Omnibus EFH Amendment 2 Groundfish Management Area Development Hotspot analysis - juvenile groundfish substrate association scoring

The Closed Area Technical Team developed scores for a series of metrics to sum and use as weights/multipliers for the gridded groundfish hotspots. For juveniles, the metrics include stock status, sub-populations, residency, and substrate association. These metrics are intended to incorporate both the need for spatial management measures (stock status) and the likelihood that the species might benefit from such measures (sub-populations, residency, stock status).

This document explains the substrate association metric, which was developed to indicate the affinity of juveniles (age 0 and 1) of particular stocks with different types of habitat. Scores were assigned on a 1-3 scale, as follows (Table 1):

Table 1 – Substrate association values

Score	***Qualitative definition***
1	Juveniles (age 0 and 1) occur almost exclusively in mud- or sand-dominated habitat types.
2	Juveniles (age 0 and 1) occur in mud- or sand-dominated habitats, but <u>also occur</u> in gravel habitats including finer gravels (granules, pebbles) and/or coarser gravels (cobbles, boulders). Associations with biological structures found in gravel environments have been documented for some of these species.
3	Juveniles (age 0 and 1) may be found in mud- or sand-dominated habitats, but have a <u>strong affinity</u> for gravel habitats including finer gravels (granules, pebbles) and/or coarser gravels (cobbles, boulders). Associations with biological structures found in gravel environments have been documented for some of these species. <u>Lack of suitable gravel habitats may significantly compromise recruitment and survival of these species.</u>

Substrate size classes are described as follows (Table 2), to correspond with the classification used in the Swept Area Seabed Impact Model (NEFMC 2011). Because substrate descriptions vary widely in the habitat literature, particle size is a useful way to compare results across studies.

Table 2 – Substrate classes by particle size range (based on Wentworth, 1922)

Substrate	***Particle size range***	***Corresponding Wentworth class***
Mud	< 0.0039-0.0625 mm	Clay (< 0.0039 mm) and silt (0.0039 – 0.0625mm)
Sand	0.0625 – 2 mm	Sand (0.0625 – 2 mm)
Granule-pebble	2-64 mm	Granule (2-4 mm) and pebble (4-64 mm)
Cobble	64 – 256 mm	Cobble (64 – 256 mm)
Boulder	> 256 mm	Boulder (> 256 mm)

Framing this discussion around fish association with substrate and assigning the highest scores to larger grain sizes is a sensible approach as the fauna associated with large grain size sedimentary habitats are more vulnerable to fishing, and this is one of the fundamental relationships that drive the SASI model. However, it should be noted that all habitats have some level of vulnerability. One example of a higher vulnerability soft-sediment habitat type is tube-dwelling cerianthid anemone aggregations in low energy mud habitats. Another is eelgrass beds occurring in nearshore sandy habitats. Juvenile fish have been documented in association with both of these biological features. In addition to being more straightforward, identifying substrate association is somewhat more practical than summarizing a more specific association with habitat, including abiotic and biotic features, because substrate distributions are more easily mapped. The substrate-driven classification at this stage in the hotspot analysis is consistent with the substrate-driven approach to habitat vulnerability modeling in SASI. The earlier choice in framing the SASI model approach was taken due to substrate data being more available and comparable region wide than biological (specifically epifaunal) data.

We reviewed the literature on fish habitat association with a focus on juvenile habitat use. Substrate affinity scores and associated rationales for all large mesh juvenile groundfish are summarized in Table 4. Tables listing the individual species references follow the summary table. A review of these subsequent tables makes clear the fact that the robustness of the body of literature supporting these substrate association assessments varies widely by species. The most helpful studies directly examine fish habitat use in-situ using visual techniques, but other must be interpreted more cautiously.

One overarching issue in this evaluation is that many studies do not specify the size or age of fish evaluated, or they explicitly pool fish across sizes/ages. The intent with the juvenile analyses was to focus on age 0 and age 1 fish (defined by size in the analysis, Table 3), so, if they were available, studies of these younger juveniles were the focus of the scoring. Another issue is that many studies infer habitat associations from the magnitude of trawl survey catches over a particular substrate type. This approach could produce imprecise associations for two reasons. First, if the spatial scale of the survey, specifically the length of each tow, is coarser/longer than the patchiness of the habitat types used by the fish, catch during a single tow could be coming from more than one substrate class. Second, in many cases the data underlying the habitat distribution maps used in these studies are of inconsistent or low resolution and/or poorly represent large grain sizes. Thus, these inferential trawl survey studies are useful for detecting general patterns across the geographic range of a species/stock, but do not precisely identify fish interaction with seabed habitats at the local level.

Table 3 – Size thresholds used to define age-0 and age-1 fish by species. For the purposes of the hotspot analysis, these lengths were rounded up to the nearest 5 cm. Spring (sp) lengths were applied to spring and fall survey data, and fall (fa) lengths were applied to fall and winter survey data. Total number of fish at a station equal to or smaller than the size were analyzed.

Species	*Juvenile size thresholds* *Age 0 and 1 length (90th percentile, cm)*
Acadian redfish	14 (Sp), 13 (Fa)
American plaice	12 (Sp), 18 (Fa)
Atlantic cod (GOM and GB stocks)	24 (Sp), 34 (Fa)
Atlantic halibut	Used winter flounder values - 18 (Sp), 28 (Fa)
Atlantic wolffish	47
Haddock (GOM and GB stocks)	24 (Sp), 34 (Fa)
Ocean pout	29
Pollock	23 (Sp), 32 (Fa)

Species	***Juvenile size thresholds Age 0 and 1 length (90th percentile, cm)***
White hake	34 (Sp), 39 (Fa)
Windowpane flounder (northern and southern stocks)	Used yellowtail flounder values - 13 (Sp), 15 (Fa)
Winter flounder (GOM and GB stocks)	18 (Sp), 28 (Fa)
Witch flounder	20 (Sp), 19 (Fa)
Yellowtail flounder (GB, CC/GOM, and SNE/MA stocks)	13 (Sp), 15 (Fa)

Table 4 – Substrate affinity scores and rationale

Species	***Score assigned***	***Rationale (for references, see individual species tables)***
Acadian redfish	3	Habitat association studies in the deep mud habitats near Stellwagen Bank found that juvenile redfish were one of the most numerous species observed on deep (50-100 m) boulder reefs. Early juveniles (age 0, <10 cm) were found primarily on the reefs themselves, while late juveniles (10-20) were found on both the reefs and among adjacent dense aggregations of cerianthid anemones. General studies across a broad range of sizes including juveniles and adults (> 20 cm) indicate association with various substrates, except for sand.
American plaice	1	No information specific to small juveniles, but general studies across a range of sizes indicate preference for mud and sand. Some evidence of association with fine gravels in other regions, but in the GOM appears to be sand/mud associated.
Atlantic cod (GOM and GB stocks)	3	A number of field and lab studies focusing on juveniles. Inshore studies generally confirm a preference among young-of-the-year juveniles for structured bottom habitats that provide shelter from predators. Habitat association studies on eastern Georges Bank indicate that there is a narrow window when recently-settled juveniles are closely associated with gravel substrates on the northern edge of the bank; later in the year they disperse and occupy a wider range of substrates. Studies in the SWGOM have found very young juvenile cod along the margins of boulder reefs, and trawl survey data from mid-coast Maine indicate that larger juveniles (10-25 cm) were far more abundant on gravel than on mud or sand bottom.
Atlantic halibut	2	There is little information available on their habitat associations. Adults are found over sand, gravel or clay substrates, but not on soft mud or rock bottom.
Atlantic wolffish	2	Attempts to relate catches of Atlantic wolffish in bottom trawl surveys to substrate types are of limited value because of survey catchability and substrate mapping issues, and the results can be somewhat contradictory. However, the data indicate that the juveniles do not have strong habitat preferences, and that adults are more widely distributed over a variety of bottom types once they leave their rocky spawning grounds.
Haddock (GOM and GB stocks)	3	Like cod, young of the year haddock settle on a variety of sediment types on eastern Georges Bank, but by August they are found primarily on gravel pavement areas (Lough et al. 1989, Valentine and Lough 1991).
Ocean pout	2	Ocean pout juveniles are found on a wide variety of substrates, including shells, rocks, algae, soft sediments, sand, and gravel.
Pollock	2	Rocky shores in the Gulf of Maine are important nurseries for juvenile pollock; pollock found further offshore are not strongly associated with any particular substrate type.

Species	***Score assigned***	***Rationale (for references, see individual species tables)***
White hake	1	General studies across a range of sizes indicate preference for mud and sand. However, it is noted that eelgrass is an important habitat for young-of-the-year juveniles. While eelgrass is a relatively vulnerable habitat type, it grows in sand and is found exclusively inshore.
Windowpane flounder (northern and southern stocks)	1	Juvenile and adult windowpane flounder are caught on sandy bottoms off southern New England and southwards but also frequent softer and muddier grounds in the GOM.
Winter flounder (GOM and GB stocks)	1	A number of studies of young-of-the-year juvenile habitat use in shallow water estuaries in southern New England clearly show a preference for mud and sand habitats, and for eelgrass along the coast of Maine. There is no information on juvenile substrate associations in deeper water.
Witch flounder	1	General studies across a range of sizes indicate a strong preference for mud and sand. No information is available for age 0 and 1 juveniles.
Yellowtail flounder (GB, CC/GOM, and SNE/MA stocks)	1	Direct observations of young of the year juveniles in the New York Bight showed settlement in the available habitat (bare sand, shell hash, sand dollars) or associated with clean sand substrates, which often included peaks of sand wave crests. Other more general studies indicate a preference across a wider range of fish sizes for coarse sand and gravel over fine sand and mud sediments.

Table 5 – Acadian redfish substrate associations

Source	***Type of study, depth range***	***Location***	***Fish sizes/ages***	***Results***
Auster et al. 1998	Visual census	Western GOM	All sizes	Redfish occurred primarily in boulder reef habitats (piled boulders with deep interstices) but also in gravel with scattered boulders.
Auster et al 2003	ROV survey	Stellwagen Bank NMS	YOY (<10 cm) and older (10-20 cm) juveniles	Early demersal phase (0-year) redfish occurred only on deep boulder reefs but late juveniles occurred both on the reefs and in dense cerianthid anemone habitats surrounding exposed boulders, but not on mud w/o anemones.
Bigelow & Schroeder 1953	Fishermen?	Gulf of Maine	All sizes	Most abundant over silt, mud, or hard bottom, rarely over sand.
Scott 1982	Trawl survey data	Scotian shelf	All sizes	Prefer fine grained and mixed sediments (gravel, silt, clay, and boulders).
Methratta and Link 2006	Analysis of trawl survey data and USGS sediment data	Gulf of Maine	All sizes	Redfish in NEFSC survey area are broadly distributed across substrate types.
Auster et al 2001	Trawl survey and acoustic data	SWGOM, Stratum 26	All sizes	High densities (nos/tow) significantly correlated with low reflectance (soft) substrates, but no trawling in rocky reef habitats.

Table 6 – American plaice substrate associations

Source	*Type of study, depth range*	*Location*	*Fish sizes/ages*	*Results*
Sparholt 1990	UNK	North Sea	UNK	Prefer soft bottom substrate
Scott & Scott 1988	Bottom trawl surveys	Canada	UNK	Frequently found on fine sand or gravel
Bowering & Brodie 1991	Bottom trawl surveys?	Canadian NW Atlantic	UNK	Frequently found on fine sand or gravel
Morgan 2000	Lab study		UNK	Clear preference for finer gravelly sand over coarser gravel.
Scott 1982	Bottom trawl surveys	Scotian shelf	All sizes	Highest catch rate on sand and gravel, but also common on sand, silt, and clay (catch rates 50-60% of catch rates on sand and gravel).
Keats 1991	SCUBA divers?	Newfoundland	UNK	Frequently collected where sandy substrates bordered areas of bedrock.
Walsh 1996	Bottom trawl surveys?	Barents Sea	All sizes?	Distribution correlated with mud substrates.
Bigelow & Schroeder 1953	Reports from fishermen?	Gulf of Maine	All sizes	Avoid rocky or hard bottom, preferring a fine, sticky but gritty mixture of sand and mud, also caught in numbers on soft, oozy mud of the deeper basins in the western GOM.
Methratta & Link 2007	Analysis of trawl survey data and USGS sediment data	GOM, GB, and southern New England	<20 cm and 20-40 cm	Substrate accounted for <2% of variance in model, primary factor was depth.
Methratta & Link 2006	Analysis of trawl survey data and USGS sediment data	GOM, GB, and southern New England	All sizes	Generally associated with fine-grained sediments, belongs to species assemblage that is significantly more abundant in fine sand-silt than in clay.
Amezcua and Nash 2001	Bottom trawl data	Irish Sea	Not given	Abundance similar in all sediments except gravel (i.e., in mud, sand, and mixed sediments). Highest catch rates were on mud. None of the differences between sediment types were statistically significant.
Auster et al 2001	Trawl survey data	SWGOM, Stratum 26	All sizes	High densities (nos/tow) significantly correlated with low reflectance (soft) substrates.

Table 7 – Atlantic cod substrate associations

Source	*Type of study, depth range*	*Location*	*Fish sizes/ages*	*Results*
Lough et al. 1989, Valentine and Lough 1991, Lough 2010	Field study with submersibles, 70-100 m	Eastern Georges Bank	YOY juveniles	Recently-settled cod and haddock are widely dispersed over the bank and are present on a range of sediment types from sand to gravelly sand to gravel pavement. However, by late July and August, these fish occur predominantly on the

Source	***Type of study, depth range***	***Location***	***Fish sizes/ages***	***Results***
				gravel pavement habitat on the northeastern part of the bank and are absent from sandy areas. It is not clear if this represents low survival on sand, or migration to gravel habitats. During late summer, as they continue to grow, they are carried to the east and southeast in the residual bottom current, and by fall they are more widely dispersed and are no longer confined to gravel pavements.
Gregory and Anderson 1997	Field study with submersibles, 18-150 m	Newfoundland	Age 1, 10-12 cm	Primarily associated with low-relief gravel substrate, Older juveniles (ages 2 - 4) were most abundant in higher relief areas with coarser substrate; e.g., submarine cliffs.
Keats et al. 1987	Field study, SCUBA divers, 2-12 m	Newfoundland	Age 1, 7.8-12.5 cm	Juvenile cod much more abundant in macroalgae beds than in adjacent areas which had been grazed bare by sea urchins, also true for older fish (12.6-23.5 cm).
Tupper & Boutilier 1995	Field study	Nova Scotia	YOY juveniles	Cod settlement was equal in sand, seagrass, cobble, and rock reef habitats, but survival and juvenile densities were higher in the more complex habitats. Growth rate was highest in seagrass beds, but predator (larger cod) efficiency was lowest, and juvenile survival highest, on rock reef and cobble. Cod settling on a rocky reef inhabited crevices in the reef.
Gotceitas et al. 1997	Field study, SCUBA divers	Newfoundland	YOY juveniles	Almost all age 0 cod were found in eelgrass beds as opposed to less structurally complex areas. Older juveniles were more abundant on mud, sand and rocky bottoms than in eelgrass.
Linehan et al. 2001	Field study, beach seines	Newfoundland	YOY juveniles, <10 cm	Juveniles more abundant in vegetated (eelgrass) than in unvegetated habitats . However, potential predators of juvenile cod were also most abundant in eelgrass.
Gotceitas & Brown 1993	Lab study	Newfoundland	6-12 cm	In absence of predator, small cod preferred sand or gravel-pebble over cobble. In the presence of the predator, they chose cobble if available, and the cobble reduced predation.
Gotceitas et al 1995	Lab study	Newfoundland	3.5-8 cm	In the presence of passive predators, small cod preferred sand substrates and avoided kelp. When exposed to an active predator, they hid in cobble if available or kelp if there was no cobble. Both cobble and kelp significantly reduced predation, and small cod appeared able to modify their behavior based on the varying risk presented by different predators.
Gotceitas et al. 1997	Lab study	Newfoundland	3.5-10 cm	With no predator, small cod preferred sand and gravel to cobble. When a predator was introduced and cobble was present, age 0 fish hid in the

Source	***Type of study, depth range***	***Location***	***Fish sizes/ages***	***Results***
				cobble or in dense eelgrass. Survival was highest in cobble or dense eelgrass.
Borg et al. 1997	Lab study	Sweden	7-14 and 17-28 cm	During daylight, fish preferred vegetation to bare sand, while at night – when juvenile cod feed in open, sandy areas – no significant choice was made. Both size classes preferred *Fucus*, the most complex habitat that was tested.
Lindholm et al, 1999	Lab study	New England	Age 0, 7-10 cm	Sponge presence significantly reduced predation compared to that on sand, with density of sponges being more important than sponge height. There was no significant increase in survival in epifauna compared to bare cobble.
Lindholm et al. 2001	Model based on results in lab study	New England	Age 0, 7-10 cm	Juvenile mortality three times higher in the least complex habitats (sand) than in most complex habitats (cobble with sponges).
Lindholm & Auster 2003, Auster & Lindholm 2005, Lindholm et al 2007	Field study	Southwest GOM		Very young juvenile cod observed along the margins of boulder reefs, hiding in cover provided by rocky substrate and epifauna when disturbed.
Auster et al 2001	Trawl survey and acoustic data	SWGOM, Stratum 26	All sizes	High densities (nos/tow) significantly correlated with high reflectance (hard) substrates.
Grabowski et al.	Trawl survey data	Mid-coast Maine	10-25 cm	Juveniles far more abundant on gravel than on mud or sand bottom. Examination of tows conducted at similar depths demonstrated that juvenile cod densities on gravel were more abundant than those on either sand (20-35 m) or mud (35-50 m).

Table 8 – Atlantic halibut substrate associations

Source	***Type of study, depth range***	***Location***	***Fish sizes/ages***	***Results***
Bigelow & Schroeder 1953	Fishermen	Gulf of Maine	All sizes	Usually found on sand, gravel, or clay, not on soft mud or rock bottom.

Table 9 – Atlantic wolffish substrate associations

Source	***Type of study, depth range***	***Location***	***Fish sizes/ages***	***Results***
NMFS 2009 ESA Status Review	Literature review	Gulf of Maine and eastern Canada	All sizes	Evaluation of observational studies and trawl survey analyses concludes that adults are closely associated with rocky habitats when spawning and guarding eggs, but juveniles and non-spawning adults are more widely distributed over a variety of substrate types.

Table 10 - Haddock substrate associations

Source	***Type of study, depth range***	***Location***	***Fish sizes/ages***	***Results***
Lough et al. 1989, Valentine and Lough 1991	Field study with submersibles, 70-100 m	Eastern Georges Bank	YOY juveniles	Recently-settled cod and haddock are widely dispersed over the bank and are present on a range of sediment types from sand to gravelly sand to gravel pavement. However, by late July and August, these fish occur predominantly on the gravel pavement habitat on the northeastern part of the bank and are absent from sandy areas. It is not clear if this represents low survival on sand, or migration to gravel habitats. During late summer, as they continue to grow, they are carried to the east and southeast in the residual bottom current, and by fall they are more widely dispersed and are no longer confined to gravel pavements.
Bigelow & Schroeder 1953	Fishermen?	Gulf of Maine	All sizes	More selective than cod, being rarely caught over ledges, rocks, or kelp or on soft oozy mud. They are chiefly taken on broken ground, gravel, pebbles, clay, smooth hard sand, sticky sand of gritty consistency, and where there are broken shells; they are especially partial to smooth areas between rocky patches.
Scott 1982	Trawl surveys	Scotian shelf	All sizes	Highest catch rates on sand and gravel, sand also high, silt and clay very low.
Auster et al 2001	Trawl survey and acoustic data	SW GOM, stratum 26	All sizes	High densities (nos/tow) significantly correlated with high reflectance (hard) substrates.
Auster and Lindholm 2005	Visual surveys	SWGOM	All sizes	Haddock observed station-keeping on bottom adjacent to partially buried boulders as well as boulders and cobbles with large sponges along margins of deep boulder reefs.
Brickman 2003	Habitat suitability map and trawl survey data	Browns Bank, Canada	Age 1 juveniles	Settlement areas coincide with presence of preferred sediment type (>90% sand plus gravel).

Table 11 – Ocean pout substrate associations

Source	***Type of study, depth range***	***Location***	***Fish sizes/ages***	***Results***
Bigelow & Schroeder 1953	Fishermen?	Gulf of Maine	Juveniles	Occur in shallow coastal waters around rocks and attached algae.
Sheehy et al 1977	???	SE of Block Island, 90 m	UNK	Use scallop shells (as shelter?)
Auster et al. 1995	ROV survey	Southern New England shelf, 55 m	UNK	Ocean quahog shell aggregates used as cover, also found in biogenic depressions.
Keats et al. 1985	Dive surveys, coastal areas	E. Newfoundland	Spawning/egg guarding adults	Observed in holes under large boulders as well as in the open early in the reproductive

Source	*Type of study, depth range*	*Location*	*Fish sizes/ages*	*Results*
				season; later in season more commonly seen in nesting holes

Table 12 – Pollock substrate associations

Source	*Type of study, depth range*	*Location*	*Fish sizes/ages*	*Results*
Hardy 1978	???	Mid-Atlantic Bight	Juveniles	EFH for juveniles on a wide variety of substrates, including mud, rocky bottom, and vegetation.
Rangeley & Kramer 1995	Visual observations	Bay of Fundy	YOY juveniles	Found in intertidal zone in algal habitats in small schools or as solitary fish during high tide. On falling tides, they schooled in the open habitat in lower intertidal and subtidal zones; rocky shores in the Gulf of Maine are important nurseries for juvenile pollock.
Lazzari & Stone 1996	Beam trawl surveys, 10 m max depth	Maine coast	YOY juveniles	Common in eelgrass beds and, to a lesser extent, in kelp dominated habitats.
Auster and Lindholm 2005	Visual surveys	SW GOM	All sizes	Observed in aggregations and schools above deep boulder reefs feeding on drifting zooplankton, or searching for prey just above reef surfaces.
Auster et al 2001	Trawl survey and acoustic data	SW GOM (stratum 26)	All sizes	Densities (nos/tow) significantly correlated with high reflectance (hard) substrates.

Table 13 – White hake substrate associations

Source	*Type of study, depth range*	*Location*	*Fish sizes/ages*	*Results*
Lazzari & Stone 1996	Beam trawl survey, max depth 10 m	Maine coast	YOY juveniles	Presence significantly related to one or more of three types of SAV-dominated habitat – eelgrass, kelp, and algae.
Scott 1982	Trawl surveys	Scotian shelf	All sizes	Absent from gravel and sand, but catch rates increased over fine deposits and peaked on clay in deep basins.
Able & Fahay 2010, Markle et al. 1982	???	NJ coast, Bay of Fundy	YOY juveniles	Younger fish are spatially segregated from older year classes by occupying shallow areas, but they are not tied to eelgrass, other vegetation, or structured habitats.
Auster et al 2001	Trawl survey and acoustic data	SWGOM (stratum 26)	All sizes	Significant negative correlation with bottom reflectance, indicating higher abundance over soft sediments.
Methratta & Link 2006	Trawl survey and sediment data	GOM, GB and southern New England	All sizes	Catch rates (mean kg/tow) much higher (5-8 x) on silt and clay than on coarse rock, fine rock, and coarse sand, 3-4 x higher than on fine sand.

Table 14 – Windowpane flounder substrate associations

Source	*Type of study, depth range*	*Location*	*Fish sizes/ages*	*Results*
Bigelow & Schroeder 1953	Reports from fishermen?	Gulf of Maine	All sizes	Caught chiefly on sand in southern New England, but also frequent softer and muddier grounds in the GOM.
Neuman et al 1998[1]	Lab study	???	YOY juveniles (<9 cm)	Prefer sand over mud.
Lazzari (personal comm.)	Beam trawl survey	Coastal Maine	YOY juveniles	Mostly caught over un-vegetated mud and sand habitats.

Table 15 – Winter flounder substrate associations

Source	*Type of study, depth range*	*Location*	*Fish sizes/ages*	*Results*
Howell et al 1999	Field study, max depth 5.5 m	Connecticut estuaries	YOY juveniles	Higher densities on muddy sediments with debris (shells, wood, leaves) or live bivalves than on sand.
Curran and Able 2002; Chang et al. 2000; Stoner et al. 2001	Field studies	NJ estuaries	YOY juveniles	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
Phelan et al 2001	Field and lab studies	Navesink River, NJ	YOY juveniles	Probability of capturing recently settled juveniles was high on medium to coarse grained sand, while slightly larger YOY juveniles were least likely to be collected on fine sediments and were most common on coarse to very coarse sand. 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.
Lazzari & Stone 2006	Field study (beam trawls) , max depth 10 m	Maine coastal estuaries	Age 0 and 1 juveniles	A logistic regression model predicted that the presence of winter flounder was positively, and significantly, related to the presence of eelgrass.
Armstrong 1987	Field study (trawls), max 8 m	Great Bay, NH	Ages 0,1 and 2	Most caught in silty mud.
Fairchild et al 2008	Field study (trawls)	Hampton-Seabrook estuary, NH	YOY juveniles	Most caught in fine to medium-size sand.

Table 16 – Witch flounder substrate associations

Source	*Type of study, depth range*	*Location*	*Fish sizes/ages*	*Results*

Source	***Type of study, depth range***	***Location***	***Fish sizes/ages***	***Results***
Methratta & Link 2006	Trawl survey and sediment data	GOM, GB and southern New England	All sizes	Catch rates trended to higher values with decreasing sediment grain size.
Powles and Kohler 1970; Scott 1982; MacDonald *et al.* 1984 (as cited in Cargnelli et al. 1999)	Trawl surveys	Bay of Fundy and eastern Canada	All sizes	The witch flounder is very closely tied to mud/silt, muddy-sand, and clay substrate and rarely occurs on any other bottom type.
Auster et al. 2001	Trawl survey and acoustic data	SWGOM (stratum 26)	All sizes	Significant negative correlation with bottom reflectance, indicating higher abundance over soft sediments.

Table 17 – Yellowtail flounder substrate associations

Source	***Type of study, depth range***	***Location***	***Fish sizes/ages***	***Results***
Bowering & Brodie 1991	Trawl surveys	Newfoundland and Labrador	All sizes	Prefer sand or sand-mud sediments.
Scott 1982	Trawl surveys	Scotian shelf	All sizes	A very high proportion favored sand and gravel substrates over sand and mixed sediments, which are frequently found in shallow water.
Methratta & Link 2006	Trawl survey and sediment data	GOM, GB, and southern New England	All sizes	Catch rates highest on coarse sand, about three times higher than on coarse and fine rock, with very low catches on fine sand and silt.
Methratta & Link 2006	Trawl survey and sediment data	GOM, GB, and southern New England	Three size classes (0-20, 20-40, >40 cm)	Smaller fish more closely associated with larger grain sizes (coarse sand, granule-pebble).
Simpson & Walsh 2004 (as cited in NEFSC 2004 EFH Update memo)	Trawl surveys?	Grand Banks	All sizes	Of the six sediment types studied, yellowtail appeared in greater numbers on sand and shell hash, gravely sand, and rock-sand sediment types. They were rarely found on mud or muddy sand substrates.
Sullivan et al. 2006	Submersible observations	Continental shelf, NY Bight	Recently-settled juveniles	Settled predominantly on mid-shelf sites (40-70m) and either mimicked available habitat (bare sand, shell hash, sand dollars) or associated with clean sand substrates, which often included peaks of sand wave crests.

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