APPENDIX IV

METHODS OF ANALYSIS FOR ASSESSMENT OF ENVIRONMENTAL CONSEQUENCES

Table of Contents:

1.0 Biological Projection Methods

The model follows, for each area i and time t, population vectors p(i,t) = (p1, p2,..., pn), where pj represents the density of scallops in the jth size class in area i at time t. The model uses a difference equation approach, where time is partitioned into discrete time steps t1, t2,…, with a time step of length ?t = tk+1 - tk. The landings vector h(i,tk) represents the catch at each size class in the *i*th region and *k*th time step. It is calculated as:

$$h(i,t_k) = [I - \exp(\Delta t H(i,t_k))]\, p(i,t_k),$$

$$h_{jj} = \begin{cases} 0 & if \quad s(j) \le s_d \\ -F_c(i,t_k)[s(j) - s_{\min}]/(s_{full} - s_{\min}) & if \; s_d < s(j) < s_{full} \\ -F_c(i,t_k) & if \quad s(j) \ge s_{full} \end{cases}$$

where I is the identity matrix and H is a diagonal matrix whose jth diagonal entry h_{jj} is given by:

Here, $s_{\min}$ is the minimum size at which a scallop is vulnerable to the gear, s_{full} is the size at which a scallop is fully vulnerable to the gear, s_d is the cull size (=$s_{\min}$) below which scallops are discarded, and $F_c(i,t_k)$ represents the capture fishing mortality rate suffered by a full recruit in area i at time t_k.

To model the effect of four inch rings, a more complex selectivity pattern was used, based on the data of W. DuPaul. Selectivity of scallops less than 99mm was reduced 41% compared to 3.5” rings described above, 23% for scallops between 99 and 104 mm, 15% for scallops between 104 and 109 mm, and 10% for scallops between 109 and 124 mm. Consistent with the observed data, total contact time and area swept per unit fully recruited fishing mortality (>88mm for 3.5” rings, >125mm for 4” rings) using four inch rings was reduced by 15%.

The landings $L(i,t_k)$ for the *i*th region and *k*th time step are calculated using the dot product of landings vector $\mathbf{h}(i,t_k)$ with the vector $\mathbf{m}(i)$ representing the vector of meat weights at shell height for the *i*th region:

$$L(i,t_k) = A_i\, \mathbf{h}(i,t_k) \bullet \mathbf{m}(i)/(w\, e_i)$$

where e_i represents the dredge efficiency in the *i*th region, and w is the tow path area of the survey dredge (estimated as 8/6080 nm^2).

Even in the areas not under special area management, fishing mortalities tend to not be spatially uniform for poorly mobile stocks such as sea scallops (Caddy 1975, Hart 2001). Fishing mortalities in 2001-2003 were specified, based on observed distributions of fishing effort (from VMS and VTR information), so that total fishing effort for each of these two years corresponds to about 26000 actual DAS (see LPUE/DAS submodel, described below). Fishing mortalities in open areas beyond 2003 (except for Alternative 1e and in the mechanical rotation options) are determined by a "fleet dynamics model", similar to that of Caddy (1975). This model estimates fishing mortalities in open areas based on (i) area-specific exploitable biomasses, (ii) observed area-specific preferences (at similar biomasses, higher fishing mortalities are observed in the Mid-Atlantic, especially in Delmarva), and (iii) so that the overall DAS or open-area F matches the target. Based on these ideas, the fishing mortality F_i in the ith region is modeled as:

$$F_i = k*f_i*B_i$$

where B_i is the exploitable biomass in the ith region, f_i is an area-specific adjustment factor to take into account preferences for certain fishing grounds (due to lower costs, shorter steam times, ease of fishing, habitual preferences, etc.), and k is a constant adjusted so that the total DAS or fishing mortality meets its target. For these simulations, f_i = 1 for all Georges Bank areas, f_i = 1.5 for New York Bight areas (Mid-Atlantic subareas 6-9), and
f_i= 3 for the southern Mid-Atlantic areas (1-5). These weightings were chosen to correspond with the much higher fishing mortalities at a given biomass observed in the Mid-Atlantic, especially in the south.

In alternative 1e (area management without rotation), fishing mortality was set at the target (0.2) in all areas open to fishing, corresponding to area-specific DAS or quotas that would occur under this proposed plan. In the mechanical rotation plans, areas are either (M-1) closed for three years and then fished at 0.32, 0.4, and 0.48, or (M-2) closed for five years and then opened for one year at F = 1.2.

Scallops of shell height less than a minimum size s_d are assumed to be discarded, and suffer a discard mortality rate of d. Discard mortality was estimated in NEFSC (2001) to be 20%. There is also evidence that some scallops not actually landed may suffer mortality due to incidental damage from the dredge. The level at which this occurs was assessed in NEFSC (2001). It depends on the dredge efficiency e and also probably bottom type. If a fraction c of the scallops remaining on the bottom suffer incidental mortality, then the incidental fishing mortality F_I can be calculated as:

$$F_I = F_L c(1-e)/e,$$

where F_L is capture fishing mortality.

Caddy (1973) estimated that c was about 0.15 to 0.2 in a relatively hard-bottom area in Canadian waters, while Murawski and Serchuk (1989) estimated that $c < 0.05$ in a sandy bottom area off of New Jersey. For Georges Bank, we used c = 0.175 from Caddy together with a dredge efficiency estimate of e = 0.5 (NEFSC 2001) to obtain an estimate of $F_I = 0.175F_L$. For the Mid-Atlantic, we used c = 0.05 (the maximum possible value from Murawski and Serchuk) together with an efficiency of e = 0.7 (NEFSC 2001) to estimate $F_I = 0.03F_L$.

The scallops grow according to a von Bertalanffy equation, so that their shell height $s(t)$ at age t (in years) is given by:

$$s(t) = L_\infty[1-\exp(-k[t-t_0])].$$

The growth equation is used to construct a matrix *G*, which specifies the fractions of each size class that remains in that size class, or grows to other size classes, in a time ? t.

Recruitment was modeled stochastically, and was assumed to be log-normal in each subarea. The mean, variance and covariance of the recruitment in a subarea was set to be equal to that observed in the historical time-series between 1982-2001. The same random number seed was used in all simulations, so that differences among simulation runs cannot be ascribed to different recruitment streams. New recruits enter the smallest size class (40-45 mm in these simulations) at a rate r_i depending on the subarea *i*, and stochastically on the year. Area-specific recruitment rates are given in Table 2.

These simulations assume that recruitment is a stationary process, i.e., no stock-recruitment relationship is assumed. The increased recruitment that have occurred in the past few years as biomass has increased suggests the possibility that recruitment overfishing may have been occurring in the years prior to 1996 (though it is also possible that oceanographic conditions could be responsible for the high recent recruitment; see NEFSC 2001). If recruitment overfishing was occurring historically, then the model projections will underestimate future recruitment, biomass, and landings. However, given that scallop egg production is currently and is projected to remain an order of magnitude higher than the levels in the 1980s and early 1990s, and that the landings under the current model assumptions are higher than those reported historically, it is likely that any stock-recruitment relationship will be saturated at these high levels of egg production. Hence, it is probable that future recruitment will not depend on the exact level of biomass (provided that the biomass remains high), and the mean future recruitment will be near its asymptotic value. This means that the *relative* yields and biomasses from the various scenarios will not be affected by the particular assumptions about recruitment made here. So while there may be some uncertainty as to the absolute levels of future recruitment, yields, and biomasses, model projections should give accurate comparisons of the relative advantages and disadvantages of different management strategies.

The population dynamics of the scallops in the present model can be summarized in the equation:

$$p(i,t_{k+1}) = r_i + G\exp(-M\Delta tH)p(i,t_k),$$

where ?$_i$ = (r_i ? t,0,0,…). The population and harvest vectors are converted into biomass by using the shell-height meat-weight relationship:

$$W = \exp[a + b\ \ln(s)],$$

where *W* is the meat weight of a scallop of shell height *s*. For calculating biomass, the shell height of a size class was taken as its midpoint. The model also keeps track of egg production, based on the fecundity - shell-height relationship of MacDonald and Thompson (1985). A summary of model parameters is given in Table 1.

Initial conditions for the population vector **p** *(i,t)* were estimated using the 2001 NMFS research vessel sea scallop survey. Catches in the survey were adjusted for catchability of a lined dredge, as described in NEFSC (2001). The initial conditions from the 2001 survey were bootstrapped using the bootstrap model of Smith (1997), so that each simulation run had both its own stochastically determined bootstrapped initial conditions, as well as stochastic recruitment stream.

Commercial landing rates (LPUE) were estimated using an empirical function based on the observed relationship between annual landing rates, expressed as number caught per day (NLPUE) and survey exploitable numbers per tow. At low biomass levels, NLPUE increases roughly linearly with survey abundance (see Fig 1). However, at high abundance levels, the catch rate of the gear will exceed that which can be shucked by a seven-man crew. The is similar to the situation in predator/prey theory, where a predator's consumption rate is limited by the time required to handle and consume its prey (Holling 1959). The original Holling Type-II predator-prey model assumes that handling and foraging occur sequentially. It predicts that the per-capita predation rate R will be a function of prey biomass B according to a Monod functional response:

$$R = \frac{aB}{b + B},$$

where a and ß are constants. In the scallop fishery, however, some handling (shucking) can occur while foraging (fishing), though at a reduced rate because the captain and one or two crew members need to break off shucking to steer the vessel during towing and to handle the gear during haul back. The fact that a considerable amount of handling can occur at the same time as foraging means that the functional response of a scallop vessel will saturate quicker than that predicted by the above equation. To account for this, a modified Holling Type-II model was used, so that the landings per unit effort (DAS) L (the predation rate) will depend on scallop (prey) exploitable biomass B according to the formula:

$$L = \frac{aB}{\sqrt{b^2 + B^2}}. \qquad (*)$$

The parameters a and ß to this model were fit to the observed fleet-wide LPUE vs. exploitable biomass relationship during the years 1982-2000 (Figure 1). The number of scallops that can be shucked should be nearly independent of size provided that the scallops being shucked are smaller than about a 20 count. The time to shuck a large scallop will go up modestly with size. To model this, if the mean meat weight of the scallops caught, g, in an area is more than 20 g, the parameters a and ß in (*) are reduced by a factor $\sqrt{20/g}$. This means, for example, that a crew could shuck fewer 10 count scallops per hour than 20 count scallops in terms of numbers, but more in terms of weight.

An estimate of the fishing mortality imposed in an area by a single DAS of fishing in that area can be obtained from the formula $F_{\mathrm{DAS}} = L_a/B_a$, where L_a is the LPUE in that area obtained by the above formula, and B_a is the exploitable biomass (in absolute units) in that area. This allows for conversion between units of DAS and fishing mortality.

The LPUE/biomass functional relationship can also be used to estimate dredge contact time and total area swept. Even when shucking time is not limited, the dredge will not be on the bottom all the time that a vessel's DAS clock is ticking. A vessel typically steams a little less than 10% of the time. The dredge can be on the bottom for nearly 90% of the remaining time; the rest of the time is needed for dredge set-out, haul-back, and dumping on deck. This implies that at low densities, when shucking is not limiting, that dredge contact time is about 19.5*D hours, where D is the number of DAS charged.

The catch rate per hour contact time should be directly proportional to biomass regardless of biomass levels. Since at low biomass, the relationship (*) reduces to $L = (a/ß)B$ (Figure 1), the predicted (numerical) landings L_0 per 19.5 hours contact time is:

$$L_0 = (a/ß)B. \qquad (**)$$

Thus, the actual bottom contact time C (in hours) per DAS charged is:

$$C = 19.5\frac{L}{L_0} = \frac{19.5b}{\sqrt{b^2 + B^2}}.$$

Since a typical vessel fishes at about 4.5 knots, and employs two 15 foot dredges, the area swept in an hour of bottom contact time is about: 4.5*2*15/6080 nm^2 = 0.0222 nm^2. Hence, the area swept, A, per DAS charged is:

$$A = \frac{19.5 * 0.0222b}{\sqrt{b^2 + B^2}}.$$

Rotational closures and openings occur according to a specified rule involving growth rates etc., as specified below. Reopened areas are specially controlled for a three-year period following reopening, with fishing mortalities usually fixed at 0.32, 0.4, 0.48 for the three years. Hudson Canyon considered harvest area for the 2003-2006 period.

Simulations were run 400 times for 30 years each. “Long-term” results are the means (and standard deviations) of the last 10 years of the 400 simulations.

Table 1. **Model parameters**

Parameter	Description	Value
Δt	Simulation time step	0.1 y
L_∞	Maximum shell height	152.46 mm (GB), 151.84 mm (MA)
K	Growth parameter	0.3374 y^{-1} (GB), 0.2997 y^{-1} (MA)
M	Natural mortality rate	0.1 y^{-1}
a	Shell height/meat wt parameter	-11.6038 (GB), -12.2484 (MA)
b	Shell height/meat wt parameter	3.1221 (GB), 3.2641 (MA)
s_0	Initial shell height of recruit	40 mm
s_{min}	Minimum size retained by gear	65 mm
s_{full}	Size for full retention by gear	88 mm
s_d	Maximum size discarded	80 mm
d	Mortality of discards	0.2
	Non-catch scallop mortality for scallops in the dredge path1	17.5% (GB)2, 3% (MA)3
e	Dredge efficiency	50% (GB), 70% (MA)
a	LPUE/biomass relationship	49056
ß	LPUE/biomass relationship	102.8

1 Hart, D.R. In press.
2 Based on observations from Caddy 1973.
3 Based on observations from Murawski and Serchuk 1989.

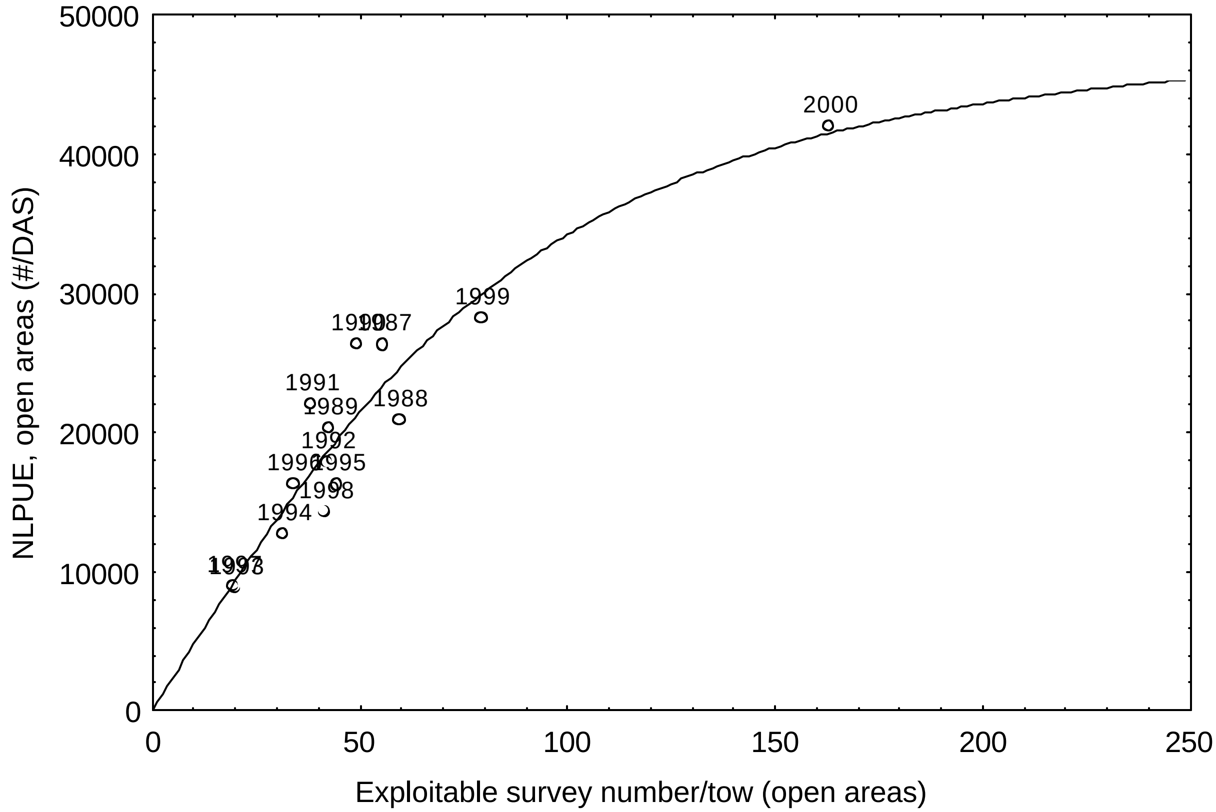


Figure 1. LPUE/biomass relationship

Table 2. **Mean and covariance of area specific log-transformed recruitment**

Mid-Atlantic

Subarea	mean	cov(1)	cov(2)	cov(3)	cov(4)	cov(5)	cov(6)	cov(7)	cov(8)	cov(9)
1	4.05	1.3	0.95	0.46	0.43	0.39	0.13	-0.02	0.08	-0.39
2	4.32	0.95	1.2	0.63	0.57	0.53	0.35	0.25	0.26	-0.21
3	4.22	0.46	0.63	0.50	0.40	0.40	0.19	0.11	0.17	0.03
4	4.05	0.43	0.57	0.40	0.83	0.52	0.32	0.35	0.37	0.19
5	4.19	0.39	0.53	0.40	0.52	0.70	0.45	0.35	0.32	0.24
6	4.36	0.13	0.35	0.19	0.32	0.45	0.52	0.38	0.30	0.17
7	4.03	-0.02	0.25	0.11	0.35	0.35	0.38	0.43	0.33	0.24
8	3.43	0.08	0.26	0.17	0.37	0.32	0.30	0.33	0.36	0.25
9	2.65	-0.39	-0.21	0.03	0.19	0.24	0.17	0.24	0.25	0.93

Georges Bank

	mean	cov(1)	cov(2)	cov(3)	cov(4)	cov(5)	cov(6)	cov(7)	cov(8)	cov(9)	cov(10)	cov(11)	cov(12)	cov(13)	cov(14)
1	2.35	2.7	0.50	0.54	0.20	-0.04	-0.18	-0.24	0.12	0.13	0.53	0.03	0.06	1.8	-0.03
2	5.48	0.50	1.0	0.15	0.03	-0.12	-0.07	-0.16	-0.19	0.36	0.10	0.10	0.01	0.26	-0.20
3	3.94	0.54	0.15	0.57	0.24	0.37	0.01	0.37	0.11	-0.01	0.13	-0.09	0.24	0.34	0.13
4	3.21	0.20	0.03	0.24	0.42	0.42	0.02	0.46	0.21	0.28	-0.11	0.26	0.05	0.19	0.39
5	2.39	-0.04	-0.12	0.37	0.42	0.97	0.18	0.95	0.06	0.39	-0.09	-0.22	0.24	0.02	0.45
6	3.34	-0.18	-0.07	0.01	0.02	0.18	0.89	0.09	0.06	0.83	0.12	-0.11	0.37	-0.11	0.23
7	3.42	-0.24	-0.16	0.37	0.46	0.95	0.09	1.3	-0.01	0.11	-0.14	-0.19	0.19	-0.09	0.45
8	2.41	0.12	-0.19	0.11	0.21	0.06	0.06	-0.01	1.5	0.06	-0.16	-0.17	0.09	0.12	1.49
9 (CAII-acc)	4.38	0.13	0.36	-0.01	0.28	0.39	0.83	0.11	0.06	2.0	-0.03	-0.02	-0.09	-0.04	0.33
10 (CAII-na)	3.66	0.53	0.10	0.13	-0.11	-0.09	0.12	-0.14	-0.16	-0.03	0.53	-0.12	0.19	0.32	-0.21
11 (CAI-acc)	3.06	0.03	0.10	-0.09	0.26	-0.22	-0.11	-0.19	-0.17	-0.02	-0.12	2.0	0.07	0.41	-0.19
12 (CA1-na)	4.94	0.06	0.01	0.24	0.05	0.24	0.37	0.19	0.09	-0.09	0.19	0.07	1.0	0.20	0.43
12 (NLS-acc)	4.03	1.8	0.26	0.34	0.19	0.02	-0.11	-0.09	0.12	-0.04	0.32	0.41	0.20	1.3	0.10
14 (NLS-na)	2.56	-0.03	-0.20	0.13	0.39	0.45	0.23	0.45	1.5	0.33	-0.21	-0.19	0.43	0.10	1.9

2.0 Essential Fish Habitat Analysis Methods

2.1 Introduction

The EFH analysis first evaluated the gears used in the scallop fishery, and determined which species had EFH that was adversely impacted by scallop fishing. The adverse impacts determination was based on a review of fishing gear effects literature relevant to the U.S. Northeast region, and the vulnerability of each species EFH to bottom tending gears. In order to evaluate the vulnerability of benthic EFH to bottom tending gear, a matrix was developed that qualitatively assessed six criteria such as the dependence of a particular species on bottom habitat for reproduction, shelter, food, and spawning behavior. Once the list of species with vulnerable EFH was identified, the various alternatives developed to minimize the impacts of scallop fishing on EFH of adversely impacted species were assessed. Many of the alternatives designed to minimize the adverse impacts of fishing on EFH include closed areas for EFH protection. Section ???, details the methods used in comparing the closed area alternatives, while Sections 2.1.1 through 2.1.5 describe the overall approach used in the EFH analyses within Amendment 10.

2.1.1 Gear Descriptions

Specifically, to describe gears, information from the NMFS VTR database and an ASMFC gear report was used. The primary source of information for gear descriptions was the EFH Omnibus Amendment (1998). Additionally, gear descriptions are provided using the Northeast Regional EFH Steering Committee's 2002 report from the Gear Effects Workshop in addition to several articles published in peer reviewed journals. See Appendix VI for a detailed description of all the fishing gears used in the Northeast region.

2.1.2 Distribution of Fishing Activity by Gear

The data used to perform this analysis were extracted from vessel trip report and clam logbook databases maintained at the U.S. National Marine Fisheries Service (NMFS) Northeast (NE) Regional Office in Gloucester, MA. Days absent calculations for trawl and dredge vessels are clearly preferable to simply summing the number of trips, but over-estimate actual fishing time since they include travel time and any other non-fishing-related activity while vessels are away from port. Thus, the GIS plots and analyses presented here do not represent fishing effort. They were only used to indicate the relative, not the absolute, distribution of fishing activity by geographical area and sediment type. Toward this end, all GIS input data were compiled and sorted into three categories: low, medium, and high degrees of activity that corresponded to cumulative percentages of 90, 75, and 50% of the total number of days at sea, or days spent fishing for each gear type during the seven-year time period. Data reported from ten minute squares (TMS) south of Cape Hatteras, North Carolina (35° N) and north of 45° N latitude in the Gulf of Maine were excluded from analysis, as were TMS-binned data from the low end (cumulative percentages >90%) of the frequency distribution. Exclusion of "low end" data (TMS with only a few trips or days) eliminated a large number of spatially misreported trips from analysis. Also included in this section are GIS plots of fishing activity for scallop dredge vessels operating in the limited access fishery during 1998, 1999, and 2000 which were derived from vessel monitoring systems (VMS) placed aboard each vessel. These plots provide a much more detailed depiction of fishing activity for dredge vessels during these three years than VTR data since they are collected at much higher spatial and temporal resolutions. Data were collected at 20-minute intervals during the time when vessel speed was less than 5 knots in order to differentiate between fishing activity and steaming time and then binned into one nautical mile squares. It is recognized that fishing activity includes other activities besides dredging, e.g., shucking time.

2.1.3 Types of Gear Effects

A number of authors have reviewed, to varying extents, existing scientific literature on the effects of fishing on habitat (e.g., Auster et al. 1996, Cappo et al. 1998, Collie 1998, Jennings and Kaiser 1998, Rogers et al. 1998, Auster and Langton 1999, Hall 1999, Collie et al. 2000, Lindeboom and de Groot 2000, Barnette 2001, National Research Council 2002). The conclusions reached by these authors is extracted from a recent NOAA report (Johnson 2002). A number of review papers have focused specifically on the physical effects of bottom trawls (e.g. ICES 1973). A working committee of the International Council for the Exploration of the Seas (ICES) issued, in November 2000, a report on the "Effects of Different Types of Fisheries on North Sea and Irish Sea Benthic Ecosystems." This report (ICES 2000) was a summary of findings based on a comprehensive report of the same title edited by Lindeboom and de Groot (1998). Alteration of physical structure, sediment suspension, changes in chemistry, and changes to benthic community are documented and described in the FEIS using peer reviewed literature and two reports (NRC and Gear Effects Workshop).

A Review of Fishing Gear Effects Literature Relevant to the U.S. Northeast Region was conducted and included in the FEIS that included the review of forty-four publications. They included all known studies (written in English) that examined the effects of the three principal mobile, bottom-tending fishing gears used in the Northeast U.S. on benthic marine habitats. Only publications that evaluated the direct habitat effects of fishing by these gears were reviewed (i.e., modifications to the physical structure of the seafloor or effects on benthic organisms that live in or on the seafloor). Effects of fishing on resource populations were not included, nor were studies that evaluated the indirect effects of fishing on marine ecosystems caused by the selective removal of species targeted by the gear or which are caught incidentally (as by-catch) during fishing. Both peer-reviewed and non-peer-reviewed publications were included, but most were peer-reviewed. To be included, accounts of research projects had to be complete and describe methods and results. Abstracts and poster presentations were not included. The summaries in this document are, in all cases, based on primary source documents. Two bottom-tending mobile gear types that are widely used in other parts of the world, but not in the Northeast U.S. – beam trawls and toothed scallop dredges – were not included even though considerable research has been conducted on their habitat effects. Also excluded were studies done on the effects of other gear types used strictly in inshore state waters in habitats where sea scallops are not found (e.g., escalator dredges in submerged aquatic vegetation) and any research relating to fixed and pelagic gear effects.

2.1.4 Vulnerability of Benthic EFH to Bottom-Tending Fishing Gears and Adverse Impacts Determinations

To evaluate the vulnerability of benthic EFH to bottom-tending fishing gears, information used included: 1) the EFH designations adopted by the NEFMC and MAFMC; 2) the results of a fishing gear effects workshop convened in Fall 2001 (NEREFHSC 2002); 3) an evaluation of the information provided in this gear effects evaluation section of this document, including the effects of fishing gear on habitat from existing scientific studies, and the geographic distribution of fishing gear use in the Northeast Region; and 4) the habitats utilized by each species and life stage as indicated in their EFH designation and supplemented by other references. A matrix (was developed for each benthic life stage for each species to determine the vulnerability of its EFH to effects from bottom tending mobile gear. Six criteria were qualitatively evaluated for each life stage based upon existing information. Each evaluation consisted of a score based upon a predefined threshold. The methods that were used to rank vulnerability were subject to a peer review by the NMFS Northeast Fisheries Science Center's review process for publications. The thresholds for adverse impact determinations were developed and reviewed by the Council's Essential Fish Habitat Technical Team. The adverse impact determinations are based on conclusions in the Gear Effects Evaluation in Section **Error! Reference source not found.**??? and is substantiated by two recent reports. The first of these (NREFHSC 2002) is the report of a workshop held in October 2001 that examined the habitat effects of gears used in the Northeast region on three substrate types (gravel, sand, and mud). The second report (Morgan and Chuenpagdee 2003) evaluated the effects of ten different commercial fishing gears on marine ecosystems in U.S. waters.

2.1.5 Minimizing Adverse Effects of Fishing on EFH

From the vulnerability analysis, it was determined that the EFH of some species in the region may be adversely impacted from scallop fishing. Thus, alternatives were developed in Amendment 10 to minimize, to the extent practicable, the adverse impacts of scallop fishing on EFH. Many of the alternatives designed to minimize the adverse impacts of fishing on EFH include closed areas for EFH protection. These alternatives were evaluated using a strategy developed by the Habitat Technical Team of the New England Fishery Management Council. Using the best available science for the entire region, the habitats within the management area were described. More specifically, the amount of various sediment types, the aerial extent of EFH designations, and biomass indices for various species were analyzed using several sources of data and methods (See Appendix IV for a detailed description of the methods used in the habitat evaluation). All of the data were analyzed using GIS, a mapping program that enables data to be analyzed geographically.

The sediments inside each alternative were evaluated based on a digitized US Geological Survey map (Poppe et al, published in 1986 and 1989), which is the only source of sediment data available that includes the entire management area. The amount and percent coverage of bedrock, gravel, gravelly sand, sand, muddy sand, and mud bottoms in each area was described. The amount and percent coverage of EFH area in square nautical miles was calculated for species with EFH vulnerable to bottom tending gear. EFH area was calculated as the number of square nautical miles included in designated ten-minute squares of longitude and latitude, as defined in the EFH Omnibus Amendment (1998) and other sources. Lastly, the Habitat Technical Team identified several trophic guilds, species assemblages, and individual benthic species that are indicators of the ecosystem characteristics of each proposed habitat closed area. Biomass data were obtained from the 1995-2001 NMFS bottom trawl survey data. As illustrated in the document, there are limitations to each of these data sets and methods, however the Council has used the best available science to describe the affected environment and evaluate the potential habitat impacts from the various alternatives under consideration.

2.2 Analytical Methods Used to Compare Closed Area Options

The NEFMC Habitat Technical Team has identified five metrics that describe habitat attributes of the closed area alternatives. These are:

1) substrate composition for six sediment types,
2) Essential Fish Habitat (EFH) for 23 species that are vulnerable to habitat disturbance by bottom-tending fishing gear,
3) biomass of five trophic guilds (species with similar diets),
4) biomass of five species aggregations,
5) biomass of six species that are closely associated with benthic environments.

All five habitat metrics were analyzed in terms of percentage composition within each proposed closed area and within the entire Northeast region (North Carolina to Maine). In addition, EFH area values were scaled for differences in area between alternatives.

In order to determine the percent of sediment, EFH, or biomass contained within each closed area alternative, a denominator had to be identified. For this analysis, the Northwest Atlantic Analysis Area (NAAA) was defined as the area within the 500 fathom line to the east, the coastline (including state waters) to the west, the Hague line to the north, and the North Carolina/ South Carolina border to the south (Figure 1). Although federal fishery management plans cannot close areas in state waters, it is important to include the area and habitat characteristics of the nearshore coastal waters in the calculations in order to more accurately evaluate the proposed area closures. The total area of the NAAA was determined to be 83,550 nmi^2.

Figure 2. Map of the Northwest Atlantic Analysis Area with sediment data (Poppe et al., 1989 and 1994).

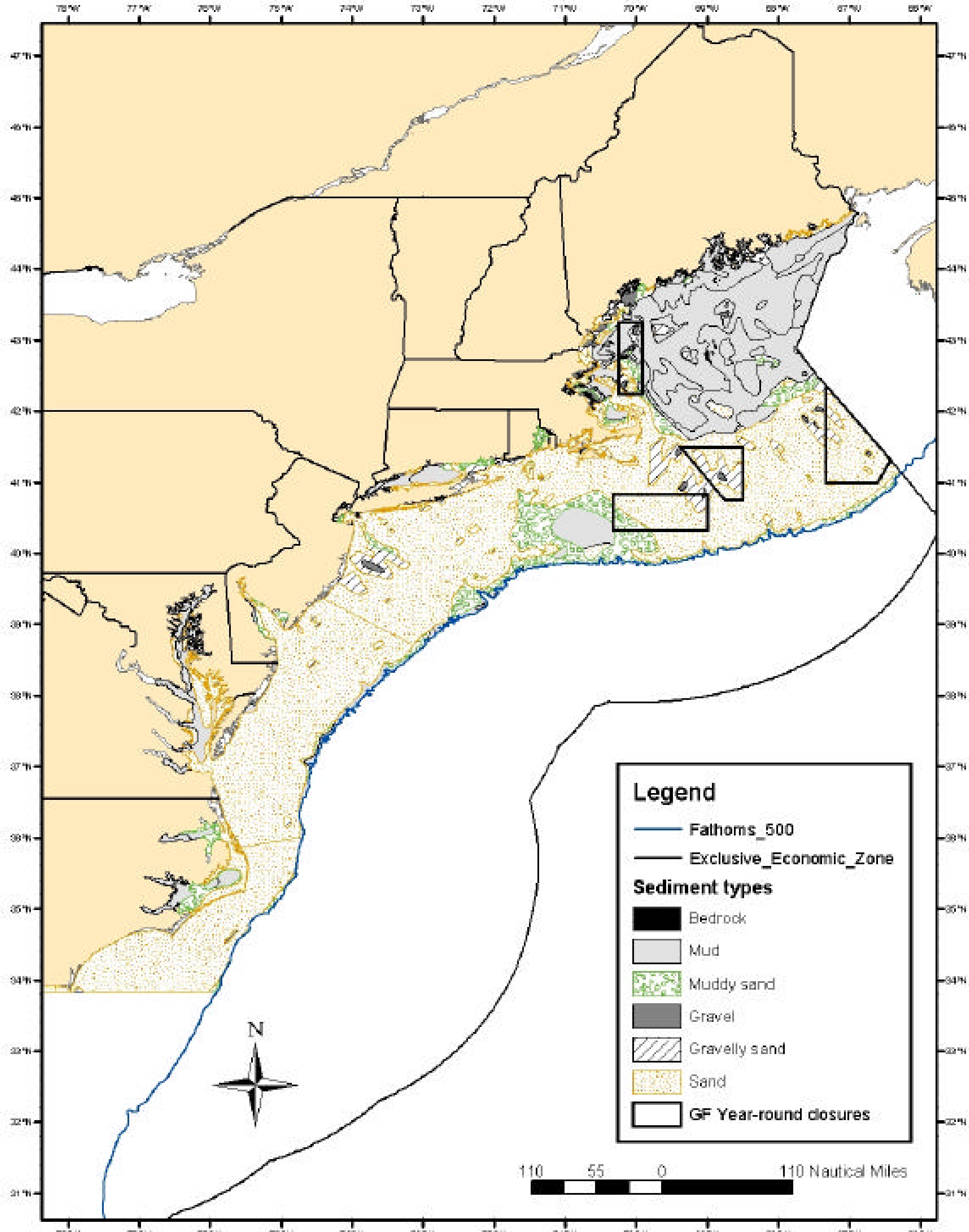
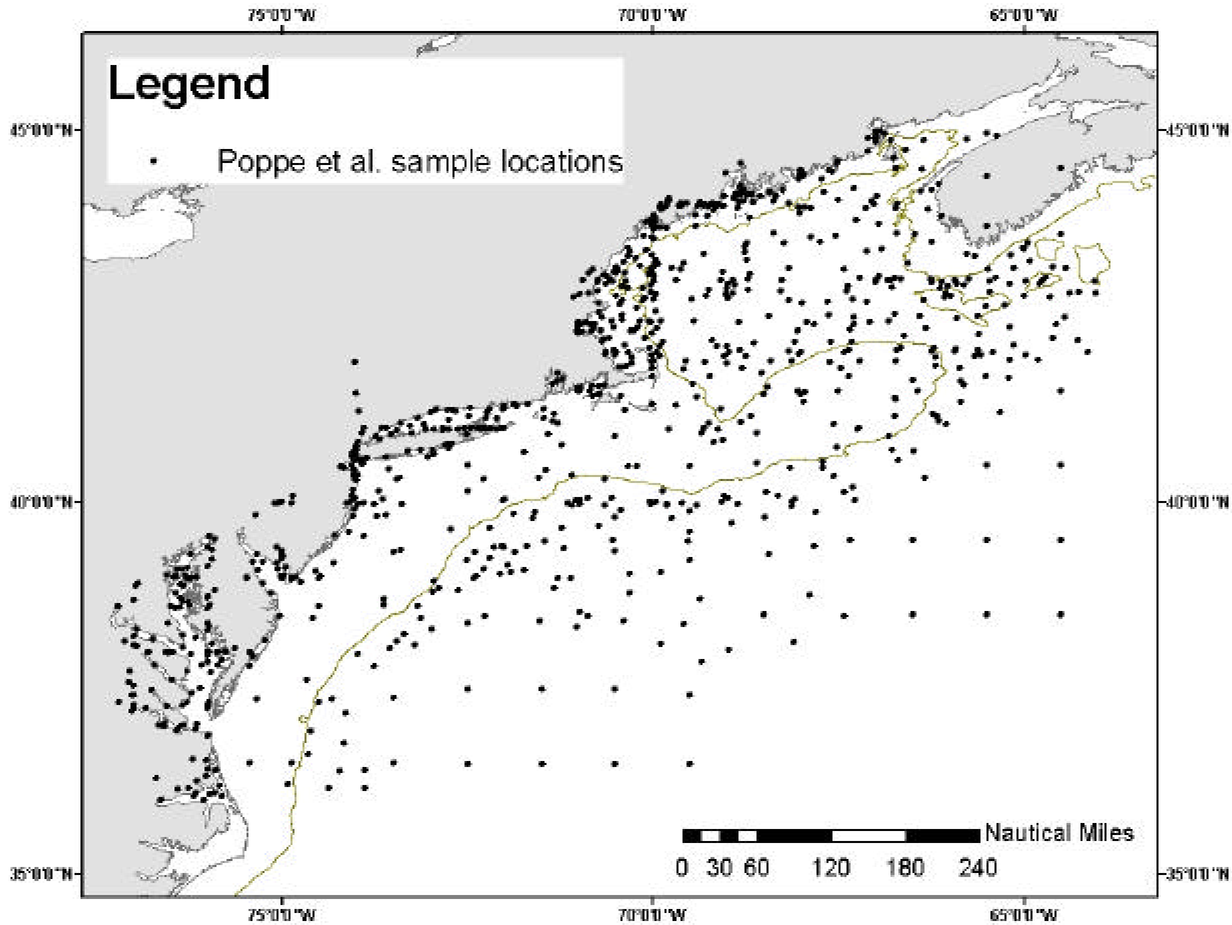


Figure 2. Sample locations used to generate Poppe et al. sediment map.



2.2.1 Sediments

Sediment data were analyzed in two different ways. First, the distribution of sediment types contained within each alternative was calculated. This analysis depicts the percent sediment composition of each closed area alternative. The second component of the sediment analysis determined the percent of each sediment type within each proposed closed area compared to the total amount of each sediment type in the Northwest Atlantic Analysis Area (see Figure 1).

Sediment data (in nmi^2) were derived from digitized maps of sediment coverage originally developed by Poppe et al. (1989, 1994) and made available by the U.S. Geological Survey (Figure 1). Sediment types were originally classified into nine distinct grain size categories ranging from clay to bedrock. For simplicity, these nine sediment categories were condensed into six (based on a recommendation from the Habitat Technical Team). The six categories used for analysis are: bedrock, gravel, gravelly sand, sand, muddy sand, and mud. Note that the geographic coordinates and areas (latitude, longitude or square decimal degrees) were based on the World Geodetic System of 1984 (WGS84), and the projected coordinates and areas (meters or nmi^2) were derived from the Universal Transverse Mercator, Zone 19 North Projection (UTM, Zone 19N). Areas covered by each sediment type within the NWA Analysis Area and within each proposed closed area were calculated using ArcView 8.1 GIS software (ESRI).

The digitized map is based on a limited number (975) of sample points, especially in offshore areas (see Figure 2) and does not accurately depict small-scale sediment distributions. The following explanation of how the maps were originally developed and their limitations was provided by the USGS:

"Bathymetry is used as a guide in placing some of the contacts between different sediment types. However, because the true boundaries between sediment types are probably highly irregular or gradational, because the extreme textural variability that characterizes some areas does not appear at this scale, and because the accuracy of the navigational systems used during the earlier studies is limited, all contacts should be considered to be inferred. In summary, the CONMAP series is old and does not accurately depict small-scale sediment distributions. This data layer is supplied primarily as a gross overview and to show general textural trends."

Additional sediment data are available in an up-dated and enlarged USGS database and have been "mapped" as point data, but they have not yet been combined with the older CONMAP data to produce a new contoured map of sediment distribution.

2.2.2 Essential Fish Habitat

Essential Fish Habitat (EFH) has been designated for life stages of 39 species in the NAAA by the New England and Mid-Atlantic Fishery Management Councils (Table 1). (Note that Atlantic salmon has been left out of the table because there are no abundance data available for this species). Each species and life stage has a written, legally-binding definition of EFH and the EFH area of most species has been delineated based on their abundance from annual stock assessment surveys in the region.

Table 1 - Species with EFH designations in the region

Species	Council	Species	Council
Atlantic cod	NE	Barndoor skate	NE
Haddock	NE	Clearnose skate	NE
Atlantic herring	NE	Little skate	NE
Monkfish	NE	Rosette skate	NE
Ocean pout	NE	Smooth skate	NE

American plaice	NE	Thorny skate	NE
Pollock	NE	Winter skate	NE
Red hake	NE	Tilefish	MA
Redfish	NE	Black sea bass	MA
Sea scallop	NE	Scup	MA
White hake	NE	Summer flounder	MA
Whiting (Silver Hake)	NE	Quahogs	MA
Windowpane flounder	NE	Surf clams	MA
Winter flounder	NE	Dogfish	MA
Witch flounder	NE	Bluefish	MA
Yellowtail flounder	NE	Butterfish	MA
Atlantic halibut	NE	Illex squid	MA
Red crab	NE	Loligo squid	MA
Offshore hake	NE	Mackerel	MA

For most species in New England and the Mid-Atlantic, EFH has been mapped for each species and life stage by individual ten-minute squares (TMS) of latitude and longitude. The amount (or percent) of EFH area occupied by EFH-designated TMS (or portions thereof) provides a useful tool for comparing the EFH value of closed area alternatives. Although EFH data for all managed species in the NAAA was calculated, the EFH component of the habitat metric analysis only includes 23 species with at least one life history stage that has been identified as having EFH that is vulnerable to bottom tending gear(Table 2). The rationale for the individual vulnerability determinations can be found in the Gear Effects Evaluation section of this document. If a species was determined to be "highly" or "moderately" vulnerable to bottom tending gears (otter trawls, scallop dredges, or clam dredges) then it was included in the EFH component of the habitat analysis. EFH area values for each vulnerable species and life stage were adjusted to account for differences in the size of the closed area alternatives by dividing EFH area in square nautical miles by the area of each proposed closed area (nmi^2). It is important to note that the legal EFH designation for many species is slightly larger than the EFH area used in this analysis. This analysis used the total EFH area within the NAAA, so it does not include the area of EFH within inshore bays and rivers. The inshore boundary of the EFH analysis, as well as the sediment and biomass analysis, is the coastline from Maine to North Carolina, thus inshore waters are not included.

Table 2 - List of species and life stages with EFH defined as "vulnerable" to bottom tending fishing gear (see Gear Effects Evaluation)

American Plaice (A)	Red Hake (A)
American Plaice (J)	Red Hake (J)
Atlantic Cod (A)	Redfish (A)
Atlantic Cod (J)	Redfish (J)
Atlantic Halibut (A)	Rosette Skate (A)
Atlantic Halibut (J)	Rosette Skate (J)
Barndoor Skate (A)	Scup (J)
Barndoor Skate (J)	Silver Hake (J)
Black Sea Bass (A)	Smooth Skate (A)
Black Sea Bass (J)	Smooth Skate (J)
Clearnose Skate (A)	Thorny Skate (A)
Clearnose Skate (J)	Thorny Skate (J)
Haddock (A)	Tilefish (A)
Haddock (J)	Tilefish (J)
Little Skate (A)	White Hake (J)
Little Skate (J)	Winter Flounder (A)
Ocean Pout (A)	Winter Skate (J)
Ocean Pout (E)	Winter Skate(A)

Ocean Pout (J)	Witch Flounder (A)
Pollock (A)	Witch Flounder (J)
	Yellowtail Flounder (A)
	Yellowtail Flounder (J)

2.2.3 Trophic Guilds

A guild is defined by Root (1967) as 'a group of species that exploit the same class of environmental resources in a similar way' and explicitly focuses on classifying species based upon their functional role in a community without regard to taxonomy. The guild is used to simplify the structure and dynamics of complex ecosystems regardless of the mechanism generating resource partitioning. Guild members play similar functional roles within ecosystems. In other words, a species guild is a group of species defined by their role within the ecosystem. In our analysis, we focused on guilds as determined by dietary similarity (determined from the stomach contents of species brought up in the trawl surveys).
Cluster analysis (based on Garrison 2000) was used to define trophic guilds found in the Northwest Atlantic Analysis Area (NAAA). The general guild structure and levels of dietary overlap are consistent across both temporal and spatial scales. Complementary analyses to the current study within the Georges Bank region identified similar trophic guilds and general stability in the trophic guild structure over the last three decades. Despite the notable changes in species composition in the Northeast shelf fish community, the patterns of trophic resource use and guild structure have remained remarkably consistent.

Five trophic guilds were identified for this analysis: benthivores, amphipod eaters, planktivores, piscivores, and shrimp and fish eaters (Table 3 – Table 7). The species and size ranges used for these guilds are delineated in the tables below.

Table 3 – List of species and species' sizes in the benthivore guild.

Benthivores	**Size**
HADDOCK	All
THORNY SKATE	S,M
YELLOWTAIL FLOUNDER	M,L
WINTER FLOUNDER	All
GULF STREAM FLOUNDER	All
WITCH FLOUNDER	All
SCUP	All
AMERICAN PLAICE	All
ATLANTIC CROAKER	All
OCEAN POUT	All

Table 4– List of species and species' sizes in the amphipod eater's guild.

Amphipod eaters	**Size**
FAWN CUSK-EEL	All
LONGHORN SCULPIN	All
WINDOWPANE	All
ATLANTIC COD	S,M
WINTER SKATE	S,M
LITTLE SKATE	S,M
RED HAKE	S,M
SPOTTED HAKE	S
WHITE HAKE	S
FOURSPOT FLOUNDER	S

YELLOWTAIL FLOUNDER	S

Table5– List of species and species' sizes in the planktivore guild.

Planktivores	**Size**
NORTHERN SAND LANCE	All
ATLANTIC HERRING	All
BUTTERFISH	All
ATLANTIC MACKEREL	All
ALEWIFE	All
SPINY DOGFISH	S,M
NORTHERN SHORTFIN SQUID	L
LONGFIN SQUID	All

Table 6 – List of species and species' sizes in the Piscivore guild.

Piscivores	**Size**
SPINY DOGFISH	L
SEA RAVEN	All
GOOSEFISH	All
BLUEFISH	All
WEAKFISH	All
SUMMER FLOUNDER	All
SPOTTED HAKE	M
ATLANTIC COD	L,XL
FOURSPOT FLOUNDER	M
SILVER HAKE	L
WHITE HAKE	L
THORNY SKATE	L,XL
WINTER SKATE	L,XL

Table 7 – List of species and species' sizes in the shrimp and fish eater's guild.

Shrimp and Fish Eaters	**Size**
POLLOCK	All
SILVER HAKE	S,M
ACADIAN REDFISH	All
WHITE HAKE	M
RED HAKE	L
SMOOTH SKATE	All

All biomass data were compiled as summed mean weights per tow (in kg) from all the tows made in each ten minute square (or portion of a square) in each proposed closed area during all NEFSC bottom trawl surveys during 1995-2001. Percentage biomass data were calculated as the ratio of the summed mean weight per tow in each proposed closed area over the total mean weight per tow for each guild in the entire NAAA.

2.2.4 Species Assemblages

Assemblages are groups of species that co-occur spatially and vary by season and by area. Certain species co-occur with others in certain areas, but do not in other areas; the same can be said for seasons/time. Each assemblage was based on co-occurrence without regard for season or time.

Cluster analysis (based on Garrison and Link 2000, Gabriel 1992) was used to define spatial-temporal assemblages (*i.e.*, principal groundfish, principal pelagics, demersals, pelagics and elasmobranchs) found in the NAAA. Species that are included in each of these assemblages are delineated in the table below. With one exception (Atlantic mackerel), all the species in the first four assemblages are unique to those groups; nineteen of the 71 species included in the demersal assemblage also occur in one of the other groups. Biomass data were compiled for each of these assemblages in the same manner as for the other biomass metrics.

Table 8 – List of species belonging to each of the spacio-temporal assemblages.

Elasmobranchs	Principle Groundfish	Pelagic Species	Principle Pelagics
SPINY DOGFISH	ATLANTIC COD	ROUND HERRING	ATLANTIC HERRING
BARNDOOR SKATE	HADDOCK	CAPELIN	ATLANTIC MACKEREL
WINTER SKATE	ACADIAN REDFISH	ATLANTIC SILVERSIDE	
CLEARNOSE SKATE	SILVER HAKE	ATLANTIC MACKEREL	
ROSETTE SKATE	RED HAKE	BUTTERFISH	
LITTLE SKATE	POLLOCK	BLUEFISH	
SMOOTH SKATE	YELLOWTAIL FLOUNDER	WEAKFISH	
THORNY SKATE	SUMMER FLOUNDER	NORTHERN SHORTFIN SQUID	
	WINTER FLOUNDER	LONGFIN SQUID	
	WINDOWPANE	BAY ANCHOVY	
	AMERICAN PLAICE	LANTERNFISH UNCL	

Demersal Species			
SMOOTH DOGFISH	BLUE HAKE	SEA RAVEN	SILVERSTRIPE HALFBEAK
SPINY DOGFISH	METALLIC CODLING	BLACK SEA BASS	SLENDER SNIPE EEL
BARNDOOR SKATE	FOURBEARD ROCKLING	ACADIAN REDFISH	FLAT NEEDLEFISH
WINTER SKATE	CUSK	TILEFISH	OFFSHORE HAKE
CLEARNOSE SKATE	ATLANTIC HALIBUT	NORTHERN SAND LANCE	ATLANTIC CROAKER
ROSETTE SKATE	AMERICAN PLAICE	STRIPED CUSK-EEL	SCUP
LITTLE SKATE	SUMMER FLOUNDER	ARCTIC EELPOUT	SPOT
SMOOTH SKATE	FOURSPOT FLOUNDER	WOLF EELPOUT	ATLANTIC SEASNAIL
THORNY SKATE	YELLOWTAIL FLOUNDER	WRYMOUTH	NORTHERN SEAROBIN
SILVER HAKE	WINTER FLOUNDER	ATLANTIC WOLFFISH	STRIPED SEAROBIN
ATLANTIC COD	WITCH FLOUNDER	OCEAN POUT	ARMORED SEAROBIN
HADDOCK	WINDOWPANE	FAWN CUSK-EEL	SEAROBIN UNCL
POLLOCK	GULF STREAM FLOUNDER	GOOSEFISH	FLYING GURNARD
WHITE HAKE	HOOKEAR SCULPIN	EEL UNCL	CUNNER

	UNCL		
RED HAKE	SCULPIN UNCL	HEADLIGHTFISH UNCL	TAUTOG
SPOTTED HAKE	MOUSTACHE SCULPIN	CONGER EEL	NORTHERN STARGAZER
LONGFIN HAKE	SHORTHORN SCULPIN	SNUBNOSE EEL	ROCK GUNNEL
HAKE UNCL	LONGHORN SCULPIN	MARGINED SNAKE EEL	

2.2.5 Individual Benthic Species

Six species (longhorn sculpin, sea raven, redfish, ocean pout, jonah crab and American lobster) were chosen by the Habitat Technical Team to use in the species component of the habitat metric analysis. These species were chosen for their close association with benthic habitats for both feeding and protection from predators. Just like the previous two biomass metrics, this analysis compared the percent of each species biomass inside the closed areas vs. the total biomass for that species in the entire Northwest Atlantic Analysis Area.

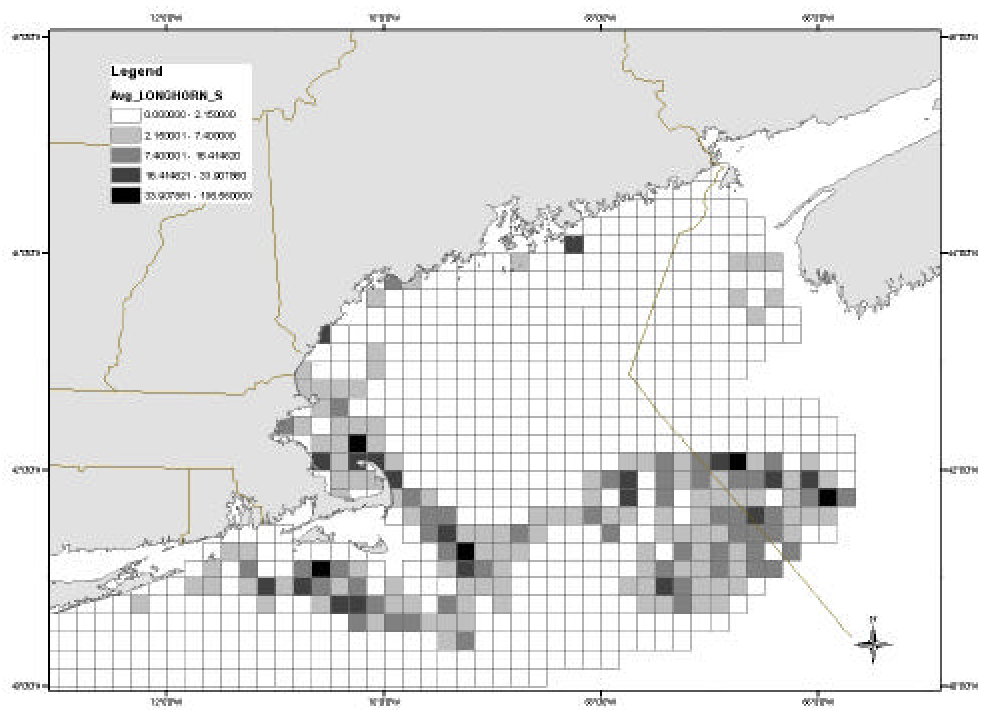


Figure 3 – Longhorn Sculpin mean wt (kg) per tow, 1995-2001 trawl surveys.

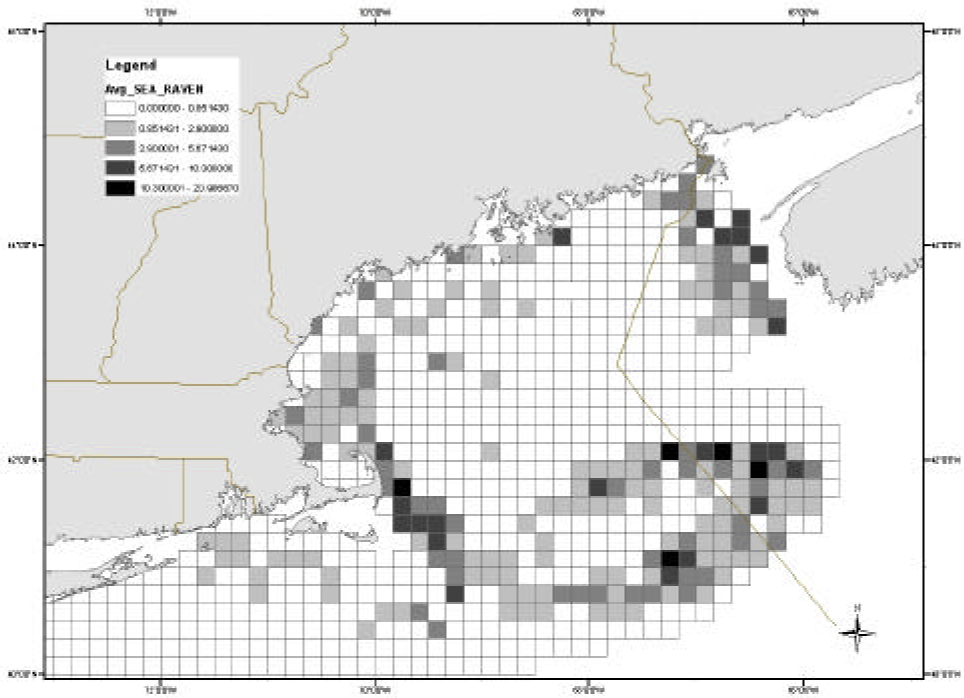


Figure 4 – Sea Raven mean wt (kg) per tow, 1995-2001 trawl surveys.

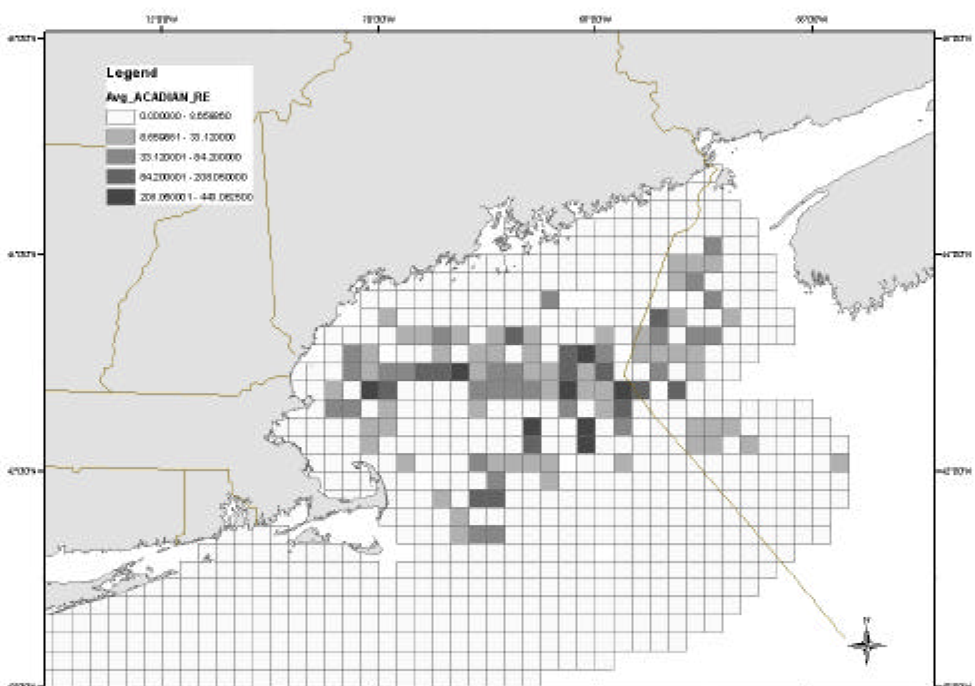


Figure 5 – Redfish mean wt (kg) per tow, 1995-2001 trawl surveys.

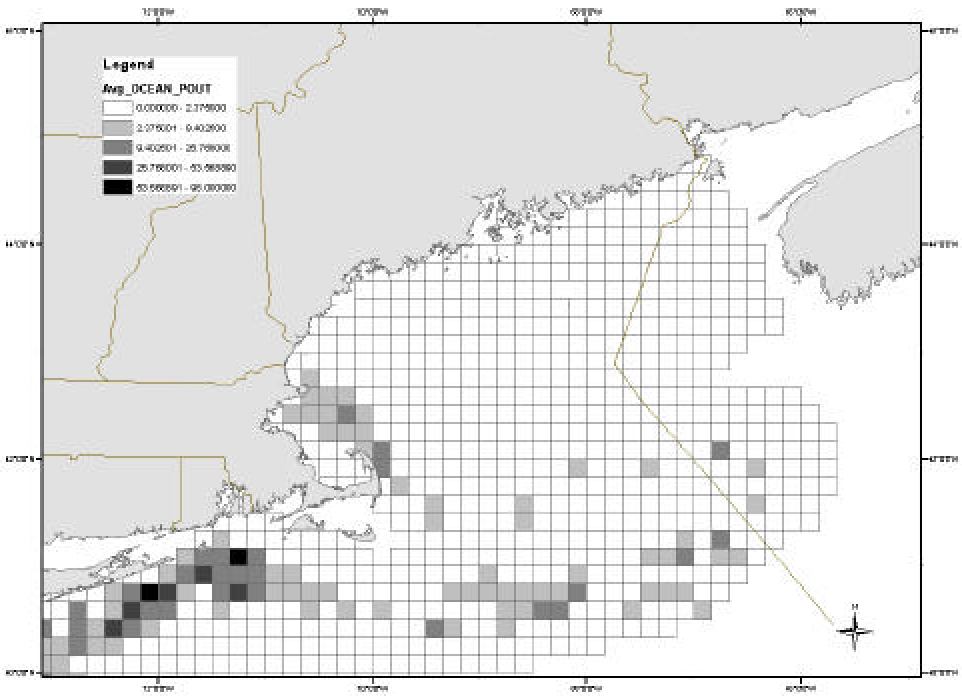


Figure 6 – Ocean Pout mean wt (kg) per tow, 1995-2001 trawl surveys.

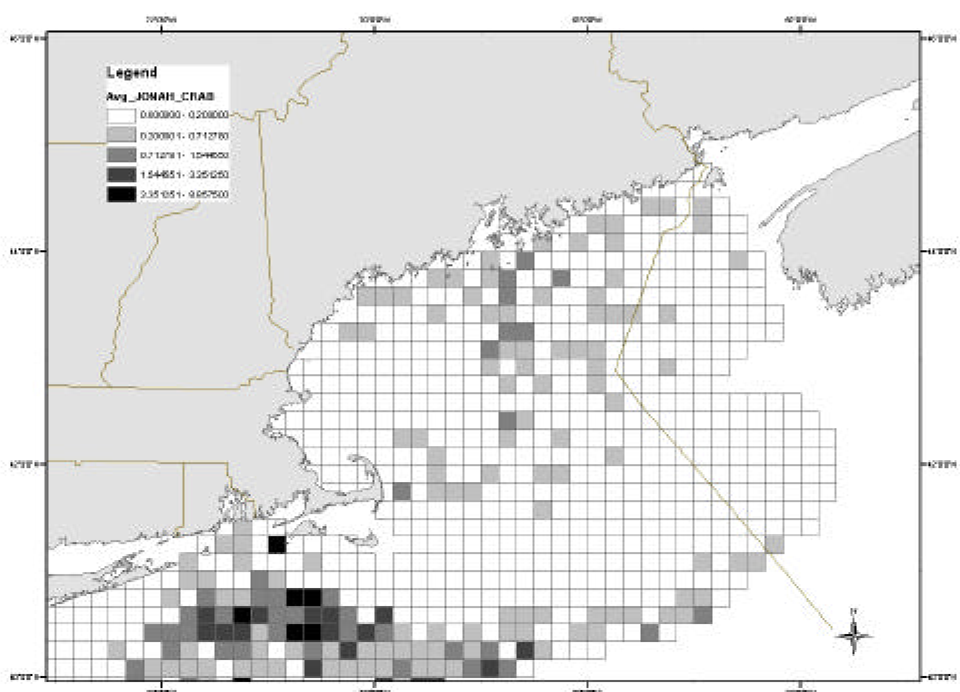


Figure 7 – Jonah Crab mean wt (kg) per tow, 1995-2001 trawl surveys.

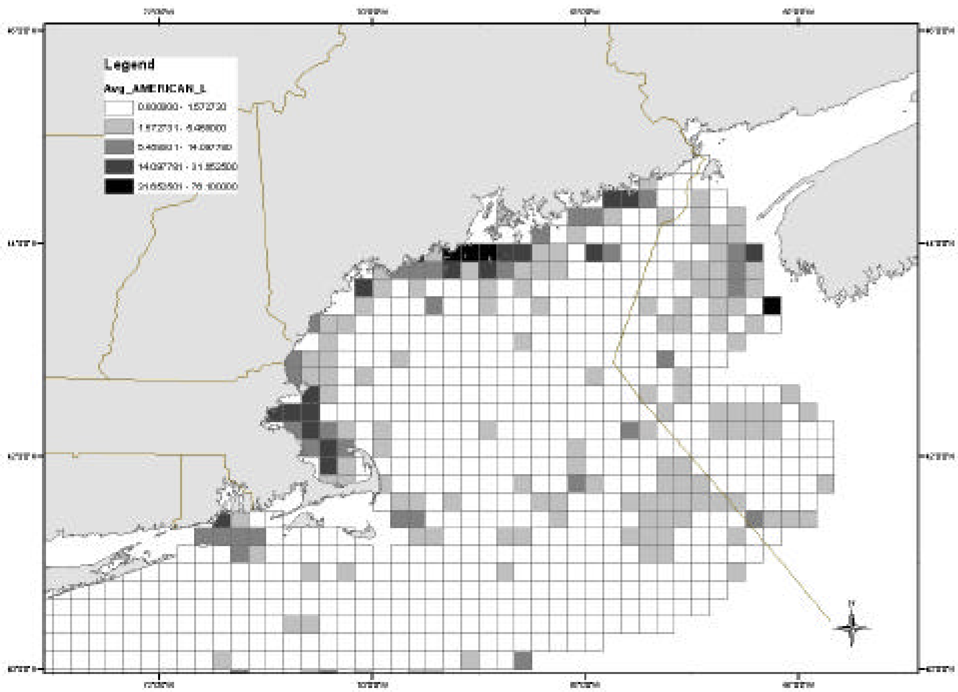


Figure 8 – American Lobster mean wt (kg) per tow, 1995-2001 trawl surveys.

ANALYTICAL METHODS USED TO IDENTIFY SOME OF THE HABITAT CLOSED AREA ALTERNATIVES (5A-D)

2.3 *Description of Working Group EFH Model to identify important habitat areas and consider productivity tradeoffs*

2.3.1 <u>Theoretical Background and Methods</u>

MacCall (1990) developed mathematical treatment of spatial population dynamics for marine fish populations. While doing so, he utilized and extended the population theory of density-dependent habitat selection which says that the marginal value of an animal's habitat is dictated not only by the physical and chemical characteristics of its environment, but also dictated by the competition for resources (food, refugia, etc.) with other individuals in the population. The realized habitat suitability of the individual is therefore affected by competition, predation, territoriality, and oceanographic/substrate conditions. MacCall (1990) postulates that individuals occupy habitats with the highest suitability to their survival and growth. It requires an assumption of an ideal free distribution where animals move, recruit to, or survive in response to marginal differences in their habitat and at higher population levels, occupy areas that would be less suitable at lower population size.

Extending the concept of density-dependent habitat suitability, originally developed by Fretwell and Lucas (1970), MacCall (1990) proposed a "Basin Model", relating habitat suitability to the intrinsic rate of population growth (r) and to population size as a function of the local carrying capacity (K) of the habitat (Figure 9). When at the carrying capacity (K) or high population size (Figure 9), the abundance distribution is affected by the fitness of the underlying habitat, but the population occurs at some level thorough its range. In an ideal free state, individuals are re-distributed such that the marginal habitat suitability due to competition is equal for all and all individuals contribute equally to the intrinsic rate of population growth (r). At lower population size, marginal habitats (outside the domain of B in Figure 9) become unoccupied. Thus at mean or low population size, the abundance distribution is proportional to the habitat value of an area to a population and to its intrinsic rate of growth (i.e. habitat is more valuable and productive to the species at location A than at locations B or other locations throughout the range). Thus, over a long time series, the mean abundance at any location is suitable as a proxy for the value of the habitat to a population.

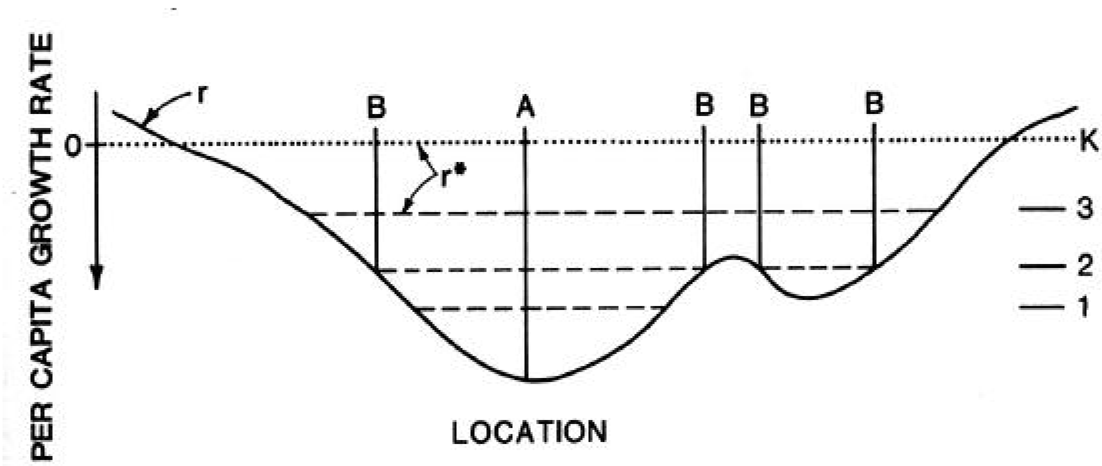


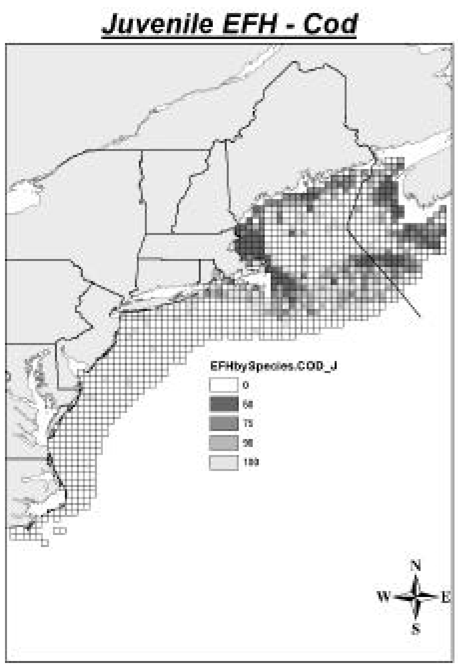
Figure 9. **Diagram of the "Basin Model", proposed by MacCall (1990), relating habitat suitability to the intrinsic rate of population growth (r) and to stock size as a proportion of carrying capacity (K).**

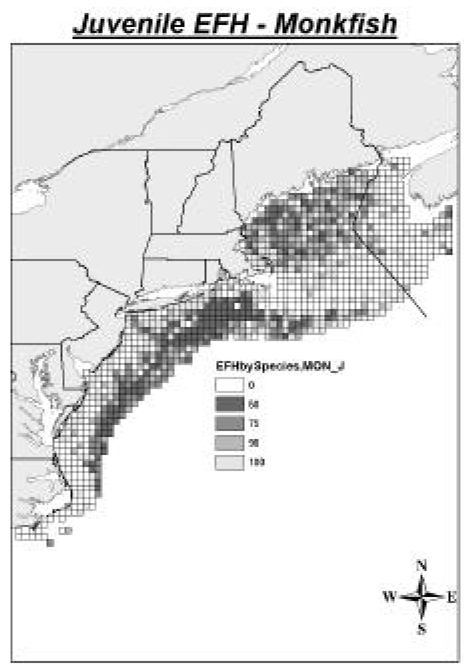
Garrison (2001) examined the spatial patterns of 27 finfish sampled by the bottom trawl survey on the NE US continental shelf (Azarovitz 1981). Although there were temporal changes in abundance and distributions, there was a strong fidelity to relatively stable faunal regions. Spatial ranges for many species however contracted at low population size (Atkinson *et al.* 1997, Wigley *et al.* 1996), often concentrating in areas having higher CPUE at high abundance (e.g. haddock in Garrison 2001).

The EFH designations in the Essential Fish Habitat amendments used median abundance data from 1963 to 1997 and were normalized with respect to differences in catchability between species (see explanation below). For each species, the abundance data was categorized by life stage (eggs, larvae, juvenile, adult) and binned by ten-minute square throughout the extensive range of the bottom trawl survey. This treatment made the data ideally suited for identifying candidate habitat closures by applying MacCall's (1990) Basin Model to the standardized abundance data in a GIS format (ArcView 8.1 for display and analysis; Minami 2000).

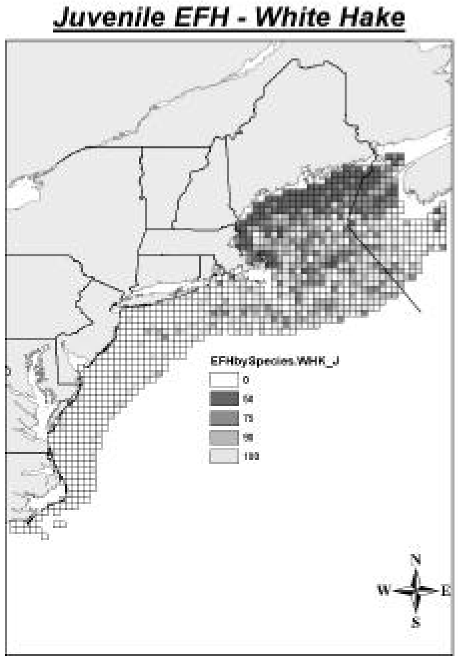
In preparation for the 1998 EFH amendment, the survey abundance data were post-stratified by ten-minute square and their geometric means were ranked for all ten-minute squares by species and life stage (eggs, larvae, juvenile, and adult). All ten-minute squares were assumed to be of equal size with a homogenous distribution of catches within a ten-minute square. Ranked from highest to lowest, a ten-minute square was designated as a '25th percentile' if the cumulative sum was less than 25% of the total summed catch, i.e. 25 percent of the total swept-area abundance for a species and life stage. By design, the squares with the highest catches therefore were often represented by much less than 25 percent of the area where a species occurred[4]. Ten-minute squares with the next 25 percent of the cumulative abundance were designated as the 50th percentile category, followed by 75th and 90th percentile categories. Finally, the EFH designations included a 100th percentile category that included all ten-minute squares where there was one or more observations during the 37 year time series, but did not contribute to more than 10 percent of the total swept area abundance.

This analysis produced maps of EFH designations by species (37) and life stage (4), producing 148 maps or data layers, with varying distributions that relate to the preferred habitats for each species. Some examples for four groundfish species [cod (Gadus morhua), monkfish (Lophius americanus), white hake (Urophycis tenuis), and yellowtail flounder (Limanda ferruginea)] are shown in Figure 10. These data, categorized by species, life stage, and EFH designation were assigned weights to account for the relative EFH value between ten-minute squares and for the association with sensitive, complex habitat for a given species and life stage.





4 A species with a uniform distribution would have 25 percent of the ten-minute squares designated as the 25th percentile, for example.



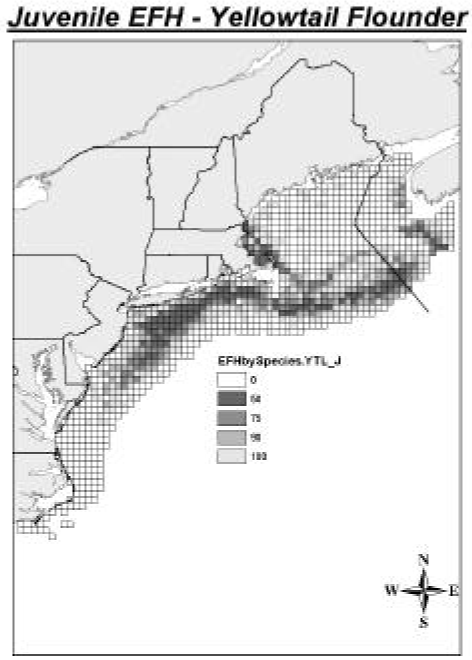


Figure 10. **Ten-minute square distributions of mean survey abundance (1963-1998) using juvenile cod, monkfish, white hake, and yellowtail flounder as examples.**

2.3.2 Enumerating EFH classifications as a proxy for habitat value

Utilizing the above percentile ranks as a starting point, ten-minute squares received an initial value based on Equation 1, where p = 50, 75, 90, and 100. This results a corresponding values of 25, 5, 1.9, and 1, respectively, reflecting a relative species/life-stage EFH index based on the abundance distributions. For this analysis, the 25th and 50th percentiles were combined into one category with an index value of 25. A subsequent sensitivity analysis was conducted, giving the 25th percentile an EFH index value of 125, but it did not materially change the eventual identification of the habitat closure areas. EFH index values using the 25th percentile were not used in the final analysis, because these rankings were unavailable for some species in the model.

Equation 1

$$5^{(100-p)/25}$$

EFH values by life stage were given unequal weight in the GIS framework to account for the stage's relationship with the bottom habitat that may be altered by fishing. Except for herring (Clupea harengus), eggs and larvae were given a zero weight and not included in the aggregate EFH value because these life stages for oceanic species are mostly pelagic and would be unaffected by bottom conditions. The EFH values for the juvenile life stage were given a weight of 4:1 relative to the adult life stage because:

- Juvenile life stage is generally more vulnerable to changes in bottom habitat
- Juvenile stage is the best metric of resource potential
- Juvenile stage generally favors an invertebrate diet, whereas adult stage tends to be piscivorous

- Adult distributions can vary due to fishing and management effects

The EFH values described above were furthermore given unequal weight in the GIS framework to account for the species association to habitat thought to be vulnerable to fishing effects and for the species management status. A working group of habitat experts and plan development team members determined which of the criteria were met by a species. This weighting factor ranged from zero to four, depending on how many of the following criteria were satisfied by the species included in the GIS framework.

- Association with bottom habitat that might be affected by fishing activities
  - i.e. does the species rely on bottom habitat for food, refuge, or another important ecological function?
- Vulnerability of bottom habitat to fishing activities
  - i.e. is there a potential conservation benefit for the habitat that is associated with the species?
- Stock status
  - i.e. is the species or stocks for that species depleted and considered overfished?
- Relative value to the fisheries
  - i.e. would there be a potential direct economic or social benefit to conserving EFH for the species?

These weights for each species in the analytic framework are shown in Table 3 under the “EFH factor weight” heading. Species with a weight of zero were not considered further in the analysis and did not contribute to the ten-minute square EFH value. These species with zero EFH value for the purposes of this analysis were either pelagic, ubiquitous over varied habitats, or both.

Table 3. **EFH and productivity data weights by species.**

Family	Species	Scientific name	EFH factor weight	EFH factor weight wo relative value	Fishery productivity weight
Clupeidae	Herring (eggs)	Clupea harengus	3	3	0
Gadidae	Cod	Gadus morhua	4	3	1
	Haddock	Melanogrammus aeglefinus	4	3	1
	Pollock	Pollachius virens	1	1	0
	Red hake	Urophycis chuss	2	2	0
	White Hake	Urophycis tenuis	3	2	0
Lophiidae	Monkfish (Goosefish)	Lophius americanus	4	3	1
Malacanthidae	Tilefish	Lopholatilus chamaeleonticeps	4	3	0
Mrrlucciidae	Whiting (Silver hake)	Merluccius bilinearis	2	1	2
Paralichthyidae	Summer flounder	Paralichthys dentatus	3	2	2
Pleuronectidae	American plaice	Hippoglossoides platessoides	4	3	3
	Halibut*	Hippoglossus hippoglossus	4	3	1
	Winter flounder	Pseudopleuronectes americanus	2	2	3
	Witch flounder	Glyptocephalus cynoglossus	3	3	3
	Yellowtail flounder	Limanda ferruginea	3	3	3
Pomatomidae	Bluefish	Pomatomus saltatrix	0	0	0
Rajidae	Skate, barndoor	Dipterus laevis	2	2	0
	Skate, clearnose	Raja eglanteria	0	0	0
	Skate, little	Leucoraja erinacea	0	0	0
	Skate, rosette	Leucoraja garmani virginica	1	1	0
	Skate, smooth	Malacoraja senta	1	1	0
	Skate, thorny	Amblyraja radiata	1	1	0
	Skate, winter	Leucoraja ocellata	0	0	0
Scombridae	Atlantic mackerel	Scomber scombrus	0	0	0
Scophthalmidae	Windowpane flounder	Scophthalmus aquosus	2	2	0
Scorpaenidae	Acadian redfish	Sebastes faciatus	4	3	1
Serranidae	Black sea bass	Centropristis striata	4	3	1
Sparidae	Scup	Stenotomus chrysops	2	2	2
Squalidae	Dogfish	Squalus acanthus	2	2	1
Stromateidae	Butterfish	Peprilus triacanthus	0	0	0
Zoarcidae	Ocean pout	Zoarces americanus	2	2	0
Loliginidae	Longfin squid	Loligo pealeii	0	0	2
Arcticidae	Ocean quahog	Arctica islandica	2	1	2
Geryonidae	Red crab	Chaceon quinquedens	0	0	0
Pectinidae	Scallops*	Placopecten magellanicus	2	1	0
Ommastrephida	Shortfin squid	Illex illecebrosus	0	0	0
Mactridae	Surf Clam	Spisula solidissima	2	1	3

Managers expressed concern that the EFH values for certain species were inappropriate because it included a weight for "Relative value to the fisheries". Although possible, no species received a weight of one solely due to this consideration and a sensitivity analysis was conducted with the weights listed in the next column of Table 3. These results did not make an appreciable difference in the distribution of aggregate EFH values for all species and life-stages.

The aggregate EFH value was calculated according to Equation 2 as the sum of the above weights multiplied by the EFH classification values for each species (37) and life-stage (juvenile and adult). These aggregate EFH values were plotted in ArcMap to allow visual inspection of the patterns to identify areas where closures might be most effective for protecting the habitat of a variety of species meeting the above criteria. Because these values were weighted, the distribution favors the highest abundance of juveniles for overfished species that are associated with vulnerable bottom habitats.

Equation 2

$$EFH_{TMS} = \sum_{p=50,75,90,100} g_p \left[\sum_{s=1}^{37} w_s \left(j * EFH_{j,s} + a * EFH_{a,s} \right) \right]$$

where: $EFH_{j,s}$; $EFH_{a,s}$ = Essential fish habitat values by ten-minute square, species, and life stage; averaged survey abundance over the 37-year time series for juveniles or adults

g_p = EFH value determined from Equation 1

w_s = EFH species weights given in Table 3

j, a = Life stage weight: 4 for juvenile data, 1 for adult data

EFH_{TMS} values were plotted using ArcMap to examine the distribution of the high valued ten-minute square and possibly identify areas that would efficiently conserve EFH for a variety of species. This distribution favors the juveniles of overfished species that are associated with vulnerable bottom habitats. Generally, the pattern shows the highest values along the inshore portions of the Gulf of Maine, along the South Channel region east of MA, in Southern New England south of RI, along the Hudson Canyon east of NJ, and along the outer shelf margin of the Mid-Atlantic region.

2.3.3 Productivity tradeoffs to account for practicality

The productivity by ten-minute square was calculated to estimate the relative cost of closing areas to protect habitat. Although individuals of some species will contribute to an export of recruits or adults from closed areas, closures potentially limit access to adult, harvestable portions of the resource. Areas with high productivity, or abundance of adult species, will tend to cost more to close than other areas given equal migratory, fishing cost, and other effects. The aggregate adult abundance data, classified into percentiles as for the EFH data above, were deemed an acceptable proxy for a more direct measure of geographic productivity. Except for sea scallops, a more direct measure of productivity was unavailable. Adult biomass, on the other hand, could be a better measure of the yield that might be harvestable from various areas, but the survey biomass data are biased by overfishing and historic exploitation patterns.

Even though the distribution of adult abundance might estimate the potential productivity of an area and its potential cost, various factors unique to each species influence whether the cost due to closure would be high or low. Similar to the criteria for EFH value, three criteria were developed to weight the influence of a species adult abundance on the overall distribution of 'productivity'. This weighting factor ranged from zero to three, depending on how many of the following criteria were satisfied by the species included in the GIS framework. Some species (e.g. whiting and longfin squid) had higher weights for productivity than for the EFH value (see "Fishery Productivity Weight" in Table 3).

- Whether the species can be caught by gear that would not be excluded by a habitat closure
    - i.e.. passive, fixed gears could substitute for a mobile, bottom tending gear that would be excluded
- Mobility of adults
    - i.e. would the individuals later become available to the fishery
- Relative value to the fisheries
    - i.e. prohibiting access to more valuable species would have a higher cost

Direct estimates of the distribution of sea scallop productivity were available by rotational management area, under consideration by managers. The long-term maximum yield had been estimated for rotation management based on estimated local recruitment, growth and realized size selection from area rotation and gear management (Hart 2003). These area estimates were distributed over the ten-minute squares within them according to Equation 3.

Equation 3. Ten-minute square sea scallop productivity.

$$P_{TMS} = \left(\frac{LTPY_{RMA} * \dfrac{i_{40-72,TMS}}{i_{40-72,RMA}}}{A_{TMS}} \right)$$

where: $LTPY_{RMA}$ = long-term potential yield for a rotation management area

$i_{40\text{-}72}$ = post-stratified index of abundance for 40 – 72 mm scallops
A_{TMS} = Area of ten-minute square (UTM projection)

Various combinations of productivity tradeoffs against aggregate EFH value were considered. The total productivity estimates, summed across species, were standardized by dividing their mean values into the mean aggregate EFH value (994.6 with four criteria weights; 799.8 with three criteria weights; see Table 4) for the 1104 ten-minute squares in the GIS framework, resulting in a set of productivity weight factors (Table 4). When subtracted from the aggregate EFH value from Equation 1, the net conservation value mean for all ten-minute squares was zero. Positive values meant that the closure of a ten-minute square would favor more EFH protection than it might cost by limiting access to adult finfish and shellfish. Negative values generally meant that a closure would protect fewer species' EFH and/or have a potentially high cost.

Equation 4

$$Q = \sum EFH_{TMS} - w_s P_s - w_g \sum_s EFH_{a,s}$$

Where: EFH_{TMS} = aggregate EFH species-weighted value for ten-minute square
P_s = long-term potential yield for sea scallops, when fished at Fmax
$EFH_{a,s}$ = aggregate, species-weighted EFH value for adult life stage
w_s = normalizing weight for sea scallop productivity
w_g = normalizing weight for standardized adult EFH distributions for groundfish and monkfish

Table 4. **Mean aggregate EFH and productivity values and productivity tradeoff weights used in** Equation 4**.**

Net conservation value (Q)	EFH value (4 factors; $\sum EFH_{TMS}$)	EFH value (3 factors; $\sum EFH_{TMS}$)	Groundfish productivity (w_1)	Groundfish productivity incl. scallops (w_s)	Sea scallop productivity (w_3; mt/nm^2)	Monkfish productivity (w_4)
Mean value in all ten-minute squares	994.6	799.8	120.2	128.5	3.325	6.137
Groundfish & Scallop (1:1)	1	0	4.137	0	149.6	0
Groundfish & Scallop (2:1)	1	0	5.516	0	99.71	0
Groundfish, scallop, & monkfish (1:1:1)	1	0	2.758	0	99.71	54.02
Groundfish & Scallop (1:1)	0	1	3.327	0	120.3	0
Groundfish incl. Scallop	0	1	6.624	0	0	0

3.0 Economic Model: Assumptions, Methodology, and Uncertainty

The economic model includes an ex-vessel price equation, a cost function and a set of equations describing the consumer and producer surpluses. The ex-vessel price equation is used in the simulation of the ex-vessel prices, revenues and consumer surplus along with the landings and average meat count from biological projections. The cost function is used for projecting harvest costs and thereby for estimating the producer benefits as measured by the producer surplus. The set of equations also include the definition of the consumer surplus, producer surplus, rent to vessels and total economic benefits.

Next section provides a historical review of the factors that affect the price of the domestic sea scallops during the last two decades along with a description of the total supply including the imports. In the following sections, the equations of the economic model are described.

3.1 Historical Background: Scallop landings and prices, meat count, and imports

Table 5**.** Landings, Imports, Prices and Meat Count

Period	Domestic Landings (million lbs)	Imports (million lbs)	Total Supply (landings+ imports)	Ex-vessel Price ($/lb)	Import Price ($/lb)	Meat Count (meats per pound)
1. 1982-1986	18	34	52	7.35	5.96	28
2. 1987-1992	34	37	71	5.06	4.48	37
3. 1993-1998	16	55	70	5.86	3.91	36
4. 1999-2001	33	46	79	4.34	3.52	27*

* Years 1999 and 2000 only.

Table 5 summarizes scallop landings, imports, meat count, ex-vessel and import price for four different periods corresponding to periods of low and high level of US sea scallop landings. Both Periods 1 (1982-1986) and 3 (1993-1998) include the years during which landings of sea scallops in the Northeast were below 20 million pounds. Periods 2 (1987-1992) and 4 (1999-2001) correspond, however, to years of high landings mostly exceeding 30 million pounds. Comparison of these periods provide some insights about the change in ex-vessel prices, quantity of imports, import prices and total supply of scallops as follows:

- Ex-vessel prices move in opposite direction to the domestic landings of sea scallops. Specifically, they were higher in periods (periods 1 and 3) of lower landings and lower in periods of high (periods 2 and 4) landings.

- In general, however, both ex-vessel and import prices of scallops exhibited a declining trend in the last two decades, especially since 1983. Figure 11 shows that average annual domestic price of scallops corrected for inflation at the 1996 cost of living (i.e., expressed in terms of 1996 constant prices) declined from over $7.35 per pound in early 1980's (period 1) to less than $5 per pound since year 2000. Similarly, the import prices per pound of scallops declined from over $6 per in the early 1980's to less than $4 since year 2000.

- Total supply, as measured by the sum total of landings and imports, has been increasing since 1982. Average annual supply increased 79 million pounds during the period 1999 to 2001 from an average of 52 million pounds during 1982-1986. The increase in the overall seafood consumption as the consumers became aware of the beneficial health impacts of fish, the decrease in the price of scallops both domestic and foreign and the increase in the disposable income of consumers were the main factors that contributed to the increase in demand for scallops.

- Imports increased substantially after 1982, from 20 million pounds to more than 40 million pounds after 1984. It is also evident from Figure 12 that imports as a substitute for domestic scallops fluctuated to fill the gap between domestic landings and the total demand for scallops, especially after 1990. Quantity of imports of scallops increased significantly during the period 1993-1998 (Period 3) in response to the rapid decline in domestic landings of scallops to less than 20 million. This trend seems to be reversed in the recent years, however, due to the recovery of the scallop resource. For example, level of imports declined to 40 million pounds in 2001 as domestic landings reached 44 million pounds in the same year.

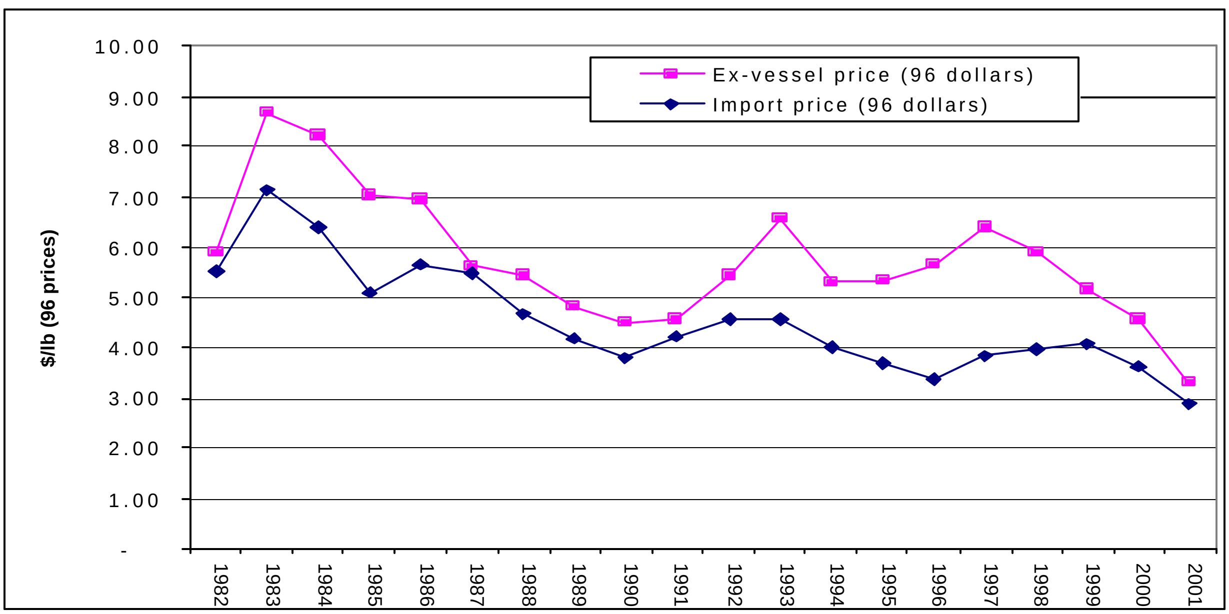


Figure 11. Ex-vessel and average price of scallops (in 1996 constant dollars)

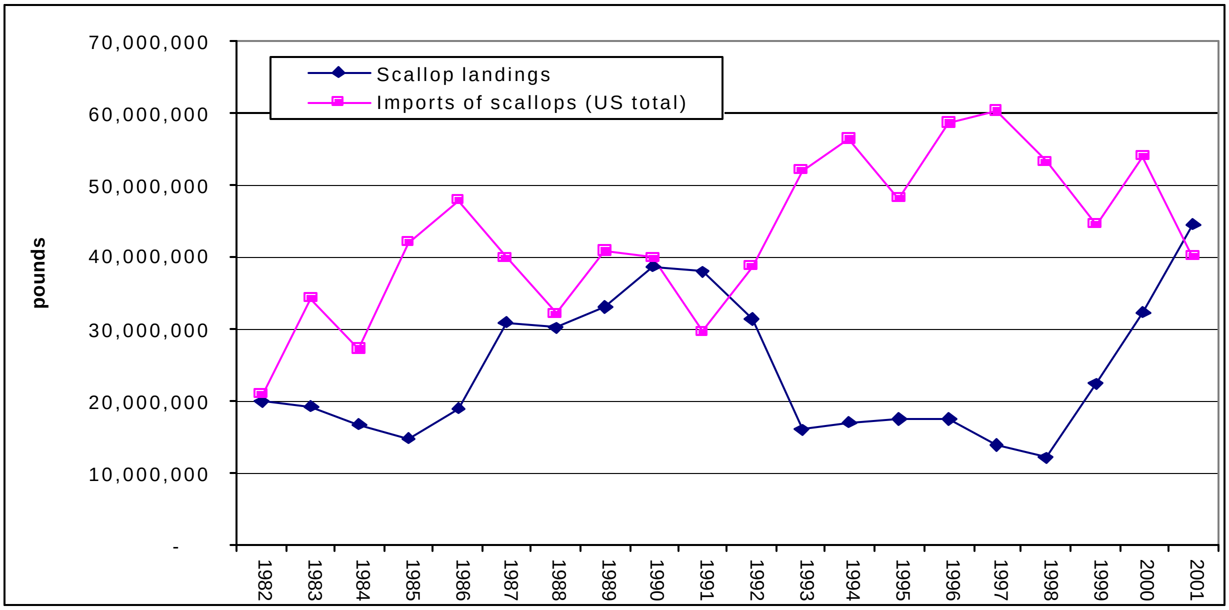


Figure 12**.** Sea scallop landings and imports (pounds)

- Table 5 shows meat count of the scallop resource available to fishing during the first two decades since 1982. Average meat count per year increased from 28 meats per pound during 1982-1986 (Period 1) to over 35 meats per pound during the next two periods ending with year 1998. The size of landed scallops were restricted by a meat count standard that first went into effect in 1982 with the implementation of the first FMP to Atlantic sea scallops. The meat count was restricted at 30 meats per pound. In June 1983, the Regional Director set the meat count at 35 meats per pound. Meat count standard was eliminated in 1994 with the implementation of Amendment 4 to the Sea Scallop FMP. With the recovery of the scallop resource in the recent years, the meat count declined to 27 meats per pound during the period 1998 to 2000, indicating that the size of the exploitable scallops available for fishing increased.

- The monthly price data collected from dealers database from January 1998 to December 2001 indicated the presence of price premium for larger scallops (Figure 13). Although price differentials between meat count categories fluctuated from month to month, In general U-10 (under 10 count) scallops earned the highest price premium. The differences in price were larger between the 30/40 count scallops and the 20/30 count scallops until the last quarter of 2000. It seems, however, that the price premium for relatively larger scallops except U-10's almost disappeared after October 2000.

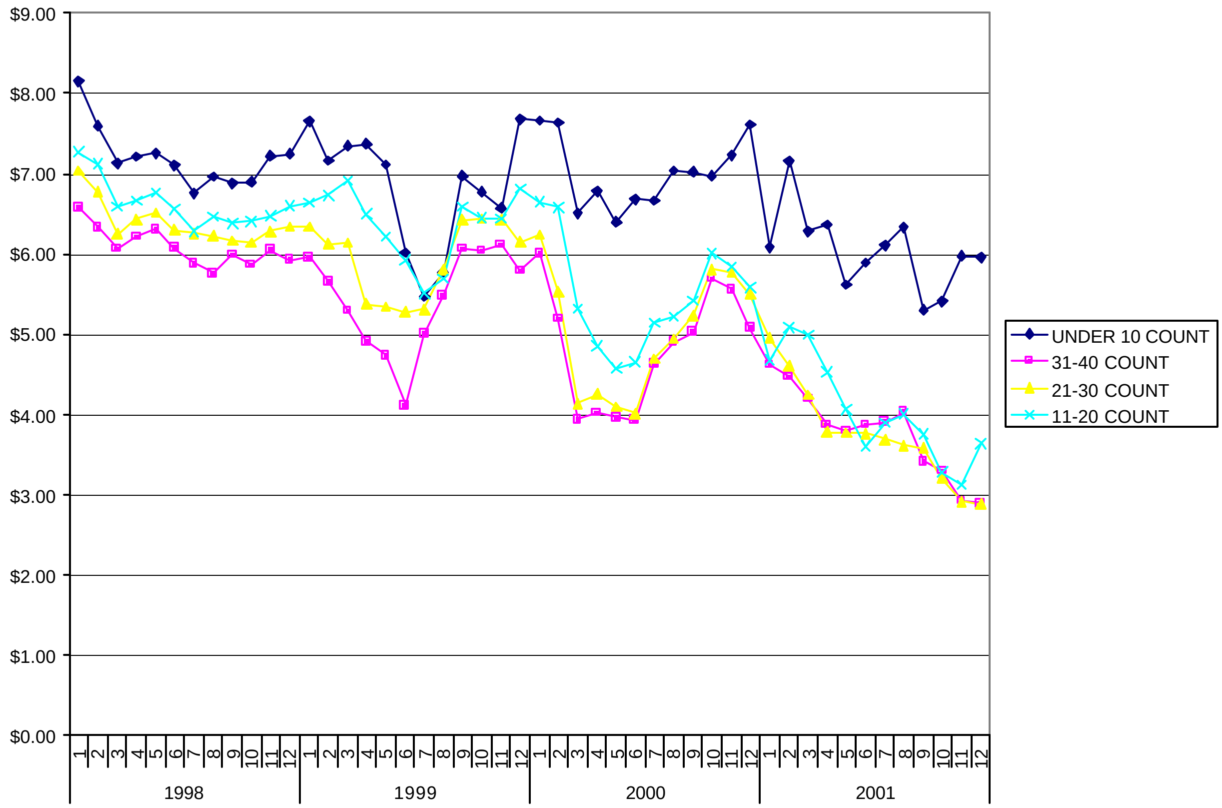


Figure 13. Price premium: Average monthly price of scallops by count .

- This is because composition of landings has changed dramatically since year 2000. The share of 11-20 count scallops in total landings increased to almost 25% and the share 21-30 scallops increased to almost 50% in year 2001 from around an average 15% and 25% respectively from 1998 and 1999 (Table 6). As the supply of 21-30 count scallops increased, their prices came closer in value to the prices of 31-40 count scallops. It seems that the price of 11-20 count scallops is following the same trend as their supply keeps increasing because of the recovery of the scallop resource and availability of larger scallops especially in the formerly closed areas.

- The U-10 scallops commanded a large price differential ranging from $1 to $2 per pound in year 2001. The percentage share of U-10's in total landings was still small, however, about 7.3% in 2000 and 3.2% in 2001 (Table 6). The continuity of the price premium for U-10's in the future is uncertain because of the expected increase in the average size of the landed scallops. In fact, analyses based on a regression of the price for U-10's and their relative supply indicated strongly that such price differentials would decrease in the future as more U-10 scallops are landed in the future years.

Table 6. Composition of sea scallop landings by count category

Count/Year	1998	1999	2000	2001
11-20 COUNT	17.34%	11.74%	18.42%	24.61%
21-30 COUNT	22.06%	25.23%	43.70%	49.82%
31-40 COUNT	13.34%	20.37%	18.31%	11.15%
41-50 COUNT	9.16%	12.58%	1.71%	0.18%
51-60 COUNT	7.44%	1.60%	0.07%	0.00%
61+ COUNT	2.60%	0.14%	0.01%	0.00%
UNDER 10 COUNT	1.66%	16.57%	7.32%	3.20%
Unclassified	26.39%	11.77%	10.48%	11.05%

3.2 Ex-vessel price equation

Ex-vessel price of sea scallops (PEXVES) is postulated to be a function of:

- domestic landings (DOMLAN, million pounds),
- disposable income per capita (PCDPI),
- average price of all scallop imports to the Northeast region (PIMPAL),
- average meat count (MCOUNT). It is estimated as the weighted average of meat count by area, weighted by the numbers and size of the areas open to fishing.
- A dummy variable, D94, as a proxy of management changes, such as the abolition of the meat count standard, since 1994.

Other things being equal, higher landings would lead to a lower price for scallops. Higher income would result in a higher price because sea scallop is considered a normal good. Higher price of scallop imports as a substitute would lead to a higher price for domestic scallops as well. Normally, larger scallops command a higher price because they are preferred in restaurant markets. Since the size of scallops is measured in meat counts per pound, smaller meat count implies that the scallops are larger compared to a pound of scallops with a higher meat count. Therefore, smaller meat count representing larger scallops would be associated with a higher ex-vessel price, implying an inverse relation between average meat count (MCOUNT) and the ex-vessel price (PEXVES).

All the price variables are corrected for inflation and expressed in 1996 prices by deflating current levels by consumer price index (CPI) for food. Per capita disposable income is also expressed in 1996 dollars by deflating nominal values with the GDP implicit deflator. The semi-log form was chosen to restrict estimated price to positive values only. The empirical estimation is shown in Equation 5.. As Figure 14 shows, this equation provides a good fit to the actual values of annual ex-vessel price.

Equation 5.

$$\begin{array}{lllllll} \text{Log(PEXVES)} = 1.1606 - & 0.0146 * \text{DOMLAN} + & 0.00002*\text{PCDPI} + & 0.1228*\text{PIMPAL} - & 0.0013*\text{MCOUNT} - & 0.1458*\text{D94} \\ \qquad (2.42) & (-6.49) & (1.30) & (3.94) & (-0.46) & (-1.73) \end{array}$$

n=18, from 1982 to 2000, adj R-sq = 0.90, D-W = 1.67, t-value in parentheses.

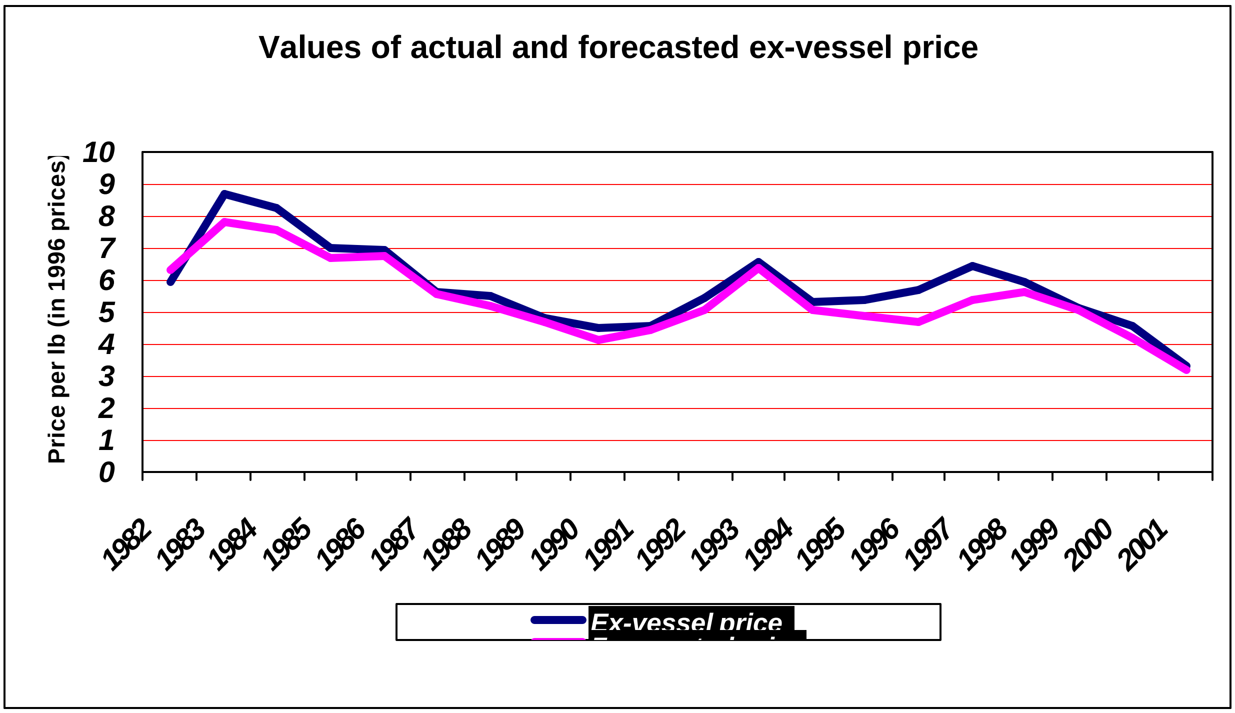


Figure 14. The actual and predicted values of ex-vessel price

3.3 Operating cost equation

Fishery management measures not only affect the level of landings and prices of scallops, but also have an impact on the trip and operating cost of vessels. Since cost data are needed for estimating producer surplus and thus net national benefits (consumer and producer surpluses), specification and estimation of cost equations are necessary for analyzing policy options. The operating cost of scallop fishing (OPC) is postulated to be a function of vessel crew size (CREW), vessel size in gross tons (GRT) and vessel days at sea (DAS).

The operational costs are assumed to change with a vessel's effort, and therefore, were assumed to decline as DAS decreased. Operating costs consist of trip costs, such as food, fuel, oil and ice, which vary with DAS, as well as half of repairs, assuming that more vessel activity will increase repair costs

This cost equation was assumed to take a double-logarithm form and estimated with data collected by the Economic and Social Science Branch of Northeast Fisheries Science Center. The detailed information on the cost/earnings data are available in two studies: Gautam and Kitts (1996) and Edwards (1997). The empirical equation presented below verifies the postulated hypothesis and has proper statistical properties.

Equation 6.

$$\underset{}{\mathrm{Log(OPC)}} = \underset{(6.31)}{4.6130} + \underset{(3.34)}{0.2531} * \mathrm{Log(CREW)} + \underset{(3.46)}{0.2743} * \mathrm{Log(GRT)} + \underset{(8.79)}{1.1134} * \mathrm{Log(DAS)}$$

n=69, adj R-sq = 0.58, D-W = 1.97, t-value in parentheses.

The operating costs were estimated in 1996 prices. The latest statistics (for July 2002) indicated that fuel costs were 9 percent higher compared to year 1996. If the recent changes in fuel prices were taken into account, the estimated operational expenses would go up by less than 9% since variable costs also include non-fuel costs such as water, ice, oil, food, and half-of repair expenses. Because the fuel prices could not be predicted for the coming years at this time, no adjustments were made to the estimated costs and gross profits in this section.

3.4 Fixed Cost Equation

The fixed costs include insurance, license, half of repairs, office expenses, professional fees (for accounting etc.,), dues, utilities, interest, dock expenses, rent, employee benefits and bank, store, auto, travel expenses.

Insurance comprised a significant proportion of the fixed costs, and amounted to over $78,790, followed by interest payments, amounting to over $40,000 in 1996 dollars and as an average of the vessels included in the cost data. Interest payments could be close to the total payments on mortgage for some vessels. Inclusion of interest payments probably overestimates fixed costs for some vessels that are already paid off.

Overall, estimated repairs averaged $69,900 a year in 1996 constant dollars and half of this, $34,965 was included in fixed costs. The other half of repairs was included in the operational costs because some part of repair expenses is related to the level of fishing activity. For example, a vessel that fishes full-time will likely need more repairs than a vessel that fishes only part-time.

Other than these costs, the vessels will incur dockside expenses and overhead no matter how many days they fish. These expenses were included in the fixed costs for all options. Section ??? in the FSEIS shows the average fixed costs by DAS-use groups for a sample of vessels included in the Gautam and Kitts (1996) cost data. Since these costs seems to be higher for vessels with a higher DAS-use, there is no evidence that that the average fixed costs per vessel increase as a vessel stay longer at the dock.[5]

---

5 Some industry members reported that some repairs that are done by crew when they are on board catching scallops will not be finished if the DAS allocations are reduced and the vessel owners will need to pay for these repairs when the boat is at the dock.

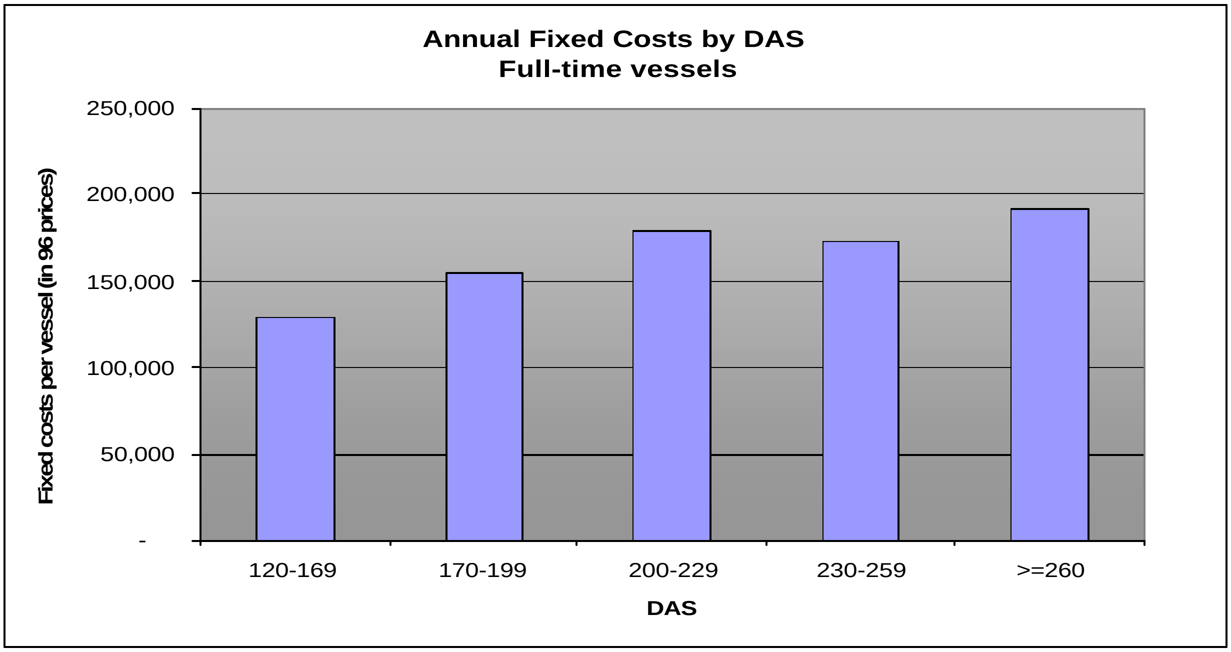


Figure 15. Annual fixed costs by DAS-use category for a sample of full-time vessels

It was estimated that the fixed costs for an average scallop vessel amounted to $163,400 in 1996 constant dollars. This estimate is based on the fixed cost regression (Equation 3) shown below, which estimates the fixed costs as a function of vessel characteristics. 6

Equation 3.

$$FC = \underset{(1.46)}{480160.22} + \underset{(1.61)}{266.54*(GRT)} + \underset{(3.22)}{88.05*HP}$$

n=75, adj R-sq = 0.16, t-value in parentheses.

3.5 Gross profits

As it is well known, the net income and profits could be calculated in various ways depending on the accounting conventions applied to gross receipts and costs. The gross profit estimates used in the economic analyses in the FSEIS rather than corresponding to a specific accounting procedure, simply show the difference of gross revenue over variable (including the

6 The cost data collected by Daniel Georgianna et.al (1999) has similar results for the fixed costs. When half of the repairs were added to the overhead costs for the consistency of the fixed costs definition, the fixed costs for the large New Bedford and New England scallop boats amounted to $172,113 in 1997. This amount included, however, taxes, and the principal and interest payments on loans, whereas the fixed cost estimates used in the vessel impact analysis above did not include taxes and the principal payments. For the boats in Mid-Atlantic this amount was much less, around $115,000. Therefore, the estimates for fixed costs in these section are close to the amount of fixed costs ($163,403) estimated for the large vessels in New England.

crew shares) and fixed expenses. It is in some ways similar to the net income estimated from cash-flow statements since depreciation charges are not subtracted from income because they are not out-of-pocket expenses.

3.6 Consumer surplus

Consumer surplus measures the area below the demand curve and above the equilibrium price. For simplicity, consumer surplus is estimated here by approximating the demand curve between the intercept and the estimated price with a linear line as follows:

CS=(PINT*DLNP-EXPP*DLNP)/2
EXPP= Ex-vessel price corresponding to landings for each policy option.
PINT=Price intercept i.e., estimated price when domestic landings are zero

DLNP= Sea scallop landings for each policy option.

Although this method may overestimate consumer surplus slightly, it does not affect the ranking of alternatives in terms of highest consumer benefits or net economic benefits.

3.7 Producer surplus

The producer surplus (PS) is defined as the area above the supply curve and the below the price line of the corresponding firm and industry (Just, Hueth & Schmitz (JHS)-1982). The supply curve in the short-run coincides with the short-run MC above the minimum average variable cost (for a competitive industry). This area between price and the supply curve can then be approximated by various methods depending on the shapes of the MC and AVC cost curves. The economic analysis presented in this section used the most straightforward approximation and estimated PS as the excess of total revenue (TR) over the total variable costs (TVC). It was assumed that the number of vessels and the fixed inputs would stay constant over the time period of analysis. In other words, the fixed costs were not deducted from the producer surplus since the producer surplus is equal to profits plus the rent to the fixed inputs. Here fixed costs include various costs associated with a vessel such as depreciation, interest, insurance, half of the repairs (other half was included in the variable costs), office expenses and so on. It is assumed that these costs will not change from one scenario to another.

PS=EXP*DLN- ΣOPC
ΣOPC = Sum of operating costs for the fleet.

Producer Surplus also equals to sum of rent to vessels and rent to labor. Therefore, rent to vessels can be estimated as:

RENTVES=PS – CREWSH[7]

Rentves= Quasi rent to vessels

---

7 CREWSH is estimated as follows: CREWSH=.60*gross revenues-trip costs. With this definition, crew shares are equivalent to crew income, i.e., their revenue net of trip expenses.

Crewsh= Crew Shares

3.8 Total economic benefits

Total economic benefits (TOTBEN) is estimated as a sum of producer and consumer surpluses and its value net of status quo is employed to measure the impact of the management alternatives on the national economy.

TOTBEN=PS+CS

3.9 Other assumptions

- The vessel costs are estimated for an average scallop vessel that has a GRT, HP, and crew size equivalent to the fleet average. All the costs are estimated in 1996 constant prices.
- The scallop revenues are estimated from projected landings and the annual price model in 1996 real prices.
- Import prices, and the disposable income are held constant at the 2001 level, but in 1996 constant prices when estimating ex-vessel prices.
- The maximum crew size is restricted at seven men.
- Crew shares are estimated using a 40/60 lay-system according to which crew receives 60% of the gross stock and pays for the trip expenses.
- A discount rate of 7% is applied to annual values in deriving present cumulative value of the revenues, costs, producer and consumer surpluses and total economic benefits.
- The results are based on the assumption that there will be sufficient effort to land the scallops predicted by the biological model and there would be no reduction in total effort. This implies that even if there were some business failures DAS would be redistributed among the remaining vessels either with regulation and/or some consolidation.

3.10 Risk and Uncertainty and Sensitivity Analyses

The sensitivity analysis presented in this section applies both to the long-term impacts of the rotational and non-rotational alternatives and to the short-term effects of the rotational management, area access and habitat closures.

The numerical estimates of the revenues, costs and benefits should be used in comparing one option with another rather than is predicting the future values of the economic variables. The absolute values of the net economic benefits and its components would change if a different discount rate was applied and/or different assumptions were used regarding the trends in disposable income, import prices and costs. Also, the estimates for landings and prices are subject to statistical errors and variability. If the standard deviations in various variables and coefficients are taken into account, the range of values for revenues, consumer and producer surpluses and net economic benefits will fall within a confidence interval around the mean values. The ranking of the options in terms of their net economic benefits relative to each other are likely to stay the same, however, as discussed below.

Sensitivity of the results to the assumptions about area access:

The economic benefits and costs were estimated assuming that the total landings from the controlled access areas will be equivalent to the estimated TACs. If, however, the vessels prefer to fish in the open areas rather than in the restricted access areas at the selected days-at-sea trade-offs and trip limits, thus landing less in these areas than the corresponding TAC levels, the results will be different than shown. If for example, LPUEs in Georges Bank closed areas fall short of the estimated LPUEs from the biological model, some scallop fishermen may choose not to fish in those areas. In that case, the actual landings may fall short of the TACs for the access, and the total landings, revenues and economic benefits for all options with area access would be less than predicted.

Sensitivity of results to the value of the discount rate:

If a lower discount rate was used for estimating the cumulative present value of the benefits, the economic benefits of options with lower fishing mortality and lower DAS allocations will increase relative to the options with higher DAS allocations. For example, if a discount rate of 3% percent was applied in estimating the present value of the net benefits, the economic benefits associated with no action would increase relative to the rotational management with access. This is because the benefits on scallop stock biomass and yield from lower fishing mortalities will be realized later in the future years and the future years would be discounted less with a 3 percent discount rate compared to a 7 percent rate.[8]

Sensitivity of the results to future values of disposable income and import prices:

The long-term impacts of all options were analyzed by asking the following question: What would be the impact of changing the proposed measures on long-term economic benefits and its components holding other variables, such as disposable income and import prices constant. For this reason, the ex-vessel price was estimated for the future years assuming the disposable income and import prices will stay constant at their 2001 value. The absolute value of the net benefits would change if a different set of assumptions were used. The ranking of the alternatives in terms of their economic benefits would still stay the same, however, for the following reasons:

- If it was assumed, as an example, the disposable income per capita (DPIPC) will increase at an average of 3% rate per year as it did in the last 10 years, the ex-vessel prices would increase under all options, increasing the value of the scallop resource and therefore total net benefits. Because those options with lower fishing mortality, i.e., lower DAS allocations and larger closures result in higher yield compared to others, the economic benefits associated with no action and the alternatives with no access to the Georges

8 An alternative discount rate that is often used in cost benefit analyses is social discount rate. OMB circular defines this rate as follows: “The social rate of time preference reflects the discount rate at which society is indifferent between a payment now and a correspondingly larger payment in a future year. It may be lower than the average real return on investment because, as a result of taxes and other distortions, individuals do not receive the full return on their investments. Most analysts use the average real rate on long-term Treasury bonds to represent the social rate of time preference. For the last 15 years, this rate has been in the range of 3 to 5 percent (http://www.whitehouse.gov/OMB/memoranda/m00-06.html).”

Bank closed areas would increase slightly relative the options with smaller closures and area access. The reverse would happen if there was a change in historical trends and disposable income declined by 3% over the same period. Even under this unlikely scenario, however, more conservative options would result in larger net economic benefits compared to the other alternatives. In general, however, the differences in net benefits one option versus another is not very sensitive to changes in disposable income within the range of its historical trend.9

- The average import price of scallops from all countries declined at an average annual rate of 3 percent during the last 10 years from 1991 to 2001, although in some years there was an increase in import prices. The continuation of a declining trend in import prices would accelerate (dampen) the decline (increase) in domestic scallop prices as the landings increase (decline) in response to changes in stock biomass. If the cost/benefit analysis was conducted assuming import prices will decline by 3 percent in the next 10 years, results would be similar to that of a declining disposable income per capita (DPIPC). Specifically, the difference in the net benefits of the more conservative options relative to the others would slightly decrease although their net benefits would still exceed the benefits of the later options.

- An increasing trend in import prices would have the reverse effect, increasing the net benefits of the more conservative options relative to the others slightly. As with the changes in the disposable income, however, the sensitivity of the relative differences in net benefits (of one option versus another) to changes in import prices are small within the range of historical trends.

Sensitivity of the results to variances in landings and price estimates:

The landings and price estimates and their variability determine to a large extent the absolute values and variability of the revenue, producer and consumer surplus, and net benefit estimates for each option. The ranking of the options in terms of their economic benefits are not expected to change, however, when the variability and the standard errors in the estimates are taken into account:

The prices were estimated using the price model (**Equation 5.**) discussed in Section 3.2. If the elasticity (i.e., responsiveness) of prices to change in landings is lower than the mean values, the absolute values of economic benefits would be less for each option. The differences in net economic benefits of one option versus another would change slightly and the relative benefits of the more conservative options would still exceed the benefits of the other options.

The landings from the biological model estimates have variability due to the possible changes in recruitment over the next 10 years and long-term. The long-term cost/benefit analysis of the rotational and the non-rotational analysis takes into account this variability in the discussion of results as presented in Section ??? in the FSEIS. If variability is taken as a measure

9 In general, the results are not very sensitive to the changes in the disposable income (DPI) as could be inferred from the coefficient of this variable in the price equation.

of risk, the risk of landings falling below the mean values is higher for the rotational options that increase closure duration or maximum biomass closed. The adaptive rotations with variable closure durations improve landings slightly compared to other rotational options. But the same alternatives also result in higher variability from one year to the next.