larger lobsters that have outgrown predators (Geraldi *et al*. 2009). This study also suggested sediment between rocky habitats may provide a corridor for short and long distance movement.

Hard Substrate

Shelter-providing habitat has been shown to be a critical requirement for recently settled and early juvenile lobsters (Wahle and Steneck 1991, Cowan 1999). Settling lobsters have been shown to actively select suitable habitat, demonstrating shelter-seeking behavior post-settlement (Cobb *et al*. 1983,Palma *et al*. 1998). EBP lobsters are primarily confined to shallow-water cobble beds or other shelter providing habitat such as rocky substratum with kelp and mussels (Wahle and Steneck 1991, Palma *et al*. 1998), which offer protection from predation (Wahle and Steneck 1992). Since larger rocks occupy more space and, therefore, provide shelter for fewer animals (Wahle and Steneck 1991), EBP lobsters would not be expected to occupy boulder habitats unless they found shelter under and among attached organisms. The shallow-water habitats for post-settled lobsters are important for development, as studies have indicated these nursery habitats may be used for the first four to five years of a lobster's benthic life (Cowan *et* *al*. 2001). Average densities of EBP lobsters in 11 of 14 unvegetated cobble quadrats in depths of 5 and 10 meters at a mid-coast Maine study site ranged from 0.1 to 3.8 m^{-2} and reached values between 6.1 and 6.9 m^{-2} in the other three (Wahle and Steneck 1991). At four cobble-with-kelp habitat sites in the same location, mean densities ranged from 1.0 to 2.8 m^{-2}.

Older juvenile and adult lobsters also utilize rocky habitats, but are less dependent on shelter from predators, so they inhabit a broader range of habitats. According to Cooper and Uzmann (1980), the most common inshore rocky habitat for juvenile lobsters (average size 40 mm CL) is a sandy substrate overlain by flattened rocks; shelters are formed by excavating sand under a rock to form U-shaped, shallow tunnels. Karnofsky *et al*. (1989) observed lobsters larger than 50 mm CL, sheltering among small boulders in a shallow cove (0.3-1.5 m at low tide) with a sand and mud bottom in Buzzards Bay, south of Cape Cod. Steneck *et al*. (1991) reported that adolescent lobsters (40-90 mm CL) in the GOM are most abundant in boulder fields. The use of shelters in rocky habitats is a critical component of lobster mating behavior (Atema *et al*. 1979).

Vegetated Hard and Soft Substrates

Juvenile and adult lobsters are also known to occupy vegetated shallows, including eelgrass and kelp beds in coastal GOM waters (Bologna and Steneck 1993, Short *et al*. 2001). In New Hampshire's Piscataqua River, lobster >40 mm CL burrowed in eelgrass beds and preferred eelgrass to bare mud, but densities were low, averaging 0.1 m^{-2} (Short *et al*. 2001). Lobsters were attracted to transplanted kelp (*Laminaria*) beds at a nearshore study site in the mid-coast region of Maine, reaching densities that were almost ten times higher (1.5 m^{-2}) than in nearby coastal areas (Bologna and Steneck 1993). They did not burrow in the sediment, but instead sought shelter beneath the kelp fronds. Kelp beds have been classified as an important habitat for adults and adolescents (Lincoln 1998). Other species of macroalgae that grow in the sub-tidal zone probably provide habitat for shelter-seeking lobsters.

Shellfish Beds

Densities of EBP lobsters in kelp and mussel (*Mytilus edulis*)-colonized bedrock habitats were similar to densities in adjacent cobble bottom at a study site in Rhode Island, but mussel beds remain unexamined as a recruitment habitat for lobsters (Wahle and Steneck 1991). Like cobble habitats, mussel beds provide abundant interstitial shelters for small EBP lobsters and are common in the intertidal and shallow sub-tidal zones in the GOM.

American Lobster (*Homarus americanus*)										
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	No									Eggs carried by females until they hatch; mature adults rare in shallow-water habitats in GOM
Larvae	Yes	Not applicable								Larvae are pelagic
EBP juveniles (4-40 mm CL)	Yes	0	0	2	0	0	2	1	1	Small age 0+ and 1+ lobsters primarily confined to cobble habitats or other habitats that provide shelter from predators, including kelp and mussels on hard substrates; larger rocks (esp boulders) provide fewer shelters; EBP juveniles do not burrow in mud
Older juveniles (40-90 mm CL)	Yes	1	1	1	2	1	1	0	0	Larger juveniles also prefer complex habitats, but rely less on shelter as they get older, so they also occupy open soft sediment habitats; known to burrow in mud; densities much higher in kelp bed than in eelgrass or other nearshore habitats
Adults (>90 mm CL)	No									Adults are rare in shallow-water habitats in GOM
Spawning adults	No									Spawning occurs primarily in deeper water

0 = life stage does not occur in this habitat type
1 = life stage is present in this habitat type, but is not common
2 = life stage is common or abundant in this habitat type

Unshaded cells indicate rankings that were based on literature review or inferred from published information for other life stages. Shaded cells indicate uncertain rankings that were based solely on best professional judgment.

Atlantic Cod (*Gadus morhua*)

Depth

A number of studies have found that shallow, nearshore habitats are more important than offshore habitats as nursery grounds for juvenile Atlantic cod (Hardy 1978, Keats 1990, Dalley and Anderson 1997, Linehan *et al*. 2001, Cote *et al*. 2004, Lough 2005, Lazzari and Stone 2006). In Massachusetts coastal waters, most of the juveniles caught in the spring bottom trawl survey are taken in 6-10 m, while in the fall the majority deeper are caught at depths greater than 16 m. Adult cod are also caught in the 6-10 m depth range in the spring, but are much more common in deeper water in the spring and fall (Lough 2005). Hardy (1978) reported that YOY cod in Massachusetts prefer depths from 8-42 m in rock pools, shallow inlets, river mouths, and harbors, but tend to leave coastal areas by mid-June. In Maine, YOY juveniles were collected in a small beam trawl at depths as shallow as one meter (Lazzari and Stone 2006). More than 95% of YOY juvenile cod captured in bottom trawl surveys in mid-coast Maine between 1992 and 2005 were in depths <20 m, but no sampling was done in depths <10 m (Jonathan Grabowski, Northeastern University, personal communication).

Studies conducted in Newfoundland estuaries reported ontogenetic patterns of distribution for juvenile cod, where age-0 fish were found almost exclusively in inshore areas, age-1 fish extended further onto shelf areas, and larger juveniles were widely distributed on the shelf (Dalley and Anderson 1997, Linehan *et al*. 2001, Cote *et al*. 2004). Linehan *et al.* (2001) suggested the shallow, nearshore marine environment (<10 m depth) may be crucial to the recruitment of age-0 cod because of its importance as refuge habitat, as such habitat affords young cod prolonged protection from larger piscivorous fish. Contrary to several other studies, MacDonald *et al*. (1984) found juvenile cod in the lower Bay of Fundy to be equally common at deeper sites (between 20 m and 80 m in depth) as adult cod.

Substrate

Vegetated and Non-vegetated Soft/fine Sediments (Mud, Sand)

Juvenile cod use both vegetated and unvegetated habitats (Borg *et al.* 1997, Grant and Brown 1998, Linehan *et al*. 2001, Laurel *et al*. 2004). Juveniles display a preference for shallow, vegetated habitats (eelgrass beds) after settlement, but remain localized over both vegetated and unvegetated habitats for several weeks, perhaps through their first winter (Grant and Brown 1998). Lazzari and Stone (2006) reported the presence of YOY juvenile Atlantic cod in southern Maine estuaries to be significantly related to eelgrass beds and not to unvegetated mud and sand, or kelp habitats. Several authors have reported predation on juvenile cod to be higher in non-vegetated compared to vegetated sites during the day and dusk, suggesting that vegetated bottom is used to avoid predation, while sandy bottom may be important for nighttime feeding activity (Borg *et al*. 1997, Linehan *et al*. 2001). Laurel *et al*. (2004) suggested juvenile cod modify their behavior with changing density, possibly as a means of exploiting poor-quality habitats when high-quality habitats are saturated with conspecifics. A number of studies have reported juveniles prefer finer grains and avoid vegetation when predators were absent (or in the presence of a passive predator), while preferring cobble and vegetation when an active predator was present (Gotceitas *et al*. 1994, 1995, 1997). Atlantic cod (presumably juveniles) have also been collected in a tidal salt marsh creek in the lower Kennebec River in Maine, but not in six other GOM salt marsh systems (Dionne *et al*. 1999).

Hard substrates

Vegetated (macroalgae)

In two studies done in Newfoundland, Cote *et al*. (2004) reported juvenile cod (ages 2 and 3) occupying boulder and kelp habitats significantly more than would be expected given the availability of these habitats in the study area, and Keats *et al*. (1987) observed juvenile cod (ages 1 and 2) to be more abundant in shallow (<10 m) macroalgal habitat (*Desmarestia* spp.) than in adjacent barren rocky habitats. In the second study, the smaller fish seemed more dependent on the algae for cover, but fed on zooplankton, while the larger ones fed on benthic epifauna, indicating that macroalgal habitat provides refuge from predators as well as food for juvenile cod. Keats *et al*. (1987) also reported that juvenile cod congregate in shallow water in the vicinity of large boulders that have their tops covered with large macroalgae (e.g., *Alaria esculenta*, *Laminaria digitata*, and *Desmarestia* spp.).

Unvegetated

Gravel habitat appears to enhance the survival of recently settled juveniles through increased predator avoidance. Several studies have stressed the importance of cobble substrates over finer-grained bottoms after settlement (e.g., Bigelow and Schroeder 1953, Colton 1978,Klein-MacPhee 2002a). In laboratory studies, Gotceitas and Brown (1993) and Fraser *et al*. (1996) found cobble habitat was preferred over finer-grained substrates when a predator was present; after a predator left, larger juveniles returned to fine grains, but smaller juveniles remained in cobble; fewer juveniles succumbed to predation in cobble than in finer-grained substrates. Before the predator was introduced, YOY juveniles preferred sand and gravel/pebble habitats over cobble. In another laboratory experiment, Lindholm *et al*. (1999) found increased habitat complexity led to decreased predator success and increased 0-yr cod survivorship. In this study, the presence of structure in bottom habitat (e.g., cobble and cobble with sponge mimics) resulted in a significant decrease in total predator-induced mortality for 0-yr cod in comparison with that observed over flat sand. Tupper and Boutilier (1995) found higher survival and densities related to shelter opportunities and reduced predation in water depths ≤ 2 m, with cobble and rock-reef providing better protection from predation than sand or eelgrass; however, juvenile cod growth rates were higher in eelgrass than other habitat types.

Shellfish Beds

No information found.

Atlantic Cod (*Gadus morhua)*										
Life History Stage	**Depth <10m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	Not applicable								Eggs are pelagic
Larvae	Yes	Not applicable								Larvae are pelagic
YOY juveniles	Yes	1	1	2	1	2	1	1	1	YOY juveniles show a preference for complex habitats (SAV, gravel, cobble) as a predator avoidance strategy
Older juveniles	Yes	1	1	1	2	0	2	1	0	Older juveniles occupy deeper water habitats than YOY juveniles; age 2 and 3 juveniles common in boulder and kelp habitats and in shallow algal habitats, disperse into unvegetated habitats in absence of predators
Adults	No									Some adults occupy shallow-water coastal habitats, but they are more common in deeper water
Spawning adults	No									Spawning generally occurs deeper than 10 m

0 = life stage does not occur in this habitat type
1 = life stage is present in this habitat type, but is not common
2 = life stage is common or abundant in this habitat type

Unshaded cells indicate rankings that were based on literature review or inferred from published information for other life stages. Shaded cells indicate uncertain rankings that were based solely on best professional judgment.

Atlantic Tomcod *(Microgadus tomcod)*

Depth

This demersal species occurs in shallow coastal, estuarine, and freshwaters. In the GOM, tomcod are found mostly at depths of less than 6 meters and are locally common around the entire coastline and in practically every estuary around Massachusetts Bay (Klein-MacPhee 2002b). They are found in unvegetated intertidal and subtidal salt marsh creeks and channels (Dionne *et al*. 1999). They migrate upriver in the late fall to spawn in a wide range of salinities (Stewart and Auster 1987). The eggs are demersal and sink to the bottom in masses or stick to vegetation, stones, or any available support (Klein-MacPhee 2002b). Larvae are generally found near the bottom in the low salinity, upper reaches of estuaries (Pearcy and Richards 1962).

YOY tomcod are generally found in the low-salinity waters in estuaries where they were hatched (Bigelow and Schroeder 1953), but Howe (1971) reported all were collected in salinities greater than 10 ppt. Throughout their range, they grow rapidly and mature during their first year (Able and Fahay 2010). Younger juveniles may remain in brackish water for their first spring and summer (Klein-MacPhee 2002b). Lazzari and Stone (2006) reported shallow-water estuaries in the GOM to be key nursery habitat for juvenile Atlantic tomcod. Given their abundance in shallow coastal waters and their small size, tomcod are probably preyed upon by a number of larger fish, but the only known predators are bluefish and striped bass (Klein-MacPhee 2002b).

Substrate

Juvenile tomcod inhabit shoal areas in coves near the mouths of rivers and subtidal flats over eelgrass, sand, and silt bottom (Howe 1971). In the upper Passamaquoddy Bay estuary (Bay of Fundy), MacDonald *et al*. (1984) reported juvenile tomcod as being common at shallow beach sites during early summer and at shallow estuarine sites (< 3 m deep) over mud and sand. Lazzari and Stone (2006) collected YOY juvenile tomcod in shallow (<10 m) coastal waters in the GOM, mostly in eelgrass habitat; a few were also collected in unvegetated sand/mud habitats and kelp, but none were collected in algae. In an earlier study, juvenile tomcod were collected over sandy bottom adjacent to *Spartina* salt marsh in a salt pond (Lazzari *et al*. 1999). In the Sheepscot estuary, Maine, a larger proportion of juvenile tomcod were found over rocky intertidal habitats than in intertidal vegetated and muddy habitats (Tort 1995).

Adult tomcod are sometimes found over eelgrass beds (Dutil *et al*. 1982). In the GOM, they inhabit shoal, muddy harbors, and are found off open shores (Klein-MacPhee 2002b). In a creek in Massachusetts, tomcod were observed spawning in *Spartina* beds, eelgrass, and under mats of floating debris (Howe 1971). In Canada, Scott and Crossman (1973) reported spawning over sand and gravel bottoms.

Atlantic Tomcod (*Microgadus tomcod*)											
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	0	1	1	1	1	1	1	0	Demersal and slightly adhesive, on vegetation, stones and other objects
Larvae	Yes	Not applicable								Pelagic, generally near bottom
YOY juveniles	Yes	1	1	1	1	2	1	1	0	In low salinity estuarine waters, more common in eelgrass, few in kelp and over sand/mud bottom; also found in rocky habitats
Older juveniles	Yes	Not applicable								See adults (tomcod mature at age 1)
Adults	Yes	1	1	1	1	1	1	1	0	Inhabit shoal waters in coves near river mouths and subtidal flats in eelgrass and over sand and mud, also in marsh creeks
Spawning adults	Yes	0	1	1	1	1	1	1	0	Migrate up rivers to spawn in brackish and freshwaters in *Spartina* and eelgrass beds and over sand and gravel

0 = life stage does not occur in this habitat type
1 = life stage is present in this habitat type, but is not common
2 = life stage is common or abundant in this habitat type

Unshaded cells indicate rankings that were based on literature review or inferred from published information for other life stages. Shaded cells indicate uncertain rankings that were based solely on best professional judgment.

Blue Mussel (*Mytilus edulis*)

Depth

Blue mussels are found throughout the entire northeast region generally in the lower intertidal and shallow sub-tidal area, but can also be found at considerable depths (Evans *et al*. 2011, Tyrell 2005, Jones 2000, Gosner 1978). Blue mussels form dense concentrations in wave-exposed areas (Tyrell 2005) and in the lower intertidal zone (Whitlatch 1982). They colonize intertidal mudflats in scattered clumps and contiguous mats (Jones 2000). Mussel beds are very common in coastal waters of the GOM (Whitlatch 1982). An evaluation of suitable shellfish habitat in coastal New Hampshire assumed a depth preference of +4 to -6 feet MLW for juvenile and adult blue mussels (Banner and Hayes 1996). They are eaten by lobsters, tautog, and cunner (Newell 1989).

Substrate

Blue mussels are found on substrates ranging from rock to coarse gravel and mud/sand if there is a firm substrate, such as stone or other mussels (Newell 1989). The initial formation of mussel beds is dependent on the existence of hard substrates, such as stones, mollusk shells or debris (Jones 2000, Whitlatch 1982). Mussels have been found to attach to hard substrates in Great Bay, NH (Jones 2000), and to form reef structures that are important for a number of fish and invertebrates. In a study of estuaries of the northeastern U.S., eelgrass was found to provide settlement substratum for spat and juvenile blue mussels (Roman *et al*. 2000). An evaluation of suitable shellfish habitat in coastal New Hampshire assumed substrate preferences of rock and shell for juvenile and adult blue mussels and preferences of rock, shell, and eelgrass for reproduction of blue mussels (Banner and Hayes 1996).

Blue Mussel (*Mytilus edulis*)											
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	Not applicable								Eggs are pelagic
Larvae	Yes	Not applicable								Larvae are pelagic
YOY juveniles	Yes	0	0	2	2	1	1	1	2	In addition to hard substrates, spat settle on eelgrass and, presumably, on macroalgae
Older juveniles	Yes	0	0	2	2	1	1	1	2	Older juveniles also found on eelgrass, but hard substrate is presumably preferred
Adults	Yes	0	0	2	2	0	0	√	2	All age groups attach to any available hard substrate, including stones in mud and sand and other mussels, with byssal threads; dense mussel beds form in intertidal mudflats when colonizers attach to some hard substrate and then provide substrate for other mussels
Spawning adults	Yes	0	0	2	2	0	0	√	2	Same as adults

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Cunner (*Tautogolabrus adspersus*)

Depth

Cunner are found all along the shoreline of the GOM, and are less common on the New Brunswick shore and in the Bay of Fundy (Munroe 2002a). They primarily occur in coastal habitats within 3 km of the shoreline. Larger fish inhabit offshore ledges and banks as deep as 46-65 m; however, most of them remain in coastal waters. In the northern part of their range, cunner can be found below the low tide mark to about 18-30 m (Munroe 2002a). They may also be found in tidal creeks, but do not occur in brackish waters. Recently spawned eggs, larvae, and juvenile cunner are closely confined to the shoreline (Munroe 2002a). Both juvenile and adult cunner live near the bottom and use complex habitats that provide shelter from predators and reduce energy expenditure (Munroe 2002a, Bradbury *et al*. 1997). Their numbers drop off rapidly a short distance from cover (Olla *et al*. 1975). Shelter availability may be a factor limiting population size (Auster 1989). Cunner are a primary prey species for cod and white hake; other predators include sea raven, skate, sculpin, and tomcod (Munroe 2002a).

Substrate

Soft Sediments

Cunner are not associated with featureless mud or sand substrates.

Hard Substrates

Bottom habitats that provide cover for juvenile and adult cunner include rock reefs, rock outcrops, boulders, and vegetated cobble bottom (Auster 1989, Levin 1991, Bradbury *et al*. 1997).

Vegetated Substrates

Juveniles and adults aggregate in vegetated bottom habitats that provide cover. Newly settled juvenile cunner have been positively correlated with algal macrophytes attached to rocky substratum. In a study conducted in shallow water (6.5 m at low tide) near Portsmouth, NH, new recruits were associated with tall filamentous and foliose algae in a site dominated by sea urchins and with tall algae in a kelp bed site (Levin 1991). Algal species that were found growing on cobble included the foliose green alga *Ulva lactuca*, two species of filamentous red algae (*Ceraminium* sp. and *Polysiphonia* sp.), two species of corticated algae (*Desmarestia* sp. and *Ahnfeltia cribrosum*), and the kelps *Laminaria sacharina*, *L. digitata*, and *Agarum cribrosum*. Cunner also use eelgrass beds (Olla *et al*. 1979), although this habitat must be less important north of Portland, Maine where rocky coastal habitats predominate. Vegetated habitats that are only present seasonally are occupied by cunner in the summer months, as habitat value decreases when plants die back (Auster 1989).

Shellfish Beds

Cunner feed on mussels (Munroe 2002a) and may use mussel beds as seasonal habitat.

Cunner (*Tautogolabrus adspersus)*										
Life History Stage	**Depth <10m ?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	Not applicable								Pelagic eggs are closely confined to shoreline
Larvae	Yes	Not applicable								Pelagic larvae present in shallow water (< 5 m)
YOY juveniles	Yes	0	0	1	1	1	2	0	1	Newly settled juveniles seek cover in kelp and other macrophytes growing on rocky substrates, also common in other structured habitats, including eelgrass and probably mussel beds.
Older juveniles	Yes	0	0	1	2	1	2	1	1	Very common in a variety of nearshore habitats that provide cover, including rocky reefs and outcrops, boulders, vegetated hard substrates, tidal creeks, and eelgrass; older juveniles presumed to make more use of larger structures (e.g., boulders) than YOY juveniles
Adults	Yes	0	0	1	2	1	2	1	1	Adults utilize the same nearshore habitats as juveniles; they can also be found in waters deeper than 10 m
Spawning adults	Yes	0	0	1	2	1	2	1	1	Spawning assumed to occur throughout depth range

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Little Skate *(Leucoraja erinacea)*

Depth

Little skate are the most common inshore skates in the GOM (McEachran and Musick 1975, McEachran 2002), occurring along the entire coastline. A few were caught in otter trawls in shallow water (<10 meters) in a small estuary in New Hampshire (Fairchild *et al*. 2008) and in experimental gillnets in depths less than 20 meters on the Maine coast (Ojeda and Dearborn 1990). Little skate were observed moving back and forth into and out of the intertidal zone on flood and ebb tides in the Bay of Fundy (Tyler 1971) and a few were collected in beach seines in the mouth of the St. Croix River estuary in Passamaquoddy Bay, New Brunswick (MacDonald *et al*. 1984). Bigelow and Schroeder (1953) mention studies that suggest little skate deposit eggs (in capsules) in water not deeper than 27 m on sandy bottoms. The egg cases have sticky filaments, which allow them to stick to the bottom (Packer *et al*. 2003).

Substrate

Little skate are generally found on sandy or gravelly bottoms, but also occur on mud (McEachran 2002). Those caught in the Hampton-Seabrook, NH estuary were on sandy bottom, while the substrate where little skate were collected in a beach seine in Passamaquoddy Bay was described as sandy with gravel or rock. Those caught on the Maine coast were in the rocky sub-tidal zone.

Little Skate (*Leucoraja erinacea*)										
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	0	2	0	0	0	0	0	0	Eggs are laid in capsules that adhere to the bottom and are found in sandy habitats
Larvae	Not applicable									Skates have no larval stage
YOY juveniles	Yes	1	2	2	0	0	0	0	0	No information specific to YOY juveniles – assumed to occupy same habitat types as older juveniles and adults
Older juveniles	Yes	1	2	2	0	0	0	0	0	Little skates are generally found on sandy or gravelly bottoms, but also occur on mud
Adults	Yes	1	2	2	0	0	0	0	0	See juveniles
Spawning adults	Yes	0	2	0	0	0	0	0	0	Assume same as eggs

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Pollock (*Pollachius virens*)

Depth

Pollock are active, schooling fish, that use the entire water column. Small one-year-old pollock (20-25 cm long) are very common in inshore GOM waters in the spring. In the southern part of Massachusetts Bay they move out in June, probably in response to rising water temperatures, then return again in the fall. Juvenile pollock are abundant all summer and fall in harbors and bays all along the GOM coast (Klein-MacPhee 2002c). One-year-old pollock were common in experimental gillnet catches in the rocky subtidal zone on the Maine coast in depths <23 meters and were described as summer-fall residents (Ojeda and Dearborn 1990). Juvenile pollock were also abundant in beach seine catches in Passamaquoddy Bay (Bay of Fundy) in the summer (MacDonald *et al*. 1984). Pollock (presumably juveniles) are also present in unvegetated intertidal and subtidal creeks and channels of salt marsh estuaries in the GOM (Dionne *et al*. 1999).

Substrate

In a five-year beam trawl survey of shallow-water habitats along the Maine coast, YOY juvenile pollock (mean length 5 cm) were common in eelgrass (*Zostera marina*) beds in the southern and mid-coast zones and, to a lesser extent, in kelp (*Laminaria longicruris*) dominated habitats in the mid-coast. They were rare in eastern Maine where less eelgrass was encountered and, overall, catch rates were very low in unvegetated sandy substrate (Lazzari and Stone 2006). The authors concluded that shallow-water habitats in the GOM are key nursery habitats for pollock.

Rangeley and Kramer (1995) observed YOY pollock in Passamaquoddy Bay moving from the subtidal zone to the open intertidal zone in large schools on rising tides, then dispersing among available depths and throughout algal habitats in small schools or as solitary fish. When in algae (brown fucoids, especially rockweed, *Ascophyllum nodosum*), they preferred dense algal habitat (>50% algal cover) over sparse algal habitat (<50% cover). On falling tides, they schooled in the open habitat in downshore intertidal and subtidal zones. According to the authors, these results support the hypothesis that pollock were using both refuging and schooling antipredator tactics during intertidal zone migrations, and that rocky shores in the GOM are important nurseries for juvenile pollock.

Pollock (*Pollachius virens*)										
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	No	Not applicable								Eggs are pelagic
Larvae	No	Not applicable								Larvae are pelagic
YOY juveniles	Yes	1	1	1	1	2	2	1	0	Pollock are very active and can be found over any kind of inshore bottom habitat depending on the state of the tide; YOY juveniles are common in rocky intertidal and subtidal habitats, especially in rockweed, and in sandy eelgrass habitats. They are less common in open sandy habitats.
Older juveniles	No									Age 1+ juveniles are not nearly as common in shallow, nearshore habitats as YOY juveniles
Adults	No									Adults on offshore banks (e.g., Cashes Ledge)
Spawning Adults	No									See adults

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Red Hake (*Urophycis chuss*)

Depth

Red hake juveniles were rare (<0.5% of total numbers caught) in fyke and beach seine catches in the lower part of the Kennebec River in one of five years of sampling, and absent in the other four years (Lazzari *et al*. 1999). This species is mentioned by Targett and McCleave (1974) as an important component of the fish fauna of Montsweag Bay in mid-coastal Maine, even though no red hake were caught during a beach seine survey in a tidal cove in the bay. A few red hake were also caught with a beam trawl and an otter trawl in shallow water in a small New Hampshire estuary (Fairchild *et al*. 2008). Lazzari and Stone (2006) collected young-of-the-year red hake in a small beam trawl in depths <10 meters along the Maine coast and concluded that shallow-water habitats in the GOM are key nursery habitats for red hake. Older juvenile and adult red hake are rarely caught in depths <10 m in the Massachusetts bottom trawl survey (Packer *et al*. 2004). Klein-McPhee (2002d) concludes that adult red hake are found in relatively deep water in the GOM, particularly in the Great South Channel and on Georges Bank. This is probably true of the age 1+ juveniles as well.

Substrate

In a five-year beam trawl survey of shallow-water habitats in three zones along the Maine coast, the presence of YOY juvenile red hake (mean length 9.3 cm) was significantly related to one or more of three types of SAV-dominated habitats: eelgrass (*Zostera marina*), kelp (*Laminaria longicruris*), and macroalgae (*Phyllophora* sp.), although some were also caught in unvegetated soft bottom habitats (Lazzari and Stone 2006). In deeper water in the GOM, red hake are found on soft bottoms (sand and mud) with few being caught on gravelly, shelly, or rocky grounds (Klein-MacPhee 2002d). Juvenile red hake are frequently found inside live scallops and inside or under mollusk shells and structure appears to be critical for their survival (Able and Fahay 1998, Klein-MacPhee 2002d). However, scallops are not very common in depths <10 m in the GOM; a similar symbiotic association has not been observed with blue mussels, the most common shellfish species that forms beds in shallow GOM coastal waters. Red hake have been collected in a tidal salt marsh creek in the lower Kennebec River in Maine, but not in six other GOM salt marsh systems (Dionne *et al*. 1999).

Red Hake (*Urophycis chuss*)											
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	No									Eggs are pelagic
Larvae	No									Larvae are pelagic
YOY juveniles	Yes	1	1	1	0	2	2	1	0	YOY juveniles are common in soft-bottom SAV-dominated habitats on the Maine coast, but are also found in unvegetated soft bottom habitats; they are also found in other types of structured bottom habitats and in live scallops – but in deeper water; juvenile red hake have not been observed in mussel beds.
Older juveniles	No									Older juveniles are in deeper water
Adults	No									Same as older juveniles
Spawning adults	No									Red hake spawn on Georges Bank and in southern New England offshore waters

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Sand Lance (*Ammodytes americanus* and *A. dubius*)

Depth

Sand lance are important prey species for a number of commercial fish species and protected marine mammals (Auster and Stewart 1986, Nizinski 2002). There are two species of sand lance: *Ammodytes americanus*, which are predominantly found in shallow coastal waters from Delaware north to Labrador, and *A. dubius,* which are more common in deeper offshore waters from North Carolina to Greenland (Nizinski *et al*. 1990, Winter and Dalley 1988). There is little overlap in the offshore distribution, but extensive overlap inshore (Winter and Dalley 1988). *A. americanus* are mostly found in shallow coastal waters and estuaries in depths of 2 m or less. They are also known to burrow above the low water mark and are common on sandy beaches throughout the GOM (Nizinski 2002). They also are found in unvegetated intertidal and subtidal creeks and channels of salt marsh estuaries (Dionne *et al*. 1999).

Sand lance eggs are demersal and slightly adhesive. Spawning mostly occurs inshore or in in shallow channels, less than 2 m deep, where current speeds are low (Auster and Stewart 1986; Nizinski 2002). Sand lance larvae are most abundant at the mouths of estuaries (Auster and Stewart 1986). After the planktonic stage of two to three months, larvae become semi-demersal (Auster and Stewart 1986). Sand lance are a common prey species for a wide variety of fishes, seabirds, and marine mammals.

Substrate

Sand lance eggs have been collected in nearshore habitats on sandy substrates or gravel. Juvenile and adult sand lance are generally found together in schools (Auster and Stewart 1986) in habitats with substrates conducive to burrowing, including sandy bottoms, sand with crushed shell or fine gravel. They are seldom seen along rocky shorelines (Nizinski 2002, Meyer *et al*. 1979). They are most commonly found among sandy substrates, where they use the sand as refuge, burrowing to rest or escape from predators. Much of their time is spent buried in the substrate, particularly at night and over winter (Auster and Stewart 1986, Nizinski 2002). They have been seen disappearing to the bottom in small groups, burying about one quarter of their bodies in the sandy bottom (Meyer *et al*. 1979). Sand lance were the most frequently caught fish in a five-year beam trawl survey of inshore waters (<10 m deep) along the Maine coast: 63% were collected over unvegetated mud and sand habitats, 29% in eelgrass, and the rest in algae (6%) and kelp (1%) (M. Lazzari, pers. comm). All were adults.

Sand Lance (*Ammodytes americanus* and *A. dubius)*										
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	0	2	2	0	1	1	1	0	Eggs are demersal and slightly adhesive, found on sand and gravel in shallow water, probably also in eelgrass beds and algae growing in sand
Larvae	Yes	Not applicable								Larvae most abundant at mouths of estuaries; after planktonic stage, larvae become semi-demersal, but presumably do not utilize benthic habitats.
YOY juveniles	Yes	1	2	1	0	1	1	1	0	Presumably found in shallow-water habitats, no information on substrate use, but assumed to be the same as older juveniles and adults
Older juveniles	Yes	1	2	1	0	1	1	1	0	Generally prefer substrates conducive to burrowing (sand, sand with shell, fine gravel)
Adults	Yes	1	2	1	0	1	1	1	0	Most common over unvegetated mud and sand bottoms, some also in eelgrass beds and a few in sand with red alga *Phyllophora* sp.
Spawning adults	Yes	0	2	2	0	1	1	1	0	Spawning mostly occurs inshore or in shallow channels, less than 2 m deep, where current speeds are low; assume substrates are same as for eggs

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Smooth Flounder (*Pleuronectes putnami*)

Depth

Juvenile and adult smooth flounder are common all along the GOM shore from the Bay of Fundy to the northern side of Massachusetts Bay, but are confined to nearshore waters, occurring chiefly in estuaries or river mouths and in sheltered bays and harbors from the tide line down to about 27 m (Klein-MacPhee 2002e). They are most abundant between 3.6 and 9 meters. Smooth flounder spawn in the winter (December-March in NH); the eggs are demersal and non-adhesive.

In the New Hampshire's Great Bay estuary, juvenile and adult smooth flounder were abundant in otter trawl catches at five stations with mean depths of 1.5-6.2 m (Armstrong 1997). They were most abundant in a mesohaline, riverine habitat, with the smallest individuals in shallower water. Intertidal mudflats were an important nursery area for YOY juveniles. Smooth flounder were the second most abundant species caught in beach seines in a cove in Montsweag Bay, Maine and are also abundant in the channels of the bay (Targett and McCleave 1974). MacDonald *et al*. (1984) reported that smooth flounder were common in bottom gillnet catches in Passamaquoddy Bay at a station with a maximum depth of 3 m. They were not listed by Dionne *et al*. (1999) as present in GOM salt marsh creeks. Given their small size and common occurrence in shallow, coastal waters, they are probably an important prey species for many larger fish.

Substrate

Smooth flounder are found mostly on soft mud bottom (Klein-MacPhee 2002e). All three studies referenced above confirm that this is the only substrate type used by this species. All of the fish caught in Great Bay were on silty mud; the bottom in the cove in Montsweag Bay was finely textured mud, rich in organic matter, with no rooted vegetation, and in Passamaquoddy Bay it was mud with gravel or rocks.

Smooth Flounder (P*leuronectes putnami*)											
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	2	0	0	0	0	0	0	0	Eggs are demersal, presumed to occur in same habitat (mud) as juveniles and adults
Larvae	Yes	Not applicable								Larvae are pelagic
YOY juveniles	Yes	2	0	0	0	0	0	0	0	Juveniles found on soft mud bottom; nursery habitat for YOY juveniles includes the intertidal zone
Older juveniles	Yes	2	0	0	0	0	0	0	0	Soft mud bottom
Adults	Yes	2	0	0	0	0	0	0	0	Soft mud bottom
Spawning adults	Yes	2	0	0	0	0	0	0	0	Spawning takes place in shallow, nearshore waters

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Soft-shell Clam (*Mya arenaria*)

Depth

Soft-shell clams are found in intertidal and shallow subtidal areas of bays and estuaries throughout the northeast region (Evans *et al* .2011, Grizzle *et al*. 2006, Jones 2000, Newell and Hidu 1986, Gosner 1978). In New England, soft-shell clams are most abundant in the intertidal area (Newell and Hidu 1986, Whitlatch 1982), and the commercial harvest of soft-shell clams is prevalent on intertidal mudflats, especially in northern New England (Roman *et al.* 2000). Furthermore, tidal flats have been found to serve as nursery grounds for soft-shell clams (Kelso 1979). An analysis of suitable shellfish habitat in coastal New Hampshire assumed a preferred depth range of +2 to -1 feet MLW for juvenile, adult and spawning soft-shell clams (Banner and Hayes 1996).

Substrate

Soft-shell clams live in soft muds, sands, compact clay, coarse gravel and between stones (Evans *et al*. 2011, Newell and Hidu 1986). In Great Bay, New Hampshire, clams have been found to be most abundant in muddy to silty sand (Jones 2000), and a firm sand/mud/clay mixture, with higher densities found in slightly firmer substrates (Langan 1997). Newell and Hidu (1986) noted that soft-shell clams grow faster in fine sediments and fastest in sand or sandy mud. While there is a range of substrates associated with soft-shell clams, Langan (1997) found that substrates that are too firm (marine clay) or too soft (soupy mud) make conditions less favorable for settlement and survival of *Mya arenaria*. An analysis of suitable shellfish habitat in coastal New Hampshire assumed that juvenile, adult, and spawning soft-shell clams prefer substrates of sand, silt, clay and silty sand (Banner and Hayes 1996).

Soft-shell Clam (*Mya arenaria*)										
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	Not applicable								Eggs are pelagic
Larvae	Yes	Not applicable								Larvae are pelagic
YOY juveniles	Yes	2	2	1	0	0	0	0	0	Preferred substrates are firm sand and mud or mixtures of the two – also found in soft mud, and gravel and between rocks; presumed to be common in eelgrass beds (in the sand)
Older juveniles	Yes	2	2	1	0	0	0	0	0	See above
Adults	Yes	2	2	1	0	0	0	0	0	See above
Spawning adults	Yes	2	2	1	0	0	0	0	0	See above

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Tautog (*Tautoga onitis*)

Depth

Tautog are most abundant from Cape Cod to Chesapeake Bay, but do occur in the GOM. Tautog are strictly coastal, especially in the northern part of their range. Their regular range in the GOM is in suitable locations from Cape Cod Bay to Cape Ann, Massachusetts; further north, they are less abundant and more localized (Munroe 2002b). North of Cape Cod, they rarely occur deeper than 9-18 m or more than 5-6 km from shore (Munroe 2002b; Steimle and Shaheen 1999). This species can be found in waters shallower than one meter and are known to feed on blue mussels in the intertidal zone (Munroe 2002b). Spawning occurs within inshore waters and at the mouths of estuaries (Munroe 2002b). Newly settled juveniles inhabit shallow areas less than a meter deep in estuaries and tidepools, and move into deeper water as they get older (Steimle and Shaheen 1999). Adults are found inshore in the summer and, though some may go into deeper waters in the winter, others may remain inshore and overwinter in shallower waters (Auster 1989, Steimle and Shaheen 1999). This species does not inhabit salt marsh creeks and channels (Dionne *et al*. 1999).

Substrate

GOM Tautog are extremely localized (Munroe 2002b) and tend to prefer habitat that provides shelter and cover. Eggs and larvae have been found over eelgrass-vegetated sites, as larvae migrate in the water column (Steimle and Shaheen 1999). Small juveniles use sea lettuce (*Ulva lactuca*) and other macroalgae for cover. Though they can be caught in seines on sandy beaches, juveniles are more often found in vegetated areas or macroalgal mats (Munroe 2002b). Availability of this sheltering habitat may be a limiting factor for juveniles less than two years old. As they grow, tautog tend to move to eelgrass and rocky habitats and may also use shellfish beds and three-dimensional objects or structures with crevices and holes. YOY tautog may prefer small boulders over cobble habitat and also use empty oyster and clam shells (Steimle and Shaheen 1999, Munroe 2002b).

The mouths of estuaries and inlets are especially important for both juvenile and adult tautog. Studies have shown that adults also prefer vegetated habitats over unvegetated (Steimle and Shaheen 1999). More tautog are found in high-density eelgrass beds (Dorf and Powell 1997). Adults can be found in a variety of sheltering habitats including vegetation, rocks, natural and artificial reefs, pilings, jetties, groins, and mussel and oyster beds (Steimle and Shaheen 1999). This dependence on cover is likely related to protection from predation. Though tautog occur in areas with cover, a substantial number are present in areas where cover is only available seasonally. Tautog return to overwintering habitat after the fall when macroalgae and eelgrass beds die back. In the winter months, tautog can be found in deep recesses or holes, and are often buried under several millimeters of sand (Olla *et al*. 1979).

Tautog (*Tautoga onitis*)										
Life History Stage	**Depth <10m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	Not applicable								Eggs and larvae are pelagic
Larvae	Yes	Not applicable								Larvae found over eelgrass beds
YOY juveniles	Yes	0	1	1	2	2	2	0	1	Newly-settled juveniles found in very shallow water (<1 m), more common in vegetated habitats that provide cover, but also caught on sandy shorelines
Older juveniles	Yes	0	0	1	2	2	2	0	2	Juveniles move into deeper water as they get older, found in eelgrass and rocky habitats, shellfish beds, and other structures with crevices and holes
Adults	Yes	0	1	1	1	2	2	0	1	Adults found in shallow water in the summer, some remain during the winter; they utilize a variety of sheltering habitats (eg vegetation, rocks, reefs, pilings, groins, and mussel beds), but prefer vegetation; some bury in sand in the winter
Spawning adults	Yes	0	0	1	1	2	2	0	1	Spawn in inshore waters and mouths of estuaries, presumed to utilize same habitats as adults

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White Hake (*Urophycis tenuis*)

Depth

Juvenile white hake were common in beam trawl and throw trap catches in shallow-water (<6 m) habitats at two locations in mid-coast Maine (Lazzari 2002). They were rare (<0.5% of total numbers caught) in fyke and beach seine catches in the lower part of the Kennebec River in one of five years of sampling, and absent in the other four years (Lazzari *et al*. 1999). They were also rarely caught in beam trawls in Penobscot Bay (4 of 378 fish caught) (Lazzari and Tupper 2002). This species is mentioned by Targett and McCleave (1974) as an important component of the fish fauna of Montsweag Bay, in mid-coastal Maine, even though no white hake were caught during a beach seine survey in a tidal cove in the bay. Juvenile white hake (<15 cm) were a common component of beach seine catches in Passamaquoddy Bay (Bay of Fundy) in the summer (MacDonald *et al*. 1984). White hake are also common in unvegetated salt marsh creeks and channels and eelgrass meadows in GOM coastal waters (Heck *et al*. 1989, Dionne *et al*. 1999).

Most, if not all, of the juvenile white hake collected in inshore GOM waters are presumed to be YOY juveniles since the mean length of 208 fish caught in beam trawls in <10 m of water along the Maine coast between 2000 and 2004 was 8.3 cm (Lazzari and Stone 2006). Markle *et al*. (1982) note that juvenile white hake in the Bay of Fundy make the transition from the pelagic to the demersal juvenile stage at 5-6 cm TL. White hake of this size are separated from juveniles >15 cm by depth, the larger ones occurring at depths >50 meters (Klein-MacPhee 2002f).

Substrates

The juveniles collected by Lazzari (2002) were common in eelgrass and unvegetated soft bottom habitats, but showed no preference for either habitat type. In a more comprehensive five-year beam trawl survey of shallow-water habitats in three zones along the Maine coast, the presence of YOY juvenile white hake (mean length 8.3 cm) was significantly related to one or more of three types of SAV-dominated habitats: eelgrass (*Zostera marina*), kelp (*Laminaria longicruris*), and algae (*Phyllophora* sp.); a few were also caught over unvegetated mud and sand (Lazzari and Stone 2006). The authors concluded that shallow-water GOM habitats are key nursery habitats for white hake.

White Hake (*Urophycis tenuis*)										
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	No	Not applicable								Eggs are pelagic
Larvae	No	Not applicable								Larvae are pelagic
YOY juveniles	Yes	1	1	0	0	2	2	2	0	YOY juveniles are more common in vegetated inshore habitats than in unvegetated mud and sans habitats, also in salt marsh tidal creeks
Older juveniles	No									Older juveniles move into deeper water (>50 meters)
Adults	No									See above
Spawning adults	No									White hake spawn on the outer continental shelf and slope

0 = life stage does not occur in this habitat type
1 = life stage is present in this habitat type, but is not common
2 = life stage is common or abundant in this habitat type

Unshaded cells indicate rankings that were based on literature review or inferred from published information for other life stages. Shaded cells indicate uncertain rankings that were based solely on best professional judgment.

Windowpane Flounder (*Scophthalmus aquosus*)

Depth

Juvenile and adult windowpane flounder occupy shallow-water GOM habitats, including the intertidal zone. The young settle in shallow inshore waters and tend to move into deeper, offshore waters as they grow (Klein-MacPhee 2002g). Juveniles (<22 cm) and adults (>=22 cm) are abundant in bottom trawl catches between 6 and 10 m in Massachusetts (NEFSC 2004). They feed exclusively on actively swimming prey (e.g., mysids, decapod shrimp, and fish larvae (Chang *et al*. 1999; Klein-MacPhee 2002g).

Substrate

Windowpane flounder are very common on sandy bottoms in southern New England and further south, but their comparative abundance in Casco Bay and in the Bay of Fundy shows that they also frequent softer and muddier grounds in the GOM (Klein-MacPhee 2002g). Laboratory experiments have shown that transitional (8-18 mm SL) and larger (32-89 mm SL) juveniles prefer sand to mud (Klein-MacPhee 2002g), perhaps because it provides a more suitable substrate for burial or because their prey are more abundant over sandy bottom.

Windowpane flounder were collected in beam and otter trawl samples in shallow sandy habitats throughout a small estuary in New Hampshire, but not in large numbers (Fairchild *et al*. 2008) and in beam trawls in Penobscot Bay (only 3 of 378 fish caught) (Lazzari and Tupper 2002). Sixty-five windowpane flounder were collected in a beam trawl during a five-year survey of shallow-water (<10 m) habitats along the Maine coast (M. Lazzari, pers. comm). Most of them (71%) were caught over unvegetated mud and sand habitats, and the rest were caught in vegetated habitats (eelgrass, kelp, and algae). This species was also collected in tidal creeks in the Little River salt marsh (Wells, Maine), but not in six other GOM salt marsh systems (Dionne *et al*. 1999).

Windowpane flounder (*Scopthalmus aquosus*)										
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs		Not applicable								Eggs are pelagic, do not occur in GOM
Larvae		Not applicable								See above
YOY juveniles	Yes	1	2	0	0	1	1	1	0	Mostly caught in unvegetated sandy habitats survey in shallow-water beam trawl survey of Maine coast; may also inhabit muddy bottom, but sand is preferred substrate.
Older juveniles	Yes	1	2	0	0	1	1	1	0	Older juveniles move into deeper water, but are still common <10 m; substrate preferences are the same for older juveniles and adults
Adults	Yes	1	2	0	0	1	1	1	0	Common in depths <10 m in Massachusetts
Spawning adults	No									Spawning occurs in the Mid-Atlantic, southern New England, and on Georges Bank

0 = life stage does not occur in this habitat type
1 = life stage is present in this habitat type, but is not common
2 = life stage is common or abundant in this habitat type

Unshaded cells indicate rankings that were based on literature review or inferred from published information for other life stages. Shaded cells indicate uncertain rankings that were based solely on best professional judgment.

Winter Flounder (*Pseudopleuronectes americanus*)

Depth

Winter flounder in southern New England and the Mid-Atlantic spawn in nearshore, marine and estuarine waters in depths of 5 m or less in the winter and early spring (Pereira *et al*. 1999, Klein-MacPhee 2002h, Able and Fahay 2010). The eggs are adhesive and laid in clusters on a variety of substrates, including sand, muddy sand, and mud and gravel, although sand seems to be the most common (Pereira *et al*. 1999). In some studies (e.g., Crawford and Carey 1985) eggs were found attached to algae. In Newfoundland and in Passamaquoddy Bay (lower Bay of Fundy) spawning occurs in less than 10 m of water (Kennedy and Steele 1971; McCracken 1963). In the southwestern GOM, recent tagging studies have shown that winter flounder spawn in deeper coastal waters, more so than in shallow nearshore waters (DeCelles and Cadrin 2010, E. Fairchild, pers. comm.). Adults may remain in spawning areas after spawning before moving into deeper water (20 m in Passamaquoddy Bay) as water temperatures increase (McCracken 1963).

Even if winter flounder in the GOM spawn primarily in deeper coastal waters, shallow nearshore benthic habitats are important nursery areas because the planktonic larvae would be transported shoreward before metamorphosing into juveniles and settling to the bottom. Shallow, nearshore habitats – including the intertidal zone (see Tyler 1971) – also provide shelter (e.g., submerged aquatic vegetation) and food resources for juvenile winter flounder. Juvenile winter flounder prey primarily on polychaetes and amphipods, organisms that are found in soft sediments. Tyler (1971) documented the movement of adult winter flounder into the intertidal zone in Passamaquoddy Bay during flood tides and proposed that it was a major feeding area for northern populations of this species.

Substrate

Vegetated and Non-vegetated Soft Sediments (Mud, Sand)

Research conducted in New Jersey shows that recently metamorphosed juvenile winter flounder are more likely to settle to the bottom in areas of low current velocity with fine sediments, but older YOY juveniles can be found on a variety of substrates (Curran and Able 2002, Chant *et al*. 2000, Stoner *et al*. 2001). Juvenile winter flounder remain in shallow-water habitats for most of their first year of life, migrating into deeper water in the fall as nearshore water temperatures decline (Able and Fahay 2010). Howell *et al*. (1999) showed that YOY juveniles in Connecticut estuaries (depths < 5.5 m) were more abundant on muddy sediments with debris (shells, wood, leaves) or live bivalves than on sand. Analysis of catch data from New Jersey's Navesink River indicated that the probability of capturing recently settled juveniles was high on medium- to coarse-grained sand (mean diameter 0.5 mm), while slightly larger YOY juveniles were least likely to be collected on fine sediments and were most common on coarse to very coarse sand (mean diameter 1 mm) (Phelan *et al*. 2001). Laboratory studies showed that smaller individuals (<40 mm SL) preferred fine-grained sediments (for burial) while larger individuals (40 mm SL) preferred coarse-grained sediments.

The most useful studies of juvenile winter flounder habitat use in coastal and estuarine GOM waters have been conducted by M.A. Lazzari and colleagues at the Maine Department of Marine Resources. Data were collected from different habitats and analyzed statistically so that the degree to which YOY and older juveniles were associated with each habitat could be evaluated quantitatively. Juvenile winter flounders (ages 0+ and 1+) were a principal component of the samples collected during these studies. The results, presented below, indicate that YOY juveniles prefer vegetated habitats, particularly eelgrass, but are also common in unvegetated, soft-sediment, nearshore habitats.

Results from a five-year beam trawl survey in 28 estuaries on the Maine coast (depth <10 meters) were presented in two publications (Lazzari and Stone 2006, Lazzari 2008). The first one dealt with the early life history stages of a variety of species and the second one focused on YOY winter flounder. During four of the five years (2001-2004), the frequency of occurrence and abundance and frequency of occurrence of YOY juveniles were higher in eelgrass (*Zostera marina*) than in kelp (*Laminaria longicruris*), drift algae (*Phyllophora* sp.), and unvegetated sand/mud habitats. In the fifth year (2000), when overall catch rates were much higher, they were distributed much more uniformly across all four habitat types (Lazzari 2008). The significant variables in a logistic regression model were year, temperature, and eelgrass presence. According to the author, these results indicate that the type of habitat most important to YOY winter flounder varies among estuaries. However, it is also possible that eelgrass is the preferred habitat, but is limited in extent so that in years when YOY juveniles are abundant, they disperse into less preferred habitats.

Data for all sizes of winter flounder collected during this study were analyzed initially by Lazzari and Stone (2006) and produced similar results. More than 60% of them were YOY juveniles and about 30% were one-year-olds. The percentage of positive tows was higher in eelgrass in all three regions of the coast, but barely so in the mid-coast region in 2000 when catch rates were high. A logistic regression model predicted that the presence of winter flounder was positively, and significantly, correlated to the presence of eelgrass in all three zones. The authors concluded that shallow-water GOM habitats (and, I would add, especially those with eelgrass) function as facultative nursery areas for winter flounder (i.e., they use both estuarine and open-water habitats). Other shallow-water GOM studies conducted by Lazzari and co-workers and by other researchers (see below) support this conclusion.

YOY and age 1+ juvenile winter flounder were collected in the inlet channel to a salt pond and on a nearby sandy beach in the lower part of the Kennebec River (mid-coast Maine) where they accounted for 2.8-7.1% of all fish caught in fyke nets and 0-2.5% in beach seine hauls during each of five different years (Lazzari *et al*. 1999). In a subsequent study, juvenile winter flounder occurred in beam trawl and throw trap catches in eelgrass and unvegetated sandy shallow-water (<6 m) habitats at two locations in mid-coast Maine, but showed no preference for either habitat type (Lazzari 2002). YOY winter flounder were also caught in 23% of tows at 10 of 14 stations in Penobscot Bay, but were most abundant at three upper bay stations. One of these was 100% mud with no vegetation, and the other two were mud plus other substrates with eelgrass (Lazzari and Tupper 2002). Juvenile winter flounder were more abundant in eelgrass beds than they were in unvegetated habitats in Maine's Damariscotta River (and dominated fish collections at night (Mattila *et al*. 1999).

Winter flounder have also been collected in eelgrass meadows and in an adjacent unvegetated sandy site in Nauset marsh on Cape Cod as well as in in coastal salt marsh estuaries in Wells, Maine and Waquoit Bay, on the south side of Cape Cod (Heck *et al*. 1989, Ayvazian *et al*. 1992). Heck *et al*. (1989) state that the eelgrass beds in Nauset marsh are nursery habitat for juvenile winter flounder. Dionne *et al*. (1999) list winter flounder as present in salt marsh tidal creeks and channels in a number of locations in the GOM.

Juvenile winter flounder (ages 0+, 1+, and 2+) were collected in a small bottom trawl in the Great South Bay estuary (New Hampshire) in depths <8 meters in silty mud (Armstrong 1987). They were most abundant at a polyhaline, open-bay habitat. Few were found in the intertidal mudflat habitat. No YOY winter flounder were caught in the upper estuary until late summer and early fall, indicating an influx from the lower estuary. In another New Hampshire estuary where bottom sediments are very homogeneous, YOY juveniles were abundant in beam and otter trawl catches in sandy habitats (Fairchild *et al*. 2008). Age 2+ winter flounder were abundant in shallow water during summer in Passamaquoddy Bay in the Bay of Fundy (MacDonald *et al*. 1984).

Hard Substrates

There are very few references to the use of hard bottom substrates by winter flounder. Klein-MacPhee (2002h) states that they (presumably adults and older juveniles) are found on hard bottom on the offshore banks (Georges Bank and Nantucket Shoals) and Crawford and Carey (1985) reported that divers found eggs on a gravel bar in a coastal pond in Rhode Island. Pereira *et al*. (1999), summarizing information found in several publications, concluded that adults – but not juveniles – are found on or over mud, sand, cobble, rocks, and boulders in depths of 1-30 m in inshore waters. We conclude that inshore hard bottom substrates, with or without vegetation, do not provide any functional value (food or shelter) for juvenile winter flounder in the GOM.

Shellfish Beds

Howell *et al*. (1999) reported that densities of YOY winter flounder in several Connecticut estuaries were highest in mud/shell-litter habitat. The mud/shell-litter habitat was mud covered by live bivalves or shells and the bivalves were *Mulinia lateralis, Mytilus edulis, Gemma gemma, Crassostrea virginica, Mercenaria mercenaria, and Noetia* spp. No other studies that compared the use of shellfish beds with other habitat types were available, so it is difficult to evaluate how important this habitat type is for juvenile winter flounder. Of the species listed above, only *Mytilus edulis* is common in shallow, inshore waters in the GOM.

Winter Flounder (*Pseudopleuronectes americanus*)										
Life History Stage	**Depth <10 m?**	**Habitat Type**								**Comments**
		Mud	**Sand**	**Gravel/ Cobble**	**Boulder/ Ledge**	**Eelgrass**	**Macro algae**	**Salt marsh**	**Shellfish beds**	
Eggs	Yes	1	2	1	0	2	1	0	0	Demersal eggs are adhesive and laid in clusters on a variety of substrates, but most commonly on sand (assume also in eelgrass)
Larvae	Yes	Not applicable								Larvae are pelagic
YOY juveniles	Yes	2	2	0	0	2	1	1	1	In the GOM, eelgrass is preferred, but other habitats are utilized when abundance is high; in CT and NJ estuaries, YOY settle in areas of low current velocity on fine sediment, sometimes with live bivalves or shells
Older juveniles	Yes	2	2	0	0	2	1	2	0	One-year-old juveniles are found on a variety of bottom types in depths <10 m, but are also common in deeper water
Adults	Yes	1	1	1	1	1	1	1	0	Adults may remain in shallow water after spawning or move into slightly deeper water on a variety of substrates , including cobble and boulders
Spawning adults	Yes	1	2	1	0	2	1	0	0	In the GOM, winter flounder apparently spawn mostly in deeper coastal waters than in southern New England, but some spawning probably occurs in shallow water as well; substrates assumed to be same as for eggs

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