Annotated Bibliography Of Habitat Associations Of Juvenile Demersal Fish In Offshore Shelf Waters From Newfoundland, The Gulf Of St. Lawrence, And The Maritimes Region

J. Linehan

Science, Oceans and Environment Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's NF Canada A1C 5X1

2004

Canadian Technical Report of Fisheries and Aquatic Sciences No. 2526

Fisheries and Oceans
Pêches et Océans

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report of
Fisheries and Aquatic Sciences 2526

2004

ANNOTATED BIBLIOGRAPHY OF HABITAT ASSOCIATIONS OF JUVENILE DEMERSAL FISH IN OFFSHORE SHELF WATERS FROM NEWFOUNDLAND, THE GULF OF ST. LAWRENCE, AND THE MARITIMES REGION

By

J.E. Linehan

Fisheries and Oceans Canada
Science, Oceans and Environment Branch
P.O. Box 5667
St. John's, NL A1C 5X1

Cat. No. Fs 97-6/2526E ISSN 0706-6457

Correct citation for this publication:

Linehan, J. 2004. Annotated bibliography of habitat associations of juvenile demersal fish in offshore shelf waters from Newfoundland, the Gulf of St. Lawrence, and the Maritimes region. Can. Tech. Rep. Fish. Aquat. Sci. 2526: iv + 54 p.

Table of Contents

ABSTRACT

Linehan, J. 2004. Annotated bibliography of habitat associations of juvenile demersal fish in offshore shelf waters from Newfoundland, the Gulf of St. Lawrence, and the Maritimes region. Can. Tech. Rep. Fish. Aquat. Sci. 2526: iv + 54 p.

Juvenile groundfish species use both inshore and offshore nursery areas with specific habitat characteristics to promote their survival. Protection from predators, competition, and foraging for food are all thought to play an important role in determining habitat utilization by demersal juveniles. This is a summary of an annotated bibliography that was completed to identify publications that contain information on the habitat associations of juvenile demersal fish in offshore shelf waters of the Northwest Atlantic. Over 200 papers were reviewed on various subjects ranging from feeding, distributions and migrations to predator interactions and habitat associations. Only those publications dealing with studies on juvenile demersal fish conducted in the Northwest Atlantic in areas of the Scotian Shelf, the Gulf of St. Lawrence, the Maritimes Region, the Newfoundland Banks, and the Mid-Atlantic Bight are included in the bibliography summaries. An emphasis was put on papers dealing specifically with interactions of various species of juvenile demersal fish with substrate. These juvenile life history stages of demersal marine fish species were found to have the strongest fish-habitat interactions. It is therefore important to put emphasis on these juvenile stages in identifying areas of critical fish habitat.

RÉSUMÉ

Linehan, J. 2004. Annotated bibliography of habitat associations of juvenile demersal fish in offshore shelf waters from Newfoundland, the gulf of St. Lawrence, and the Maritimes region. Can. Tech. Rep. Fish. Aquat. Sci. 2526: iv + 54 p.

Pour accroître leurs chances de survie, les poissons de fond juvéniles utilisent à la fois des aires de croissance situées dans les eaux du large et d'autres se trouvant dans les zones côtières, aires dont les habitats ont des caractéristiques particulières. On croit que la protection contre les prédateurs, la concurrence entre poissons et la quête de nourriture sont des facteurs qui jouent un rôle important dans la façon dont l'habitat est utilisé par les poissons juvéniles démersaux. Le lecteur trouvera ici un sommaire d'une bibliographie commentée, établie pour recenser les publications contenant de l'information sur l'association entre l'habitat et les poissons démersaux dans les eaux de plateau du large de l'Atlantique Nord-Ouest. On a examiné plus de 200 documents portant sur divers sujets, allant de l'alimentation, de la distribution et des migrations des poissons à leurs interactions avec les prédateurs et à leur association à un habitat. Seules les publications traitant d'études de poissons démersaux de l'Atlantique Nord-Ouest qui évoluent dans des eaux du plateau néo-écossais, dans le golfe du Saint-Laurent, dans la Région des Maritimes, sur les bancs de Terre-Neuve et dans le golfe médio-atlantique sont incluses dans le sommaire de la bibliographie. L'accent a été mis sur les documents qui portent en particulier sur les interactions des poissons juvéniles démersaux avec le substrat. On a déterminé que c'est aux stades juvéniles de leur cycle biologique que les poissons démersaux ont le plus d'interactions avec l'habitat. Il importe donc de tenir pleinement compte de ces stades juvéniles lorsqu'on identifie des zones d'habitat essentiel du poisson.

INTRODUCTION

When juveniles of many groundfish species reach a certain size they settle to the ocean bottom to feed (Methven 1999). Many authors have proposed that these now demersal juvenile fish move into nursery areas with specific habitat characteristics that promote their survival. Inshore areas have been shown to be important nursery areas for many species of juvenile demersal fish including: Atlantic cod (*Gadus morhua*) (Cote *et al.* 2001; Gotceitas and Brown 1993; Gotceitas *et al.* 1997; Grant and Brown 1998; Gregory *et al.* 1996, 1997; Keats *et al.* 1987; Ojeda and Dearborn 1990; Tupper and Boutilier 1995a and b), white hake (*Urophycis tenuis*) (Black and Miller 1991; Horne and Campana 1989), winter flounder (*Pleuronectes americanus*) (Able 1999; Horne and Campana 1989; Howell *et al.* 1999), summer flounder (*Paralichthys denatus*) (Able 1999; Packer *et al.* 1999; Packer and Hoff 1999) and pollock (*Pollachius virens*) (Rangeley and Kramer 1995, 1998) to name a few. From various field and laboratory studies we know that newly settled juvenile demersal fish in nearshore environments actively select bottom habitats consisting of various combinations of particle size and complexity to enhance their growth rate and survival from potential predators (Gotceitas and Brown 1993; Gotceitas *et al.* 1995; Lindholm *et al.* 1999; Linehan *et al.* 2001; Walters and Juanes 1993).

While the dispersal and migrations of some juvenile fishes have been studied extensively in offshore areas (Anderson 1993; Bulatova 1962, 1970; Cohen 1985; Dalley and Anderson 1994, 1997; Frank *et al.* 1994; Lough and Potter 1993; Perry and Neilson 1988; Shacknell *et al.* 1997, 1999; Suthers *et al.* 1989) studies of habitat associations of juvenile fish species offshore has been limited.

Juvenile demersal fish have been shown to settle in offshore nursery areas that are quite often associated with areas where these fish also spawn. There, loose gyres will retain larvae over the offshore banks, where they will be held in close proximity with their prey and develop into juveniles (Shacknell *et al.* 1999; Suthers *et al.* 1989). Species of juvenile demersal fish often found in association with particular habitats in more offshore areas include: Atlantic cod (*Gadus morhua*) (Anderson 1993; Bulatova 1962, 1970, Cohen *et al.* 1985; Dalley and Anderson 1994, 1997; Gregory *et al.* 1997; Gregory and Anderson 1997; Lough *et al.* 1989); haddock (*Melanogrammus aeglefinus*) (Bulatova 1962; Lough *et al.* 1989; Marshall and Frank 1995; Scott 1982); silver hake (*Merluccius bilinearis*) (Auster *et al.* 1991; Auster *et al.* 1995; Auster *et al.* 1997; Edwards and Emery 1968; Steves and Cowen 2000); red hake (*Urophycis chuss*) (Auster *et al.* 1991; Edwards and Emery 1968; Steiner *et al.* 1982); little skate (*Raja erinacea*) (Auster *et al.* 1991; Auster et al.1995); witch flounder (*Glyptocephalus cynoglossus*) (Burnett *et al.* 1992; Powles and Kohler 1970), yellowtail flounder (*Limanda ferruginea*) (Walsh 1992), and American plaice (*Hippoglossoides platessoides*) (Swain *et al.* 1998; Walsh 1982). These studies use various techniques ranging from video and trawl surveys to sonar and bathymetric analysis to demonstrate the utilization of various habitats by demersal fish at different spatial scales. In a lot of cases the environment in which these studies are conducted is not homogeneous but instead contains a variety of essential habitat types that exist at different scales (Langton *et al.* 1995; Malatesta and Auster 1999). From a management perspective scale is only one of the issues that must be considered when making decisions about habitat conservation. Fisheries impacts on essential fish habitat are also a major concern for decision-makers. Fishing can have many negative impacts on habitat (i.e. structural habitat components, community structure, and ecosystem processes) that can ultimately affect demersal fish populations (Auster and Langton 1999; Auster *et al.* 2001; Diaz *et al.* 2003; Langton and Auster 1999a and b; Langton *et al.* 1996; Lindholm *et al.* 1999; Norse and Watling1999).

Numerous variables are reported to play a role in the habitat selection by fish in the offshore including; temperature (Anderson 1993; Page *et al.* 1994; Scott 1982), salinity (Page *et al.* 1994; Scott 1982), depth (Page *et al.* 1994), and substrate characteristics (Lough *et al.* 1989; Scott 1982). Protection from predators (Lough *et al.* 1989), competition (Powles and Kohler 1970; Scott 1982; Swain *et al.* 1998), and foraging for food (Auster *et al.* 1997) are also thought to play an important role in determining habitat utilization by demersal juveniles. In order for fisheries managers to develop precautionary conservation strategies for habitat protection (e.g. Marine Protected Areas, and fishing gear restrictions) it has become increasingly important for us to have a better understanding of the habitat requirements of the various critical life stages of marine fish species at various temporal and spatial scales. By putting emphasis on the juvenile life history stages of demersal fish species we will hope to gain an understanding of fish-habitat interactions at one of the most critical stages and at a stage where impacts and conservation strategies may be the most ecologically significant.

This document summarizes significant results of selected studies on habitat associations of juvenile demersal fish in offshore shelf waters from Newfoundland, the Gulf of St. Lawrence, and the Maritimes region. Some studies from the eastern coast of the United States are also included. A search for papers was conducted using both Aquatic Sciences and Fisheries Abstracts (ASFA) and WAVES (online catalogue). Thirty-four studies were reviewed that included information on a total of thirty-eight species of demersal fish (Table 1). Information on the associations of these species of juvenile demersal fish with various habitats types was summarized (Table 2) and the following information, was recorded for each study: purpose, species, length/age, location and date of study, depth, temperature, salinity, bottom type, data sets used and contact information. A brief summary on the general ecology and distribution of some species of juvenile demersal fish is also provided.

OBJECTIVE

(i) Identify publications that contain information on the habitat associations of juvenile demersal fish in offshore shelf waters from the North West Atlantic with emphasis on the Nova Scotian Shelf.
(ii) Review selected publications; identify the species of demersal juvenile fish and what habitat associations have been looked at.
(iii) Prepare an annotated bibliography of all pertinent publications with a brief summary.

SPECIES SUMMARIES DESCRIBING ESSENTIAL FISH HABITAT ASSOCIATIONS

Atlantic cod (*Gadus morhua*)

Atlantic cod, *Gadus morhua*, are distributed in the northwest Atlantic Ocean from Greenland to Cape Hatteras, North Carolina (Fahay *et al.* 1999). In Atlantic Canada distribution densities were found to be highest off Newfoundland, in the Gulf of St. Lawrence and on the Scotian Shelf (Fahay *et al.* 1999).

The life history of the Atlantic cod includes a pelagic egg, larvae and juvenile stage with juveniles settling into a demersal habitat at about 40-60 mm. Coloration during this initial descent mimics the substrate, reducing predation (Lough *et al.* 1989).

Juveniles may tolerate a wider range of temperatures than adults and several studies have stressed this and the importance of cobble substrates over finer grained bottoms after settlement may be critical to avoid competition and predation by old conspecifics (Lough *et al.* 1989).

Haddock (*Melanogrammus aeglefinus*)

Haddock (*Melanogrammus aeglefinus*), are a demersal gadoid species that are found on both sides of the North Atlantic (Cargnelli *et al.* 1999a). In the western Atlantic, haddock are distributed form Greenland to Cape Hatteras, North Carolina (Cargnelli *et al.* 1999a).

Haddock spawn over gravel substrate and they have pelagic egg, larvae and juvenile stages much like that of the Atlantic cod. After 3-5 months the pelagic juveniles descend toward the bottom and adapt to a demersal lifestyle (Cargnelli *et al.* 1999a).

After settling, haddock have been found to be closely associated with pebble gravel bottom (Lough *et al.* 1989). Demersal juveniles and adults are both generally found at depths between 50-100 m (Scott 1982) and at temperatures of 4.5-10°C (Cargnelli *et al.* 1999a).

Silver hake (*Merluccius bilinearis*)

Silver hake, *Merluccius bilinearis*, are a demersal fish species that can be found well distributed on the continental shelf of the northwest Atlantic Ocean. Silver hake have pelagic eggs and larvae that after about 2 months descend to the bottom as juveniles (Morse *et al.* 1999).

Auster *et al.* (1997) found that silver hake were often found in association with microhabitat features to avoid visual predators and co-occur with preferred prey species.

Red hake (*Urophycis chuss*)

Red hake (*Urophycis chuss*) is a demersal fish species that occurs in the waters of the Northwest Atlantic Ocean from Southern Newfoundland to North Carolina (Steimle *et al.* 1999). Red hake, have pelagic egg, larvae, and juvenile stages. These juveniles remain pelagic until they reach approximately 30-40 mm TL at which time they descend to the bottom (Steimle *et al.* 1999).

Shelter is a critical habitat requirement for red hake which are commonly found associated with sea scallops beds in the Bay of Fundy, Scotian Shelf, and Georges Bank (Markle *et al.* 1982; Steiner *et al.* 1982).

American plaice (*Hippoglossoides platessoides*)

The American plaice, *Hippoglossoides platessoides*, is a pleuronectid flatfish that inhabits both sides of the North Atlantic (Johnson *et al.* 1999a). In the Northwest Atlantic it is common from the coast of Labrador, south from Hamilton Inlet, Newfoundland, on the Grand Banks, and in the Gulf of St. Lawrence. American plaice have both pelagic eggs and larvae. Newly metamorphosed juveniles settle to the bottom where their pigment patterns develop (Johnson *et al.* 1999a).

Both juveniles and adult of American plaice have been found to co-occur on the Grand Banks of Newfoundland at very similar depths and near-bottom temperatures, indicating that the nursery grounds for juveniles are not isolated from commercial fishing grounds (Walsh 1982).

Witch flounder (*Glyptocephalus cynoglossus*)

The witch flounder (*Glyptocephalus cynoglossus*), is a right-eyed flounder of the Pleuronectid family which occurs on both sides of the Atlantic Ocean (Cargnelli *et al.* 1999b). They are common throughout the Gulf of Maine and occur in deeper areas of Georges Bank and along the continental shelf as far south as Cape Hatteras, North Carolina (Cargnelli *et al.* 1999b).

American plaice have pelagic eggs and larvae and they have the longest pelagic juvenile stage among the species of the family Pleuronectidae with descent to the bottom occurring at 4-12 months of age (Cargnelli *et al.* 1999b).

Juveniles and adults are found at temperatures ranging from about 0 to 15°C, and salinities of 31-36 ppt (MacDonald *et al.* 1984). Witch flounder juveniles are quite often found in deeper water than the adults which may prevent direct food competition with young of the more abundant species of cod and American plaice in continental shelf areas (Powles and Kohler 1970).

Witch flounder are found over mud, clay, silt, or muddy sand substrates (Powles and Kohler 1970; MacDonald *et al.* 1984). This close association with soft substrate may be the result of their preference for specific prey species found there or as a means of shelter. Auster *et al.* (1991) also showed small-scale habitat associations of witch flounder with depressions in mud bottom, which could possibly serve as a means of evading strong currents.

Yellowtail flounder (*Limanda ferruginea*)

The yellowtail flounder, *Limanda ferruginea*, is a member of the pleuronectid family that inhabits the waters along the Atlantic coast of North America from the Gulf of St. Lawrence, Labrador, and Newfoundland to the Chesapeake Bay (Johnson *et al.* 1999b).

Yellowtail flounder have pelagic eggs and larvae and transform to a juvenile at approximately 11.6-16 mm SL at which point they adopt a demersal lifestyle (Johnson *et al.* 1999b).

Juvenile yellowtail flounder prefer to settle into sand or sand-mud sediments (Walsh 1992). Sediments can indirectly influence distribution by the composition of benthic food items preferred by yellowtail founder, which feed exclusively on surficial and interstitial macrofauna (Walsh 1992). These sandy substrates can also provide places for newly settled fish to hide and avoid predators (Walsh 1992).

Table 1. Distribution of studies by fish species.

Species	**Scientific Name**	**Reference Number**
Atlantic cod	*Gadus morhua*	2,3,7,8,9,11,12,13,16,17,19,20,21,22,32
Haddock	*Melanogrammus aeglefinus*	3,7,8,11,22,25,27
Gadid spp.		23
Silver hake	*Merluccius bilinearis*	3,4,5,6,7,15,19,29,30,31
Red hake	*Urophycis chuss*	3,5,6,15,24,28
Spotted hake	*Urophycis regius*	14,15
White hake	*Urophycis tenius*	6,24
Longfinned hake	*Urophycis chesteris*	6
Little skate	*Raja erinacea*	5,6
Winter skate	*Raja ocellata*	3
Thorny skate	*Raja radiate*	3
Raja spp.		14, 23
Yellowtail flounder	*Pleuronectes ferrugineus*	3,19,30,31,34
Witch flounder	*Glyptocephalus cynoglossus*	3,10,26
American plaice	*Hippoglossoides platessoides*	3,7,32,33
Summer flounder	*Paralichthys denatus*	14
Gulf Stream flounder	*Citharichthys arctifrons*	31
Fourspot flounder	*Hippoglossina oblonga*	15,31
Winter flounder	*Pleuronectes americanus*	3
Atlantic halibut	*Hippoglossus hippoglossus*	7
Pleuronectiformes Sp.		5,6,23
Sand Lance	*Ammodytes* spp.	3,7,14
Four bearded rockling	*Enchelyopus cimcrius*	3
Daubed shanny	*Lumpenus maculates*	3
Redfish spp.		3,7
Pollock	*Pollachius virens*	3,7
Atlantic wolffish	*Anarhichas lupus*	3
Longhorn sculpin	*Myoxocephalus octodecemspinosus*	3,5,6
Ocean pout	*Macrozarces americanus*	3,5,6
Sea raven	*Hemitripterus americanus*	3
Butterfish	*Peprilus triacanthus*	5,6
Scup	*Stenotomus chrysops*	5,6,14
Bluefish	*Pomatomus saltatrix*	6
Blackbellied rosefish	*Helicolenus dactylopterus*	6
Grenadier	*Coryphaenoides rupestris and Nezumia bairdii*	6
Monkfish	*Lophius americanus*	5,14
Sea robin	*Prionotus* sp.	5,14
Tilefish	*Lopholatilus chamaeleonticeps*	1

Table 2. Habitat associations of various species of juvenile demersal fish.

	Mud/ Silt	Sand	Sand/ Gravel	Pebble/ Cobble	Boulder	Burrows/ Biogenic Depressions	Shells	Tubes	Sea Scallops
Atlantic cod			X	X	X				
Haddock			X	X					
American plaice		X							
Yellowtail flounder		X							
Witch flounder						X			
Flounder						X			
Ammodytes spp.		X							
Fourspot flounder		X							
Silver hake		X				X		X	
Gulf Stream flounder	X								
Tilefish						X			
Ocean Pout						X	X		
Little skate							X		
Red hake						X	X		X
Spotted hake									X
Snailfish									X
Long finned hake					X	X			
Scup						X			
White hake						X			
Blackbellied rosefish						X			
Longhorn Sculpin						X	X		

ANNOTATED BIBLIOGRAPHY

Able, K.W., Churchill, C.B., Cooper, R.A., and Uzmann, J.R. 1982. Burrow construction and behavior of tilefish, *Lopholatilus chamaeleonticeps*, in Hudson Submarine Canyon. Environ. Biol. Fishes 7(3): 199-205.

Reference (#)	Able *et al.* 1982 (1)
Purpose of study	Presentation of the results of submersible observations of juvenile and adult tilefish burrows and behavior in Hudson submarine canyon.
Species of fish	Tilefish (*Lopholatilus chamaeleonticeps)*
Length/Age	Juvenile (approximately 10-20 cm TL) and Adult
Date	August 17-27, 1979
Location	Hudson submarine canyon
Depth	110-230 m
Temperature	10-12 °C
Salinity	-
Bottom type	Flat surface covered with varying thickness (0-1 cm) of recent sediments (silt) which overlaid a stiff gray clay of unknown depth.
Data set used	'Nekton Gamma' research submersible - 22 daytime dives (55 hours of daytime observations)
Access to data	Rutgers University
Contact name and information	Kenneth Able Department of Zoology and Center for Coastal and Environmental Studies Rutgers University New Jersey, US

Over 150 juvenile and adult tilefish (*Lopholatilus chamaeleonticeps*), were observed in and around vertical burrows in the clay substrate of portions of Hudson submarine canyon. Both juvenile and adult tilefish occupied burrows, the size and shape of which varied with the size of the fish and the occurrence of associated species. The smallest juveniles occupied simple vertical shafts in the substrate whereas, larger fish were found in much larger burrows (up to 4-5 m in diameter and at least 2-3 m deep) that were funnel shaped in cross-section with the upper conical portions containing numerous smaller burrows of associated crabs.

The nature of the sediments may be critical to burrow construction and thus an important factor determining the distribution and abundance of tilefish. Construction of large burrows must require malleable but temporally stable sediment.

Both juvenile and adult tilefish swam into the burrows head first and exited tail fist. This behavior, which would preclude the possibility of ambushing prey, and evidence of predation by sharks and other tilefish, suggests that the burrow acts as a refuge from predators.

Anderson, J.T. 1993. Distributions of juvenile cod in NAFO Divisions 2J3KL during fall, 1981-92, in relation to bathymetry and bottom temperature. NAFO SCR Doc. 93/68, Serial No. N2252.

Reference (#)	Anderson 1993 (2)
Purpose of study	An analysis of the Canadian fall research vessel survey data for young cod, ages 1-4 years, for the 2J3KL management area to describe their general distributions during the fall, and how these varied over time in relation to bathymetry and bottom temperature.
Species of fish	Atlantic cod (*Gadus morhua*)
Length/Age	1-4 year old juveniles
Time	October to December 1981-92 (except the 3L survey in 1984 which started July 26-November 26.
Location	2J3KL management area
Depth	Age 1 and 2 - <200 m Age 3 and 4 - >300 m and <100 m
Temperature	Age 1 and 2 - <1°C Age 3 and 4 – 2 °C and 0°C
Salinity	-
Bottom type	-
Data set used	Canadian fall research vessel survey data - random stratified design using Engels 45 high rise bottom trawl
Access to data	Department of Fisheries and Oceans P.O. Box 5667 St. John's, NL A1C 5X1
Contact name and information	John Anderson (Section Head) 709-772-2116 AndersonJT@dfo-mpo.gc.ca

One-year-old cod occurred most frequently in two locations: 1) off the southern Labrador/NE Newfoundland coast; and 2) on the northern Grand Bank. Notably, one year old cod were not caught offshore on Hamilton, Belle Isle or Funk Island Banks. The distribution of two year old cod occurred over a broader area and also occurred further offshore. Two-year-old cod were observed frequently on Hamilton and Funk Island Banks, on the nose of the Grand Banks and in the most southerly part of the survey area in the vicinity of the Virgin Rocks.

The distributions of cod aged 3 and 4 years were very similar. Highest concentrations occurred in four distinct areas: 1) in the deep water (>300 m) on the shoreward and southern sides of Hamilton Bank; 2) in the deep water between Belle Isle and Funk Island Banks; 3) in the deep water south of Funk Island Bank and north of the Grand Bank; and 4) on the Grand Bank at the southern limit of the surveyed area. On the northeastern Newfoundland shelf, the abundance of 3- and 4-yr-old cod was notably lower in the surveyed area closest to shore where 1- and 2-yr-old cod were most abundant. The separate distribution of 1-yr old cod from 3 to 4-yr-old cod for both areas suggests different habitats are occupied by these age groups. The overlap of age 2 cod with these distributions suggests a gradual shift in habitat occurs during the second year of life.

There was a significant non-linear relationship between the area occupied by a particular year-class and its abundance. The data demonstrated that the lowest year-classes occurred in smaller areas, whereas there appeared to be an upper limit to the spatial distribution of juvenile cod for the most abundant year-classes. This relationship suggests that there is a limit to the available habitat for juvenile cod and that density dependence may occur at high abundances due to a limit of suitable habitat.

On the Northeastern Newfoundland Shelf there was a clear association of cod distributions with both temperature and bottom depth. One year old cod occurred predominantly nearshore in shallower water (<200 m deep) which was cold (<1°C). This relationship was somewhat true for 2-yr-old cod, but was less clear due to their broad distribution. In contrast, cod 3- and 4 yr-old occurred predominantly offshore in deep water (>300 m deep) that was relatively warm (= 2°C). These distributions suggest an age-dependent separation in distributions as a function of habitat; primarily bottom temperatures which are depth-dependent over the Shelf. On the Grand Bank however there was no similar association of cod with cold and warm water temperatures, due to the occurrence of cold water throughout the area. This suggests that factors other than temperature are responsible for the ontogenetic differences in distribution. Other factors relating to the obviously different distribution at age might include habitat cover to avoid predation, and food availability.

Auster, P.J., Joy, K., and Valentine, P.C. 2001. Fish species and community distributions as proxies for seafloor habitat distributions: the Stellwagen Bank National Marine Sanctuary example (Northwest Atlantic, Gulf of Maine). Environ. Biol. Fishes 60: 331-346.

Reference (#)	Auster *et al.* 2001 (3)
Purpose of study	To demonstrate that distribution and abundance data from trawl samples for single species and communities of fishes can be used as proxies for the distributions of habitats at a landscape scale.
Species	20 different species: Northern sand lance (*Ammodytes americanus*), winter skate (*Raja ocellata*), four bearded rockling (*Enchelyopus cimcrius*), American plaice (*Hippoglossoides platessoides*), silver *hake (Merluccius bilinearis*), Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), witch flounder (*Glyptocephalus cynoglossus*), white hake (*Urophycis tenuis*), daubed shanney (*Lumpenus maculatus*), Acadian redfish (*Sebastes faciatus*), pollock (*Pollachius virens*), Atlantic wolfish (*Anarhichas lupus*), winter flounder (*Pleuronectes americanus*), longhorn sculpin (*Myoxocephalus octodecemspinosus*), red hake (*Urophycis chuss*), ocean pout (*Macrozarces americanus*), yellowtail flounder *(Pleuronectes ferrugineus)*, thorny skate *(Raja radiata)*, and sea raven (*Hemitripterus americanus)*.
Length/Age	Juvenile
Date	Data analyzed was from 1970-94.
Location	Western Gulf of Maine within the Boundary of the Stellwagen Bank National Marine Sanctuary.
Depth	-
Temperature	-
Salinity	-
Bottom type	Soft-bottom, gravel, sand
Data set used	Trawl data, Acoustic data
Access to data set	National Marine Fisheries Service Northeast Fisheries Science Center
Contact name and information	Auster, Peter J. - Science Director NOAA's National Undersea Research Center, The University of Connecticut at Avery Point Groton, Connecticut 06340, USA Phone: 860-405-9118/9121 Fax: 860-445-2969 E-Mail: auster@uconnvm.uconn.edu

This study has produced results that confirm, in general, the spatial concordance of fish communities and species sampled using trawl surveys with seafloor habitats. Fish communities were correlated with reflectance values but all communities did not occur in unique sediment types. This suggests that use of community distributions as proxies for habitats should include the caveat that a greater number of communities within an area could indicate a greater range of habitat types.

Single species distributions showed relationships between abundance and reflectance values (high reflectivity generally corresponds to coarse sand and gravel, and low reflectivity generally corresponding to mud and fine sands), which demonstrates that patterns in habitat associations can be resolved for single species from trawl samples at this spatial scale. Only three species did not show significant patterns based on the reflectance data (i.e. northern sand lance, winter skate, and four bearded rockling). Of the 20 species in this study 12 had statistically significant relationships between abundance and reflectance value. Among these species were American plaice, silver hake, Atlantic cod, haddock, witch flounder, white hake, daubed shanney, and four bearded rockling. Acadian redfish, pollock, Atlantic wolffish, and winter flounder had weak but significant relationships. Some species that have previously been shown to have affinities for microhabitat structures or particular sediment types at small spatial scales (i.e. longhorn sculpin, red hake, and ocean pout) did not have a significant correlation using data collected at the spatial resolution of a trawl set.

It was found that correlating habitats with the distributions of single species could be validated using those species where life history and habitat requirements were known. Species with known habitat association could therefore be used to infer habitat requirements of co-occurring species and could be used to identify a range of habitat types. In this study, high densities of American plaice (e.g. >200 fish tow-1) occurred over soft sediments, yellowtail founder occurred (e.g. >40 fish tow-1) over sand, and haddock (e.g. >50 fish tow-1) occurred over hard substrates such as sand-gravel. These findings were consistent with those of previous studies conducted on habitat associations of these same Species of fish. From a mechanistic perspective, associations of juveniles with particular habitats may be the result of either differential mortality of early benthic phase individuals or active habitat selection.

Auster, P.J., Malatesta, R.J., and Donaldson, C.L.S. 1997. Distribution responses to small-scale habitat by early juvenile silver hake, *Merluccius bilinearis*. Environ. Biol. Fishes 50: 195-200.

Reference (#)	Auster *et al.* 1997 (4)
Purpose of study	Describes relationship between 0-year silver hake and the distribution of amphipod tubes.
Species	Silver hake (*Merluccius bilinearis*)
Length/Age	Early Juvenile (0-year). Total Length: 1.5-5 cm
Location/Time	Southern New England, subregion of the Middle Atlantic Bight (40°50'N, 70°55'W)
Depth	55m
Temperature	8.7-11.4°C
Salinity	-
Bottom Type	Silt sand bottom with amphipod tubes
Data set used	Underwater transects with ROV
Access to data set	NOAA's National Undersea Research Center, The University of Connecticut at Avery Point Groton, Connecticut 06340, USA
Contact name and information	Auster, Peter J. - Science Director Phone: 860-405-9118/9121 Fax: 860-445-2969 E-Mail: auster@uconnvm.uconn.edu

Silver hake, *Merluccius bilinearis*, were found to be associated with structure (= amphipod tubes) during their early juvenile period (0-year). Silver hake occurred at higher densities on bottoms with greater amphipod tube cover at a 55 m deep site. When undisturbed, most silver hake were partially buried in the bottom near clumps of amphipod tubes (87% of 487 individual 0-year hake were within approximately one body length of a clump of amphipod tubes). The dorsal coloration of 0-year silver hake mimicked the pattern of amphipod tubes when viewed against the bottom.

Presence - absence data from dives at other sites on the Southern New England continental shelf showed that 0-year silver hake were found only in areas with amphipod tube cover and bottom water temperatures between 8.7-11.4°C. The one station with amphipod tube cover that did not have co-occurring silver hake had a bottom water temperature of 16.7°C. This data suggests that the distribution of microtopographic features affect small-scale distribution of silver hake populations. This distribution pattern could be the result of either selective settlement into appropriate habitats or differential predation with higher survivorship in more complex habitats. From the data it seems that 0-year silver hake occur in patches of dense amphipod tube cover to avoid visual predators and co-occur with their preferred prey (i.e. amphipods and shrimps).

Auster, P.J., Malatesta, R.J., LaRose, S.C., Cooper, R.A., and Stewart, LL. 1991. Microhabitat utilization by the megafaunal assemblage at a low relief outer continental shelf site - Middle Atlantic Bight, USA. J. Northw. Atl. Fish. Sci. 11: 59-69.

Reference (#)	Auster *et al.* 1991 (5)
Purpose of study	Describes small-scale habitat variability, faunal-microhabitat relationships related to species specific behavior patterns
Species of fish	Red hake (*Urophycis chuss*), silver hake (*Merluccius bilinearis*),; little skate (*Raja erinacea*), ocean pout (*Macrozoarces americanus*), longhorned sculpin (*Myoxocephalus octodecimspinosus*), scup (*Stenotomus chrysops*), butterfish (*Peprilus triacanthus*), flounder (Pleuronectiform spp.), monkfish (*Lophius americanus*) and sea robin (*Prionotus* sp.).
Length/Age	Juvenile ?
Time	May 1987, July and November 1988
Location	"The Fingers" - a low relief outer continental shelf site Middle Atlantic Bight, US (40°50'N, 70°55'W)
Depth	55 m
Temperature	-
Salinity	-
Bottom type	Flat sand with amphipod tubes, sand wave crest, shell (dense patches and individual valves of the ocean quahog), and biogenic depression (whether in flat sand or under and around shell).
Data set used	Two person submersible DSRV Delta - video transect, still photos ROV - video
Access to Data	NOAA's National Undersea Research Center, The University of Connecticut at Avery Point Groton, Connecticut 06340, USA
Contact name and information	Auster, Peter J. - Science Director Phone: 860-405-9118/9121 Fax: 860-445-2969 E-Mail: auster@uconnvm.uconn.edu

All mobile taxa may utilize a variety of microhabitats but small-scale distributions of many benthic megafaunal taxa are correlated with specific microhabitat features. These features vary on the scale of meters, contributing to the patchy distribution of megafaunal species.

Four microhabitat types were defined: flat sand with amphipod tubes, sand wave crests, shell (single valve and valve aggregations) and biogenic depressions. No significant species associations were found for the sand wave crest habitat. Fauna essentially occurred at random within this microhabitat. The shell habitat however, had the most species per unit area. Interstices of overturned and overlapping valves served as shelter sites for many of the juvenile fish observed. Aside from their potential shelter benefit, specific microhabitat features were also found to serve as functional aids to foraging. Temperature mediated mesoscale shifts in megafaunal-microhabitat associations were also found for several species. If each species complex represented groups of functionally similar species, microhabitat features may be important factors influencing the small-scale distribution of megafaunal species across the continental shelf.

Auster, P.J., Malatesta, R.J., LaRosa, S.C. 1995. Patterns of microhabitat utilization by mobile megafauna on the southern New England (USA) continental shelf and slope. Mar. Ecol. Prog. Ser. 127: 77-85.

<table>
<tr><td>Reference (#)</td><td>Auster <i>et al.</i> 1995 (6)</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Purpose of study</td><td>Are associations of mobile fauna with various microhabitats a common behavioral attribute of species in cold temperate marine assemblages?</td></tr>
<tr><td>Species of fish</td><td>Ocean pout (<i>Macrozoarces americana</i>), Silver hake (<i>Merluccius bilinearis</i>), Longhorn sculpin (<i>Myoxocephalus octodecemspinosus</i>), Butterfish (<i>Peprilus tricanthus</i>), Flounder (Pleuronectiformes), Bluefish (<i>Pomatomus saltatrix</i>), Little skate (<i>Raja erinacea</i>), Scup (<i>Stenotomus chrysops</i>), Red hake (<i>Urophycis chuss</i>), Blackbellied rosefish (<i>Helicolenus dactylopterus</i>), White hake, (<i>Urophycis tenius</i>), Grenadier (<i>Coryphaenoides rupestris and Nezumia bairdii), and</i> Longfinned hake <i>(Urophycis chesteris).</i></td></tr>
<tr><td>Length/Age</td><td>Juvenile</td></tr>
<tr><td>Time</td><td>Summer of 1989-91</td></tr>
<tr><td>Location (sites were located on low-relief bottoms across the southern New England continental shelf and slope).</td><td>
<table>
<tr><th>Year</th><th>Dive System</th><th>Depth (m)</th><th>Temp (°C)</th><th>Location</th></tr>
<tr><td>1989</td><td>'Delta'</td><td>55</td><td>11.6</td><td>40° 50.3'N, 70° 55.6'W</td></tr>
<tr><td>1990</td><td>'NR-1'</td><td>712</td><td>4.3-5.1</td><td>39° 54.0'N, 71° 00.0'W</td></tr>
<tr><td>1991</td><td>'Delta'</td><td>240</td><td>10.3-11.4</td><td>40° 00.5'N, 71° 19.3'W</td></tr>
<tr><td></td><td>'NURP 1'</td><td>33-55</td><td>10.4</td><td>41° 00.8'N, 71° 32.6'W</td></tr>
<tr><td></td><td></td><td></td><td>14.9</td><td>41° 12.7'N, 71° 37.9'W</td></tr>
<tr><td></td><td></td><td></td><td>11.4</td><td>40° 50.3'N, 70° 55.6'W</td></tr>
</table>
</td></tr>
<tr><td>Depth</td><td>55 m</td></tr>
<tr><td>Temperature</td><td>-</td></tr>
<tr><td>Salinity</td><td>-</td></tr>
<tr><td>Bottom type</td><td>Shell, burrow, biogenic depression, biogenic depression with adjacent burrow, sand wave crest, boulder and burrowed clay outcrop.</td></tr>
<tr><td>Data set used</td><td>Video transects using DSVs 'Delta' and 'NR-1' and behavioral observations using the 'NURP 1' ROV</td></tr>
<tr><td>Access to Data</td><td>NOAA's National Undersea Research Center, The University of Connecticut at Avery Point Groton, Connecticut 06340, USA</td></tr>
<tr><td>Contact name and information</td><td>Auster, Peter J. - Science Director
Phone: 860-405-9118/9121
Fax: 860-445-2969
E-Mail: auster@uconnvm.uconn.edu</td></tr>
</table>

The use of microhabitat features is a common behavioral attribute of fishes and crustaceans across the continental shelf and upper slope. In this study non-random distribution and associations with specific microhabitats were found for 8 taxa from diurnal transects and 6 taxa from nocturnal transects at 55 m. For example Silver hake (*Merluccius bilinearis*) and little skate (*Raja erinacea*) were associated with particular microhabitats during the day but were randomly distributed at night. These shifts in pattern were attributed to diel differences in feeding behavior. Non-random distributions and associations with microhabitat were also found for 3 of 6 taxa at a 240 m (outer shelf) site and 5 of 6 taxa at a 712 m (slope) site from diurnal transects.

The use of microhabitat features were found to occur in assemblages where predators of focal organisms were abundant and where prey density allowed ambush predator tactics. From this study continental shelf and slope regions appear to support predator and prey densities sufficient to elicit a shelter-seeking behavior. However, the density of deep-sea fishes was found to decline with depth and these fish therefore did not need to seek shelter from predators. The density of prey is also too low at deep sea sites to elicit ambush predator tactics.

Associations with microhabitat features were found to enhance individual fitness possibly by reducing contact with potential predators and enhancing the ability to capture prey. Individuals occupying various microhabitat features were observed retreating into the interstices of the shell, among valves on the sediment surface, into depressions in the sediment surface and into burrows. Whether for predator avoidance or prey capture, microtopographic features on the continental shelf may serve to block visual and acoustic (i.e. proprioceptive) recognition.

Breeze, H., Fenton, D.G., Rutherford, R.J., and Silva, M.A. 2002. The Scotian Shelf: an ecological overview for ocean planning. Can. Tech. Rep. Fish. Aquat. Sci. 2393.

Reference (#)	Breeze *et al.* 2002 (7)
Purpose of study	This report provides and overview of the distribution, feeding and habitat requirements for the various life stages of groundfish species.
Species of fish	Atlantic cod (*Gadus morhua*) , haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), silver hake (*Merluccius bilinearis*), sand lances (Ammodytes spp.), redfishes (Sebastes spp.), American plaice (*Hippoglossoides platessoides*), and Atlantic halibut (*Hippoglossus hippoglossus*).
Length/Age	Larvae, juvenile, adults
Date	-
Location	Scotian Shelf
Depth	Various
Temperature	Various
Salinity	-
Bottom type	Various
Data set used	Summary from previous studies
Access to Data	-
Contact name and information	H. Breeze Maris Consulting Harris Street Halifax, NS, B3K 1H3

When larvae of many groundfish species reach a certain size they move to the ocean bottom and feed on invertebrates and small fish living there. Many authors have proposed that demersal juvenile fish move into nursery areas with specific habitat characteristics that promote the survival of the young fish. For example, inshore regions have been proposed as important nursery areas for juvenile groundfish. Inshore regions could provide protection from predators in the complex habitats found there. In the winter, these fish migrate to deeper warmer waters of the shelf. As they grow, the juvenile fish can be found at a greater distance from the coast, moving to offshore banks as adults.

Particular species appear to have preferences for specific habitats. For example, juvenile winter founder, *Pseudopleuronectes americanus*, is found predominantly in coastal habitats Horne and Campana 1989; Howell *et al.* 1999), while silver hake, *Merluccius bilinearis*, is found predominantly in the offshore (Koeller *et al.* 1989). Juvenile red hake, *Urophycis chuss*, is found in association with scallop beds in the Bay of Fundy, Scotian Shelf, and Georges Bank (Markle *et al.* 1982).

This report provides and overview of the distribution, feeding and habitat requirements for the various life stages of Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), silver hake (*Merluccius bilinearis*), sand lances (Ammodytes spp.), redfishes (Sebastes spp.), American plaice (*Hippoglossoides platessoides*), and Atlantic halibut (*Hippoglossus hippoglossus*).

Bulatova, A.Y. 1962. Some data on distribution of young cod and haddock off Labrador and Newfoundland. ICNAF Redbook Part III: 69-78.

Reference (#)	Bulatova 1962 (8)
Purpose of study	Presentation of data on the distribution of young cod and haddock off Labrador and Newfoundland.
Species of fish	Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*)
Length/Age	Young juveniles (17-36 cm)
Date	March 1954–October 1961
Location	Offshore of Newfoundland and Labrador
Depth	170-250 m (Flemish Cap), 200-300 m (Grand Bank), 100-200 m (tail of Grand Bank), 40-70 m (St. Pierre Bank and Green Bank)
Temperature	2-3.5°C
Salinity	-
Bottom type	-
Data set used	Bottom trawl survey
Access to Data	Bottom trawl surveys were conducted by the Polar Research Institute
Contact name and information	A.Yu. Bulatova

This contribution is based on 1636 hauls by bottom trawl from 50 research cruises off Labrador and Newfoundland conducted by the Polar Institute from March, 1954 to October 1961.

Labrador and North Newfoundland – Cod

South of Hamilton Inlet Bank on the slopes of the channel, 200-300 m, and temperatures around 2°C a concentration of young cod was noticed in all years investigated. In 1961 more than 100 young cod were caught per hour trawling, on the southern part of Hamilton Bank at depths between 160-180 m and a temperature of 1.6°C, and on the south-east slope at depths of 200-380 m and at a temperature of 2.7°C.

On the north-eastern part of the bank hauls contained 20-30 specimens (60 specimens in 1961) per one hour haul at depths of 270-340 m and a temperature of 3-3.5°C.

Flemish Cap - Cod

Young cod were concentrated on the shallow part of the bank and on its eastern slope at a depth of 170-250 m. On the north, south and western slopes of the bank at depths of over 300 m young cod catches were few or did not occur at all in the catches.

Grand Newfoundland Bank - Cod

On the north-eastern slope of the Bank trawl catches of up to 153 young per haul were made at depths of 200-300 m with temperatures of below 2°C. At more than 300 m the young were not found despite numerous hauls.

On the eastern slope the young were distributed between 200-300 m during the winter. In summer the young were distributed on the shallow part of the bank where temperatures were rising due to the summer heating.

The concentration of young cod in the "tail" region of the Grand Bank was found between 100-200 m.

St. Pierre Bank. Green Banks – Cod

Young cod were found to be distributed in the warmer southern parts of St. Pierre and Green Banks. Especially large amounts of cod were caught in 45-70 m.

Haddock

In the autumn-winter and spring-summer periods haddock were located in the southern part of the Grand Bank and on its south-western slope, and also in the southern part of St. Pierre and Green Banks. Young haddock (<35 cm) were distributed in shallow waters wider in the summer than in the winter period. More often young haddock were taken in the catches at depths of between 50-150 m and up to 200 m.

Bulatova, A.Y. 1970. Abundance of young cod in the waters off Newfoundland. ICNAF Res. Doc. 70/51.

Reference (#)	Bulatova 1970 (9)
Purpose of study	To investigate the relative abundance of young cod during their first three years of life.
Species of fish	Atlantic cod (*Gadus morhua*)
Length/Age	Age 1-4 year old juveniles (up to 40 cm)
Date	April–July 1969
Location	ICNAF Subarea 3
Depth	85-350 m
Temperature	-0.1-5.8°C
Salinity	-
Bottom type	-
Data set used	Trawl survey
Access to data	
Contact name and information	A. Yu. Bulatova

Results of investigations of the distributions of young cod that were carried out in April - July in 1969 in ICNAF Subarea 3 were presented.

The North Newfoundland Bank (Division 3K)

In June-July 1969 the young were distributed in loose concentrations. As in previous years they occupied depths of 150-350 m, and occurred mainly in near-bottom waters at temperatures from 1 to 3°C. Catches taken off the coast were somewhat greater compared to those taken in the offshore part of the Bank.

The Great Newfoundland Bank (Division 3L, 3N, and 3O)

Evidently in April the young start migrating from the slopes to the shallows of the Great Newfoundland Bank and their distribution corresponds to the spreading of the near-bottom waters with different temperature gradients.

In the northeastern part of the bank, small cod up to 40 cm in length were distributed over a large area at depths from 100 to 250 m with temperatures of 0-1.5°C. The waters of the bank less than 100 m deep had near-bottom temperatures from 0.2 to 0.4°C and very low catches of young cod.

To the south the number of young cod in the catches increased gradually reaching a maximum in the western part of the southwest slope with a water temperature of 2°C at 85 m in depth.

Also in May, young from the southeastern part of the Bank remained on the slope in a stream of cold water at a depth of 100-200 m and a temperature of 0.2-0.8°C.

The Saint Pierre Bank (Division 3P)

On St. Pierre Bank, young were caught in the smallest numbers off the coast. Their number increased in catches toward the continental slope, where 723 specimens were taken at 100-150 m (at 5.7°C) and 809 specimens at 0.5°C.

Burnett, J., Ross, M.R., Clark, S.H. 1992. Several biological aspects of the witch flounder (*Glyptocephalus cynoglossus* (L.)) in the Gulf of Maine-Georges Bank Region. J. Northwest Atl. Fish. Sci. 12: 15-25.

Reference (#)	Burnett *et al.* 1992 (10)
Purpose of study	To present an analysis, including information pertaining to growth, length-weight relationships, fecundity, maturation, spawning, and distribution of witch flounder. To evaluate the hypothesis that juvenile witch flounder are distributed at greater depths than adults.
Species of fish	Witch flounder (*Glyptocephalus cynoglossus*)
Length/Age	Juvenile
Date	1963-84
Location	Gulf of Main - Georges Bank region in NAFO Subarea 5
Depth	112 m in winter - 198 m in summer and autumn
Temperature	4.63-7.62°C
Salinity	-
Bottom type	-
Data set used	Bottom-trawl survey cruises conducted by the Northeast Fisheries Center (NEFC) in NAFO Subarea 5
Access to Data	National Marine Fisheries Service, Northeast Fisheries Science Center Woods Hole, Massachusetts 02543, USA
Contact Name and Information	Jay Burnett Phone: 508-495-2000/2286 Fax: 508-495-2297 E-Mail: jay.burnett@noaa.gov

This paper attempted to evaluate the previously stated hypothesis that juvenile witch flounder (*Glyptocephalus cynoglossus*) are distributed at greater depths than adults. Distributions of juveniles (0-20 cm TL) and adults (>30 cm TL) were not significantly different for any reason with respect to bottom temperature (See Table 3). However, from the data that was collected (See table below) juvenile and adult witch flounder appeared to be segregated by depth, but the relative position of the life stages with respect to depth varied seasonally. Adults maintained an annual mean depth of 147 m, while juveniles were found at shallower depths than adults in winter and spring with a mean depth of 112 m and 137 m respectively, and greater depths in summer and autumn with a mean depth of 198 m.

Segregation of the distributions of the life stages of witch flounder, with juveniles occupying greater depths than adults, could be a mechanism to minimize food competition of juveniles with juvenile Atlantic cod (*Gadus morhua*) and American plaice(*Hippoglossoides platessoides*) at shallower depths.

Table 3 (Table 6 in Burnett *et al.* 1992). Distribution of juvenile (<21 cm TL) and adult witch flounder collected during NEFC bottom trawl survey cruises, 1963-81, in relation to season, depth and temperature, and tests for significance of differences in distribution by depth and temperature, between juveniles and adults obtained from Kruskal-Wallis analysis (** = significantly different at P<0.01 level; NS = not significantly different, P > 0.05).

	Juveniles			Adults				
		Mean depth	Mean Temp		Mean depth	Mean Temp	Significance	
Season	Number	(m)	(°C)	Number	(m)	(°C)	Depth	Temp
Winter	15	112.1	4.63	1 170	153.2	5.13	**	NS
Spring	121	137.5	5.10	8 826	159.2	5.45	**	NS
Summer	19	198.4	6.22	1 946	131.9	6.17	**	NS
Autumn	148	198.1	7.62	8 099	153.8	7.29	**	NS

Cohen E.B., Green Jr., D.C., and Hayden, B.P. 1985. Some preliminary results of juvenile cod and haddock studies of Georges Bank in 1984 and 1985. ICES C.M. 1985/G:74.

Reference (#)	Cohen *et al.* 1985 (11)
Purpose of study	To investigate the hypothesis that predation mortality after the larval period may be the dominant factor in year class variability. A comparison of different types of gear to best sample pelagic and demersal juveniles.
Species of fish	Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*)
Length/Age	Juvenile (20-80mm)
Date	August-November 1980, and August 26-27, September 11-13, October 20-21, November 3-5, 1984
Location	Georges Bank
Depth	60-80 m
Temperature	-
Salinity	-
Bottom type	-
Data set used	Bottom-trawl survey cruises as a part of NEFC MARMAP program 36 Yankee Otter trawl..
Access to data	National Marine Fisheries Service, Northeast Fisheries Science Center Woods Hole, Massachusetts 02543, USA
Contact name and information	Edward Cohen

During the July cruise, haddock were distributed all over the bank [outside the well-mixed area on the central bank (<60 m)]. By August the bulk of haddock shifted to the eastern portion of the bank. Cod were generally distributed more to the east than haddock in July. In August the bulk of the cod juveniles were found on the Northeast Peak and along the northern edge of the bank.

The bottom trawl caught more haddock during the day (107 fish/tow) than during twilight (36fish/tow). During the August cruise slightly more haddock were caught during the day (232 fish/tow) than at night (219 fish/tow) with the cookie trawl. The roller-rigged trawl, however, caught more haddock at night (96 fish/tow). This indicates that haddock may be right on the bottom during the day and were missed by the roller trawl riding over them. This is consistent with the fact that the roller net catches more haddock after dark when haddock may move slightly off the bottom.

More cod were caught with the cookie-rigged trawl on the July cruise at twilight (322 fish/tow) than during the day (234 fish/tow). Not enough cod were caught in August for any analysis. If this is related to the diel distribution of cod, it means that cod are more closely associated with the bottom during twilight than during the day. While this implies a reverse diel distribution from most species, perhaps cod are on the bottom during twilight to feed.

Dalley, E.L., and Anderson, J.T. 1994. Distribution and abundance of demersal juvenile cod (*Gadus morhua*) from inshore to offshore locations on the Northern Grand Bank and Northeast Newfoundland Shelf in December, 1992. NAFO Sci. Coun. Studies 21: 91-103.

Reference (#)	Dalley and Anderson 1994 (12)	
Purpose of study	To present results of a survey that's purpose was to determine distribution and abundance of demersal juvenile northern cod.	
Species of fish	Atlantic cod (*Gadus morhua*)	
Length/Age	Age 0-3	
Date	December 1992	
Location	Sampling stations within each of the 5 major bays along the Northeast coast of Newfoundland and along 6 transect that extend from 37-55 km off the coast across the shelf to the shelf break.	
Depth	60 m - 637 m	
Temperature	1.26-+3.76	
Salinity	-	
Bottom type	-	
Data set used	Three-bride Campelen 1800 mesh shrimp trawl	
Access to data	Department of Fisheries and Oceans P.O. Box 5667 St. John's, NL A1C 5X1	
Contact name and information	Edgar Dalley (Research Biologist) 709-772-2002 DalleyE@dfo-mpo.gc.ca	John Anderson (Section Head) 709-772-2116 AndersonJT@dfo-mpo.gc.ca

The results indicated a tendency for the smallest fish (LG0), and to a lesser extent the LG1, to be more restricted to the inshore than offshore areas. With increasing size there was a tendency for the juveniles to be more widely distributed on the shelf, and in the case of LG3, some of the larger catches were taken near the shelf edge. The fact that nearly all LG0 were restricted to the inshore area, supports the hypothesis that the inshore areas harbours the early life history stages of cod.

Dalley, E.L., and Anderson, J.T. 1997. Age-dependent distribution of demersal juvenile Atlantic cod (*Gadus morhua*) in inshore/offshore northeast Newfoundland. Can. J. Fish. Aquat. Sci. 54 (Suppl. 1): 168-176.

Reference (#)	Dalley and Anderson 1997(13)
Purpose of study	To describe the results of a 3 year study that was conducted to determine the distribution of age 0-3 juvenile cod in inshore and offshore locations.
Species of fish	Atlantic cod (*Gadus morhua*)
Length/Age	Age 0-3 Max length of 391 mm
Date	December 1992, December 1993-January 1994, December 1994-January 1995
Location	Sampling stations within each of the 5 major bays along the Northeast coast of Newfoundland and along 6 transect that extend from 37-55 km off the coast across the shelf to the shelf break.
Depth	Min depth ~ 60 m
Temperature	-
Salinity	-
Bottom type	-
Data set used	Three-bride Campelen 1800 mesh shrimp trawl
Access to data	Department of Fisheries and Oceans P.O. Box 5667 St. John's, NL A1C 5X1
Contact name and information	Edgar Dalley (Research Biologist) 709-772-2002 DalleyE@dfo-mpo.gc.ca John Anderson (Section Head) 709-772-2116 AndersonJT@dfo-mpo.gc.ca

During early winter 1992-94, demersal juvenile cod utilized habitats within each of the large northeast bays, throughout the Northeast Newfoundland Shelf, and on the Northern Grand Banks (NAFO Div. 3KL). An ontogenetic pattern in distribution existed in the study areas whereby age 0 fish were distributed almost exclusively in the inshore, age 1 fish extended further onto shelf areas, and larger juveniles were widely distributed on the shelf.

During all three years, there was a statistically significant ($p<0.001$) inverse correlation between catch rate of age 0 and 1 juvenile cod and water depth. There was also no statistical correlation between catch rate of age 0, 1, or 2 cod and temperature. However, for all three years, there was a significant positive relationship ($p<0.01$) between catch rate at age 3 and temperature.

Younger juveniles appeared to prefer the cooler, shallower water of the inshore, whereas age 2 cod appeared to be intermediate between these young juveniles and older age 3 juvenile cod which were found to be associated with warmer, deeper shelf water.

Diaz, R.J., Cutter Jr., G.R., and Able, K.W. 2003. The importance of physical and biogenic structure to juvenile fishes on the shallow inner continental shelf. Estuaries 20(1): 12-20.

Reference (#)	Diaz *et al.* 2003 (14)
Purpose of study	To demonstrate a quantitative relationship between habitat complexity and fish abundance.
Species of fish	Sand lance *(Ammodytes* spp.), Anchovi (*Anchoa mitchilli)*, Conger eel (*Conger oceanicus)*, Carcharhinidae, Black Sea bass (*Centropristis striata)*, Weakfish (*Cyniscion regalis)*, Monkfish (*Lophius americanus)*, (*Menticirrus saxatilis)*, Smooth dogfish (*Mustelus canis)*, *Ophidion marginatum*, Summer flounder (*Paralichthys dentatus)*, Sea robin (*Prionotus carolinus)*, *P. evolans*, *Raja eglantaria*, *Raja* spp., Sciaenidae, Scup (*Stenotomus chrysops)*, Spotted hake (*Urophycis regia), Urophycis* spp.
Length/Age	Juvenile
Date	June 1998 and May 1999
Location	The inner continental shelf in the central portion of the mid-Atlantic Bight. Most of the effort was concentrated on Fenwick Shoals (38°27.5'N, 74°55.9'W).
Depth	-
Temperature	-
Salinity	-
Bottom type	Habitats were classified in terms of visible physical and biological characteristics. Bottom relief was classified as being large (Bedforms >30 cm wavelength and about 10 cm wave height as estimated from the video images), small (bedforms <30 cm wavelength and <5 cm wave height), and flat (no bedforms and relief <1 cm). Biological features were classified as patch-mat (dense patches of tubes or organisms to continuous cover or tubes), some (single tube, organism, or biogenic structures), and None (no obvious biogenic structures). Shell hash was classified by percentage coverage of the sediment surface into three categories: <10%, 10-50%, and >50%. Bottom with >50% shell coverage was considered to be shell bed habitat.
Data set used	Beam trawl and video
Access to data	Same as below
Contact name and information	R.J. Diaz Virginia Institute of Marine Science, College of William and Mary P.O. Box 1346 Gloucester Point, Virginia, 23062 Phone: 804-684-7364 Fax: 804-684-7399 e-mail: diaz@vims.edu

A quantitative association for juvenile fishes between and within benthic habitats was found in this study and was related primarily to bedform size and amount of biogenic structure. The incidence of fishes was about four-times higher for large bedforms (>30 cm wavelength and about 10 cm crest height) relative to smaller bedforms (<30 cm wavelength and about 5 cm crest height). For biogenic structure, going from high patch-mat tube densities to lower densities or no biogenic structure increased fish incidence by 5.4 and 3.3 times, respectively.

Proximity of complex and simple habitats was shown to be important in the diel use of habitat and in balancing pressure of refuge from predation provided by complex habitats with increased resources available in simpler habitats. The more spatially complex biogenic habitats tended to have more fish during the day and simpler physically structured habitats more fishes at night. For example, habitats that were comprised of *Diopatra* and *Asabellides* tube mats had about twice as may fishes relative to bare sandy habitats (8.3-9.9 versus 4.0-4.1 fishes 100 m^{-2}, respectively). At night, the pattern was reversed with more fishes present in the bare sandy habitats (12.4-13.5 versus 5.6-8.7 fishes 100m^{-2}).

Ammodytes spp., were the most habitat specific of all fish in this study and occurred only on dynamic coarser sands near the top of shoals. Other species, such as *Urophycis regia*, showed less habitat preference and occurred in all habitats during both day and night.

This study has demonstrated that, mesoscale and microscale habitat for juvenile fishes is very important particularly as refuge from predation. At smaller scales, much of the relief on the inner continental shelf is contributed by bedforms or sand waves and biogenic structures such as tubes, shell beds, or pits. Combining the effects of physical relief and biogenics, the habitat with the highest incidence of fishes had large bedforms with some biogenic structure. The significant relationships of fishes with bedform size and density of biogenic structure demonstrates that small changes in physical habitat can make the difference between unacceptable and essential habitat for juvenile fishes.

Edwards, R.L., and Emery, K.O. 1968. The view from a storied sub The "Alvin" Off Norfolk, Va. Comm. Fish. Rev. 30(8-9): 48-55.

Reference (#)	Edwards and Emery 1968 (15)
Purpose of study	To observe closely a series of underwater ridges and their fauna.
Species of fish	Red hake (*Urophycis chuss*), spotted hake (*U. regius*), silver hake (*Merluccius bilinearis*), and fourspot flounder (*Paralichthys oblongus*)
Length/Age	?
Date	July 17-18, 1967
Location	Off Norfolk, Virginia
Depth	20 to 25 fathoms
Temperature	-
Salinity	-
Bottom type	Coarse, grayish-brown, sand.
Data set used	2 dives in DSRV "Alvin"
Access to data	Woods Hole Oceanographic Institute
Contact name and information	R.L. Edwards Fishery Research Biologist BCF Biological Laboratory Wood Hole, Mass. 02543 K.O. Emery Senior Scientist Woods Hole Oceanographic Institution Woods Hole, Mass. 02543

Alvin is a deep-diving research vessel designed specifically for oceanographic research. Here it was used to investigate the nature of submarine ridges and to observe the distribution of bottom organisms and bottom sediments.

The bottom communities that were observed were many. The bottom generally was coarse, grayish-brown sand. For reasons that were not understood at the time, bottom communities changed radically without an accompanying observable change in the bottom sediment.

Some of the more interesting biological observation, by species, follow:

Red hake

As expected from previous research with the underwater camera, red hake were almost always closely associated with other objects on the bottom. They were seen frequently with sea scallops. The larger fish tended to stay close to objects, whereas the smaller fish tended to get in or under such things as shells, sponges, or litter.

Spotted hake

The spotted hake behaved in much the same manner as the red hake but seemed to associate less with other objects on the bottom.

Silver hake

Small groups of silver hake were seen moving along slowly, mostly within 1 fathom or so of the bottom. At about noon, no fish were observed off the bottom. Single fish only were seen, resting quietly in shallow depressions for the rest of the day

Fourspot flounder

Fourspot flounders were numerous. Two size groups were apparent, the smaller averaging 3-5 in long, the larger about 10-12 in long. They were observed to be resting quietly on the bottom, but they were not covered or buried.

Gregory, R.S. and Anderson , J.T. 1997. Substrate selection and use of protective cover by juvenile Atlantic cod *Gadus morhua* in inshore waters of Newfoundland. Mar. Ecol. Prog. Ser. 146: 9-20.

Reference (#)	Gregory and Anderson 1997 (16)
Purpose of study	To investigate the habitat preferences and use of cover of age 1- to 4-year-old juvenile cod in inshore waters.
Species of fish	Atlantic cod (*Gadus morhua*)
Length/Age	Age 1-4
Date	April 1995
Location	Placentia Bay (Near Long Island and Haystack Bank)
Depth	<150 m (generally between 25-75 m)
Temperature	-1.0-0.5 °C
Salinity	-
Bottom type	Habitat types were characterized by depth, substrate particle size, bathymetric relief, and the presence or absence of macroalgae.
Data set used	Deep sea submersible (PISCES IV and SDL-1) A total of 32 hours of "on-bottom' videotape, audiotape and written records from 9 daylight dives and 1 night dive.
Access to data	Department of Fisheries and Oceans P.O. Box 5667 St. John's, NL A1C 5X1
Contact name and information	Robert Gregory (Research Scientist) 709-772-4491 GregoryR@dfo-mpo.gc.ca John Anderson (Section Head) 709-772-2116 AndersonJT@dfo-mpo.gc.ca

Age 1- to 4-yr-old juvenile cod exhibit age-specific associations with substrate. From their pattern of activity in relation to cover these fish appeared likely to be using specific substrate characteristics for protection from predators. These activity patterns also appeared to change with age, suggesting that the behavioral mechanism of predator avoidance for cod is also age-specific.

The presence of juvenile cod appeared to be associated with specific combinations of substrate types and bathymetric relief. Of old juveniles (age 2-4, >15 cm TL), 80% were found to be associated with areas of course substrate and high bathymetric relief (i.e. submarine cliffs). In contrast, 59% of young juveniles (age 1, 10-12 cm TL) were found primarily in areas with a gravel substrate and low relief. Old juveniles were often associated with individual substrate features (e.g. a single rock, boulder, or crevice) and exhibited a significant increase in activity (oriented swimming speed) with increasing distance from such features. Young juveniles exhibited no such association with specific substrate features, although they exhibited greater variation in activity (non-oriented swimming speed).

These results suggest that substrate which is ideal for one age group of cod may be completely inappropriate for another and that density-dependent factors could be important well into the demersal juvenile stage for cod in instances where the availability of heterogeneous bottom habitat is low.

Gregory, R.S., Anderson, J.T, and Dalley, E.L. 1997. Distribution of juvenile Atlantic cod (*Gadus morhua*) relative to available habitat in Placentia Bay, Newfoundland. NAFO SCS 29: 3-12.

Reference #	Gregory *et al.* 1997 (17)
Purpose of study	An investigation of the availability of suitable habitat by juvenile Atlantic cod in Placentia Bay, Newfoundland.
Species of fish	Atlantic cod (*Gadus morhua*)
Length/Age	Age 1-4
Date	April 4-5 and April 22-25, 1995 and October 3-November 1, 1995.
Location	Placentia Bay (Near Long Island and Haystack Bank)
Depth	<150 m (between 60-120 m)
Temperature	-
Salinity	-
Bottom type	Habitat types were characterized by depth, substrate particle size, bathymetric relief, and the presence or absence of macroalgae.
Data set used	Deep sea submersible (PISCES IV and SDL-1) and groundtruthed QTC VIEW integrated acoustic seabed classification system. A total of 40 hours of "on-bottom' videotape, audiotape and written records from 13 daylight dives and 2 night dives.
Access to data	Department of Fisheries and Oceans P.O. Box 5667 St. John's, NL A1C 5X1
Contact name and information	Robert Gregory (Research Scientist) 709-772-4491 GregoryR@dfo-mpo.gc.ca John Anderson (Section Head) 709-772-2116 AndersonJT@dfo-mpo.gc.ca

Substrate selection by juvenile cod was found to be age specific. In this paper the availability of suitable habitat for and the use of this habitat by juvenile Atlantic cod (*Gadus morhua*) was investigated. The study area was heterogeneous with respect to bathymetric relief, substrate particle size, and presence of macroalgae. Within the immediate vicinity of the dive area the bottom substrate varied in composition from mud/silt (<0.1 cm diameter) to bedrock.

Age 2-4 juvenile cod were found to be associated with areas of coarse substrate and high bathymetric relief, whereas age 1 cod were found primarily in areas with a gravel substrate and low relief. Juvenile cod of neither age group exhibited selection for substrates with macroalgae cover.

The results of this investigation clearly indicate two main aspects of juvenile cod distribution within the study area of Placentia Bay. First, of the habitat of all types available in the study area, only a small amount of it appears to be suitable for juvenile cod. Second, although age 1 and age 2-4 cod tend to occupy the same general areas within the study area, the areas where they are most predominant exhibit only a modest degree of spatial overlap. Age 1-4 juvenile cod exhibited age-specific associations with substrate that, from their pattern of activity in relation to cover, appeared likely to be a result of using specific substrate characteristic for protection from predators.

Langton, R.W., and Auster, P.J. 1999. Marine fishery and habitat interactions: to what extent are fisheries and habitat interdependent? Fisheries 24(6): 14-21.

Reference (#)	Langton and Auster 1999 (18)
Purpose of study	This article discusses the consequences of current fishery practices on habitat integrity and fish production in marine systems.
Species of fish	General
Length/Age	Juvenile
Date	-
Location	-
Depth	-
Temperature	-
Salinity	-
Bottom type	-
Data set used	Article Review
Access to data	
Contact name and information	Richard W. Langton Maine Department of Marine Resources P.O. Box 8 West Boothbay Harbor, ME

Fishing disturbs the benthic community; directly affecting survival of young fish, but it may have an ecosystem-level impact as well, e.g., at levels significantly removed form the immediate ecological processes supporting the production of fish. Therefore, the linkage to fish production is not readily apparent but may be equally important when considered at the appropriate scale. This article discusses the consequences of current fishery practices on habitat integrity and fish production in marine systems through discussing various studies which focus on essential fish habitat, the ecological consequences of fishing methods, and the need for precautionary approaches to fisheries management.

Survival of early-benthic-phase fishes has been shown to be habitat-dependent so that one can postulate a linkage between the percent cover of the benthic organism that offers emergent cover for the settling fish and their survival through this critical life history stage. A fishing disturbance that coincides with the time of settlement of the sessile benthic invertebrates would have a devastating impact on the subsequent arrival and survival of the early-benthic-phase fishes. In contrast, fishing at the point in time when the emergent epifauna has already served as cover for the fishes, and the cover provided by the benthic species in reduced, fishing effect would be minimal.

Nutrient regeneration and primary production were also shown to be affected by fishing. If the benthic primary production is unavailable for demersal zooplankton and planktivorous fishes, juvenile fish that depend on demersal zooplanktors will be forced to spend more time searching for food and may expose themselves to a much greater predation risk.

Langton, R.W., Auster, P.J., and Schneider, D.C. 1995. A spatial and temporal perspective on research and management of ground fish in the Northwest Atlantic. Rev. Fish. Sci. 3(3): 201-229.

Reference (#)	Langton *et al.* 1995 (19)
Purpose of study	Review article of the different scales that have been the focus of fisheries research and discusses the use of multistage analysis for research and its applications to management of the resource.
Species of fish	Commercially important ground fish - Atlantic cod (*Gadus morhua*), yellowtail founder (*Pleuronectes ferruginous*), silver hake (*Merluccius bilinearis*) etc.
Length/Age	Juvenile
Date	-
Location	-
Depth	-
Temperature	-
Salinity	-
Bottom type	-
Data set used	Article Review
Access to data	
Contact name and information	Richard W. Langton Maine Department of Marine Resources P.O. Box 8 West Boothbay Harbor, ME

Patterns in the distribution of megafaunal organisms, especially mobile fauna such as ground fish, can be found on a multitude of scales. This article addresses the question of how we integrate our knowledge of fish and fishers, at multiple scales, and produce a management structure that maintains stock at sustainable levels. It does this by reviewing patterns and processes exhibited by both fishers and fish through a hierarchy of temporal and spatial scales. Large-scale population surveys, for example, document the persistence of patterns in population structure and geographic range of fish populations. In contrast to regional-scale patterns in population structure, where both fish and fishers interact and react at the scale of a fishing ground. Research has also demonstrated that fish distributions can be attributed to variability in small-scale physical and biological structures in their environment. The scale of these responses is on the order of centimeters to meters and is defined as microhabitat relationships. The impact of fishing and the behavior of animals at the fishing ground and habitat scales are cumulative at the population level where current management plans operate. Management actions must, however, be considered not only at the population level, but also at smaller scales in order to have predictable effects.

At small spatial and temporal scales, microhabitat associations have been demonstrated for many species associated with the substrate, including the early life-history stages of groundfish. The underlying behavioral mechanisms could likely be attributed to feeding success and predator avoidance because they have been found to reinforce microhabitat associations for fish.

Langton , R.W., Steneck, R.S., Gotceitas, V., Juanes, F., Lawton, P. 1996. The interface between fisheries research and habitat management. N. Am. J. Fish. Manag. 16(1): 1-7.

Reference (#)	Langton *et al.* 1996 (20)
Purpose of study	To outline a procedure to assist fisheries managers in prioritizing scientific information in relation to the absolute biological limit to resource harvesting
Species of fish	Atlantic cod (*Gadus morhua*)
Length/Age	All life stages
Date	-
Location	-
Depth	-
Temperature	-
Salinity	-
Bottom type	-
Data set used	-
Access to data	
Contact name and information	Richard W. Langton Maine Department of Marine Resources P.O. Box 8 West Boothbay Harbor, ME

This study suggests that economically important fisheries that have relatively small essential habitats and habitats that are important for more than one target species rank higher in terms of management priority.

To identify essential habitats, sufficient knowledge must exist to evaluate all major phases in the life history, representing both ontogenic and functional shifts, for each species of interest. This study proposed that the importance of essential habitat be approached by developing a habitat-life history matrix for each species of interest.

In principle, the habitat-life history matrix integrates large-scale distribution (e.g., distance from shore, water depth, pelagic versus benthic and local habitat characteristics (e.g., substrate characteristics, complexity, or both)) with distinct ontogenetic or functional phases in a species' life history. Known associations between life history phases and habitat can then also be arrayed in the matrix. It is also important to recognize whether a "critical phase" exists in the species' life history and whether information about the habitat "requirements" during this phase are lacking.

The distribution of newly settled juveniles of Atlantic cod for example has been shown to be severely restricted to the gravel pavement on the northern edge of Georges Bank. The complexity of this gravel pavement allows a relatively large proportion of larvae to continue development. The resulting distribution of juveniles indirectly defines an essential habitat for a critical life stage and thereby emphasizing the importance of habitat quality and availability in determining the recruitment success of juvenile fishes.

Lindholm, J.B., Auster, P.J., Ruth, M., and Kaufman, L. 2001. Modeling the effects of fishing and implications for the design of marine protected areas: juvenile fish responses to variations in seafloor habitat. Conserv. Biol. 15(2): 424-437.

Reference (#)	Lindholm *et al.* 2001 (21)
Purpose of study	To use a dynamic model to: a) link patterns in habitat-mediated survivorship of post settlement juvenile cod with spatial variations in habitat complexity; b) simulate habitat change based on fishing activities, and; c) determine the role of marine protected areas in enhancing recruitment success.
Species of fish	Atlantic cod (*Gadus morhua*)
Length/Age	Juvenile
Date	-
Location	Stellwagen Bank National Marine Sanctuary
Depth	-
Temperature	-
Salinity	-
Bottom type	-
Data set used	-
Access to data	-
Contact name and information	James B. Lindholm National Undersea Research Center for the North Atlantic & Great Lakes University of Connecticut at Avery Point, 1084 Shennecossett Road, Groton, CT 06340

The results of this study demonstrated that patterns in the shape of response surfaces that show the relationship between juvenile cod survivorship and density as well as movement rate were similar regardless of functional response type. Juvenile cod movement rates and post-settlement density were critical for predicting the effects of marine protected-area size on survivorship, and that habitat change caused by fishing has significant negative effects on juvenile cod survivorship and use of marine protected areas can improve such effects.

The dynamic model used in this study demonstrated distinct patterns in juvenile cod survivorship and linked those patterns to seafloor habitat quality and fishing-induced alteration of seafloor habitat. Juvenile cod survivorship was found to be highest in unaffected regions, which are those areas where an MPA was established and fishing-induced alteration of the seafloor did not occur. These regions included pebble-cobble bottom with dense coverage of emergent epifauna and boulder habitats. Affected regions which are those areas where no MPA was established and the seafloor had been significantly affected by fishing activity, including pebble-cobble bottom with no emergent epifauna and disturbed boulder habitats. Here juvenile cod survivorship was significantly lower than within regions protected by an MPA.

The results of this study indicated that juvenile survivorship varied with the size, configuration, and orientation of MPAs designed to protect representative samples of flat sand and mud, pebble-cobble, and boulder habitats. Given that the fishing industry is a key stakeholder in decisions regarding the use of MPAs for conservation of diversity, understanding the role of MPAs in the dynamics of ecologically important species is critical.

Lough, R.G, Valentine, P.C., Potter, D.C., Auditore, P.J., Bolz, G.R., Neilson, J.D., and Perry, R.I. 1989. Ecology and distribution of juvenile cod and haddock in relation to sediment type and bottom currents on eastern Georges Bank. Mar. Ecol. Prog. Ser. 56: 1-12.

Reference (#)	Lough *et al.* (22)
Purpose of study	To report significant new observations on the ecology of recently-settled juvenile cod and haddock on northeastern Georges Bank. To determine the absolute abundance of demersal 0-group cod and haddock and their degree of aggregation in relation to bottom type and time of day.
Species of fish	Atlantic cod (*Gadus morhua*) and Haddock (*Melanogrammus aeglefinus* L.)
Length/Age	0-group Juvenile
Date	August 4-13, 1986, and July 25-31, 1987.
Location	Northeastern Georges Bank
Depth	70-100 m
Temperature	-
Salinity	-
Bottom type	Pebble-gravel
Data set used	'Johnson-Sea-Link I' submersible - 18 dives 'Delta' submersible - 32 dives Bottom trawl surveys 'Delaware II'
Access to data	National Marine Fisheries, Northeast Fisheries Center Woods Hole, Massachusetts 02543, US
Contact name and information	R. Gregory Lough 508-495-2000 Ext. 2290 Gregory.Lough@noaa.gov

Recently-settled 0-group cod and haddock were observed by submersible dives and research bottom trawls to inhabit primarily a large pebble-gravel deposit located on the Northeastern edge of Georges Bank at 20-100 m water depth. In June-July, the pelagic juvenile fish that are widespread on the bank, become demersal and were present in abundance on the lag pebble gravel on the northeastern part of the bank. In contrast, at the same time of year, demersal juveniles generally are absent in areas of the bank covered by rippled sand, sand waves and ridges, and gravelly sand.

The diel behavior of the juvenile cod and haddock, and their seasonal location on the bank, suggests that aggregations of young demersal gadids drift in the clockwise current gyre of the bank. So juveniles that settle on the pebble gravel in June and July drift to the east and southeast over the gravel toward the eastern end of the bank. By mid-August they change direction and move to the west over varied sedimentary environments of sand and sandy gravel.

Two environmental factors were hypothesized that could favor the survival of the juvenile fish on the pebble gravel habitat: (1) food availability and/or (2) predation avoidance. The gravel fauna on the northeastern edge is considered to be one of the richest and most complex benthic communities of Georges Bank. The types of prey that both cod and haddock feed on may therefore be most abundant in waters on the gravelly northern edge of Georges Bank where the young juvenile fish are found. More weight however was given to a predation-avoidance hypothesis because the coloration or the juvenile gadids so mimics the mottled appearance of the pebble bottom that it could make them less vulnerable to predation there than on the lighter, more evenly colored sand bottom. The textured pebble bottom is a background that softens fish silhouettes and obscures movement that predators cue on. The survival of juvenile cod and haddock on Georges Bank is therefore closely linked to both specific current patterns and sedimentary environments.

MacDonald, J.S., Dadswell, M.J., Appy, R.G., Melvin, G.D., and Methven, D.A. 1984. Fishes, fish assemblages, and their seasonal movements in the lower Bay of Fundy and Passamaquoddy Bay, Canada. Fish. Bull. 82(1): 121-139.

Reference (#)	MacDonald *et al.* 1984 (23)
Purpose of study	This study examines spatial and temporal variation in fish diversity and abundance over a 5-yr period at two offshore stations within Passamaquoddy Bay, one off shore station in the Bay of Fundy, and at inshore and beach stations in Passamaquoddy Bay.
Species of fish	62 fish species including; pleuronectids, cottids, gadoids, clupeids, and rajids
Length/Age	Juveniles and adults
Date	1976-81
Location -	Three offshore stations in the Bay of Fundy and in Passamaquoddy Bay. Twelve estuarine, intertidal and inshore marine stations were sampled within Passamaquoddy Bay and Head Harbour Passage.
Depth	-
Temperature	-
Salinity	-
Bottom type	Substrates of most sites were composed of sand and/or mud, and gravel or rock. Estuarine stations had extremely soft mud bottoms and station 2 had extensive eel grass beds
Data set used	Fish were collected monthly using a ¼-35 shrimp trawl along a 1.6 km transect
Contact name and information	J. Stevenson MacDonald Department of Fisheries and Oceans West Vancouver Laboratory Vancouver BC V7V 1N6

Five fish assemblages, dominated by pleuronectids, cottids, gadoids, clupeids, and rajids, were identified form collections taken during a 5-yr survey in the lower bay of Fundy region. Individual assemblages occurred in each of estuarine, beach, pelagic, and offshore hard- and soft-bottom habitats. Species and/or age-class components within assemblages varied seasonally but in general, each assemblage was distinct. There was a progressive seaward displacement of these assemblages from shallow, inshore to deeper, offshore habitats in winter followed by a reversal during summer. Yearly changes in species occurrence and abundance during the study period were predominantly attributable to variation in ocean climate. Long-term changes in abundance of two commercial species at one of the sampling sites, since a similar study there in 1965, appear related to population fluctuations in the Bay of Fundy and the Gulf of Maine. The beach habitat apparently served as a major nursery area for juvenile gadoids, pleurnectids, and clupeids.

Markle, D.F., Methven, D.A., and Coates-Markle, L.J. 1982. Aspects of spatial and temporal cooccurrence in the life history stages of the sibling hakes, *Urophycis chuss* (Walbaum 1792) and *Urophycis tenuis* (Mitchill 1815) (Pisces: Gadidae). Can. J. Zool. 60: 2057-2078.

Reference (#)	Markle *et al.* 1982 (24).
Purpose of study	To describe the extent of ontogenetic environmental partitioning between *U. chuss* and *U. tenuis* and relate major differences to their life history tactics.
Species of fish	Hakes: *Urophycis chuss* and *Urophycis tenuis*
Length/Age	All life history stages Demersal juveniles (*U. tenuis* 5-150 mm, *U. chuss* 25-85 mm)
Date	May-June 1979, June-October 1979
Location - of Demersal Juveniles	Georges Bank (scallop beds), Passamaquoddy Bay (scallop beds), Nova Scotia - New Brunswick (Estuaries), Cumberland Basin (estuary 2-18 m depth), Passamaquoddy Bay and vicinity (estuary 28-73 m depth).
Depth	Scallop beds in the Gulf of St. Lawrence are in the depth range of 11-37 m
Temperature	*U. chuss* in scallop beds prefer 4 °C
Salinity	-
Bottom type	Eelgrass - Near shore and scallop beds
Data set used	Scallop dredge, scuba, ROM, shrimp trawl
Contact name and information	Douglas F. Markle The Huntsman Marine Laboratory St. Andrews NB E0G 2X0

The amount of coexistence in the sympatric sibling hake species *U. chuss* and *U. tenuis*, appears to be a function of ontogeny, with each life history stage showing different probabilities of interspecific encounters. Demersal juveniles coexist the least since *U. chuss* is inquiline with scallops and *U. tenuis* is in near shore shallows.

The demersal juveniles of *U. chuss* and *U. tenuis* appear to be completely segregated. Both species are in habitats where predation is presumably reduced and where growth appears to be rapid.

White hake (U. tenuis)

Juvenile white hake (*U. tenuis)* become demersal at about 50-60 mm TL. In this species of hake there is intraspecific segregation, with older juveniles and young adults bathymetrically segregated from the youngest demersal juveniles in summer which can be found in very shallow water among eelgrass.

Red hake (U. chuss)

All juveniles of red hake (*U. chuss)* greater than about 25-30 mm SL are found in symbiotic relationship with scallops. Juvenile *U. chuss* apparently seek refuge by hiding in the mantle cavities of scallops during the day. The modal size (130 mm) of scallops harboring *U. chuss* was about 150% of the modal standard length (85 mm) of the fish. This suggests selection for relatively large scallops by June. The duration of the inquiline relationship is dependent on the size structure of the local scallop population and the presence of 4°C or warmer water temperatures. When juveniles are too big for scallops the association ends, although large juveniles and young adults have been shown to remain near scallop beds, water temperatures permitting.

Marshall, C.T. and Frank, K.T. 1995. Density-dependent habitat selection by juvenile haddock (*Melanogrammus aeglefinus*) on the southwestern Scotian Shelf. Can. J. Fish. Aquat. Sci. 52: 1001-1017.

Reference (#)	Marshall and Frank 1995 (25)
Purpose of study	Develop a statistical model describing the relationship between local density and total abundance-at-age for sub areas within the stock range of juvenile haddock on the southwestern Scotian Shelf
Species of fish	Haddock (*Melanogrammus aeglefinus*)
Length/Age	Age 1 and 2
Date	Summer 1970-95
Location	Southwestern Scotian Shelf
Depth	-
Temperature	-
Salinity	-
Bottom type	-
Data set used	Bottom trawl surveys by DFO (Halliday and Koeller 1981) Yankee 36 (1970 - 1981) Western II A (1982 - Present) Towed at a constant speed for 30 min or approximately 3.2 km.
Contact name and information	C. Tara Marshal Department of Oceanography Dalhousie University Halifax NS B3H 4J1 Kenneth T. Frank Marine Fish Division Department of Fisheries and Oceans Bedford Institute of Oceanography Box 1006 Dartmouth NS B2Y 4A2

Marshall and Frank described an alternative approach to modeling the distributional response to variation in total abundance using data for juvenile haddock from the southwestern Scotian Shelf. Annual bottom trawl surveys having a stratified random design were used to estimate the local density of haddock age 1 and 2 in each strata. Density-dependent habitat selection was found unlikely to generate significant correlations between mean size-at-age and abundance-at-age for juvenile haddock in the southwestern Scotian Shelf because the proportional abundance of juveniles remains approximately constant for three sub areas of differing growth rates.

Differences in the proportional abundance of age 1 haddock among sub areas of the stock range indicate that the majority of age 1 haddock are found on Browns Bank or in strata lying to the east of Browns Bank. A very small proportion (<10%) of age 1 haddock are found in the Bay of Fundy. There was little change in the proportional abundance of age 1 haddock as total abundance-at-age increased for all three sub areas of the stock range. The proportional abundance of age 2 haddock was approximately equal (33%) for the three sub areas. Although there was a slight decrease in the proportional abundance of age 2 haddock in strata east of Browns Bank with increasing abundance, variation observed with increasing abundance-at-age was negligible relative to differences between the two age classes. Two mechanisms could potentially explain the increased abundance of age 2 haddock in the Bay of Fundy: (I) directed migration of juveniles form Browns Bank to the Bay of Fundy during their second year; and (ii) enhanced survival of juveniles in the Bay of Fundy.

The gradient in habitat suitability, as defined by the distributional response of juvenile haddock to increasing abundance, did not correspond to the spatial gradient in growth rates. For example, a large portion of the Bay of Fundy (strata 85, 91, and 95) was classified as marginal habitat in a distributional sense despite the rapid growth rates observed in these strata. Thus, resource utilization does not appear to be maximized in juvenile haddock. Given that haddock maintain this spatial gradient in size-at-age throughout their life, the assumption that they are free to move among habitats according to resource availability is probably invalid.

Powles, P.M., and Kohler, A.C. 1970. Depth distributions of various stages of witch flounder (*Glyptocephalus cynoglossus*) off Nova Scotia and in the Gulf of St. Lawrence. J. Fish. Res. Board Can. 27: 2053-2062.

Reference (#)	Powles and Kohler 1970 (26)
Purpose of study	This study provides evidence for ecological isolation between larvae, juveniles, and adults, off Nova Scotia and in the Gulf of St. Lawrence, and suggests that short but regular seasonal movements are undergone by the adults.
Species of fish	Witch Flounder (*Glyptocephalus cynoglossus)*
Length/Age	Juvenile up to 5 years old (Up to 30 cm long)
Date	1957 and 1958
Location -	Nova Scotia and the Gulf of St. Lawrence
Depth	Primarily over 100 fathoms with peaks at 100 and 140 fathoms
Temperature	-
Salinity	-
Bottom type	-
Data set used	Research surveys and samples from commercial catches. In research surveys the following gears were used; a) standard #41.5 Iceland trawl with small mesh liner and #36 Yankee otter trawl and liner b) 12-ft Isaacs-Kidd midwinter trawl and 1-m plankton net c) Norwegian deep-sea shrimp trawl (Squires 1961).
Contact name and information	P.M. Powles Trent University Peterborough ON

Larvae, juveniles, and adults of witch flounder off Nova Scotia and in the Gulf of St. Lawrence were found to occupy largely discrete niches. Fish newly metamorphosed and up to 30 cm long (5 years old) were caught mainly at 100-160 fathoms (180-288 m).

Juvenile fish were found widely in both the Nova Scotia banks area and the Gulf of St. Lawrence. In the Nova Scotia Banks area small fish were found in deep holes, but areas off the continental shelf were not explored to any great extent. It is inferred that the deepwater distribution of young witch flounder prevents direct food competition with young of the more abundant species, cod and American plaice, on the continental shelf areas.

Scott, J.S. 1982. Distribution of juvenile haddock around Sable Island on the Scotian Shelf. J. Northwest Atl. Fish. Sci. 3: 87-90.

Reference (#)	Scott 1982 (27)
Purpose of study	This paper describes initial observations on the distribution of juvenile haddock in the shallows around Sable Island.
Species of fish	Haddock (*Melanogrammus aeglefinus*)
Length/Age	0-group and 1-group haddock (6-17 cm and 18-29 cm respectively)
Date	August 10-20, 1981
Location -	Around Sable Island
Depth	Age 0 - 27.2-36.6 m and Age 1-36.6-45.7 m
Temperature	-
Salinity	-
Bottom type	-
Data set used	Western II A bottom-trawl
Contact name and information	J.S. Scott Department of Fisheries and Oceans Marine Fish Division Biological Station St. Andrews NB E0G 2X0

An intensive bottom-trawl survey of the shallows around Sable Island on the Scotian Shelf revealed large concentrations of 0-group and 1-group haddock, *Melanogrammus aeglefinus*. Approximately 50,050 haddock were caught during the survey around Sable Island, of which 57.5% were age-group 0, 41.2% were age-group 1, and the remainder (1.3 %) were age-group 2 and older. Spatial distributions were uneven and differed between the groups with the main concentrations of 0-group haddock being found in 15-20 fathom (27.2-36.6 m) water, and the 1-group fish showed, to a lesser degree, a preference for the 20-25 fathom (36.6-45.7 m) depth zone. The 0-group fish were aggregated in areas of moderate to low concentrations of 1-group fish, particularly in shallow water north and southeast of the island where the 1-group fish were virtually absent. The major concentration of 1-group fish were in deeper water to the west and east of the island where 0-group fish were not abundant, and the aggregation south of the island was located between two aggregations of 0-group fish.

Segregation by size was also evident for 0-group fish with the smallest fish located south of Sable Island and a general increase in length eastward and westward from the island. It is suggested that the shallows around Sable Island are important nursery areas for young haddock and should be considered for protection.

Steiner, W.W., J.J. Luczkovich and B.L. Olla. 1982. Activity, shelter usage, growth and recruitment of juvenile red hake *Urophycis chuss*. Mar. Ecol. Prog. Ser. 7: 125-135.

Reference (#)	Steiner *et al.* 1982 (28)
Purpose of study	To examine various aspects of the behavior of early benthic juvenile red hake recently descended from the plankton, in relation to selected environmental factors.
Species of fish	Red hake (*Urophycis chuss)*
Length/Age	Juvenile (23-116 mmTL)
Date	June 1980-May 1981 and January 12th - 17th 1981
Location -	40°15'N, 73°50'W, 40° 08' N, 73° 44' W, and 40° 08'N, 73° 35'W
Depth	30 m, 34 m, and 38 m
Temperature	-
Salinity	-
Bottom type	Scallop beds
Data set used	Monthly samplings by scallop dredge aboard the NOAA/NMFS vessel RV Kyma'. Continuous 24 h sampling aboard a commercial fishing vessel. Laboratory experiments.
Contact name and information	William W. Steiner U.S. Department of Commerce National Oceanic and Atmospheric Administration National Marine Fisheries Service Northeast Fisheries Center Sandy Hook Laboratory Highlands, New Jersey 07732, USA

Juvenile red hake *Urophycis chuss* live in symbiotic associations with sea scallops *Placopecten magellanicus*, immediately following the hake's descent from the planktonic post-larval stage to the benthos. *U. chuss* showed a clear association with sea scallops, using them for shelter by either resting within the scallops' mantle cavity, or more commonly, beneath the scallops in a depression dug by the fish between the lower valve of the scallop and the sand substrate.

Hake, ranging in size from 23 to 116 mm (TL), inhabited scallop shelters more often by day, when the fish are least active, than by night when the hake are most active. Mean size of hake inhabiting scallops increased with larger scallops. Small scallops (<100 mm) contained predominantly small hake (25-65 mm), but large scallops (>120 mm) contained a wide size range of juvenile hake (26-116 mm).

Results suggest that the use of sea scallops as shelter is an important resource for juvenile red hake.

Steves, B.P., and Cowen, R.K. 2000. Settlement, growth, and movement of silver hake *Merluccius bilinearis* in nursery habitat on the New York Bight continental shelf. Mar. Ecol. Prog. Ser. 196: 279-290.

Reference (#)	Steves and Cowen 2000 (29)
Purpose of study	This paper examines the size and age at settlement, distribution, and post-settlement growth of 0-group silver hake on the continental shelf of the NYB.
Species of fish	Silver hake (*Merluccius bilinearis*)
Length/Age	0-group (15-55 mm)
Date	June 1996-July 1997
Location -	Continental shelf of the New York Bight
Depth	47-95 m
Temperature	8-10°C
Salinity	-
Bottom type	-
Data set used	Ten 3 day cruises monthly with 2 m beam trawl
Contact name and information	Brian P. Steves Marine Sciences Center State University of New York at Stony Brook Stony Brook, New York 11794-5000, USA E:mail: Steves@serc.si.edu

Silver hake *Merluccius bilinearis* from the New York Bight were examined for the quality and quantity of their offshore settlement and nursery habitats. Post-settlement growth rates along a temperature gradient (8-12°C) indicate that silver hake in areas of cooler bottom temperatures (~9°C) were not only larger and more abundant, but also faster growing. The peak abundance of the tube-dwelling amphipod *Unciola irrorata,* which acts as an important food source for silver hake, within the NYB is at a depth greater than 60 m, corresponding well to the areas of higher abundance and growth, and lower temperatures. Movements of early juveniles imply that settlement habitat is more specific than juvenile nursery habitat. Overall, the outer portion (60-95 m) of the continental shelf serves as important nursery habitat for silver hake.

Steves, B.P., Cowen, R.K., and Malchoff, M.H. 1999. Settlement and nursery habitats for demersal fishes on the continental shelf of the New York Bight. Fish. Bull. 98: 167-188.

Reference (#)	Steves *et al.* 1998 (30)
Purpose of study	To provide a first-order analysis of the species that uses the shelf as settlement and nursery habitat during the course of a year and to address the relation of these distributions to environmental correlates.
Species of fish	Thirty-three species. Dominant species are silver hake (*Merluccius bilinearis*) and yellowtail founder (*Pleuronectes ferruginous)*
Length/Age	0-group juveniles
Date	June 1996-July 1997
Location -	Continental shelf of the New York Bight
Depth	20-95 m
Temperature	Nearshore stations (5-20°C at the 25-m isobath) Midshelf stations (4.3-14°C at 50 m) Offshore stations (7-11°C at 90 m)
Salinity	31-35.5 psu
Bottom type	Surficial sediments range form fine sand along the southern shore of Long Island to pebbly gravel off the coast of New Jersey. The sediments vary in color from yellow ochre to greenish gray and in composition from biogenic calcium carbonate to quartz and feldspar.
Data set used	Ten 3 day cruises monthly with 2 m beam trawl. Twenty-one stations sampled during each cruise were arranged in three transects.
Contact name and information	Brian P. Steves Marine Sciences Center State University of New York at Stony Brook Stony Brook, New York 11794-5000, USA e-mail: Steves@serc.si.edu

Many commercially and ecologically important species of demersal fishes in the New York Bight settle onto the continental shelf throughout the course of the year. Between June 1996 and July 1997, settlement and nursery habitats of age-0 demersal fish on the continental shelf on the New York Bight were investigated. A total of 21, 309 fish representing 47 species were collected in 659 tows. Of these 47 species, 33 included age-0 juveniles, and 25 included near-settlement size individuals. The two dominant species, *Pleuronectes ferruginous* and *Merluccius bilinearis*, constituted 88.9% of the total catch of age-0 fish.

Within the NYB, several environmental gradients describe the spatial and temporal distributions of settlement habitats. Species-environment relationships from the ordination analysis reveal that temperature and depth explain most of the among-species variance in habitat associations.

Other variables such as salinity, the abundance of benthic organisms, mean sediment size, as well as the proximate location of other essential habitats (e.g. estuaries), were correlated to distance off-shore and depth and are thus possible contributors to observed habitat preferences. The indirect effects of these spatial variables on habitat quality may be associated with how they correlate with the distribution of important factors or combinations of factors, or with both. For example, age-0 inquiline Snailfish (*L. inquilinus*) are found almost exclusively in association with the presence of sea scallops. The distribution of these fishes on the mid to outer shelf is therefore not necessarily directly affected by any physiological response to depth or distance offshore; rather, they are probably most affected by their dependence on sea scallops for shelter.

Age-0 demersal fishes utilize the continental shelf of the NYB as both settlement and nursery habitat. According to these findings, the shelf of the NYB can be divided into three broad nursery areas (inner, middle, and outer shelves) and can be described by species assemblage as well as by hydrography.

Sullivan, M.C., Cowen, R.K., Able, K.W., and Fahay, M.P. 2000. Spatial scaling of recruitment in four continental shelf fishes. Mar. Ecol. Prog. Ser. 207: 141-154.

Reference (#)	Sullivan *et al.* 2000 (31)
Purpose of study	This study uses a hierarchical sampling program to: a) identify the spatial scales over which abundances of 4 species of recently settled benthic fishes are most variable on the NYB continental shelf; b) calculate the relative amount of variability encompassed at these respective scales; c) develop an appropriate mechanistic framework for evaluating the processes responsible for generating local recruitment variability.
Species of fish	Yellowtail flounder (*Limanda ferruginea*), fourspot flounder (*Hippoglossina oblonga*), Gulf Stream flounder (*Citharichthys arctifrons*), silver hake *(Merluccius bilinearis*)
Length/Age	Juvenile
Date	(August 3-12, 1994; September 4-10, 1997; August 18-24, 1999)
Location -	New York Bight
Depth	-
Temperature	Yellowtail = minimum of 6°C
Salinity	-
Bottom type	Fourspot flounder settled into a high energy environment characterized by sand-wave ripples, scattered shell hash and cerianthid anemone fields Gulf Stream flounder settled into a barren, low-energy mud/silt landscape of polychaete mounds and marginated seastars.
Data source	Video census of juvenile fishes from 3 late-summer submersible cruises
Access to data	Video - Delta Oceanographics, Channel Island Harbor, California)
Contact name and information	Mark C. Sullivan Marine Sciences Research Center State University of New York at Stony Brook Stony Brook, New York, 11794-5000, USA

A hierarchical sampling design was used to calculate the percent variability in abundance partitioned over 4 nested scales: submersible transect (~100 m), site (~10 km), shelf zone (~25 km), and sampling line (~100 km). For all years, early juveniles of yellowtail founder were highly concentrated at the shelf-zone scale, where abundances followed the thermal contours of a mid-shelf cold pool of remnant winter water. Conversely, fourspot flounder and Gulf Stream flounder were highly site-dependent, bounding the distribution of yellowtail flounder at inner and outer shelf sites, respectively. Silver hake exhibited moderate to high variability partitioned over several scales.

Spatial information on settlement pattern and intensity is critical for accurately characterizing where benthic species are found and why. This study showed that cross-shelf patterns of settlement were similar among years (with the exception silver hake), suggesting that juveniles require discrete nursery habitats which are utilized consistently from year to year (inner shelf: fourspot flounder, mid-shelf: yellowtail flounder, outer-shelf: Gulf Stream founder). In the NYB shelf benthic fish distributions become less specialized and more cosmopolitan as the adult stage is approached, underscoring the critical contribution of early stage benthic habitats to subsequent survival and growth.

Although the variability curves were found to be virtually identical for Fourspot flounder and Gulf Stream flounder, they tended to settle into vastly different shelf habitats. Fourspot flounder settled into a high energy environment characterized by sand-wave ripples, scattered shell hash and cerianthid anemone fields, whereas Gulf Stream flounder settled into a barren, low-energy mud/silt landscape of polychaete mounds and marginated seastars.

The results of this study also showed that in years where individuals saturated entire submersible transects, transect-level variability in abundance approached zero and the bulk of explained variability was contributed by sites and zones. This suggests a scenario whereby a species is swamping a given microhabitat selection is virtually impossible. In contrast, during years of low overall abundance, species tended to exhibit high among-transect variability - presumably a result of differential mortality or some form of habitat selection.

Swain, D.P., G.A. Chouinard, R. Morin, and Drinkwater, K.F. 1998. Seasonal variation in the habitat associations of Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*) from the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 55: 2548-2561.

Reference (#)	Swain *et al.* 1998 (32)
Purpose of study	To describe seasonal variation in habitat associations of Atlantic cod and American plaice from the southern Gulf of St. Lawrence.
Species of fish	Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*)
Length/Age	Age 2+
Date	September 1993, 1994, 1995, and 1996
Location -	Southern Gulf of St. Lawrence (Magdalen Shallows) and Cabot Strait
Depth	Age 2+ cod (depth = 46-51 m (Sept) and depth = 195-244 m (Jan)
Temperature	Age 2+ cod (Temp = 1.0-1.7°C (Sept) and temp – 4.9-5.3°C (Jan)
Salinity	-
Bottom type	-
Data source	Bottom trawl surveys by the RV *Alfred Needler* in the southern Gulf of St. Lawrence (NAFO Division 4T)
Contact name and information	D. P. Swain Department of Fisheries and Oceans Gulf Fisheries Center P.O. Box 5030 Moncton NB E1C 9B6 E:mail: swaind@mar.dfo-mpo.gc.ca

This paper compared habitat associations of southern Gulf of St. Lawrence Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*) between the summer feeding season on the Magdalen Shallows and the overwintering period in the Cabot Strait. Habitat associations of southern Gulf cod and plaice differed markedly between summer and winter, with both species occupying much warmer and deeper waters in winter than in summer. The effect of cod age on temperature distribution reversed between the two seasons, with younger cod occupying warmer water than older cod in summer and colder water in winter. Selection of both depth and temperature by cod tended to be more significant in September than in January. The reduced statistical significance of habitat selection by cod in winter was associated with a more aggregated distribution in this season.

The contrast between seasons in habitat associations was particularly strong for plaice. The median habitats occupied by plaice were 58-67 m and –0.1 to 0.3°C in September and 374-426 m and 5.2-5.4°C in January. Habitat selection by plaice was significant in both seasons.

Walsh, S.J. 1982. Distribution and abundance of pre-recruit and commercial-sized American plaice on the Grand Bank. J. Northwest Atl. Fish. Sci. 3: 149-157.

Reference (#)	Walsh, 1982 (33)
Purpose of study	To investigate the hypothesis that areas that serve as nursery grounds for American plaice are ultimately recruited to the exploitable population located on the slopes of the bank.
Species of fish	American plaice (*Hippoglossoides platessoides*)
Length/Age	<30 cm
Date	Spring 1971-80
Location -	Grand Bank of Newfoundland
Depth	56-366 m
Temperature	~0°C
Salinity	-
Bottom type	-
Data source	Groundfish surveys of the Grand Bank in the spring (Div. 3L and 3N in 1971-80 and Div. 30 in 1973 and 1975-80) Surveys were conducted by the Canadian RV *A.T. Cameron* with a Yankee No. 41.5 otter trawl
Contact name and information	S. J. Walsh Department of Fisheries and Oceans Northwest Atlantic Fisheries Centre P.O. Box 5667 St. John's NL A1C 5X1 E-mail: WalshS@dfo-mpo.gc.ca

Length compositions of American plaice, *Hippoglossoides platessoides* (Fabr.), and catches on the Grand Bank from spring stratified-random groundfish surveys during 1971-80 were analyzed to assess the distribution and relative abundance of pre-recruits and commercial-sized fish. Highest concentrations of both groups occurred on the north and northeast slopes of the bank which are strongly influenced by the cold Labrador Current.

In each of the three major divisions of the Grand Bank, pre-recruits tended to prefer slightly greater depths, on the average, than commercial-sized American plaice, but the differences are not considered significant in view of the apparently large variances associated with the weighted mean depths. However, on the northern half of the bank (Div. 3L), both pre-recruit and commercial-sized fish tended to prefer considerably greater depths (92-183 m) than those inhabiting the southern half of the bank (Div. 3N and 3O) (118-143 m and 107-115 m, respectively).

Both pre-recruit and commercial-sized American plaice were found in the same general areas at very similar depths and near-bottom temperatures, indicating that the nursery grounds for juveniles are not isolated from commercial fishing grounds.

Walsh, S.J. 1992. Factors influencing distribution of juvenile yellowtail flounder (*Limanda ferruginea*) on the Grand Bank of Newfoundland. Neth. J. Sea. Res. 29(1-3): 193-203.

Reference (#)	Walsh 1992 (34)
Purpose of study	This paper will report on new observations of factors influencing the distribution of juvenile yellowtail flounder.
Species of fish	Yellowtail flounder (*Limanda ferruginea*)
Length/Age	Age 1 group (5.6-7.4 cm) and Ages 2- 4
Time	Last week of August and the first 2 weeks of September 1985, 1986, 1988, and 1989 and November 1-13, 1987.
Location -	Grand Bank of Newfoundland
Depth	55-56 m
Temperature	-1.20 to 5.8°C
Salinity	-
Bottom type	Sand
Data source	Juvenile flatfish survey using Yankee 41 shrimp trawl (*Wilfred Templeman*)
Contact name and information	S. J. Walsh Department of Fisheries and Oceans Northwest Atlantic Fisheries Centre P.O. Box 5667 St. John's NL A1C 5X1 E-mail: WalshS@dfo-mpo.gc.ca

Yellowtail flounder is an important commercial fish species, but very little is known about its early life history or ecology. Beginning in 1985, bottom trawl surveys have been conducted annually to determine distribution and abundance of juvenile yellowtail flounder on the Grand Bank. It was found that both juveniles and adults maintain their shallow water depth distribution despite wide fluctuations in temperature.

Based on the analyses of the distribution of age-1 group and older juveniles (up to age 4 years) and incorporating historical information on egg and larval surveys, physical oceanography, and substrate type in the region it was found that all early life history stages were retained in the same geographic area, on and adjacent to the Southeast Shoal on the southern Grand Bank.

Age-1 group and older juveniles were consistently found on a sandy substrate of the western and central areas of the Southwest Shoal, but no juveniles were found in the gravel-sized sediment of the northwest region or in the finer sand-mud sediments of the southwest. This indicates that sediment size is an important factor influencing distribution.

The similarities in distribution of larvae and age-1 group juveniles from the 1985-89 surveys, suggest that successful settlement of 0-group juveniles is dependent on reaching the preferred sediment-size substrate. Sediments also indirectly influence distribution by the composition of benthic food items preferred by yellowtail flounder, which feed exclusively on surficial and interstitial macrofauna. Sandy substrate could also provide places for the newly settled fish to hide and avoid predators

These observed patterns of distribution of eggs, larvae, and juveniles points to the Shouthwest Shoal area as being an oceanic nursery site for Grand Bank yellowtail flounder.

REFERENCES

Able, K.W. 1999. Measures of juvenile fish habitat quality: examples form a national estuarine research reserve. Am. Fish. Soc. Symp. 22: 134-147.

Able, K.W., Churchill, C.B., Cooper, R.A., and Uzmann, J.R. 1982. Burrow construction and behavior of tilefish, *Lopholatilus chamaeleonticeps*, in Hudson Submarine Canyon. Environ. Biol. Fishes 7(3): 199-205.

Anderson, J.T. 1993. Distributions of juvenile cod in NAFO Divisions 2J3KL during fall, 1981-92, in relation to bathymetry and bottom temperature. NAFO SCR Doc. 93/68, Serial No. N2252.

Auster, P.J., and Langton, R.W. 1999. The effects of fishing on fish habitat. Am. Fish. Soc. Symp. 22: 150-187.

Auster, P.J., Joy, K., and Valentine, P.C. 2001. Fish species and community distributions as proxies for seafloor habitat distributions: the Stellwagen Bank National Marine Sanctuary example (Northwest Atlantic, Gulf of Maine). Environ. Biol. Fishes 60: 331-346.

Auster, P.J., Malatesta, R.J., and Donaldson, C.L.S. 1997. Distribution responses to small-scale habitat by early juvenile silver hake, *Merluccius bilinearis*. Environ. Biol. Fishes 50: 195-200.

Auster, P.J., Malatesta, R.J., and LaRosa, S.C. 1995. Patterns of microhabitat utilization by mobile megafauna on the southern New England (USA) continental shelf and slope. Mar. Ecol. Prog. Ser.127: 77-85.

Auster, P.J., Malatesta, R.J., LaRose, S.C., Cooper, R.A., and Stewart, LL. 1991. Microhabitat utilization by the megafaunal assemblage at a low relief outer continental shelf site - Middle Atlantic Bight, USA. J. Northw. Atl. Fish. Sci. 11: 59-69.

Black, R., and Miller, R.J. 1991. Use of the intertidal zone by fish in Nova Scotia. Environ. Biol. Fishes 31: 109-121.

Breeze, H., Fenton, D.G., Rutherford, R.J., and Silva, M.A. 2002. The Scotian Shelf: an ecological overview for ocean planning. Can. Tech. Rep. Fish. Aquat. Sci. 2393.

Bulatova, A.Y. 1962. Some data on distribution of young cod and haddock off Labrador and Newfoundland. ICNAF Redbook, Part III: 69-78.

1970. Abundance of young cod in the waters off Newfoundland. ICNAF Res. Doc. 70/51.

Burnett, J., Ross, M.R., Clark, S.H. 1992. Several biological aspects of the witch flounder (*Glyptocephalus cynoglossus* (L.)) in the Gulf of Maine-Georges Bank Region. J. Northwest Atl. Fish. Sci. 12: 15-25.

Cargnelli, L.M., Griesbach, S.J., Berrien, P.L., Morse, W.W., and Johnson, D.L. 1999a. Essential fish habitat source document: Haddock, *Melanogrammus aeglefinus*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-128.

Cargnelli, L.M., Griesbach, S.J., Packer, D.B., Berrien, P.L., Morse, W.W., and Johnson, D.L. 1999b. Essential fish habitat source document: witch flounder, *Glyptocephalus cynoglossus*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-139.

Cohen E.B., Green Jr., D.C., and Hayden, B.P. 1985. Some preliminary results of juvenile cod and haddock studies of Georges Bank in 1984 and 1985. ICES C.M. 1985/G:74.

Cote, D., Moulton, S., Scruton, D.A., and McKinley, R.S. 2001. Microhabitat use of juvenile Atlantic cod in a coastal area of Bonavista Bay, Newfoundland. Trans. Am. Fish. Soc. 130: 1217-1223.

Dalley, E.L. and Anderson, J.T. 1994. Distribution and abundance of demersal juvenile cod (*Gadus morhua*) from inshore to offshore locations on the Northern Grand Bank and Northeast Newfoundland Shelf in December, 1992. NAFO Sci. Coun. Studies 21: 91-103.

1997. Age-dependent distribution of demersal juvenile Atlantic cod (*Gadus morhua*) in inshore/offshore northeast Newfoundland. Can. J. Fish. Aquat. Sci. 54 (Suppl 1): 168-176.

Diaz, R.J., Cutter Jr., G.R., and Able, K.W. 2003. The importance of physical and biogenic structure to juvenile fishes on the shallow inner continental shelf. Estuaries 20(1): 12-20.

Edwards, R.L., and Emery, K.O. 1968. The View From a Storied Sub The 'Alvin" Off Norfolk, Va. Comm. Fish. Rev. 30(8-9): 48-55.

Fahay, M.P., Berrien, P.L., Johnson, D.L., and Morse, W.W. 1999. Essential fish habitat source document: Atlantic cod, *Gadus morhua*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-124.

Frank, K.T., Drinkwater, K.F., and Page, F.H. 1994. Possible causes of recent trends and fluctuations in Scotian Shelf/Gulf of Maine cod stocks. ICES Marine Science Symposium 198: 110-120.

Gotceitas, V., and Brown, J.A. 1993. Substrate selection by juvenile Atlantic cod (*Gadus morhua*): effects of predation risk. Oecologia, 93: 31-37.

Gotceitas, V., Fraser, S., and Brown, J.A. 1995. Habitat use by juvenile Atlantic cod (*Gadus morhua*) in the presence of an actively foraging and non-foraging predator. Mar. Biol. 123: 421-430.

1997. Use of eelgrass beds (*Zostera marina*) by juvenile Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci. 54: 1306-1319.

Grant, S.M. and Brown, J.A. 1998. Nearshore settlement and localized populations of age 0 Atlantic cod (*Gadus morhua*) in shallow coastal waters of Newfoundland. Can. J. Fish. Aquat. Sci. 55: 1317-1327.

Gregory, R.S. and Anderson, J.T. 1997. Substrate selection and use of protective cover by juvenile Atlantic cod *Gadus morhua* in inshore waters of Newfoundland. Mar. Ecol. Prog. Ser. 146: 9-20.

Gregory, R.S., Anderson, J.T., and Dalley, E.L. 1996. Use of habitat information in conducting assessments of juvenile cod abundance. NAFO SCR DOC. 96/23.

1997. Distribution of juveniles Atlantic cod (*Gadus morhua*) relative to available habitat in Placentia Bay, Newfoundland. NAFO SCS. 29: 3-12.

Horne, J.K., and Campana, S.E. 1989. Environmental factors influencing the distribution of juvenile groundfish in nearshore habitats of Southwest Nova Scotia. Can. J. Fish. Aquat. Sci. 46: 1277-1286.

Howell, P.T., Molner, D.R., and Harris, R.B. 1999. Juvenile winter flounder distribution by habitat type. Estuaries 22(4): 1090-1095.

Johnson, D.L., Berrien, P.L., Morse, W.W., and Vitaliano, J.J. 1999a. Essential fish habitat source document: American plaice, *Hippoglossoides platessoides*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-123.

1999b. Essential fish habitat source document: yellowtail flounder, *Limanda ferruginea*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-140.

Keats, D.W., Steele, D.H., and South, G.R. 1987. The role of fleshy marcoalgae in the ecology of juvenile cod (*Gadus morhua* L.) in inshore waters off eastern Newfoundland. Can. J. Zool. 65: 49-53.

Langton, R.W., and Auster, P.J. 1999a. Managing essential fish habitat: what are the next steps? Fisheries 24(6): 30-31.

1999b. Marine fishery and habitat interactions: to what extent are fisheries and habitat interdependent? Fisheries 24(6): 14-21.

Langton, R.W., Auster, P.J., and Schneider, D.C. 1995. A spatial and temporal perspective on research and management of ground fish in the Northwest Atlantic. Rev. Fish. Sci. 3(3): 201-229.

Langton, R.W., Steneck, R.S., Gotceitas, V., Juanes, F., and Lawton, P. 1996. The interface between fisheries research and habitat management. N. Am. J. Fish. Manag. 16(1): 1-7.

Lindholm, J.B., Auster, P.J., Ruth, M., and Kaufman, L. 1999. Habitat-mediated survivorship of juvenile (0-year) Atlantic cod *Gadus morhua*. Mar. Ecol. Prog. Ser. 180: 247-255.

2001. Modeling the effects of fishing and implications for the design of marine protected areas: juvenile fish responses to variations in seafloor habitat. Conserv. Biol. 15(2): 424-437.

Linehan, J.E., Gregory, R.S., and Schneider, D.C. 2001. Predation risk of age-0 (Gadus) relative to depth and substrate in coastal waters. J. Exp. Mar. Biol. Ecol. 263: 25-44.

Lough, R.G., and Potter, D.C. 1993. Vertical distribution patterns and diel migrations of larval and juveniles haddock *Melanogrammus* aeglefinus and Atlantic cod Gadus morhua on Georges Bank. Fish. Bull. 91: 281-303.

Lough, R.G, Valentine, P.C., Potter, D.C., Auditore, P.J., Bolz, G.R., Neilson, J.D., and Perry, R.I. 1989. Ecology and distribution of juvenile cod and haddock in relation to sediment type and bottom currents on eastern Georges Bank. Mar. Ecol. Prog. Ser. 56: 1-12.

MacDonald, J.S., Dadswell, M.J., Appy, R.G., Melvin, G.D., and Methven, D.A. 1984. Fishes, fish assemblages, and their seasonal movements in the lower Bay of Fundy and Passamaquoddy Bay, Canada. Fish. Bull. 82(1): 121-139.

Malatesta, R.J. and Auster, P.J. 1999. The importance of habitat features in low-relief continental shelf environments. Oceanologica Acta 22(6): 623-626.

Markle, D.F., Methven, D.A., and Coates-Markle, L.J. 1982. Aspects of spatial and temporal cooccurrence in the life history stages of the sibling hakes, *Urophycis chuss* (Walbaum 1792) and *Urophycis tenuis* (Mitchill 1815) (Pisces: Gadidae). Can. J. Zool. 60: 2057-2078.

Marshall, C.T. and Frank, K.T. 1995. Density-dependent habitat selection by juvenile haddock (*Melanogrammus aeglefinus*) on the southwestern Scotian Shelf. Can. J. Fish. Aquat. Sci. 52: 1001-1017.

Methven, D.A. 1999. Annotated bibliography of demersal fish feeding with emphasis on selected studies from the Scotian Shelf and Grand Banks of the northwestern Atlantic. Can. Tech. Rep. Fish. Aquat. Sci. 2267.

Morse, W.W., Johnson, D.L., Berrien, P.L., and Wilk, S.J. 1999. Essential fish habitat source document: Silver hake, *Merluccius bilinearis*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-135.

Norse, E.A., and Watling, L. 1999. Impact of mobile fishing gear: the biodiversity perspective. Am. Fish. Soc. Symp 22: 31-40.

Ojeda, F.P. and Dearborn, J.H. 1990. Diversity, abundance, and spatial distribution of fishes and crustaceans in the rocky subtidal zone of the Gulf of Maine. Fish. Bull. 88(2): 403-410.

Page, F.H., Losier, R.J., Smith, S.J., and Hatt, K. 1994. Associations between cod, and temperature, salinity, and depth within the Canadian groundfish bottom trawl surveys (1970-1993) conducted in NAFO Divisions 4VWX and 5Z. Can. Tech. Rep. Fish. Aquat. Sci. 1958.

Packer, D.B. and Hoff, T. 1999. Life History, habitat parameters and essential fish habitat of mid-Atlantic summer flounder. In: L.R. Benaka (ed.) Fish Habitat: essential fish habitat and rehabilitation. Am. Fish. Soc. Symp 22, Bethseda, MD, pp. 76-92.

Packer, D.B., Griesbach, S.J., Berrien, P.L., Zeitlin, C.A., Johnson, D.L. and Morse, W.L. 1999. Summer flounder, Paralichthys dentatus, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE 151.

Perry, R.I., and Neilson, J.D. 1988. Vertical distributions and trophic interactions of age-0 Atlantic cod and haddock in mixed and stratified waters of Georges Bank. Mar. Ecol. Prog. Ser. 49: 199-214.

Powles, P.M. and Kohler, A.C. 1970. Depth distributions of various stages of witch flounder (*Glyptocephalus cynoglossus*) off Nova Scotia and in the Gulf of St. Lawrence. J. Fish. Res. Bd. Can. 27: 2053-2062.

Rangeley, R.W., and Kramer, D.L. 1995. Use of rocky intertidal habitats by juvenile pollock *Pollachius virens*. Mar. Ecol. Prog. Ser. 126: 9-17.

1998. Density-dependent antipredator tactics and habitat selection in juvenile pollock. Ecology 79(3): 943-952.

Scott, J.S. 1982. Distribution of juvenile haddock around Sable Island on the Scotian Shelf. J. Northwest Atl. Fish. Sci. 3: 87-90.

Shacknell, N.L., Frank, K.T., Petrie, B., Brickman, D., and Shore, J. 1999. Dispersal of early life stage haddock (*Melanogrammus aeglefinus*) as inferred from the spatial distribution and variability in length-at-age of juveniles. Can. J. Fish. Aquat. Sci. 56: 2350-2361.

Shacknell, N.L., Frank, K.T., Shore, J., Hannah, C., and Loder, J. 1997. Spatial evolution of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) year classes on the Scotian Shelf as inferred form growth variation of juveniles. ICES CM 1997/T:36.

Steimle, F.W., Morse, W.W., Berrien, P.L., and Johnson, D.L. 1999. Essential fish habitat source document: Red hake, *Urophycis chuss*, Life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-133.

Steiner, W.W., Luczkovich, J.J., and Olla B.L. 1982. Activity, shelter usage, growth and recruitment of juvenile red hake *Urophycis chuss*. Mar. Ecol. Prog. Ser. 7: 125-135.

Steves, B.P., and Cowen, R.K. 2000. Settlement, growth, and movement of silver hake *Merluccius bilinearis* in nursery habitat on the New York Bight continental shelf. Mar. Ecol. Prog. Ser. 196: 279-290.

Steves, B.P., Cowen, R.K., and Malchoff, M.H. 1999. Settlement and nursery habitats for demersal fishes on the continental shelf of the New York Bight. Fish. Bull. 98: 167-188.

Sullivan, M.C., Cowen, R.K., Able, K.W., and Fahay, M.P. 2000. Spatial scaling of recruitment in four continental shelf fishes. Mar. Ecol. Prog. Ser. 207: 141-154.

Suthers, I.M., Frank, K.T., and Campana, S.E. 1989. Spatial comparison of recent growth in postlarval Atlantic cod (*Gadus morhua*) off southwestern Nova Scotia: Inferior growth in a presumed nursery area. Can. J. Fish. Aquat. Sci. 46(Suppl. 1): 113-124.

Swain, D.P., Chouinard, G.A., Morin, R., and Drinkwater, K.F. 1998. Seasonal variation in the habitat associations of Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*) from the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 55: 2548-2561.

Tupper, M., and Boutilier, R.G. 1995a. Effects of habitat on settlement, growth, and postsettlement survival of Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci. 52: 1834-1841.

1995b. Size and priority at settlement determine growth and competitive success of newly settled Atlantic cod. Mar. Ecol. Prog. Ser.118: 295-300.

Walsh, S.J. 1982. Distribution and abundance of pre-recruit and commercial-sized American plaice on the Grand Bank. J. Northwest Atl. Fish. Sci. 3: 149-157.

1992. Factors influencing distribution of juvenile yellowtail flounder (*Limanda ferruginea*) on the Grand Bank of Newfoundland. Neth. J. Sea. Res. 29(1-3): 193-203.

Walters, C.J., and Juanes, F. 1993. Recruitment limitation as a consequence of natural selection for use of restricted feeding habitats and predation risk taking by juvenile fishes. Can. J. Fish. Aquat. Sci. 50: 2058-2070.