

- REVISED PROPOSAL -
Candidate HAPC Proposal – 12 May 2005
Habitat Areas of Particular Concern: A Multi-Species Approach for Juveniles of Eight Over-Fished Species

Brief Statement of Proposal. This proposal identifies important habitat areas for juveniles of eight over-fished species managed by the NEFMC. Juvenile fishes were used because they are particularly vulnerable to habitat losses and because their growth and maturation is essential to fisheries management objectives. Habitat areas were identified based on abundance patterns revealed by 33 years of NMFS research surveys within the Southern New England (SNE), Georges Bank (GB), and the Gulf of Maine (GOM) regions. Candidate HAPC sites were identified using a site-selection computer program, making it possible to efficiently meet targets for each species. Targets were defined based on relative abundance (fish/tow) using a ten minute square (TMS) grid system. The goal was to find the smallest set of TMS that met targets for the suite of species. With this proposal we present sets of candidate HAPCs, one set per region, which meet multi-species habitat conservation objectives.



Summary statement of proposal objectives. The objective of this proposal was to identify habitat areas of particular concern, for the juveniles of over-fished species, using abundance patterns as a guide. A minimal set of locations within each of three biogeographic regions was identified that included habitat areas for each of the species.

Supportive data and other information (Topic 5). This topic is addressed in the following sections and in the attached documents.

Synopsis of proposal revision. This HAPC proposal has been revised on the basis of comments provided by a joint meeting of the NEFMC Habitat Advisory Panel and Habitat Program Development Team, 13 April 2005. Following the presentation of the methods below, we present two new systems of HAPCs (alternatives #1 and #2), and then include our original proposal as alternative #3. The primary changes we have instituted include limiting site selection to juvenile EFH in US waters and giving preference to site selection within existing fisheries management closures. We have also updated the species lists for the three biogeographic regions to reflect the most current information on over-fished classifications, and eliminated a few of the TMS that were judged to have received very limited sampling by NMFS (i.e. less than 4 tows). Additionally, several reviewers suggested that our original set of areas (alternative #3) might not capture a sufficient portion of juvenile habitat for a precautionary system of HAPCs (i.e about 5% of total area). We have addressed this by including a new alternative that captures a slightly larger proportion of the habitat areas for juvenile fish (alternative #1).

Background and overview of approach. This revised HAPC proposal is submitted on behalf of the Conservation Law Foundation (CLF) and the World Wildlife Fund-Canada (WWF) in response to the request for proposals (RFP) posted on the New England Fisheries Management Council (NEFMC) web site (<http://www.nefmc.org/habitat/>).

Recognizing that marine conservation, including effective fisheries management, must be carried out on the basis of entire ecological regions, CLF and WWF-Canada have worked cooperatively toward conserving the marine ecosystems that our two countries share and which have supported our fisheries for centuries. The ecological boundaries of the region do not follow political demarcations, but are defined by features of the ocean and seafloor, the distributions of organisms, and the ecological processes they embody. The proposal before you is derived from the ongoing cooperative work of CLF and WWF on marine ecosystem conservation and integrated ocean management, and concerns three biogeographic regions: Gulf of Maine / Bay of Fundy (GOM), Georges Bank (GB), and Southern New England (SNE). GOM and GB both include portions that are Canadian and effective ecosystem-based management must continue to include international coordination (Figure 1).

Candidate HAPC sites were chosen on the basis of habitat used by the juveniles of eight managed demersal species, each of which is currently identified as *over-fished* within one or more of the regions by the National Marine Fisheries Service. The appropriate stewardship of areas used by these species is expected to be important to the long-term productivity of their populations, and the fisheries they support. Our analysis focuses on juvenile fish because juveniles are at high risk of predation and dependent upon features of bottom habitats that are particularly vulnerable to degradation. Additionally, juveniles are essential to rebuilding plans and sustainable fisheries, yet are not commercially valuable until grown.

The first two HAPC alternatives presented in this revised proposal are based on sites within the U.S. waters managed by the NEFMC. A third alternative is based on entire biogeographic regions and includes several sites within Canadian waters. The appropriate stewardship of areas used by these species is expected to be important to the long-term productivity of these populations and the marine ecosystems they depend upon.

We propose a multi-species approach because the productivity of over-fished populations can be most efficiently benefited by identifying habitat areas that are simultaneously supportive of multiple species, and multi-species approaches are fundamental to ecosystem based management. The essence of the approach we used can be conveyed with the following simple example. Given three locations of comparable size, with the first supportive of a flounder, the second of cod, and the third being supportive of both species, the third location would be a *spatially efficient* choice for designation as HAPC since the objectives for both species are met while holding the area, boundary length, and the number of sites to a minimum. This is an oversimplification of the site-selection program we employ here, but illustrates the basic idea.

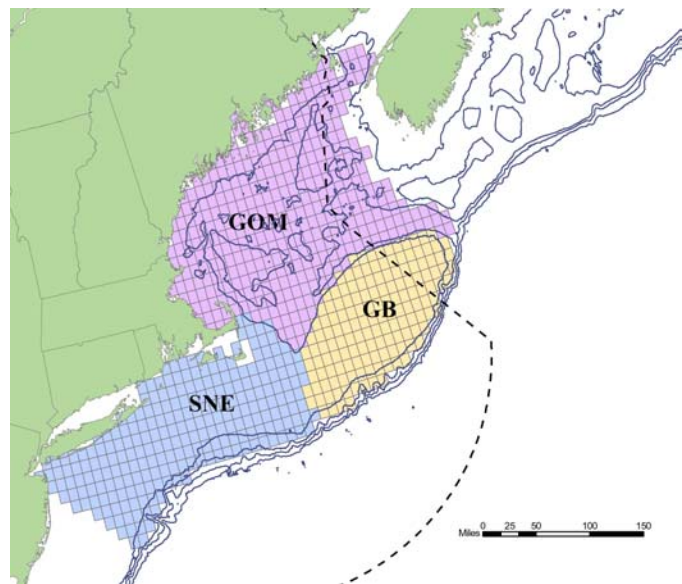


Figure 1. Biogeographic regions with TMS grid. Targets, based on normalized relative abundance, were set within each biogeographic region for derivation of HAPC areas.

We utilized the relative abundance of juveniles as a guide for coarse-scale (ten minute squares - TMS) identification of locations containing the habitat characteristics supportive of each of these species. Thus, areas where abundance has been found to be high are taken as areas that either contain habitat appropriate to population growth or exhibit the physical conditions that would allow biological habitat features to return with adequate management. For example, invertebrate animals such as sponges, bryozoans, and bivalves can provide important habitat features for young fish but these features can be lost in areas that are impacted (Auster and Langton, 1999; Auster *et al.*, 1996; Collie *et al.*, 1997; Collie *et al.*, 2000a). These biogenic habitat features usually regenerate once destructive impacts are reduced. The use of abundance measures to map habitat for fishes in the Gulf of Maine region has been examined previously (Auster *et al.*, 2001; Cook and Auster, 2005).

The method we used for identifying the HAPCs was designed to identify sets of areas that simultaneously provide critical habitat for multiple species. This computer-based technique (MARXAN) searches through the multiple maps of relative abundance, seeking to find combinations of areas that are important for all the species while keeping the total area, boundary length, and the number of isolated sites to a minimum. This is typically achieved by finding those areas that are used by multiple species when possible, and by including some areas where one or a few species are in high abundance if necessary. The result is a system of HAPCs that efficiently meets goals for all of the over-fished species included in the analysis. The analysis was designed to meet habitat goals separately within each of three biogeographic regions to ensure that regional differences in population structure and ecology would be captured in the proposed system of HAPCs.

Methods used for identifying HAPCs.

Choice of Species and Life History Stage. Eight demersal fish species (Table 1) were selected for analysis based on their status as *over-fished* (NMFS, 2003) in one or more of three biogeographic regions managed by the NEFMC (GOM, GB or SNE). Atlantic halibut was excluded from our analysis because its abundance was too low for a reliable assessment of its abundance distribution (i.e. criterion: fewer than 200 individuals per biogeographic region). Since species status differs between the biogeographic regions, the number of species used for site selection varied slightly from region to region for the generation of alternatives #1 and #2 (i.e. $n = 5-7$). Haddock on GB is currently classified as over-fished, but has recovered substantially in recent years. GB haddock were included as we judged this precautionary for this recently over-fished population. Cod is not identified as over-fished in SNE, but the NMFS survey data indicate areas of high juvenile abundance within what we define as the SNE region, and SNE has historically supported a significant cod population. We have therefore included cod in site selection for SNE. Alternative #3 is based on all eight species in all regions.

Our analysis focused on the juvenile life history stage because demersal juveniles are vulnerable to adverse impacts to Essential Fish Habitat (EFH). As noted above, juvenile fish are particularly vulnerable to predation and are dependent upon bottom structure for predator evasion and energy conservation (Lough, 2004). Structures provided by benthic epifauna and abiotic relief, such as sand-waves (Auster *et al.*, 2003), offer shelter from predators (Gotceitas and Brown, 1993; Lindholm *et al.*, 1999; Lindholm *et al.*, 2001; Lough, 2004; Tupper and Boutilier, 1995) and prevailing currents (Gerstner, 1988; Lough and Bolz, 1989; Malatesta and Auster, 1999). These features are degraded by a variety of bottom-contacting human activities including dredges, trenching plows, and mobile fishing gear (Auster and Langton, 1999; Auster

et al., 1996; Collie *et al.*, 1997; Collie *et al.*, 2000a; Collie *et al.*, 2000b; Hermsen *et al.*, 2003; Lindholm *et al.*, 2004).

Table 1: Species List for each biogeographic region and length at maturity (LM). Those regions for which a given species was included in the analysis are indicated (X).

Common Name	Species	SNE	GB	GOM	LM (cm)
Atlantic cod	<i>Gadus morhua</i>	X	X	X	35
Haddock	<i>Melanogrammus aeglefinus</i>		X	X	32
White hake	<i>Urophycis tenuis</i>	X	X	X	35
American plaice	<i>Hippoglossus platessoides</i>	X	X	X	27
Winter flounder	<i>Pseudopleuronectes americanus</i>	X			27
Yellowtail flounder	<i>Limanda ferruginea</i>	X		X	26
Windowpane flounder	<i>Scophthalmus aquosus</i>	X			22
Ocean pout	<i>Macrozoarces americanus</i>	X	X	X	29

The juvenile life history stage was defined based on length at maturity (LM) following procedures used by NMFS for EFH (Reid *et al.*, 1999). Data on juvenile abundance were extracted from the NMFS survey data using LM to segregate juveniles from adults. It is recognized that maturity criteria may be defined in a variety of different ways (Burnett *et al.*, 1989), and that this produces variability to the published maturity length estimates. Length at maturity estimation is further complicated by regional differences in maturity within a species, changes in size at maturity from year-to-year, impacts of harvesting on population structure, and variation in apparent size at maturity that are a consequence of when samples were taken relative to the normal spawning period(s) of the species in question (Halliday, 1987). Thus we acknowledge that the length at maturity criteria utilized here are estimates subject to a variety of sources of error. Nevertheless, we feel that the maturity lengths developed by the scientists for EFH are the best choice for our analysis of a large data set, spanning large temporal and spatial extent (Table I).

Data source and analysis. The data used for our HAPC analysis were collected by the US National Marine Fisheries Service (NMFS) as described previously (Brown *et al.*, 1996), and are the same data that have been used for EFH designation. Surveys employed a random sampling design with stratification by depth and location. Standard bottom trawl gear (with a fine cod-end liner) was towed at about 10.5 km/hr, for a 30 minute trawl, or *set*, of 5.25 km (1.8 nm). Sampling was carried out throughout the year, but was heaviest during the spring and fall, with fewer trawls during the mid-summer and winter. The analyses presented here were based on original NMFS data collected from 1970 through 2003, provided by the NEFSC.

There was reasonably complete spatial coverage of survey effort across the biogeographic regions, but distribution of effort was not uniform, with certain areas being sampled more intensively than others (Figure 2). The number of trawls per TMS was used to correct abundance estimates in order to reduce the influence of local sampling differences. Nevertheless, there is a recognized, but non-quantified, relationship between confidence in abundance estimates and the number of replicate samples (tows), with increased confidence at those sites

that were most heavily sampled. This is a difficult effect to evaluate due to multiple sources of variance including time of year and annual variations in populations.

For alternatives #1 and #2 of this revised proposal we applied the criterion that only those TMS that had been sampled with at least four trawls be included. The primary consequence of this was the elimination of a small number of near-shore TMS, and a consequent slight reduction in the spatial coverage of the data set. For our original HAPC proposal we chose to use the full data set in order to achieve the largest area coverage possible, even though sampling in some areas was less than we would have liked.

Distributions of relative abundance were examined for individual species within the three biogeographic regions. In this proposal, the term *relative abundance*, is defined by the average number of juvenile fish, of a given species, obtained in all the standardized survey trawls available for a particular ten minute square (i.e. relative abundance has been corrected for effort). We refer to this as *relative abundance* because this metric is thought to be proportional to the true abundance for the species (i.e. the actual number of juveniles per area), and indicative of the species' abundance distribution across squares for the species. Thus, one can examine a map of relative abundance and identify places where that species has been most abundant relative to other places. However, quantitative comparisons between species may be problematic since the efficiency of the sampling method is not expected to be uniform across species. In our analysis we use this measure only for within species determinations of relative abundance. It is recognized that there may also be some within species biases resulting from dependence of sampling efficiency on habitat type, but we assume that this effect is not substantial enough to obscure the patterns for which we are looking.

Because the distribution of counts per trawl was not Gaussian (i.e. statistically *normal*), including some extreme values, we utilized a standard normalization procedure, the natural log transform. For each species and TMS, the number of individual juveniles taken in each of the available trawls was obtained. These counts (c) were log transformed: $\text{Ln}(c + 1.0)$. Normalized relative abundance (A) was computed using the sum of these transformed counts and number of trawls per planning unit (n_t): $A = (\sum \text{Ln}(c + 1) \div n_t)$. Maps of normalized relative abundance have been provided for each species in this proposal. These values can be converted

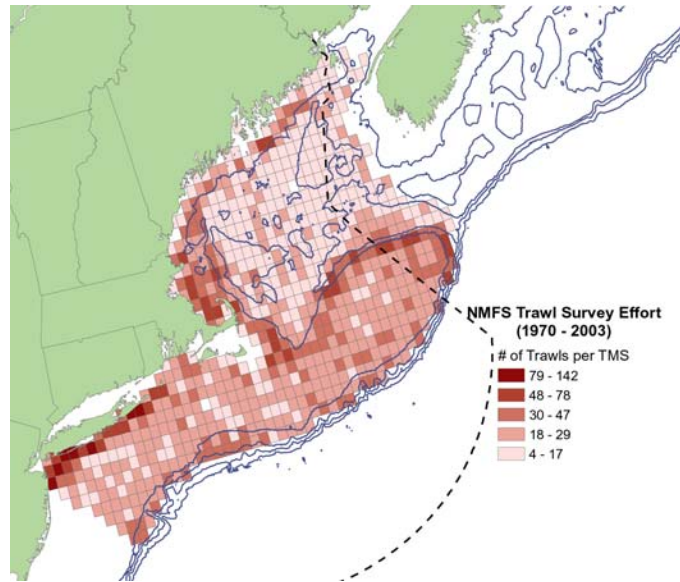


Figure 2. NMFS research survey trawl effort. The number of trawls within each TMS was counted and depicted based on color density, with darker squares having a higher total number of trawls. These data were used to correct abundance estimates for sampling effort. Areas with fewer than 4 trawls are not shaded and were excluded from the analysis for alternatives #1 and #2. The Hague Line, separating US from Canadian waters, is shown as a dashed black line.

back to individuals/tow by subtracting 1.0 from e^A as illustrated in (Figure 3). As a compliment to the maps of normalized relative abundance, we have also identified those TMS where abundance was in the top 20% for the species. For a given species, within each biogeographic region, the mean and standard deviation (sd) was computed for the subset of TMS where fish were sample (i.e. those with non-zero abundance values). The upper fifth of the abundance distribution (i.e. top 20%) was identified from the mean and sd and presented below with abundance maps for each species.

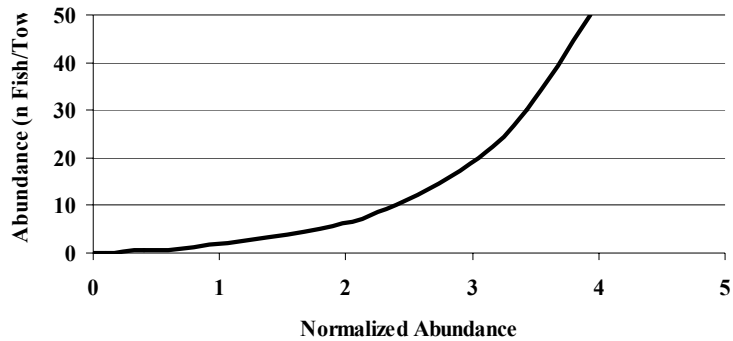


Figure 3. Relationship between normalized relative abundance and mean count per tow.

Computer-based HAPC site selection: MARXAN. The identification of important areas for a single species is relatively simple but arriving at an efficient plan that meets goals for multiple species is more difficult, and we employed a computer-based method for this. A variety of computer programs for efficient *site selection* have been developed and applied to planning tasks in a wide range of terrestrial and marine settings (Beck and Odaya, 2001; Leslie *et al.*, 2003). These programs are useful *tools* for finding efficient combinations of locations (e.g. ten minute squares) that meet multiple goals (e.g. abundance targets for fish). The essential idea is to meet all of the specified goals while keeping the area needed to a minimum, selecting adjacent planning units whenever possible and keeping the lengths of perimeter boundaries short so that the selected sites are aggregated to some extent. These tools are also useful because they can draw on a wide range of data types, and can be used to develop a variety of alternative plans, each performing well in terms of meeting the specified goals.

For this proposal, we employed a program known as *MARXAN* (Possingham *et al.*, 2000), a program that has been used for marine conservation planning in a number of countries including Australia (Leslie *et al.*, 2003; Stewart and Possingham, 2002), and the U.S. (Cook and Auster, 2005). The program and its uses have been detailed on several websites (e.g. www.ecology.uq.edu.au/marxan.htm; www.mosaic-conservation.org/cluz/marxan1.html) and in a manual available electronically (Ball and Possingham, 2000). *MARXAN* is based upon an optimization algorithm known as *simulated annealing* (Kirkpatrick *et al.*, 1983). The problem solved by *MARXAN* is a bit like searching through a complex topography and attempting to find some particular combination of desired conditions. As a simplified example, consider searching through an ecological region that has been partitioned into a grid of 100 ten minute squares. Imagine that one had a goal of finding the best combination of just two squares as defined by the abundance of just two different species – which pair of squares does the best job? Even in this very simple scenario, one must consider nearly 5,000 pair-wise combinations before arriving at an answer. Site selection with *MARXAN* is not typically limited to a specific number of squares (e.g. two as in this example) making the task more involved. The number of comparisons required increases dramatically with slight increases in the complexity of the planning problem, such as considering multiple species.

MARXAN is used to automate this kind of task, making it feasible to search through complex data landscapes, with multiple goals. For a detailed explanation of MARXAN, we refer readers to the sources cited here and provided in the supplementary materials for this proposal.

The input to our site selection analysis consisted of multiple *data layers*, each layer corresponding to one of the over-fished species (Table I). The layers were made up of an array of normalized relative abundance values, one for each map location, or TMS. The computer was then given instructions that were used in site selection. Foremost among these instructions were those that defined the primary goals for site selection, or *targets*.

In developing the proposed HAPCs, the targets were set as a proportion of the normalized relative abundance for juveniles of each species, within each biogeographic region. This was done in three steps. First, the mean of the normalized relative abundance values was determined based on all those TMS with non-zero values. Second, those TMS with normalized relative abundance equal to, or greater than, the mean were selected for the MARXAN analysis. This was done to ensure that targets were not met by selecting from among TMS of poor quality as judged by abundance; it was assumed that locations where the fish were most abundant were also the best habitat. Third, the sum of the normalized relative abundance values from all of these selected TMS was computed and used for setting the target for each species. The targets were set at either 20% (alternative #1) or 10% (alternatives #2 and #3) of this sum. The abundance targets defined in this way correspond a smaller proportion of the total abundance summed across all TMS, just over half as much.

In setting targets we sought to strike a balance between needed benefits for fish populations and potential costs associated with limiting human impacts within HAPC areas. The larger of the targets (20%) is more precautionary from the standpoint of rebuilding these over-fished populations (alternative #1). The relationship between targets as we have defined them, and the total area needed to meet targets, depends on the spatial distributions of the particular species examined. For the analysis presented here, the 20% abundance target resulted in selecting approximately 10% of the area of each biogeographic region. This is a relatively small proportion, and, other things being equal, even larger managed areas could reasonably be considered for the growth of juvenile fish (15-25%). The smaller target (10%) was selected as a minimal solution that would have a relatively small impact on fishing and other activities (alternatives #2 and #3). Site selection was performed with targets specified separately for each biogeographic region to ensure that differences in stock structure, at the scale of the biogeographic regions, would be reflected in the design of HAPC areas.

When we ran the site selection program, there was some range of values attained for the species, but an acceptable set of sites (i.e. *solution*) had to attain a minimum of 90% of the specified target. In some cases, reaching the desired target for one species required that slightly more than the specified target was included for another species (i.e. *target overshoot*). Target overshoot can occur, for example, if two species have overlapping spatial distributions, but the population density for one is higher than the other, so that the target for one can not be attained without also causing the overshooting for the other.

Site selection was further governed by instructions that forced the process to hold the area used to a minimum (i.e. minimum number of TMS) and also forced aggregation whenever possible (i.e. groups of TMS were preferred over isolated squares). Because the selection method was designed to hold area to a minimum, the program tended to seek out and use those TMS with the highest relative abundance values, attaining targets based on the fewest TMS.

The terms that influence site selection in MARXAN are incorporated in a mathematical function, known as the *objective function* (box below), and the value of this function is used to both guide the success of the selection process and quantify the quality of the end result. The program seeks to find sets of areas for which the objective function reports the smallest value. The output value is determined by the sum of the *costs* of the planning units (e.g. TMS), a penalty for not fully achieving the targets, and a term that increases with the distances around the perimeters of the selected sites (i.e. a term that governs the value placed on aggregation - *BLM*).

$$\sum_{Sites} Cost + BLM \sum_{Sites} Boundary + \sum_{ConValue} CFPF \times Penalty + Cost\ Threshold\ Penalty(t)$$

For our derivation of HAPCs, we used MARXAN in a relatively simple way, with each species treated identically. The penalty weighting used for failing to attain targets was also held constant for all species (i.e. the *penalty factor* – *CFPF* was set to 1.0). The parameter governing aggregation, the *boundary length modifier* (*BLM*), was set to a relatively high value (*BLM* = 4.0) so that the sites would be aggregated whenever possible. The extent to which aggregation was possible was determined by the distributions of the species. For example, if two species had entirely non-overlapping distributions, aggregation is not possible unless large areas are selected. For the species used, the distributions allowed reasonable aggregation while meeting targets with 1 to 6 HAPCs sites within each biogeographic region. The Cost Threshold Penalty parameter was not used.

In this revised proposal we used the cost term of the objective function to influence site selection during the generation of alternatives #1 and #2. By selectively setting the cost of certain TMS higher than others we reduced their value for deriving sets of HAPC areas. The cost of the non-EFH TMS and the TMS within Canadian waters (i.e. NE Tip of GB and NE GOM) were set five times higher than the other TMS (i.e. cost of 10 compared 2). Similarly, the TMS that fell within existing permanent fisheries management areas were set to a slightly reduced (cost = 1) to increase their value during site selection. In this fashion, site selection was influenced toward areas that can be readily managed by the NEFMC. However, with this approach the site selection program was still able draw on all the areas if necessary, but just at a higher cost in some instances. The abundance distributions were such that targets were readily attained for all species within US waters and in areas designated as juvenile EFH for these species (Figure 4). In the original HAPC proposal, now alternative #3, all TMS were assigned the same cost and some sites were selected in non-EFH and non-US areas. Note that the units of cost are arbitrary and only meaningful in relative terms.

With most data sets, MARXAN can usually identify multiple sets of areas that meet the specified targets because the goal is normally to select only some portion of each feature (e.g. some amount of the abundance of a given species), and features typically occur in a variety of locations. The fishes used in the present analysis are widely distributed and one can identify many sets of areas that do a reasonable job of meeting targets while keeping total area to a minimum. The objective function allows one to rank the performance of a range of different sets of areas, or solutions. Under each of the three different sets of conditions used for this proposal, we used MARXAN to generate 100 solutions and then selected the best ones, based on the objective function, to present as our three HAPC alternatives.

HAPCs and EFH Designations. Our analysis was carried out with a TMS grid because the data from the NMFS research surveys generally provide adequate sampling at this scale. Our HAPCs correspond to the same TMS grid provided on the NERO websites dealing with EFH (www.nero.noaa.gov/hcd/; www.nero.noaa.gov/hcd/index2a.htm) and summarized in this proposal (Appendix A and B). We recognize that EFH has not been defined on a per TMS basis, but rather on the basis of a number of characteristics that could be used to differentiate among areas within each TMS. Nevertheless, we feel that HAPC selection, like EFH designation, must be guided by the best available data on the actual distributions of fish, and a finer-scale analysis for the biogeographic regions analyzed here is not currently possible. A composite picture of the juvenile EFH designations for the eight species analyzed here (Table I) is provided in Figure 4.

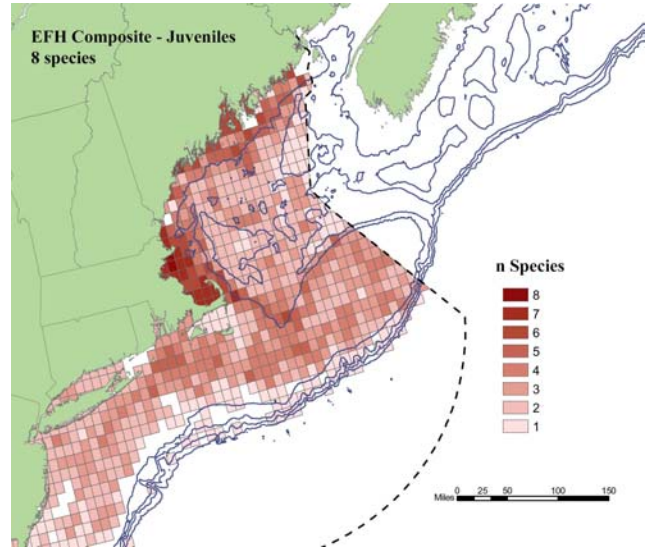


Figure 4. Composite map summarizing the juvenile EFH designations for the eight species used to identify HAPC sites (see Table I). The data summarized here were provided courtesy of NFFMC

Substrate characteristics within HAPCs. The analysis of substrate data was based on USGS data (Poppe and Polloni, 2000). Each ten minute square was classified according to a generalized substrate classification scheme and the HAPCs were summarized on this basis (Figure 5).

Results of analysis: proposed HAPCs (Topic 4).

Under each of three alternatives, a set of areas identified within each biogeographic region is presented as a potential system of HAPCs. As a group, each could perform well in a plan to strengthen these specific populations of commercially important fishes. Within each of the regions, the selected areas are complimentary in the sense that in combination they achieve the targets specified for the analysis, each cluster of TMS contributing in different ways to reaching the targets for the suite of species. The abundance data used are illustrated below (Figure 6).

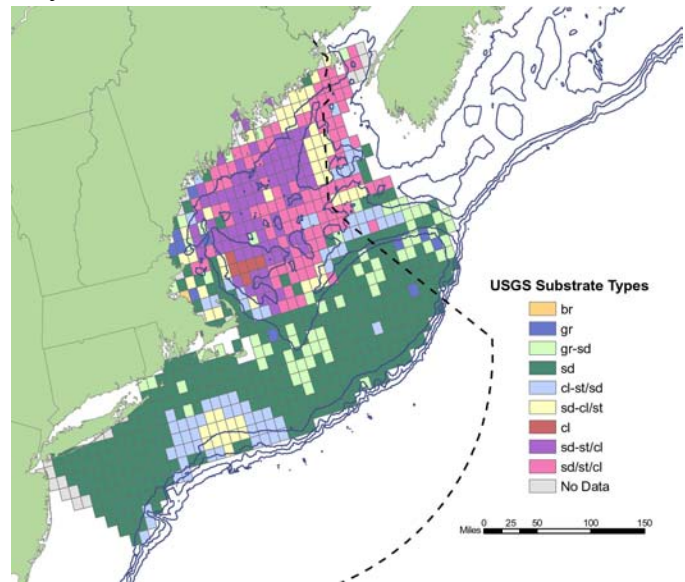


Figure 5. USGS substrates data coded by 10 minute squares. Based on Poppe and Pollone 2000.

Figure 6

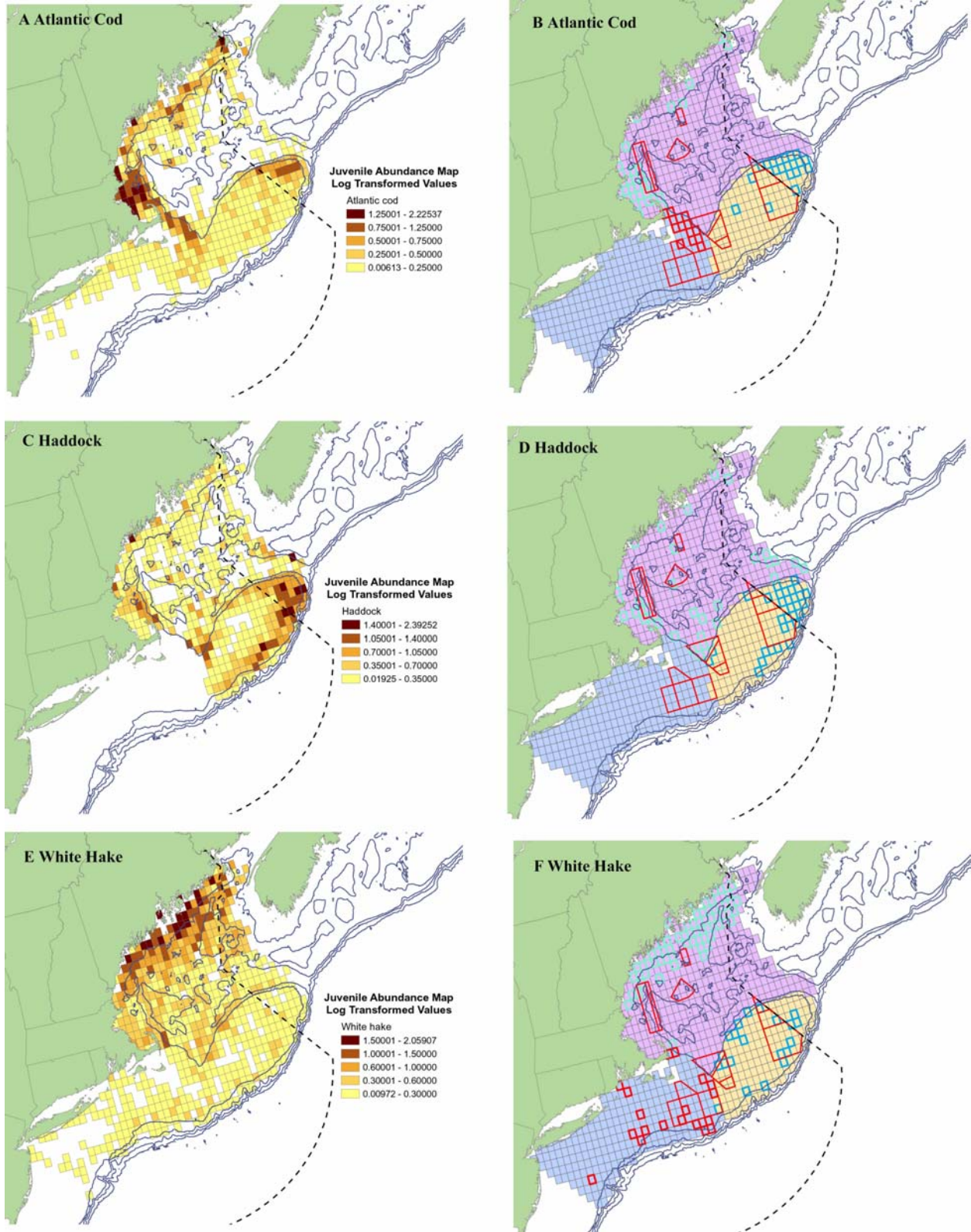


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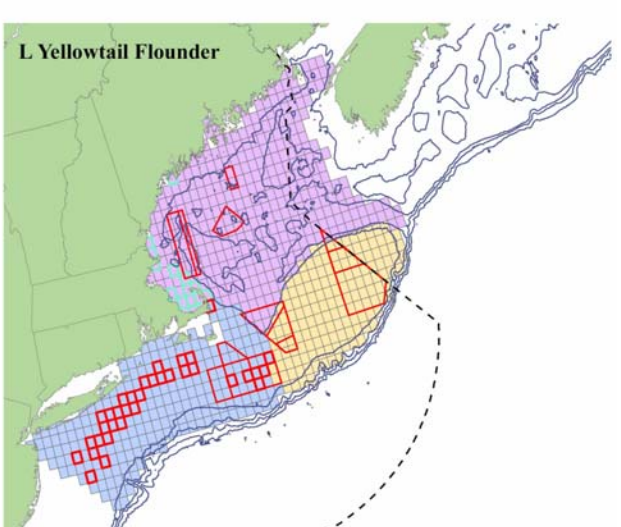
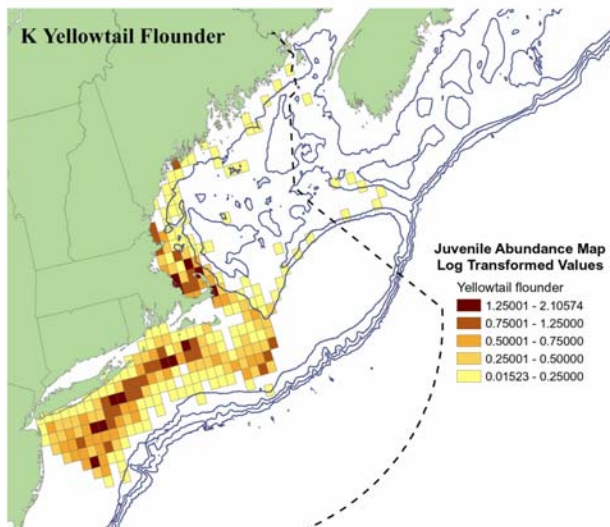
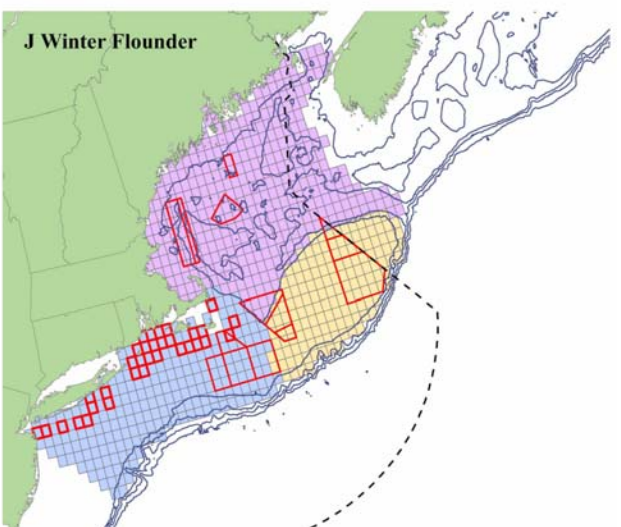
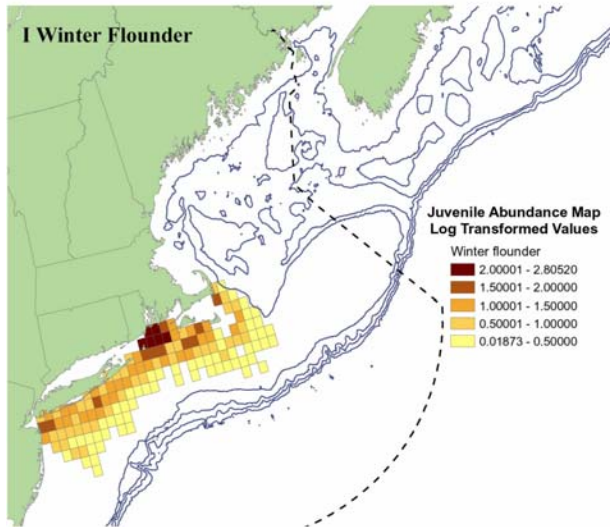
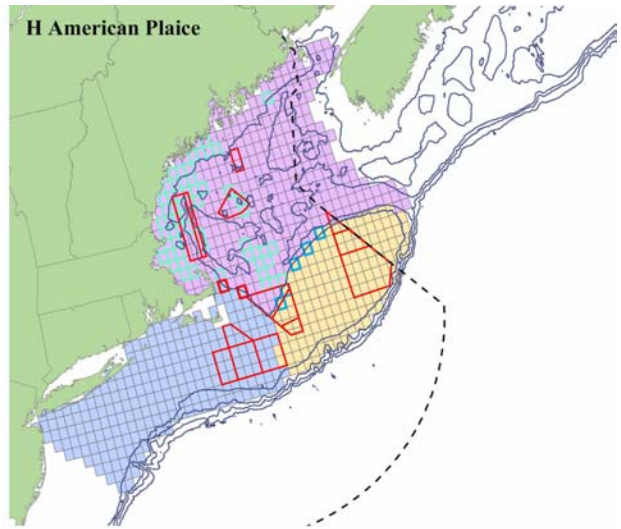
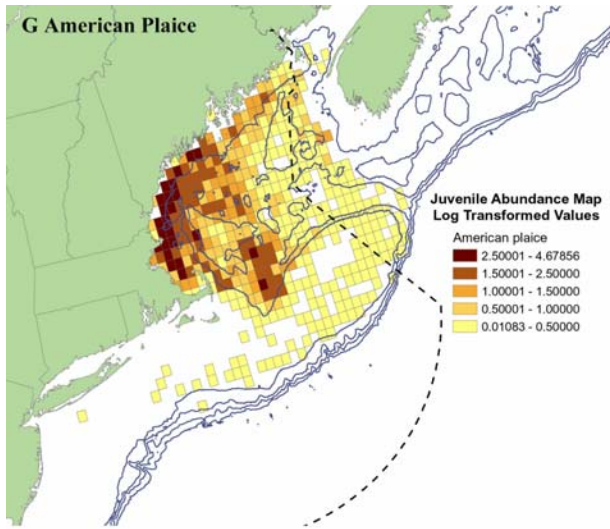


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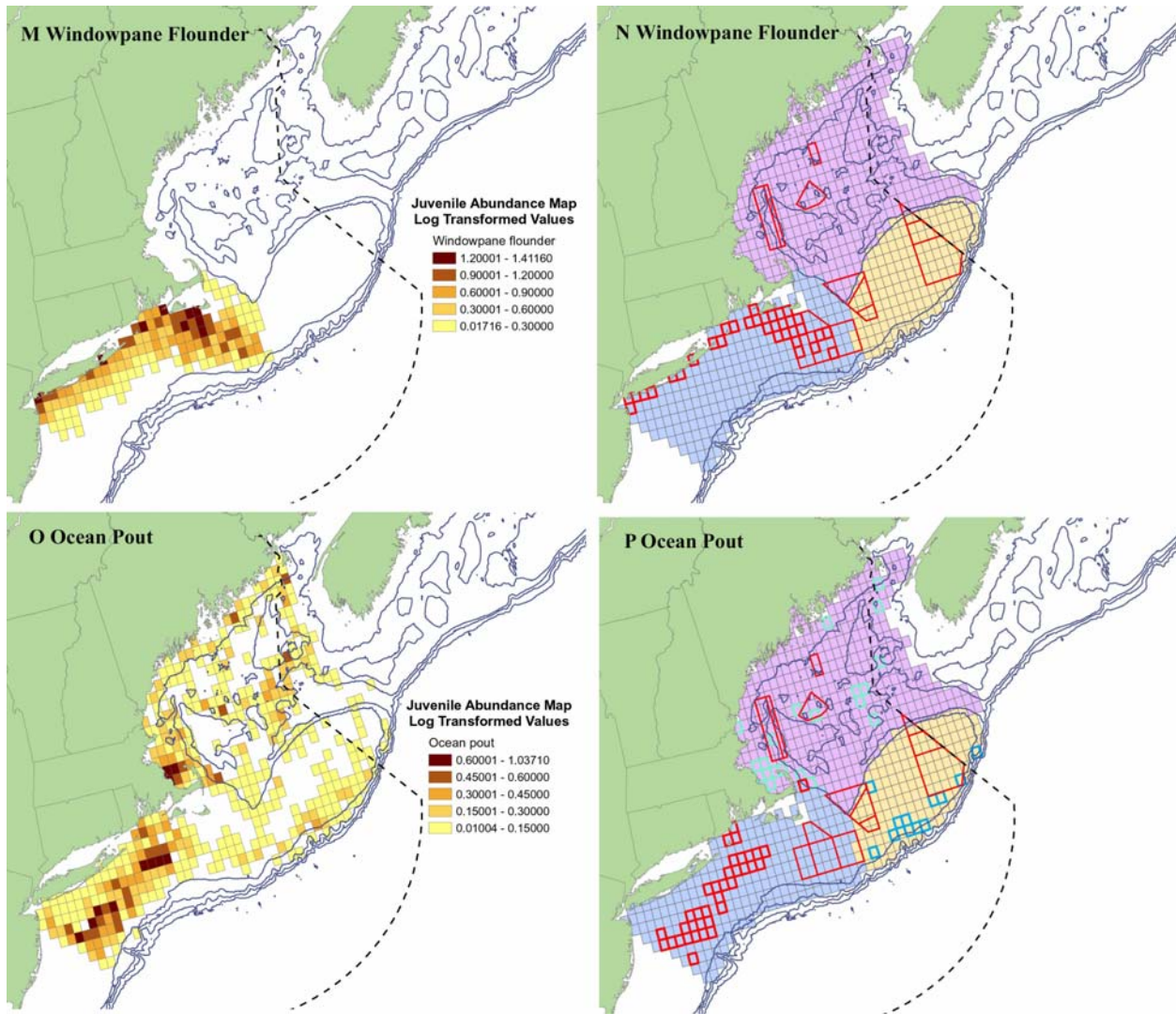


Figure 6. Normalized relative abundance distributions each species used to derive proposed HAPC areas. For each species, the left panel (e.g. A) provides a color-density coded map of abundance. The right panel (e.g. B) indicates only those ten minute squares where juveniles abundance was in the top 20 % for the bioregion. These areas correspond to the most densely shaded TMS in the left column. The red perimeters in the right column show some of the year-round fisheries closures. Note that abundance data are only provided in the regions for which a given species was included in the analysis (see Table I). For example, windowpane flounder was used for identifying HAPC sites in SNE, but not in the other regions for alternatives #1 and #2.

Alternative #1: Target of 20% with Variable Cost for TMS. With an abundance target of 20% and site selection configured to favor US EFH and sites within existing closed areas, a set of areas was identified within each of the three biogeographic regions that optimally met targets for juveniles of our over-fished species (Table I) within US EFH (Figure 7; Table II). Under this alternative, the HAPCs were based on four sites within SNE, three on GB, and five sites in the GOM. Sites ranged from small single TMS sites of about 74 square nm to clusters large as 17 TMS, or about 1,242 nm square. The proportion of each biogeographic region required ranged from 7 to 13%, or about 9% on average. There was substantial overlap between the selected sites and existing fisheries management areas. With a target of 20% based only on the TMS with greater than average abundance, the sites selected hold approximately 14% of the total relative abundance for each species. The contribution of individual HAPC areas to the targets is illustrated in Figure 8.

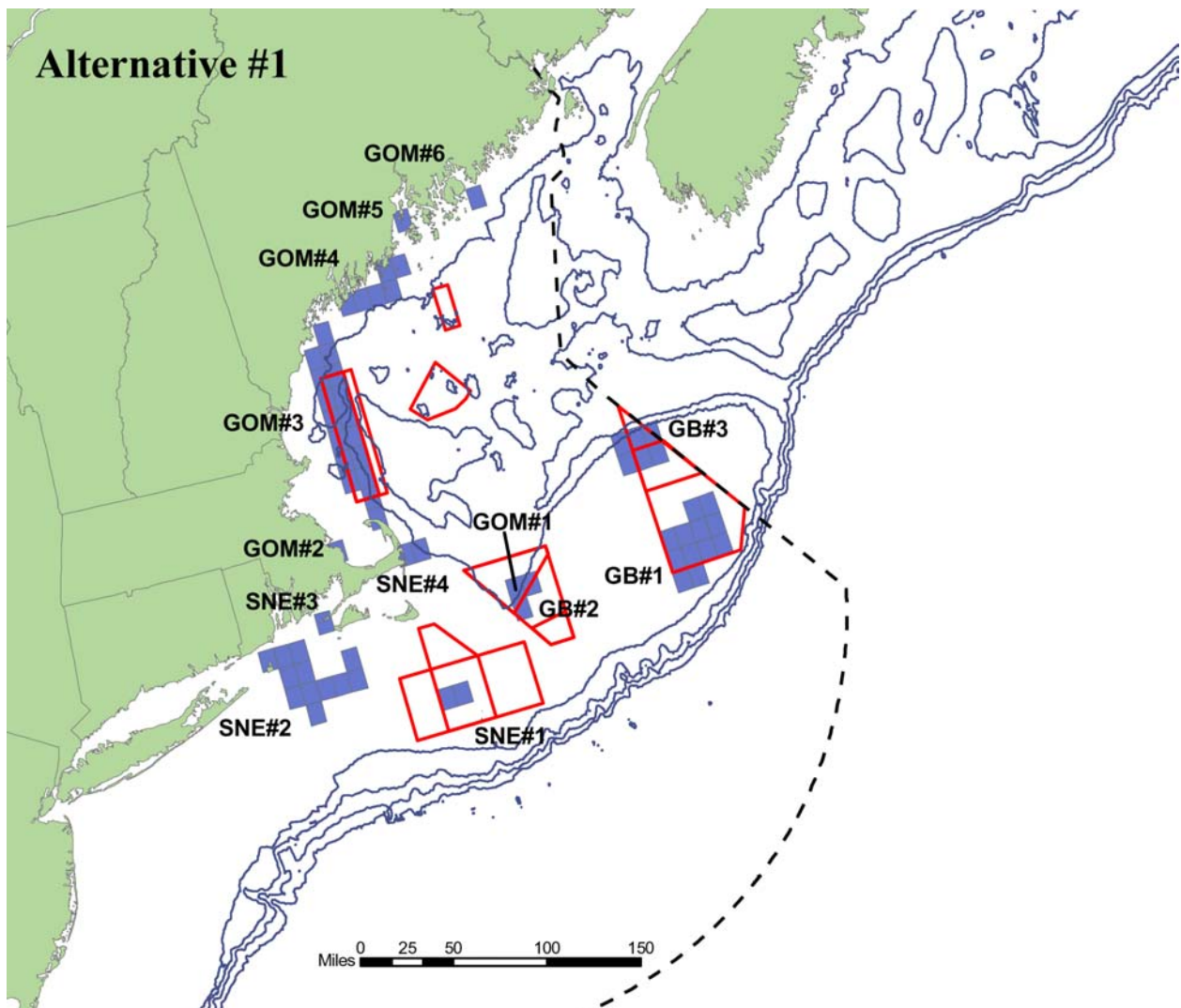


Figure 7. System of HAPC areas selected for alternative #1, based on an abundance target of 20% and guided toward US EFH and closed areas.

Table II Alternative #1. HAPC coordinates as TMS centers – decimal degrees.

BGR	nm sq	HAPC %	HAPC ID	n TMS	nm sq	% BGR	Longitude	Latitude	
SNE	17,729	7.17	SNE#1	2	150.7	0.85	-69.75	40.58	
								-69.92	40.58
			SNE#2	12	898.8	5.06	-71.42	40.92	
							-71.25	41.08	
							-70.75	41.08	
							-71.25	41.25	
							-71.58	41.25	
							-71.25	40.92	
							-71.08	40.92	
							-70.92	40.92	
							-71.42	41.08	
							-70.75	40.92	
							-71.25	40.75	
							-71.42	41.25	
			SNE#3	1	74.5	0.42	-70.92	41.42	
SNE#4	2	148.3	0.84	-69.75	41.75				
				-69.92	41.75				
GOM	25,761	7.64	GOM#1	1	74.7	0.29	-68.92	41.25	
			GOM#2	1	74.0	0.29	-70.58	41.92	
			GOM#3	17	1241.7	4.82	-70.08	43.08	
							-70.08	42.25	
							-70.25	42.42	
							-70.25	42.58	
							-70.08	42.75	
							-70.25	42.75	
							-70.08	42.08	
							-70.25	42.92	
							-70.08	42.42	
							-70.25	43.08	
							-70.08	43.25	
							-70.25	43.25	
							-70.08	43.42	
-70.25	43.42								
-70.08	43.58								
-70.08	42.92								
-70.08	42.58								

								-69.25	43.92
								-69.08	43.92
			GOM#4	6	432.7	1.68		-69.75	43.75
								-69.58	43.75
								-69.42	43.75
								-69.25	43.75
			GOM#5	1	71.7	0.28		-68.92	44.25
			GOM#6	1	71.7	0.28		-68.08	44.25
GB	11,426	13.04	GB#1	12	897.1	7.85		-66.75	41.42
								-66.75	41.25
								-67.08	41.25
								-67.25	41.25
								-67.25	41.08
								-67.08	41.08
								-66.92	41.25
								-66.75	41.08
								-66.92	41.42
								-67.25	40.92
								-67.08	40.92
								-66.92	41.08
				-68.92	41.08				
				-68.75	41.25				
				-67.08	41.92				
				-67.25	41.92				
				-67.42	41.92				
				-67.08	42.08				
	-67.25	42.08							
	-67.42	42.08							

Southern New England HAPCs - A#1. SNE targets (7 spp, Table I) were met based on four clusters of TMS with a combined area of about 7% of the region (17,729 nm sq), requiring a total of 17 TMS. SNE#1 fell entirely within the Nantucket Lightship Habitat Closed Area, and is classified as sand bottom. Juvenile white hake, windowpane and yellowtail flounder were particularly abundant within the two TMS comprising this area. The largest area, SNE #2, was due East of Montauk Point and comprised of 12 TMS, or an area of 899 nm sq. Most of this area has been classified as sand bottom, with a quarter classified as gravel-sand. SNE#2 was heavily used by five of the seven species examined in SNE, including ocean pout, white hake, windowpane, winter and yellowtail flounder. SNE#3 was a smaller (1 TMS, 74 nm sq), sandy bottom, area at the mouth of Buzzard's Bay. Winter and windowpane flounder had relatively high abundance at this site. SNE#4 was made up of two sand-bottom TMS (148 nm sq) just off Chatham. Like SNE#2, this area was particularly important for most of the SNE species (5 of 7),

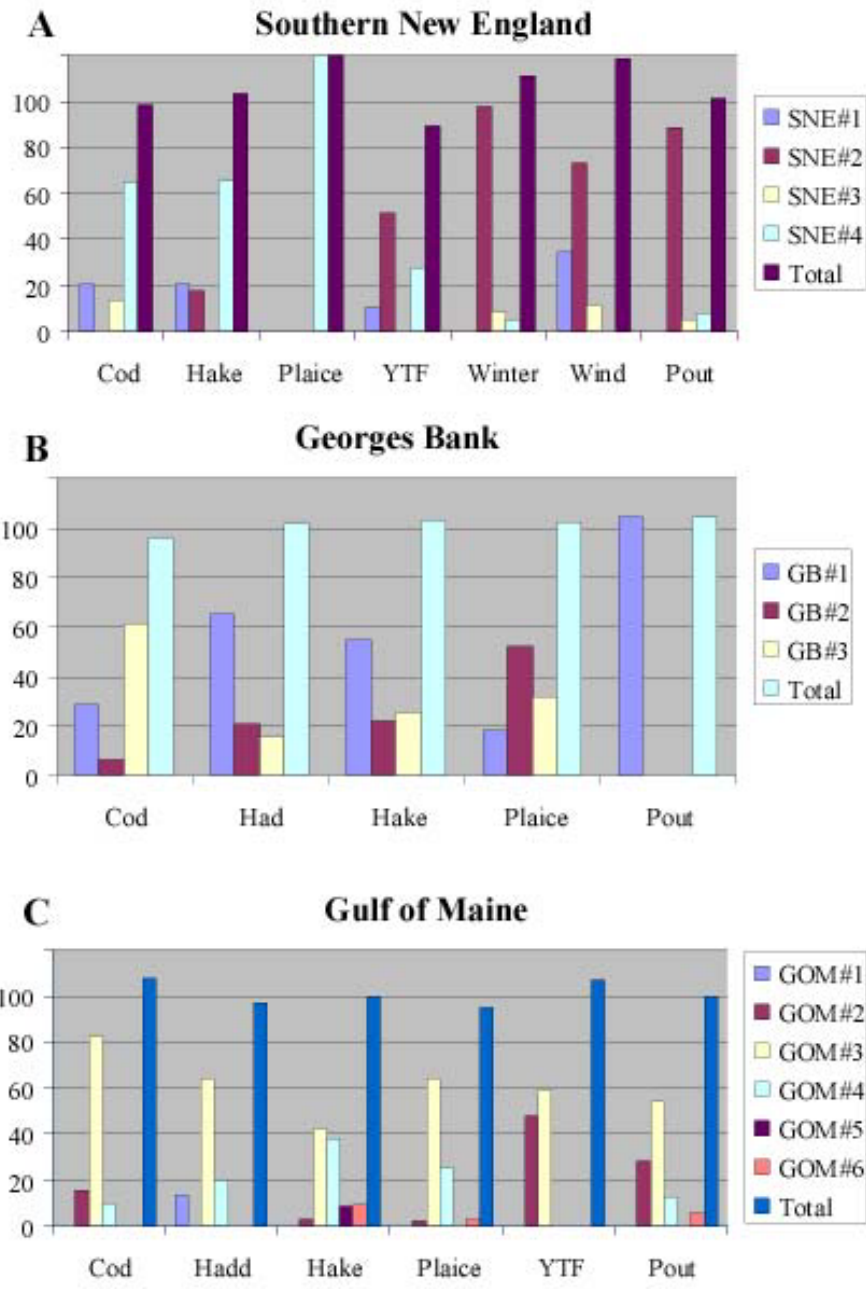


Figure 8. Contribution of individual HAPC sites to meeting targets with each biogeographic region. For example, in SNE (A) sites 1, 3, and 4 contribute to meeting the target for cod, but site 2 contributes nothing for cod. However, site 2 makes a major contribution (over 90%) for winter flounder. In each case, the last bar shows the sum of the other bars as a percent of target reach (Total), ideally 100%

including juvenile cod and American neither of which had high abundance at the other SNE sites. Ocean pout, yellowtail flounder and white have also had relatively high abundance at SNE #4.

Georges Bank HAPCs – A#1. On GB, meeting abundance targets (5 spp, Table I) required three sites that were substantially coextensive with fisheries closed areas (CA) I and II. These sites were made up of a total of 20 TMS, covering about 13% of the region, or 11,426 nm sq. GB#1 overlapped with the Southern part of CA II, consisting of 13 TMS (897 nm sq) of sand-bottom habitat. The abundance of juvenile cod, haddock and white hake was high within GB#1. GB#2 was the smallest site, consisting of two gravel-sand bottom TMS within CA II (149 nm sq), on the boundary between the GB and GOM biogeographic regions. This area was contiguous with GOM#1. Juvenile haddock and American plaice were relatively abundant within GB#2. GB#3 consisted of six TMS (443 nm sq) situated at the Northern edge of the bank, overlapping with CA II and an existing cod HAPC. GB#3 had a mixture of sand and sand-gravel bottom, and relatively high abundance for juvenile cod, haddock and white hake.

Gulf of Maine HAPCs – A#1. Six clusters of TMS were selected to meet GOM targets for juvenile fishes (n=6spp, Table I), with a combined extent of about 8% of the region (25,761 nm sq). GOM#1 was a single sand-bottom TMS (75 nm sq) adjacent to GB#2, forming a cluster of 3 TMS straddling the GOM-GB boundary in the Great South Channel. This area was important for meeting the target for juvenile haddock. GOM#2 was also a single TMS (74 nm sq) near shore at Manomet Point. USGS data did not allow us to classify the bottom type at this site. The abundance data indicated that this was an important area of juvenile cod, yellowtail flounder and ocean pout. The third GOM site (GOM#3) was the largest, extending over about 5% of the region (17 TMS, 1,242 nm sq) and overlapping extensively with the Western Gulf of Maine Closed Area as well as a portion of the Stellwagen Bank Sanctuary. This site included a mix of bottom types including sand, gravel, and various combinations of sand, silt and clay. GOM#3 included high abundance areas for all six of the species analyzed for this region, including substantial areas with high abundance for juvenile cod. GOM #4, comprised of 6 TMS (433 nm sq), was with varied bottom including sand, and combinations of sand, silt and clay (Figure 5). Juvenile white hake and American plaice were abundant throughout this area, and haddock in portions of the area. Within Penobscot Bay, GOM#5 was another single TMS site (72 nm sq), of unclassified bottom type. Juvenile white hake were abundant at GOM#5. GOM#6, the last of four single TMS sites in the GOM region, was located due East of Mt Desert, and the bottom was classified as sandy-clay with silt. This was an area of high relative abundance for white hake, and moderate abundance for American plaice and ocean pout.

Alternative #2: Target of 10% with Variable Cost for TMS. Alternative #2 was developed identically to alternative #1 except that the abundance targets were reduced to 10%. These lower targets for juvenile fish were met through a series of areas that occupied about 3% of each region, or half that for alternative #1 (Figure 9, Table III). This included three sites in SNE, four in GB, and five in the GOM. The majority of locations selected for this second alternative were included in alternative #1, with just three non-overlapping TMS.

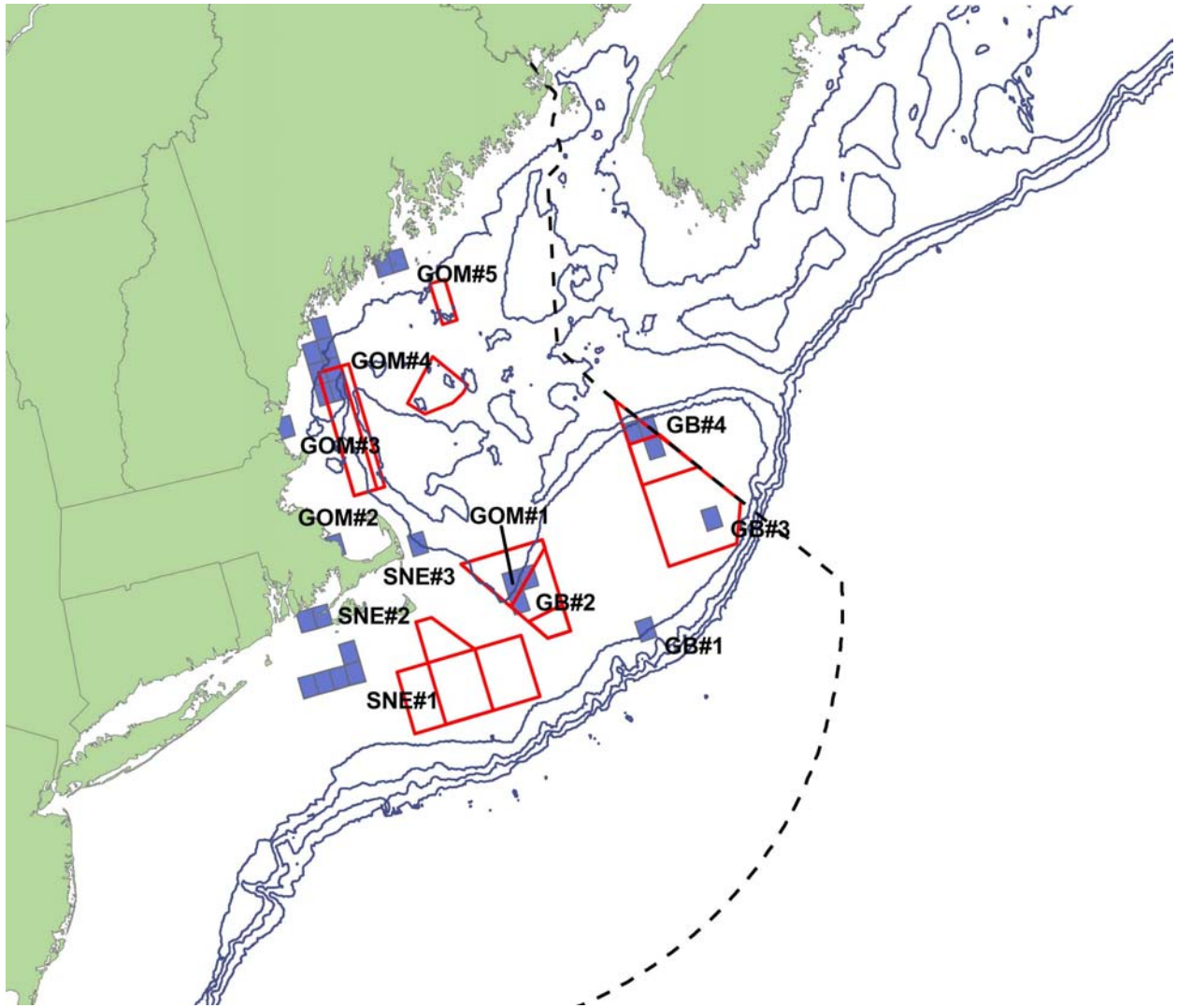


Figure 9. System of HAPC areas selected for alternative #2, based on an abundance target of 10% and guided toward US EFH and closed areas.

Southern New England HAPCs – A#2. The three locations selected in SNE for alternative #2 were largely the same as those chosen in alternative #1, with the exception that no site was selected within the Nantucket Lightship Habitat Closed Area. The combined area was 3% of this region, or 17,729 nm sq. The first site, SNE#1, was due East of Montauk Point, comprised of 5 TMS (375 nm) on sandy bottom. This area was particularly important for winter flounder, yellowtail flounder, and ocean pout. SNE#1 was entirely contained within the corresponding alternative #1 site, made up of 12 TMS. SNE#2 was a smaller site comprised of two TMS at Buzzards Bay (149 nm sq), with one TMS in common with an alternative #1 site. Windowpane and winter flounder were abundant at this site. SNE#3 was a single sand-bottom TMS, just off Chatham, sharing one of two TMS with a similar site in Alternative #1. The abundances of juvenile American plaice, cod, ocean pout, and white hake were all relatively high within the single TMS at SNE#3.

Georges Bank HAPCs – A#2. With the reduced abundance target for alternative #2, the set of HAPC areas for GB included only one TMS not included in the first alternative, and this constituted a fourth site based on a single TMS near the shelf break on the Southern edge of GB (i.e. GB#1). The remaining three sites were very similar to those chosen in the first alternative. The combined extent of these sites was 4.6% of the area, or 11,426 nm. GB#1 (75 nm sq) was sand-bottom and a high abundance area for ocean pout and white hake. The GB#2 of this alternative was identical to that in the first alternative, composed of two gravel-sand bottom TMS within CA II (149 nm sq), on the boundary between the GB and GOM biogeographic regions. This area was contiguous with GOM#1, and had high abundance for Juvenile haddock and American plaice. GB#3 was a single TMS in the Southern part of CA II, with sand bottom and particularly high abundance for haddock and white hake. Three TMS (222 nm sq) were selected in the Northern end of CA II (GB#4), in a sand-bottom area where the abundance was relatively high for white hake.

Gulf of Maine HAPCs – A#2. Again, in the GOM there was a high degree of correspondence between sites selected under the 10% and 20% targets. Two of the sites were identical (i.e. GOM#1 and #2). A total of five sites were selected comprising 3.4% of the GOM region, or 25,761 nm sq. GOM#1 was a single sand-bottom TMS (75 nm sq) in the Great South Channel, contiguous with GB#2. Juvenile haddock were relatively abundant at this site. GOM#2 was also a single TMS (74 nm sq), near shore at Manomet Point. USGS data did not allow classification of the bottom type at this site. GOM#2 was an important area of juvenile cod, yellowtail flounder and ocean pout. GOM#3 was a single TMS (73 nm sq) located at the coast of New Hampshire, and had gravel bottom. This area was particularly important for cod, haddock, and yellowtail flounder. This location was not included under alternative #1. Further North, GOM#4 was a larger area consisting of seven TMS (508 nm sq) partially overlapping the Western Gulf of Maine Closed Area. Bottom types included gravel, sandy-gravel, sand, and a mix of sand-silt-clay. Juvenile white hake and American plaice were in high abundance in this area. At the mouth of Penobscot Bay, two coastal TMS made up the last GOM site, GOM#5 (144 nm sq). The bottom was a mix of sand, silt and clays. GOM#5 had high abundances for white hake, American plaice and haddock.

Table III Alternative #2. HAPC coordinates as TMS centers – decimal degrees.

BGR	nm sq	HAPC %	HAPC ID	n TMS	nm sq	% BGR	Longitude	Latitude
SNE	17,729	2.95	SNE1	5	374.9	2.11	-70.75	40.92
							-70.75	41.08
							-70.92	40.92
							-71.08	40.92
							-71.25	40.92
			SNE2	2	149	0.84	-71.08	41.42
							-70.92	41.42
SNE3	1	74.2	0.42	-69.75	41.75			
GOM	25,761	3.39	GOM1	1	74.7	0.29	-68.92	41.25
			GOM2	1	74.0	0.29	-70.58	41.92
			GOM3	1	73.0	0.28	-70.75	42.92
			GOM4	7	508.3	1.97	-70.08	43.58
							-70.25	43.42
							-70.08	43.42
							-70.25	43.25
							-70.08	43.25
			GOM5	2	144	0.56	-70.08	43.08
							-70.25	43.08
							-69.25	43.92
-69.08	43.92							
GB	11,426	4.56	GB1	1	75.4	0.66	-67.75	40.58
			GB2	2	149.5	1.31	-68.92	41.08
							-68.75	41.25
			GB3	1	74.7	0.65	-66.75	41.25
			GB4	3	221.6	1.94	-67.08	41.92
							-67.25	42.08
						-67.08	42.08	

Alternative #3: Target of 10% with Equal Cost for All TMS. Alternative #3 was generated as a proposal for HAPCs in the original submission to the NEFMC (Figure 10, Table IV). The relative abundance targets used here (10%) were the same as those for alternative #2 above. However, there were a number of differences in other aspects of site selection. First, all the species listed in Table I of this revised proposal were used for site selection under alternative #3, within all three biogeographic regions. For alternatives #1 and #2, the species lists were specific to each biogeographic region as indicated in Table I. Second, the cost of TMS used by the objective function in MARXAN was held constant for all TMS, so site selection was not directed toward US waters, EFH, or to existing closures as in alternatives #1 and #2. Third, all the TMS for which there were NMFS survey data were included during site selection, and some of these were excluded for alternatives #1 and #2 based on the revised criterion that a minimum of four trawls per TMS was required.

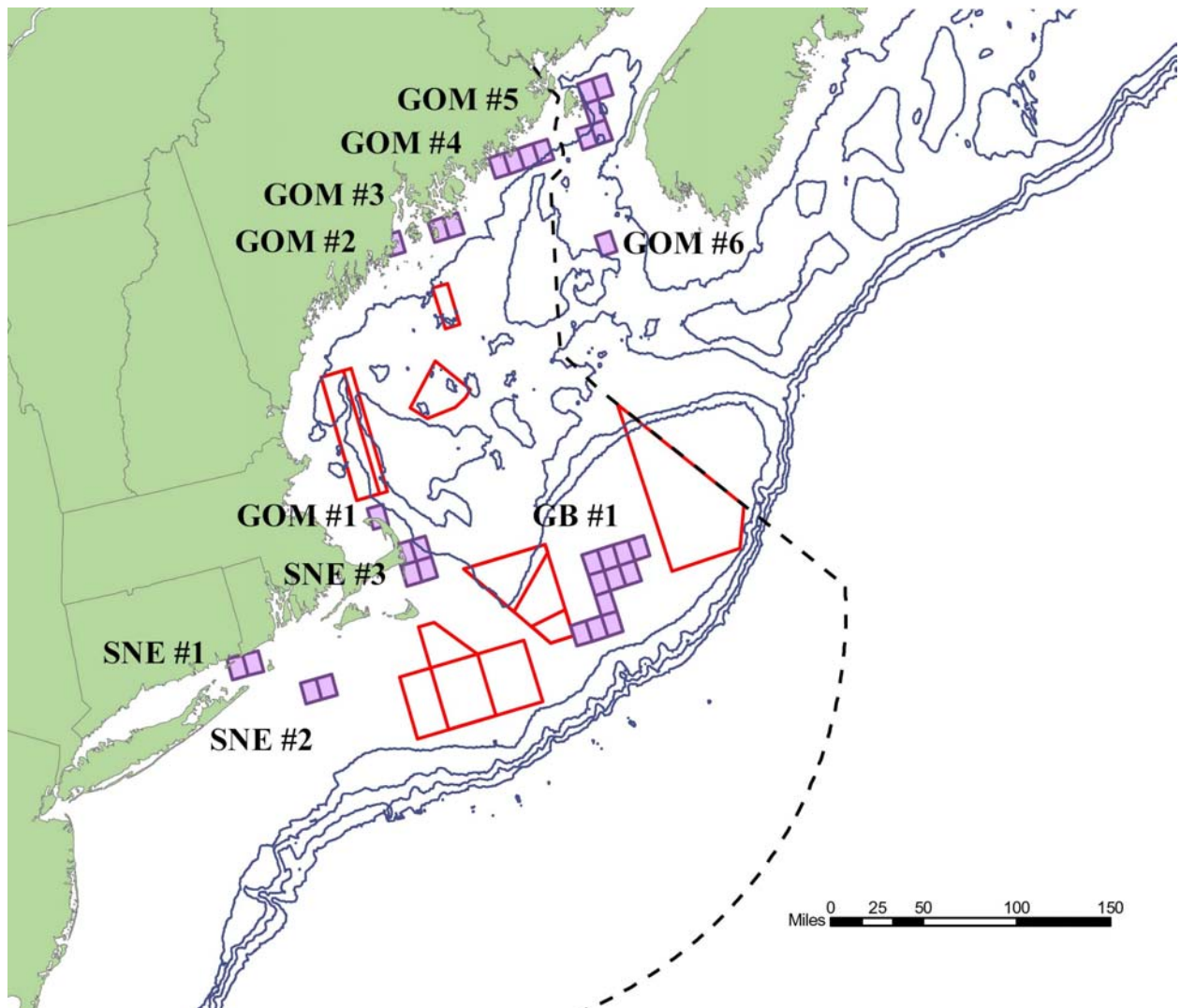


Figure 10. System of HAPC areas selected for alternative #3, based on an abundance target of 10%. Note that the costs of all TMS were equal, and several sites fell in Canadian waters, and in areas not currently designated as EFH for the juvenile species used. This analysis is based on all 8 species in each region, and includes a small number of TMS that were sampled fewer than 4 times.

Under alternative #3, a set of areas was identified within each of the three biogeographic regions that optimally met the juvenile abundance targets (i.e. 10%) for the eight fish species. Within the Southern New England region, targets were met through three areas comprised of eight TMS (SNE #1-3), and covering an area of about 3% of this region. On Georges Bank, a single cluster of eleven TMS was required (GB #1), covering an area of about 7% of the bank. In the Gulf of Maine, six areas composed of fourteen TMS were needed (GOM #1-6) and their combined extent was about 3% of this biogeographic region. As described below, these areas represent a mix of some of areas of high abundance for one or a few species, and other areas that are used by a larger number of species, each occurring at more moderate abundance.

Southern New England HAPCs – A3. In SNE, areas were identified near Fisher’s Island at the CT-RI border (SNE #1), due East of Montauk Point (SNE #2) and at the elbow of Cape Cod just off-shore of Chatham (SNE #3). The SNE #1 site was near shore and shallow, and the bottom was characterized as gravel-sand (Figure 5). There was little of this bottom type within this region overall, and even less in the shallow near-shore areas. Limited surveying of this area indicates that this is a particularly important area for juvenile winter and windowpane flounder (Figure 6). This is also one of several areas where juvenile ocean pout were abundant. The SNE #2 site was further off-shore with a sandy bottom, and used by juveniles of several of the species examined. This area was most heavily utilized by juvenile yellowtail flounder and ocean pout. Near Monomoy Island, SNE #3 was another sandy bottom area used by a number of species including juvenile cod, haddock and white hake.

Georges Bank HAPCs – A3. Targets were fully met for juveniles of Georges Bank Cod and the remaining suite of species within a single larger site on George’s Bank (GB #1; Table IV). Portions of this sandy area were used heavily by windowpane and yellow tail flounder, and targets were modestly exceeded for these species.

Gulf of Maine HAPCs – A3. Six HAPC areas were required to meet abundance targets in the GOM region, with two in Canadian waters. The most Southerly site (GOM #1) was located just off Race Point Cape Cod, and was based on a single TMS in a sandy bottom area. Used by all the species examined, this area was most heavily inhabited by juvenile haddock, ocean pout, and yellowtail flounder. GOM #2 was located along the Maine coast in Penobscot Bay, near Rockland, and was also a single TMS. Much of this region is rocky, but the USGS substrate data did not allow classification of this site. Within GOM, sampling indicated this was a site with high abundance for juvenile white hake and moderate abundance of American plaice. Further East, the third GOM site (GOM #3) was off Mt. Desert in Blue Hill Bay (Figure 10), including Swans Island and Isle a Haute, and consisted of two TMS. The bottom was a mix including gravel-sand and sandy-silt-clay (Figure 5). GOM #3 contributed the most to meeting targets for juvenile cod and white hake. GOM #4 consisted of four TMS, located in the area of Beals Island, with sandy-clay / silt bottom type. Most of the species were sampled at this site and white hake were particularly abundant.

Table IV Alternative #3. HAPC coordinates as TMS centers – decimal degrees. Note that all surveyed TMS (n trawls \geq 1) were included for this analysis, yielding small differences in the areas (nm sq) reported here compared with tables II and III.

BGR	nm sq	HAPC %	HAPC ID	n TMS	nm sq	% BGR	Longitude	Latitude			
SNE	20,040	3.21	SNE#1	2	161.3	0.81	-71.92	41.25			
							-71.75	41.25			
			SNE#2	2	162.7	0.81	-71.25	40.92			
							-71.08	40.92			
			SNE#3	4	319.4	1.59	-69.92	41.58			
							-69.92	41.75			
							-69.75	41.58			
							-69.75	41.75			
			GOM	28,895	3.17206	GOM#1	1	79.0	0.27346	-70.08	42.08
						GOM#2	1	75.2	0.26011	-69.08	44.08
GOM#3	2	150.3				0.52	-68.58	44.08			
							-68.42	44.08			
GOM#4	4	298.1				1.03	-67.75	44.42			
							-67.58	44.42			
							-67.42	44.42			
							-67.25	44.42			
GOM#5	5	237.8				0.82	-66.75	44.42			
							-66.58	44.42			
							-66.58	44.58			
							-66.58	44.75			
GOM#6	1	76.1				0.26340	-66.42	44.75			
GOM#6	1	76.1				0.26340	-66.92	43.58			
GB	12,345	7.23	GB#1	11	892.1	7.23	-68.42	40.75			
							-68.25	40.75			
							-68.08	40.75			
							-68.08	40.92			
							-68.08	41.08			
							-68.08	41.25			
							-67.92	41.08			
							-67.92	41.25			
							-67.75	41.08			
							-67.75	41.25			
							-67.58	41.25			

The remaining two GOM sites were within Canadian waters. GOM #5 was made up of a cluster of five TMS near Grand Manan Island, an area predominated by sand-clay/silt (Figure 5). There was moderate abundance at this site for the three gadoid species, and for American plaice and winter flounder. This was a site where a number of species were in moderate abundance, including juvenile cod, American plaice, haddock, ocean pout, and white hake, with a few winter flounder also taken here.

Relationship of proposed HAPCs to existing EFH – A3. The areas currently designated as EFH are extensive for the juvenile life history stage of the suite of over-fished species examined here (Figure 4; Appendix A-B). In the SNE region, all of the alternative #3 proposed HAPC areas fall within EFH with the exception of two TMS as the SNE #1 site. All of the TMS selected on Georges Bank are currently designated as EFH, and within the U.S. portion of the GOM region only the GOM #3 site (2 TMS) is not currently EFH. Additionally, the largest SNE site (SNE# 3) coincides with juvenile cod EFH, as does a portion of the GB site (GB #1) and several of the GOM sites.

Discussion of proposed HAPCs.

The sets of areas identified here for HAPC designation (Alternatives #1-3) are each based on a simple set of criteria defined by the spatial distribution of juvenile fishes. The site selection tool employed is powerful and can be readily adapted to generate alternative proposals. For example, new alternatives (i.e. #1 and #2) presented in this revised proposal were developed based on modified targets, a adjustments to the species lists for the three regions, the incorporation of the boundaries of current EFH and the US-Canada boundary. This methodology can be particularly valuable because it forces one to focus attention on the identification of appropriate data and criteria rather than the choice of sites *per se*. Once decisions have been made about data, appropriate targets and the parameters used by MARXAN, the site selection process proceeds yielding sets of sites that meet the conditions agreed upon *a priori*. In this sense, the method is relatively objective and transparent. Even if the method may not at first seem particularly transparent, it is fully specified and documented.

Given a single set of conditions, the method can often generate a number of sets of areas that are all reasonably good, in so far as their attainment of the targets. This is a strength of the method and should not come as a surprise since there are multiple places where these fish are found. Since we are identifying only some small portion of these places as potential HAPC, it follows that different combinations of areas might be used to more or less accomplish the same goal. In this proposal we presented the set of areas that did this job the best under each alternative, with minimal area, number of isolated sites, and boundary length.

It is critical to note that the sets of areas presented here are *complimentary*. That is, the sites within a given biogeographic region, taken together, meet the specified targets. If a subset of these sites was considered, the specified targets would no longer be fully represented within them, and the proportion of each target held in the subset would not be uniform. One might say that the individual sites, in isolation, do not have the same value they hold as part of the whole group. If, for example, one wanted to identify just one HAPC in a particular bioregion, it would not make sense to choose one part of a group of areas as presented here without careful analysis of the specific attributes of that site.

The set of HAPC areas proposed under alternative #1 does the best job of meeting the juvenile fish habitat conservation objectives and the practical concerns raised in response to our

original proposal (now alternative #3). Alternative #1 is more precautionary in that it targets a slightly larger portion of prime juvenile habitat. It is more practical because it is based entirely on EFH within US waters, and because many of the selected sites fall in existing fisheries closures. There is growing concern about re-building the Georges Bank cod population, particularly in light of the failures of cod in Canadian waters. Alternative #1 includes important habitat areas for GB cod. Alternative #2 has many of the same characteristics but would not be likely to have the same benefit to fish populations because it encompasses less overall abundance and area.

For the original proposal, alternative #3, we chose to allow site selection to be driven by the best systematic survey data available for the region, focusing on a vulnerable life-history stage for eight species whose populations have been compromised. We elected not to constrain our original analysis by the current EFH designations, the US-Canada boundary, or existing management areas. This was a scientifically sound approach, governed by biological data and ecological regions, but presented several policy issues, including the selection of areas in Canadian waters. The policy issues were resolved by including policy constraints in the analysis for the generation of alternatives #1 and #2. This kind of decision has the potential to compromise biological objectives. However, with the particular set of biological targets used in site selection, we were able to achieve an excellent system of proposed HAPC areas within the policy constraints. There are other ecosystem management needs for the GOM and GB that can not be attained without US-Canadian coordination. While this adds complication, it is essential to recognize that ecological regions are at least as important as political boundaries for effective resource management. This proposal is itself the product of a U.S.- Canadian international cooperation and CLF and WWF Canada and we encourage the NEFMC to give international coordination a high priority as it develops management plans for our shared biogeographic regions, the GOM and GB.

Justification for Council action based on NMFS final rule (Topic 3).

CRITERION 1: Importance of Historic and Current Ecological Function. The analysis presented here is designed to identify HAPC sites using survey data over a period of more than three decades. We have not specifically examined historical trends over this period for this analysis. Locations where abundance has been historically high through the sample period (1970-2003) will, however, show up as sites with high normalized relative abundance in our analysis and thus have a high likelihood of inclusion during site selection. Our analysis does not allow us to explicitly distinguish between current and past ecological importance.

CRITERION 2: Sensitivity to Anthropogenic Stresses (Topic 6). The candidate HAPCs identified here are areas that are heavily used by juveniles of over-fished demersal species. As detailed above (*Choice of Species and Life History Stage*), these locations are sensitive to anthropogenic stresses since a number of common marine uses are known to degrade the suitability of these habitat areas for juvenile fish. Activities that frequently disturb the bottom where these animals live can degrade the habitat in at least two important ways. First, structures provided by benthic epifauna and abiotic relief, such as sand-waves (Auster *et al.*, 2003), offer shelter from predators (Gotceitas and Brown, 1993; Lindholm *et al.*, 1999; Lindholm *et al.*, 2001; Lough, 2004; Tupper and Boutilier, 1995) and prevailing currents (Gerstner, 1988; Lough and Bolz, 1989; Malatesta and Auster, 1999). These features are degraded by a variety of bottom-contacting human activities including dredges, trenching plows, and various types of fishing gear

(Auster and Langton, 1999; Auster *et al.*, 1996; Collie *et al.*, 1997; Collie *et al.*, 2000a; Collie *et al.*, 2000b; Hermesen *et al.*, 2003; Lindholm *et al.*, 2004).

Second, dredging, trenching and bottom trawling, for example, interrupt natural behavior such as feeding and evading predators. If frequent, this kind of behavioral disturbance within an area will reduce the quality of the habitat by making the areas less suitable for the growth of young fish.

There is a substantial literature on bottom types, recovery rates, and natural rates of disturbance (Collie *et al.*, 2000b). In general, deeper areas are typically subjected to less natural disturbance than shallow, and the fauna in the deeper environments are more sensitive to additional anthropogenic stresses. Sandy shallow areas are subject to more natural disturbance and populated by fauna that have adapted to this through long periods of evolution. Nevertheless, it should not be assumed that adding to the cumulative stress in such higher energy locations will be without consequence for fish and other organisms living in these areas. Thus, while several of the over-fished species we have included in our analyses do utilize sandy bottoms (e.g. flounders), we maintain the pre-cautionary view that locations supportive of these species are sensitive to anthropogenic stresses even if sandy and shallow (Kaiser *et al.*, 2004; Lindholm *et al.*, 2004). Even increased behavioral disturbance constitutes an adverse effect on these particularly important habitat. Our HAPC proposal includes a mix of bottom types, some of which are considered relatively resilient, but all these areas captured by our analysis should be considered sensitive to anthropogenic stresses due to the abundance of juveniles in these areas.

CRITERION 3: *Extent of Current or Future Development Stresses (Topic 6).* To the best of our knowledge, there is no immediate threat posed by planned developments that coincide with the system of HAPCs we propose here. However, the pressures on shallow off-shore areas for the development of offshore energy projects are mounting steadily (e.g. LNG terminals, off-shore wind, gas pipelines; drilling for gas and oil on the continental shelf). The use the sea floor as a source of gravel and sand is also a continuing threat to the particularly important areas of EFH we identify in this proposal. The designation of the HAPCs we propose could serve to minimize the potential adverse effects of these kinds of development stresses, contribute to stock rebuilding, and to the value and diversity of fisheries in the region.

CRITERION 4: *Rarity of the Habitat Type.* Those locations where the abundance of juvenile fishes is relatively high are uncommon or *rare* by definition. The analysis presented here for the identification of HAPC selects these places, and in this sense the HAPCs meet criterion 4.

In order to understand what the *habitat* is for a given species of fish during a particular life history stage (e.g. juvenile), one begins by examining *where* the fish are found. This endeavor yields the most certain picture of *where* the habitat is for the species, and this is in large part how maps of EFH have been made in the past. The next step, describing *what* defines the habitat, is much less certain. In the absence of experimental work on habitat selection, one is left with correlations between abundance and those attributes of the marine environment that one has the ability, or forethought, to measure (e.g. bottom type, depth, salinity). Some of the listed attributes may not directly determine where the fish are found, and the list very likely will fail to include some of the factors which do directly influence distribution. Thus, beyond mapping relative abundance, defining habitat is a challenging and important task.

It is complicated to know whether or not those physical attributes of the environment that lead to high abundance are themselves rare since we often are not certain what they are. For example,

we observe that juvenile cod are typically found in areas where the bottom is characterized a cobble-gravel, and the water depth is 25-75 meters (Appendix B). Nevertheless, cod are not uniformly abundant in locations that fit this description. There are some such places where juvenile cod are in very low abundance and others where abundance is relatively high. Those places where abundance is very high may have features that determine this, but these may be features we have failed adequately measure (e.g. circulation patterns, availability of plankton, characteristics of the benthos). The observation of uneven distributions of animals within what we take as the definition of their habitat leaves open an important question. Is the habitat common but incompletely used or is the habitat that supports high abundance actually relatively rare but as yet incompletely described?

In our derivation of HAPCs we have sought to capture those places where relative abundance is high, and suggest that is pre-cautionary to take these as relatively rare habitats of high value for fish populations.

Discretionary Topics

Foreseeable impacts of proposal (Topic A)

As noted in the RFP, the designation of areas as HAPCs has no social or economic impacts. These proposed HAPCs focus on juvenile fish for over-fished species because juvenile fish survival and growth to maturity is a critical component to re-establishing sustainable fish populations. As discussed, juveniles are at high risk of predation and dependent upon features of bottom habitats that are particularly vulnerable to degradation caused by bottom contacting equipment, including dredges, trenching plows, mobile fishing gear, and stationary gear during storms. In view of this, an appropriate suite of management measures should be implemented that would maintain the integrity of these habitat areas and minimize mortality to juveniles. This will maximize the benefits of the proposed HAPCs and help ensure the recovery and long-term productivity of these populations.

The foreseeable impacts of management measures designed to maintain the integrity of the proposed HAPC areas presented here can be predicted to an extent by comparing these areas with the spatial distribution of fishing activity. Spatial analysis of fishing activities has been carried out by a number of agencies and is included in the EIS for Amendment 13. This analysis focuses on those gear types that would be most likely to impact juvenile habitat (Amendment 13 EIS at II-1207 thru II-1211). This analysis was used in our original proposal for a rough analysis of some of the potential impacts of the original set of proposed HAPC areas (i.e. alternative #3). If one of the new alternatives proposed here is considered further, a similar analysis could easily be conducted to examine the foreseeable impacts of that proposal. Additional and more refined data should also be used for a more detailed analysis of the potential impacts of management measures that could restrict certain fishing activities in the various proposed HAPCs.

While considering these potential impacts, it is important to keep in mind that our proposal is designed to meet goals for over-fished species in the most efficient way possible, and the proposed areas represent only a small fraction of the region analyzed (i.e. about 10%). Implementation of management measures designed to maximize the ecological benefits of these habitat areas may result in some impact to fishing interests, including some displacement of effort to other areas. Nevertheless, implementation of management measures which maintain the integrity of these HAPC areas and help ensure rebuilding of these depleted fish stocks will also have significant economic benefits to the fishery. A fully rebuilt groundfish fishery, after all, is

expected to more than double landings and perhaps triple the revenues over those currently realized, according to the long term economic impact analyses in the Amendment 13 EIS.

Possible alternative solutions (Topic B)

In this proposal, we present three alternative sets HAPC sites that could be used to meet a number of important goals for multi-species fisheries management and the recovery of over-fished populations. As demonstrated, the methodology is particularly valuable because it can readily generate a variety of alternatives. The NEFMC could clearly use MARXAN as a tool to generate additional alternatives, for example, using additional managed species, or higher abundance targets.

With heightened concern about Georges Bank cod, the Council could develop an alternative for the GB region that further augments HAPC for cod. Figure 6 shows juvenile cod abundance, with those TMS that had unusually high abundance (i.e. top 20%) shown in the left column. Additional high abundance areas for juvenile cod could be designated as HAPC based on this information to strengthen the conservation of this jeopardized population. If additional near-shore data on important juvenile cod habitat areas is available to the council, these data should also be considered in the development of plans targeted at this particular species.

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APPENDIX A
NOAA-NMFS Essential Fish Habitat Descriptions

Source: <http://www.nero.noaa.gov/hcd/>

Essential Fish Habitat Description - American plaice (*Hippoglossoides platessoides*)

Juveniles: Bottom habitats with fine-grained sediments or a substrate of sand or gravel in the Gulf of Maine as depicted in Figure 6.3. Generally, the following conditions exist where most American plaice juveniles are found: water temperatures below 17° C, depths between 45 and 150 meters and a wide range of salinities.

Essential Fish Habitat Description Atlantic cod (*Gadus morhua*)

Juveniles: Bottom habitats with a substrate of cobble or gravel in the Gulf of Maine, Georges Bank, and the eastern portion of the continental shelf off southern New England as depicted in Figure 1.3. Generally, the following conditions exist where cod juveniles are found: water temperatures below 20° C, depths from 25 - 75 meters, and a salinity range from 30 - 35‰.

Essential Fish Habitat Description - Haddock (*Melanogrammus aeglefinus*)

Juveniles: Bottom habitats with a substrate of pebble gravel on the perimeter of Georges Bank, the Gulf of Maine, and the middle Atlantic south to Delaware Bay as depicted in Figure 2.3. Generally, the following conditions exist where haddock juveniles are found: water temperatures below 11°C, depths from 35 - 100 meters, and a salinity range from 31.5 - 34‰.

Essential Fish Habitat Description - Ocean pout (*Macrozoarces americanus*)

Juveniles: Bottom habitats, often smooth bottom near rocks or algae in the Gulf of Maine, Georges Bank, southern New England and the middle Atlantic south to Delaware Bay as depicted in Figure 5.3. Generally, the following conditions exist where ocean pout juveniles are found: water temperatures below 14° C, depths less than 80 meters, and salinities greater than 25‰.

Essential Fish Habitat Description - White hake (*Urophycis tenuis*)

Juveniles: *Pelagic stage* -- Pelagic waters of the Gulf of Maine, the southern edge of Georges Bank, and southern New England to the middle Atlantic as depicted in Figure 12.3. White hake juveniles in the pelagic stage are most often observed from May through September. *Demersal stage* -- Bottom habitats with seagrass beds or a substrate of mud or fine-grained sand in the Gulf of Maine, the southern edge of Georges Bank, and southern New England to the middle Atlantic as depicted in Figure 12.3. Generally, the following conditions exist where white hake juveniles are found: water temperatures below 19° C and depths from 5 - 225 meters.

Essential Fish Habitat Description - Windowpane flounder (*Scophthalmus aquosus*)

Juveniles: Bottom habitats with a substrate of mud or fine-grained sand around the perimeter of the Gulf of Maine, on Georges Bank, southern New England and the middle Atlantic south to Cape Hatteras as depicted in Figure 14.3. Generally, the following conditions exist where windowpane flounder juveniles are found: water temperatures below 25° C, depths from 1 - 100 meters, and salinities between 5.5 - 36‰.

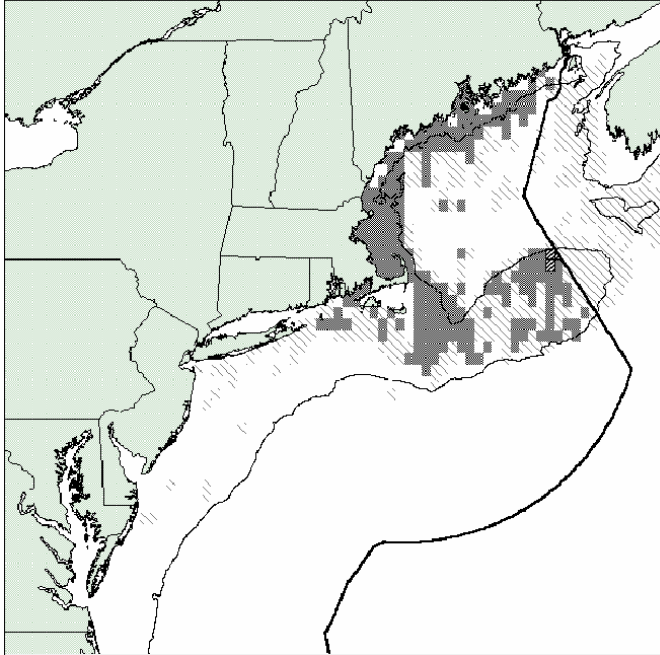
Essential Fish Habitat Description - Winter flounder (*Pleuronectes americanus*)

Juveniles: Bottom habitats with a substrate of mud or fine grained sand on Georges Bank, the inshore areas of the Gulf of Maine, southern New England and the middle Atlantic south to the Delaware Bay as depicted in Figure 15.3. Generally, the following conditions exist where juvenile winter flounder are found: water temperatures below 25°C, depths from 1 - 50 meters, and salinities between 10 - 30‰.

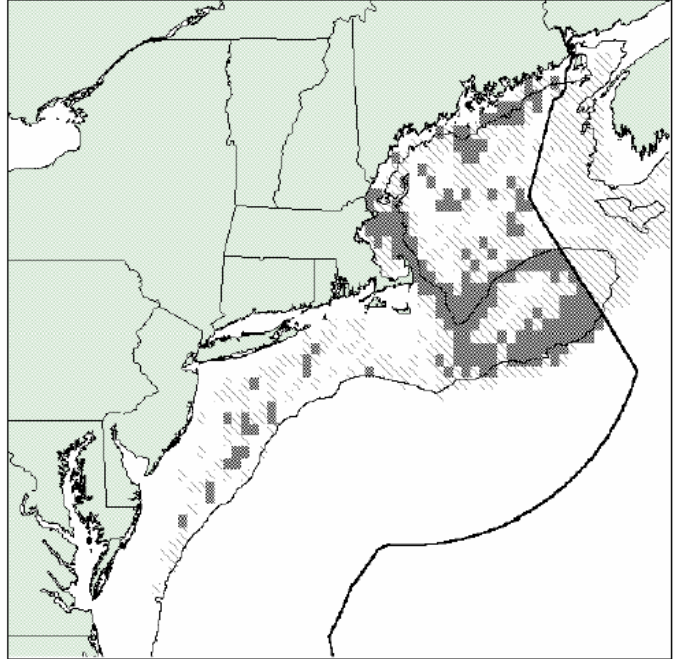
Essential Fish Habitat Description Yellowtail flounder (*Pleuronectes ferruginea*)

Juveniles: Bottom habitats with a substrate of sand or sand and mud on Georges Bank, the Gulf of Maine, and the southern New England shelf south to Delaware Bay as depicted in Figure 17.3. Generally, the following conditions exist where yellowtail flounder juveniles are found: water temperatures below 15° C, depths from 20 - 50 meters and a salinity range from 32.4 - 33.5‰.

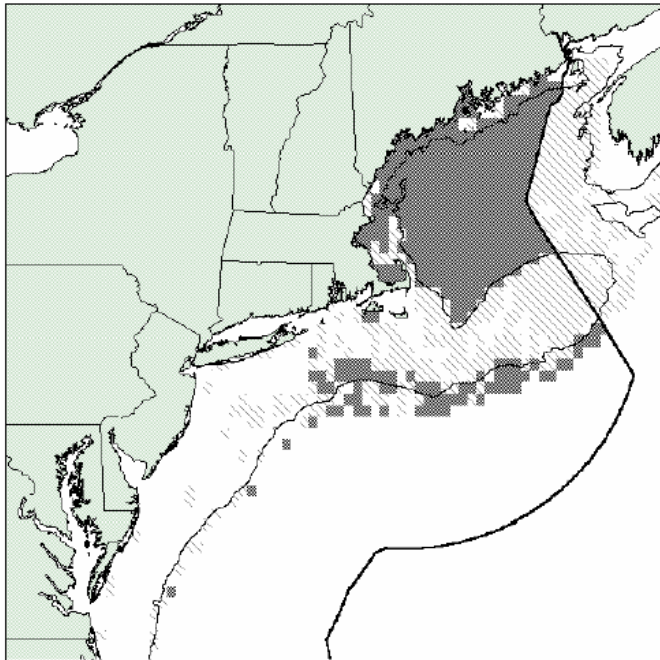
Essential Fish Habitat
Atlantic cod (*Gadus morhua*) Juveniles



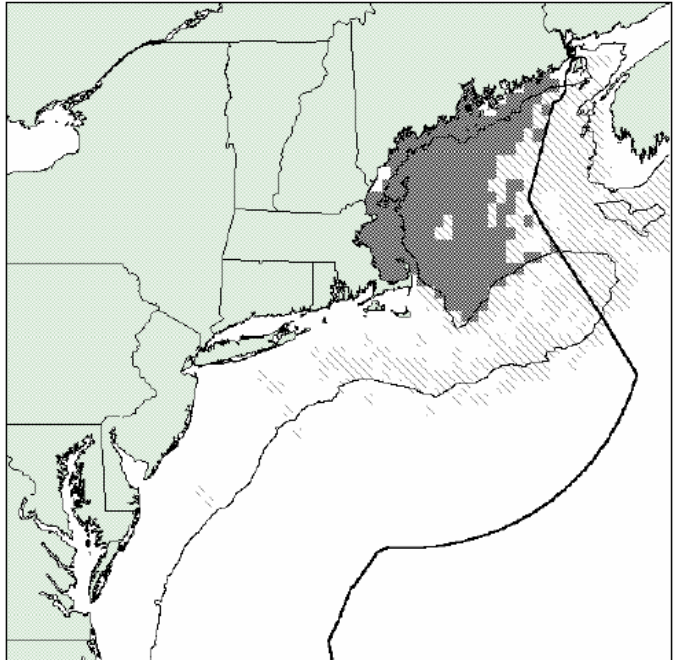
Essential Fish Habitat
Haddock (*Melanogrammus aeglefinus*) Juveniles



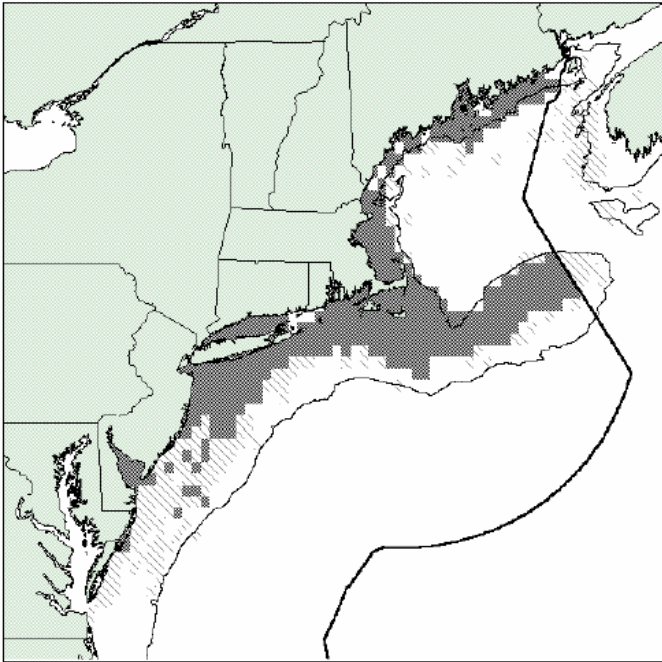
Essential Fish Habitat
White hake (*Urophycis tenuis*) Juveniles



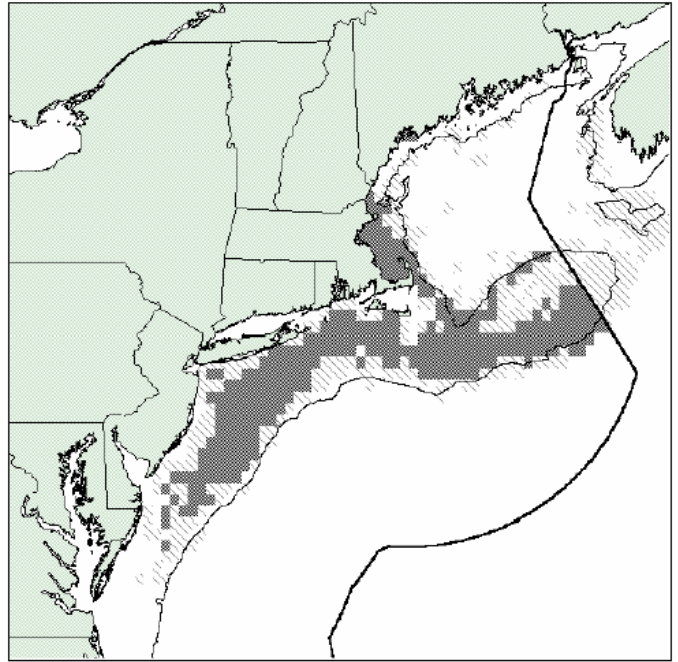
Essential Fish Habitat
American plaice (*Hippoglossoides platessoides*) Juveniles



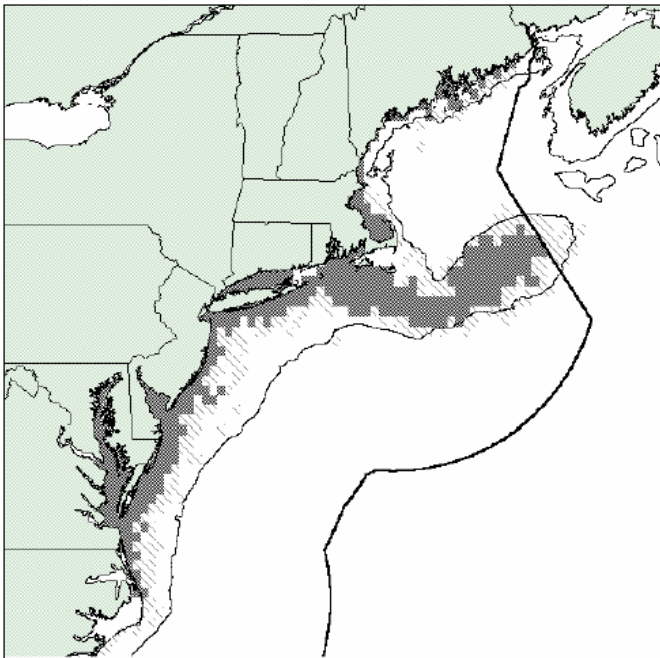
Essential Fish Habitat
Winter flounder (*Pleuronectes americanus*) Juveniles



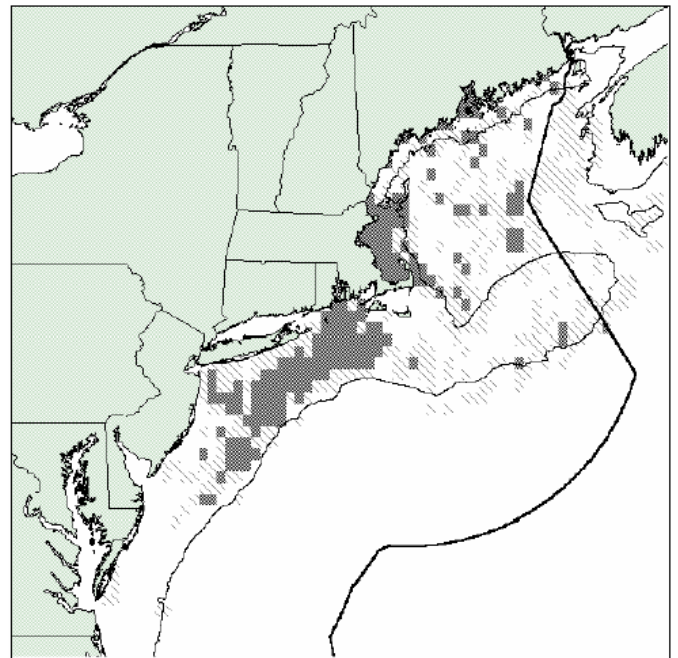
Essential Fish Habitat
Yellowtail flounder (*Pleuronectes ferruginea*) Juveniles



Essential Fish Habitat
Windowpane flounder (*Scophthalmus aquosus*) Juveniles



Essential Fish Habitat
Ocean pout (*Macrozoarces americanus*) Juveniles



APPENDIX B

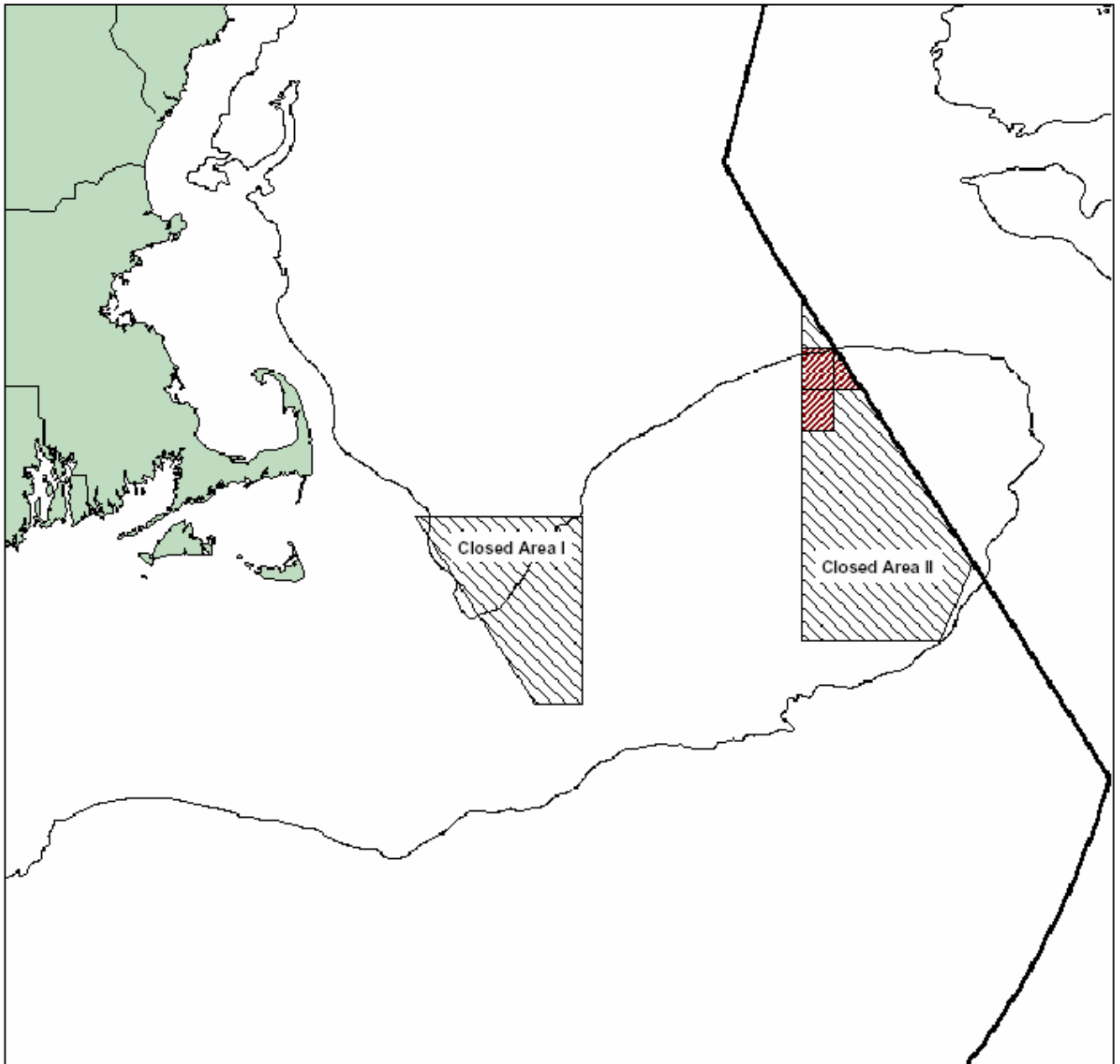
3.3.1 Atlantic cod HAPC

http://www.nero.noaa.gov/hcd/sec_3.pdf

Several sources document the importance of gravel/cobble substrate to the survival of newly settled juvenile cod (Lough et al. 1989; Valentine and Lough 1991; Gotceitas and Brown 1993; Tupper and Boutilier 1995; Valentine and Schmuck 1995). A substrate of gravel or cobble allows sufficient space for newly settled juvenile cod to find shelter and avoid predation (Lough et al. 1989; Valentine and Lough 1991; Gotceitas and Brown 1993; Tupper and Boutilier 1995; Valentine and Schmuck 1995). Particular life history stages or transitions are sometimes considered "ecological bottlenecks" if there are extremely high levels of mortality associated with the life history stage or transition. Extremely high mortality rates attendant to post-settlement juvenile cod are attributed to high levels of predation (Tupper and Boutilier 1995). Increasing the availability of suitable habitat for post-settlement juvenile cod could ease the bottleneck, increasing juvenile survivorship and recruitment into the fishery. For these reasons, areas with a gravel/cobble substrate meet the first criterion for habitat areas of particular concern. Specific areas on the northern edge of Georges Bank have been extensively studied and identified as important areas for the survival of juvenile cod (Lough et al. 1989; Valentine and Lough 1991; Valentine and Schmuck 1995). These studies provide reliable information on the location of the areas most important to juvenile cod and the type of substrate found in those areas. These areas have also been studied to determine the effects of bottom fishing on the benthic megafauna (Collie et al. 1996; Collie et al. 1997). Gravel/cobble substrates not subject to fishing pressure support thick colonies of emergent epifauna, but bottom fishing, especially scallop dredging, reduces habitat complexity and removes much of the emergent epifauna (Collie et al. 1996; Collie et al. 1997). Acknowledging that a single tow of a dredge across pristine habitat will have few long-term effects, Collie et al. (1997) focus on the cumulative effects and intensity of trawling and dredging as responsible for potential long-term changes in benthic communities. For these reasons, the identified area on the northern edge of Georges Bank meets the second criterion, as well as the cumulative effects consideration, for designation as a habitat area of particular concern.

Collie et al. (1997) also describe the relative abundance of several other species such as shrimps, polychaetes, brittle stars, and mussels in the undisturbed sites. These species are found in association with the emergent epifauna (bryozoans, hydroids, worm tubes) prevalent in the undisturbed areas. Several studies of the food habits of juvenile cod identify these associated species as important prey items (Hacunda 1981; Lilly and Parsons 1991; Witman and Sebens 1992; Casas and Paz 1994; NEFSC 1998). These areas provide two important ecological functions for post-settlement juvenile cod relative to other areas: increased survivability and readily available prey. These areas are also particularly vulnerable to adverse impacts from mobile fishing gear.

Figure 6: Habitat Area of Particular Concern for Juvenile Atlantic Cod



The shaded areas represent Closed Areas I and II, as indicated.



The darkened area within Closed Area II represents the Habitat Area of Particular Concern for juvenile Atlantic cod.

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Bold references are available electronically and provided as supporting documentation here. Others are available from government web-based sources.