Method of analysis for assessing the impacts of management measures affecting the spatial distribution of fishing

The potential impacts of management options that either close or open fishing areas for any gear type relative to the status quo were assessed based on estimates for Z_{net} and *e*. This document explains how these estimates were used to produce the analysis in the Omnibus alternatives document.

Contents

Tables

Figures

1.0 Background - Z_{net} and *e*

To assess the costs and benefits of fishing activities by each gear type in our region, we simply construct a ratio estimator using the adverse effects from fishing (Z) and the profits derived from fishing (X). We call this the environmental impact coefficient, or *E.*

$$E = \frac{Z}{X} \qquad (1)$$

Here *E* represents the domain-wide ratio of adverse effect to fishing vessel profits. Because of the granularity of the SASI model, however, it can be scaled down to the individual gear type (*i*) and parcel (*p*) level, with parcels being 100km^2 grid cells or a combination of grid cells. Further, because *Z* is a time-dependant variable, a true estimate of the adverse effect of fishing requires summing all of the adverse effects from each individual fishing event across all years in which they are felt. This lifecycle estimate of adverse effect, its net stock (Z_{net}), is defined as

$$z^{net}{}_{ip} = \sum_{t=1}^{n} z_{ip} \qquad (2)$$

where t is the duration, in years, of the adverse effect for each unit of fishing activity. The length of the adverse effect lifecycle for a given fishing event is directly related to the recovery times of the structural habitat features inferred to the substrate(s) found within the parcel being fished. Incorporating Z_{net} into equation (1) and indexing across gear types and parcels gives us

$$e_{ip} = \left(\frac{z^{net}}{x} \right)_{ip} \qquad (3)$$

where x_{ip} is the profit ($) derived as a result of fishing by gear type *i* at parcel *p*. Profit (x) is calculated as the product of all revenues r and variable trip-level costs c across gear types i and parcels p as

$$x_{ip} = (r - c)_{ip} \qquad (4)$$

Note that crew remuneration is not included in c, nor is the price of leasing either DAS or ACE in fisheries where such leases are available. Profit is not discounted over the duration of the adverse effect, as the monetary benefits of fishing are instantaneous.

Data

Z_{net} is parameterized using VTR data for actual fishing trips made by vessels fishing with any of the ten gear types used in the SASI model during the 1996-2009 timeframe. The SASI document contains a more complete discussion on the treatment of these data. a meaningful trip cost model.

Table 1 shows the mean Z_{net} and trip length by gear type and year.

The x variable is composed of r, trip-level revenue, and c, trip-level costs. Trip-level revenues were generated using a combination of dealer reported-landings and, when dealer-level data are not available or incomplete, self-reported VTR data. Observer data were used to estimate two trip-level cost models, and these models were applied to the VTR in-domain point data used in the SASI model. The time frame for observer data collection is 2003-2009, whereas the time series for the SASI model is 1996-2009. This inconsistency is likely to induce bias, as trip-level costs (particularly fuel costs) may not be representative at the earlier years. VTR trips with no valid location data were deleted. All values are converted to 2007 dollars using the Bureau of Labor Statistics producer price index for unprocessed and packaged fish, series WPU0223.

Trip costs were sensitive to trip duration, and therefore separate cost models were estimated for trips less than 24 hours and for trips equal to or greater than 24 hours. Trip cost, the dependant variable, are the sum of the following costs: ice, food, fuel, intra-trip vessel or gear damage, miscellaneous supplies, water, oil and bait. Several model specifications and combinations of explanatory variables were explored. The final model specifications are presented in Table 2 and Table 3. Gillnet and longline are categorical variables in the cost models, representing the presence of that gear used on a trip; crew is a continuous variable representing the number of crew plus captain; ln_dur is the natural log of the total trip duration measured in hours; vhp^2 is the vessel horsepower squared. Table 4 presents the annual sum of trip revenues, trip costs and profits by gear type. Hydraulic clam dredge gear is, unfortunately, excluded from this analysis due to difficulties in computing trip-level revenue and insufficient observer data for generating a meaningful trip cost model.

Table 1 – Mean Znet and trip length (days) by year and gear type

	Generic otter trawl		Shrimp trawl		Squid trawl		Raised footrope trawl	
Year	Z_{net}	trip length	Z_{net}	trip length	Z_{net}	trip length	Z_{net}	trip length
1996	-5.54	1.9	-1.34	0.55	-4.85	2.36	.	.
1997	-5	1.71	-1.41	0.6	-3.74	2.12	.	.
1998	-4.79	1.64	-1.35	0.55	-4.92	2.5	.	.
1999	-4.81	1.68	-1.3	0.57	-3.33	2.09	.	.
2000	-4.14	1.55	-1.32	0.51	-2.59	1.39	.	.
2001	-3.85	1.64	-1.16	0.5	-3.37	1.85	.	.
2002	-3.16	1.46	-1.25	0.61	-3.34	1.84	.	.
2003	-3.32	1.51	-1.09	0.47	-4.73	2.51	-1.03	0.96
2004	-3.18	1.45	-1.11	0.48	-3.84	2.07	-1.04	0.61
2005	-3.08	1.41	-1.07	0.49	-4.88	2.71	-0.78	0.56
2006	-3.13	1.43	-1.01	0.46	-4.11	2.18	-0.75	0.81
2007	-3.27	1.43	-1.12	0.5	-3.61	2.05	-0.76	0.54
2008	-3.09	1.36	-1.16	0.5	-3.79	2.02	-0.7	0.44
2009	-3.44	1.28	-1.13	0.45	-4.58	2.39	-0.87	0.46

	Limited access scallop dredge		General category scallop dredge		Longline		Gillnet	
Year	Z_{net}	trip length	Z_{net}	trip length	Z_{net}	trip length	Z_{net}	trip length
1996	-3.83	7.06	-0.1	0.44	-0.04	0.73	0	0.79
1997	-3.08	6.36	-0.12	0.45	-0.03	0.75	0	0.64
1998	-3.28	6.02	-0.13	0.46	-0.03	0.76	0	0.63
1999	-2.92	5.73	-0.13	0.46	-0.28	0.63	0	0.72
2000	-2.73	5.92	-0.17	0.53	-0.02	0.69	0	0.72
2001	-2.82	6.09	-0.18	0.55	-0.05	0.68	0	0.73
2002	-2.59	7.08	-0.18	0.54	-0.03	0.86	0	0.67
2003	-2.4	6.61	-0.16	0.56	-0.02	0.82	0	0.64
2004	-2.15	5.84	-0.15	0.59	-0.02	0.72	0	0.61
2005	-1.3	3.27	-0.16	0.61	-0.03	0.74	0	0.61
2006	-1.15	2.6	-0.19	0.67	-0.03	0.71	0	0.58
2007	-1.44	2.78	-0.18	0.67	-0.03	0.72	0	0.51
2008	-1.72	2.95	-0.17	0.64	-0.04	0.8	0	0.53
2009	-2.35	3.53	-0.16	0.59	-0.03	0.86	0	0.48

	Pots and traps	
Year	Z_{net}	trip length
1996	-0.01	0.58
1997	-0.01	0.58
1998	-0.01	0.57
1999	-0.01	0.58
2000	-0.01	0.54
2001	-0.01	0.54
2002	-0.01	0.53
2003	-0.01	0.55
2004	-0.01	0.54
2005	-0.01	0.52
2006	-0.01	0.53
2007	-0.01	0.53
2008	-0.01	0.55
2009	-0.01	0.56

Table 2 – Trip cost model with natural log of trip cost as dependant variable for trips less than 24 hours, Adj R-sq = 0.525 (OLS)

Variable	Parameter Estimate	Standard error	t value	Pr > |t|
Intercept	2.90496	0.06213	46.75	<.0001
gillnet	-0.57755	0.02764	-20.9	<.0001
longline	0.24488	0.06531	3.75	0.0002
CREW	0.32479	0.01631	19.92	<.0001
ln_dur	0.86415	0.02679	32.26	<.0001

Table 3 – Trip cost model with natural log of trip cost as dependant variable for trips greater than or equal to 24 hours, Adj R-sq = 0807 (OLS)

Variable	Parameter Estimate	Standard error	t value	Pr > |t|
Intercept	1.8691	0.09207	20.3	<.0001
vhp2	1.81E-07	3.35E-08	5.41	<.0001
gillnet	-0.76861	0.04381	-17.54	<.0001
CREW	0.14529	0.01171	12.41	<.0001
ln_dur	1.2594	0.02187	57.58	<.0001

Table 4 – Mean trip value, cost, profit and trip duration (days) by year and gear type, $1,000's

	Generic otter trawl				Shrimp trawl				Squid trawl			
Year	Trip value	Trip cost	Profit	Trip duration	Trip value	Trip cost	Profit	Trip duration	Trip value	Trip cost	Profit	Trip duration
1996	7,434	1,787	5,648	1.9	2,032	357	1,675	0.55	11,696	2,199	9,497	2.36
1997	6,951	1,569	5,381	1.71	1,687	387	1,300	0.6	9,048	1,874	7,174	2.12
1998	6,559	1,479	5,080	1.64	1,598	346	1,252	0.55	12,414	2,495	9,919	2.5
1999	6,757	1,533	5,225	1.68	1,246	347	899	0.57	8,815	2,026	6,789	2.09
2000	6,667	1,395	5,272	1.55	1,664	315	1,349	0.51	6,157	1,232	4,925	1.39
2001	7,104	1,485	5,619	1.64	943	309	634	0.5	7,726	1,704	6,021	1.85
2002	6,559	1,317	5,242	1.46	1,318	404	914	0.61	8,139	1,674	6,466	1.84
2003	6,935	1,365	5,570	1.51	1,296	289	1,006	0.47	12,132	2,394	9,738	2.51
2004	7,252	1,311	5,941	1.45	1,299	290	1,009	0.48	11,742	1,923	9,819	2.07
2005	6,297	1,266	5,031	1.41	1,153	291	862	0.49	17,315	2,722	14,594	2.71
2006	6,665	1,288	5,376	1.43	1,420	283	1,137	0.46	11,469	2,115	9,354	2.18
2007	6,358	1,306	5,053	1.43	1,447	322	1,125	0.5	10,069	2,084	7,985	2.05
2008	6,639	1,231	5,408	1.36	1,302	316	986	0.5	9,474	1,966	7,507	2.02
2009	6,388	1,155	5,234	1.28	1,231	290	940	0.45	14,255	2,310	11,946	2.39

	Raised footrope trawl				Limited access scallop dredge				General category scallop dredge			
Year	Trip value	Trip cost	Profit	Trip duration	Trip value	Trip cost	Profit	Trip duration	Trip value	Trip cost	Profit	Trip duration
1996	.	.	.	.	44,695	10,804	33,891	7.06	972	294	678	0.44
1997	.	.	.	.	38,452	9,399	29,053	6.36	1,074	281	793	0.45
1998	.	.	.	.	29,936	8,666	21,270	6.02	976	288	688	0.46
1999	.	.	.	.	47,359	8,265	39,095	5.73	1,231	294	936	0.46
2000	.	.	.	.	57,423	8,725	48,698	5.92	1,643	454	1,189	0.53
2001	.	.	.	.	56,322	8,989	47,333	6.09	1,712	438	1,274	0.55
2002	.	.	.	.	62,417	10,546	51,872	7.08	1,753	392	1,361	0.54
2003	3,139	791	2,349	0.96	61,867	9,617	52,250	6.61	1,884	390	1,494	0.56
2004	2,253	383	1,870	0.61	67,458	8,153	59,305	5.84	2,337	441	1,897	0.59
2005	2,112	454	1,658	0.56	42,911	4,129	38,782	3.27	3,008	479	2,529	0.61
2006	2,932	661	2,270	0.81	24,753	3,043	21,710	2.6	2,343	493	1,850	0.67
2007	2,123	381	1,742	0.54	26,566	3,338	23,228	2.78	2,343	497	1,846	0.67
2008	1,979	343	1,636	0.44	32,499	3,729	28,770	2.95	2,444	471	1,973	0.64
2009	2,072	358	1,714	0.46	41,260	4,695	36,565	3.53	2,636	458	2,178	0.59

	Longline				Gillnet				Pots and traps			
Year	**Trip value**	**Trip cost**	**Profit**	**Trip duration**	**Trip value**	**Trip cost**	**Profit**	**Trip duration**	**Trip value**	**Trip cost**	**Profit**	**Trip duration**
1996	2,725	592	2,133	0.73	2,792	320	2,473	0.79	2,342	432	1,911	0.58
1997	2,641	640	2,001	0.75	2,609	263	2,346	0.64	2,086	418	1,668	0.58
1998	2,711	645	2,065	0.76	2,670	253	2,417	0.63	1,865	409	1,456	0.57
1999	2,737	463	2,274	0.63	3,293	282	3,010	0.72	2,232	416	1,816	0.58
2000	2,452	517	1,935	0.69	3,068	265	2,803	0.72	2,189	372	1,817	0.54
2001	2,719	484	2,235	0.68	2,937	265	2,672	0.73	1,948	376	1,572	0.54
2002	3,057	625	2,432	0.86	3,015	244	2,771	0.67	2,008	372	1,636	0.53
2003	2,885	621	2,265	0.82	2,813	239	2,575	0.64	2,112	390	1,722	0.55
2004	4,061	584	3,477	0.72	2,558	228	2,331	0.61	1,982	381	1,601	0.54
2005	3,884	564	3,320	0.74	2,791	221	2,570	0.61	2,086	371	1,715	0.52
2006	2,985	546	2,440	0.71	2,545	216	2,328	0.58	1,971	362	1,608	0.53
2007	3,057	627	2,430	0.72	2,408	196	2,213	0.51	1,813	366	1,447	0.53
2008	2,787	654	2,133	0.8	2,343	201	2,142	0.53	1,834	381	1,453	0.55
2009	3,006	684	2,322	0.86	1,963	185	1,779	0.48	1,812	395	1,417	0.56

Summary of e results

To summarize the relationship between costs and benefits for each gear type, *e* is calculated as the unweighted mean value across all years and all parcels (Table 5). This estimate includes only parcels with three or more trips per year and with three or more years of data. The reported standard deviation applies to *e* at the parcel level across time—relatively lower standard deviations (such as the raised footrope, squid and shrimp trawls) indicate fisheries with similar *e* coefficients within the same parcel across time, and higher standard deviations (such as gillnets and longlines) represent higher inter-annual variability.

In Table 5, the *e* coefficient may accurately be interpreted as the quality-adjusted area swept, in square kilometers, that results from the generation of $1,000 of gross profit at the individual trip level. The number of grid cells meeting the requirement of three or more trips in a year and three or more years in the dataset are noted; this indicates that use of some gears, e.g. shrimp trawls and raised footrope trawls, is highly spatially localized.

The rank order and magnitude of the adverse effect generated per dollar provide a useful approach to understanding the impacts of various fishing gears on structural habitat. Here we can see that fixed gears are much more efficient, in terms of adverse effect, at generating fishing profits than mobile gears. Even within those classes there is variation—trawls generate an order of magnitude greater adverse effect per unit of fishing profit than scallop dredges; gillnets and pots and traps similarly generate less adverse effect per unit profit than longlines.

Table 5 – Unweighted mean *e* across all included grid cells and years, by gear type

Gear	# grid cells	Mean *e*	Stddev *e*
Generic otter trawl	1271	5.00	8.30
Shrimp trawl	96	8.10	11.73
Squid trawl	195	2.82	3.69
Raised footrope trawl	5	1.48	1.71
Limited access scallop dredge	446	0.64	1.05
General category scallop dredge	215	0.68	1.09
Longline	110	0.11	0.26
Gillnet	688	0.03	0.08
Pots and traps	601	0.04	0.07

2.0 Impacts analysis methods for closure removal options

We acknowledge here that attempting to assess changes in the spatial distribution of fishing due to area-based regulatory change is extremely difficult. In the Northeast region we have used two models with relative success—the Closed Area model (CAM) for assessing impacts in the groundfish fishery, and the SAMS model in the scallop fishery. Unfortunately, the large size and high level of granularity found in the SASI model does not present an easy path for the integration of those two models, though we believe that with some work the SAMS model would be an ideal basis for predicting changes in adverse effect that may result from changes in spatial management.

Site choice models, which predict where fishing vessels will re-distribute their fishing effort after closures or openings based on expected profits, are commonly used for these types of analyses. Unfortunately, they have only been successfully utilized to predict effort redistribution across much lower levels of granularity—on the order of 10 to 50 sites, rather than the 200-1,000 sites with active fishing in the SASI model. They are also extremely complicated models that take years to develop. A fully parameterized and operational site choice model covering all areas and gear types assessed within the SASI framework would certainly be valuable at this phase of analysis, but such a model is unavailable.

To allow the Council and public adequate consideration of the potential impacts of changes in spatial management regulations, we utilize the basic mechanics of SASI to demonstrate whether the proposed spatial regulation will result in GREATER or LESSER adverse effects, holding other inputs constant.

The basic questions to be addressed in modeling these effects are:

(1) How much different will adverse effects be in the areas potentially being opened?
(2) How much different will catch rates be?
(3) How much effort will flow into these areas?

We have little empirical data (aside from SAPs and fisheries in rotational management areas) upon which to base cost (adverse effects) and benefit (profits) estimates on. **Therefore, as a first approximation, in most cases, we base our estimates on the potential profits and adverse effects from parcels that are proximate to and potentially representative of the profits and adverse effects likely to be observed within the opened area if fishing were allowed.** These estimates are then propagated to the newly fishable areas.

Eleven separate regions were selected as sub-sets of existing habitat and year-round management closures: Closed Area 1 east, north and west (Figure 1); Closed Area 2 south, central and north (Figure 2); Nantucket Lightship east and west (Figure 3); Cashes; Jeffries; and the Western Gulf of Maine (Figure 4). Note that these regions are comprised of whole 100km^2 grid cells. The figures show which cells were used in the fished and unfished scheme. Some cells were coded in the model as both fished and unfished because in terms of areal extent, most of the cell was within a closure, but there were substantial VTR data available for the cell (due to high levels of fishing along the closure boundary). In the figures, the unfished cells overlay the fished, so not all fished cells are visible.

To answer question (1) above, we compare Z_∞ estimates from the fishable areas with estimates from their matched unfished areas. Remember that Z_∞ represents the theoretical vulnerability of underlying habitats in a grid cell or parcel given uniform fishing effort. Table 6 provides the difference between similar fished and unfished areas in percentage terms. These percentages were then used to scale up or down the Z_{net} estimates for the unfished areas found inside current closures.

For question (2), we begin with the assumption that catch rates and therefore profits for all fisheries will be higher than they are in the proximate similar areas, though we are unsure of how much higher they may be. To model this, we apply a factor ranging from 1 to 1.5 times observed proximate profits and iterate the model stochastically. For scallop dredge gears, where catch rates inside area closures are known to be significantly higher than 1.5 times proximate outside areas, we randomly apply a factor that ranges from 1 to 4 times observed proximate profits. [1]

Because we have no economic or behavioral model upon which to base the *amount* of effort likely to flow into a newly opened area, we use a similar stochastic estimation method. Effort flowing into newly opened areas is likely to be similar in distribution to the observed effort in proximate currently opened areas, and linearly related in magnitude. We therefore use observed profits in these areas as a basis for estimating profits derived from newly opened areas. To do this, we apply a range of between 1 and 5 times the observed proximate open-area profits to the newly opened areas. All profits flowing into these newly open areas are subtracted uniformly from the observed profits over the entire domain; profits are thus held constant, and changes in resulting Z_{net} are reported.

Data from all years 1996-2009 are averaged to construct the profit and Z_{net} estimates for each parcel. Each of the eleven potential open areas is assess individually. Due to computing power limitations at the NEFSC, only 15 iterations of the stochastic model were performed.

[1] In some limited areas, e.g. WGOM, Cashes Ledge, and Jeffreys Bank pre-closure, actual data were used and the catch rate increase factors were not applied.

Figure 1 – Closed Area 1 fished and unfished parcels

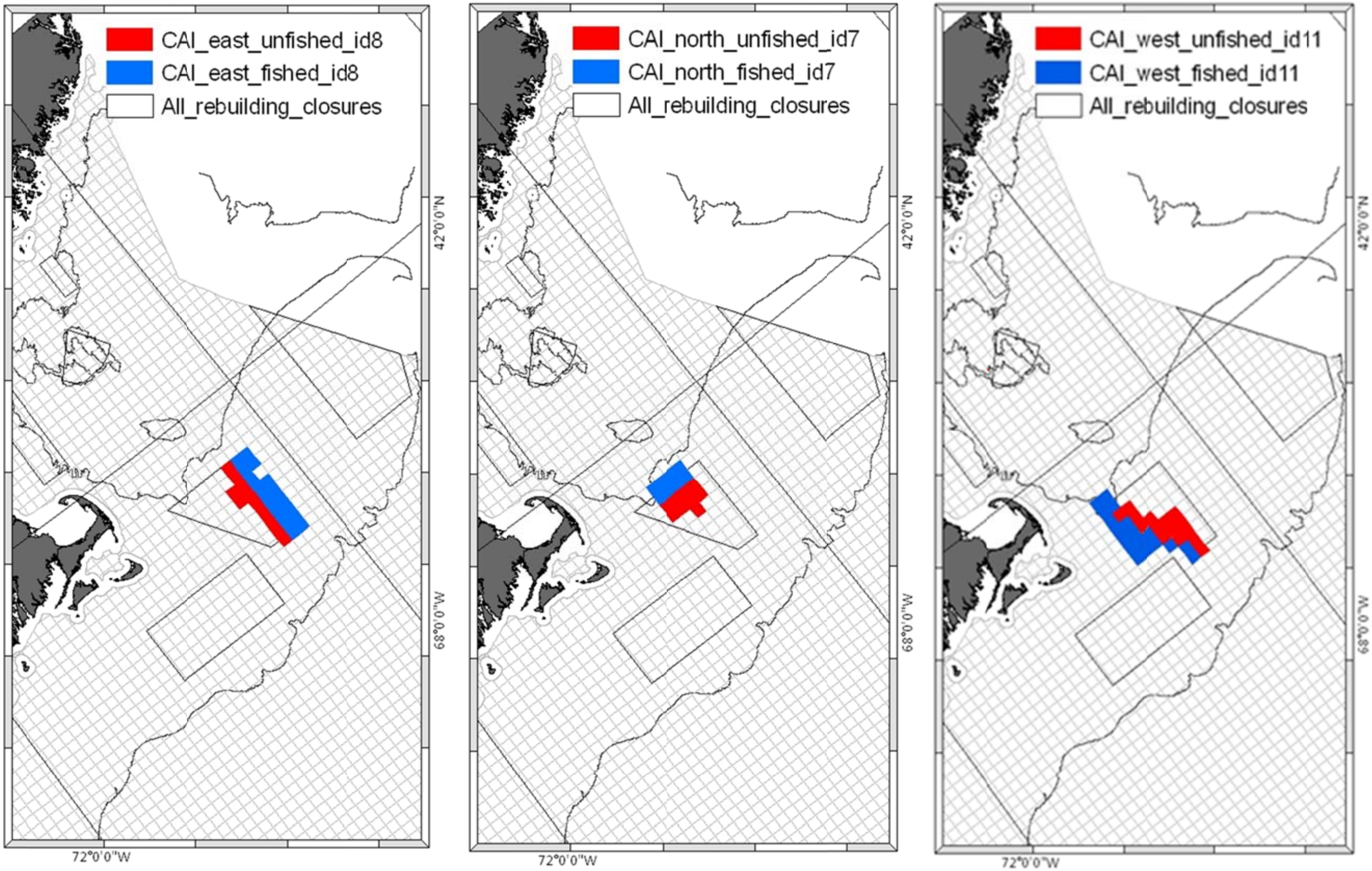

Figure 2 – Closed Area 2 fished and unfished parcels

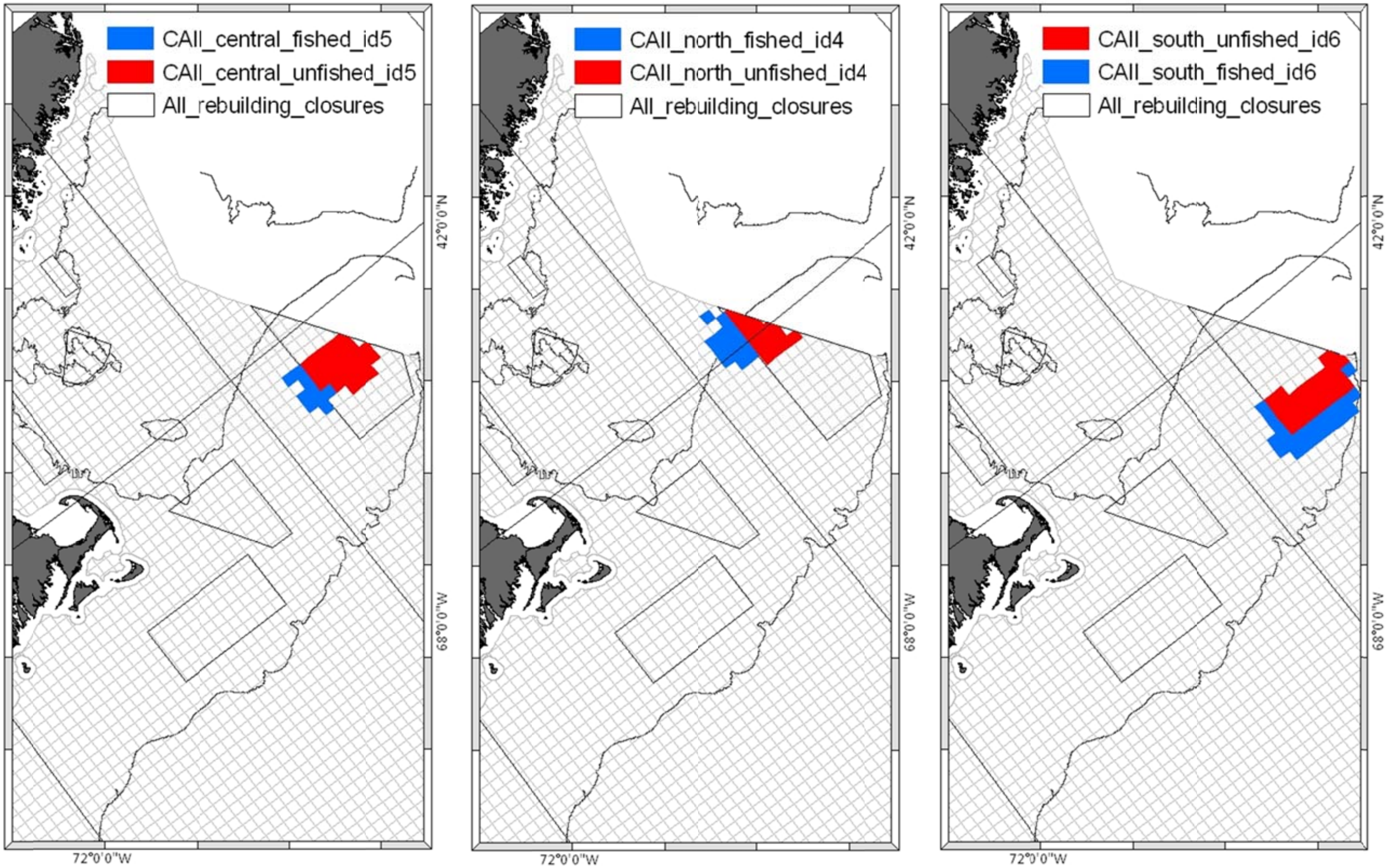

Figure 3 – Nantucket Lightship Closed Area fished and unfished parcels

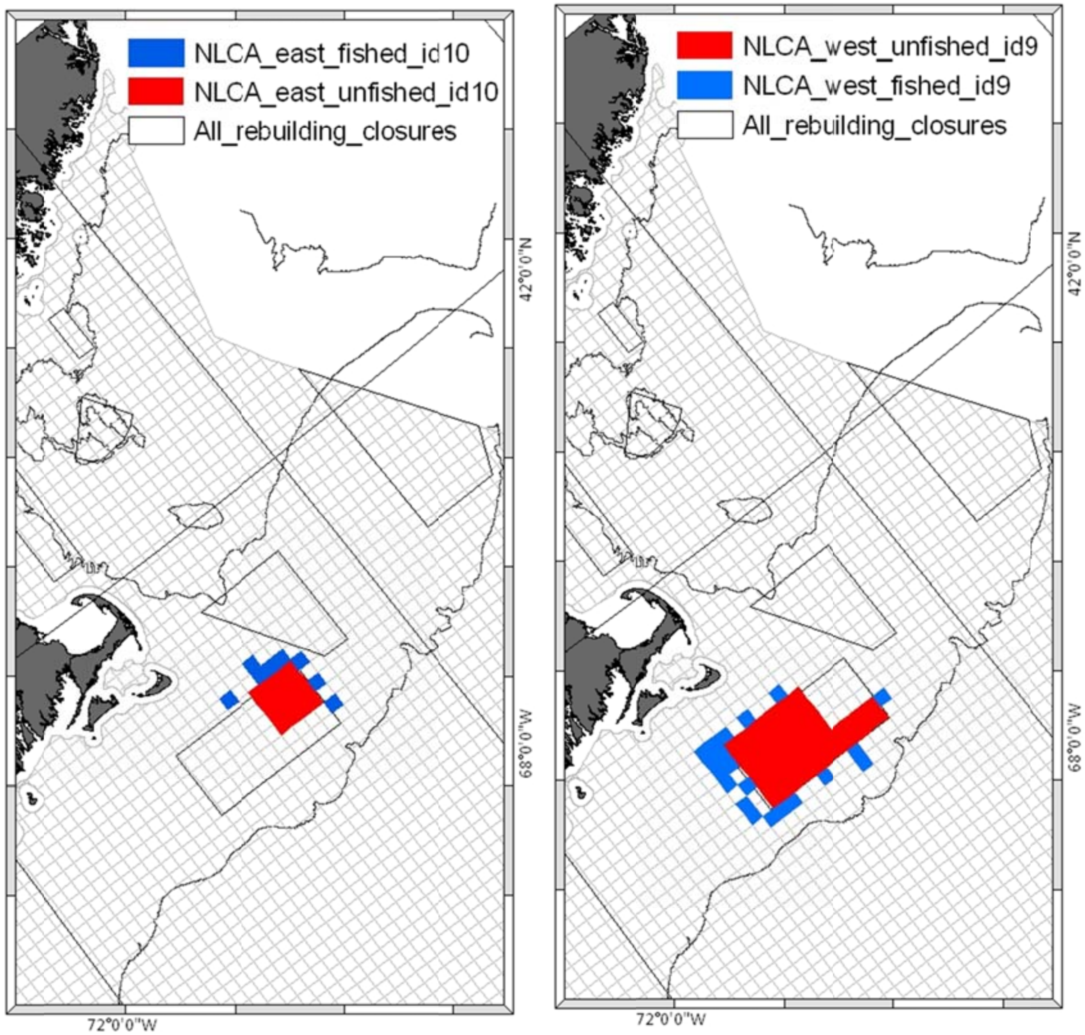

Figure 4 – Western Gulf of Maine Closed Area, Cashes Closed Area and Jeffries Bank Closed Area

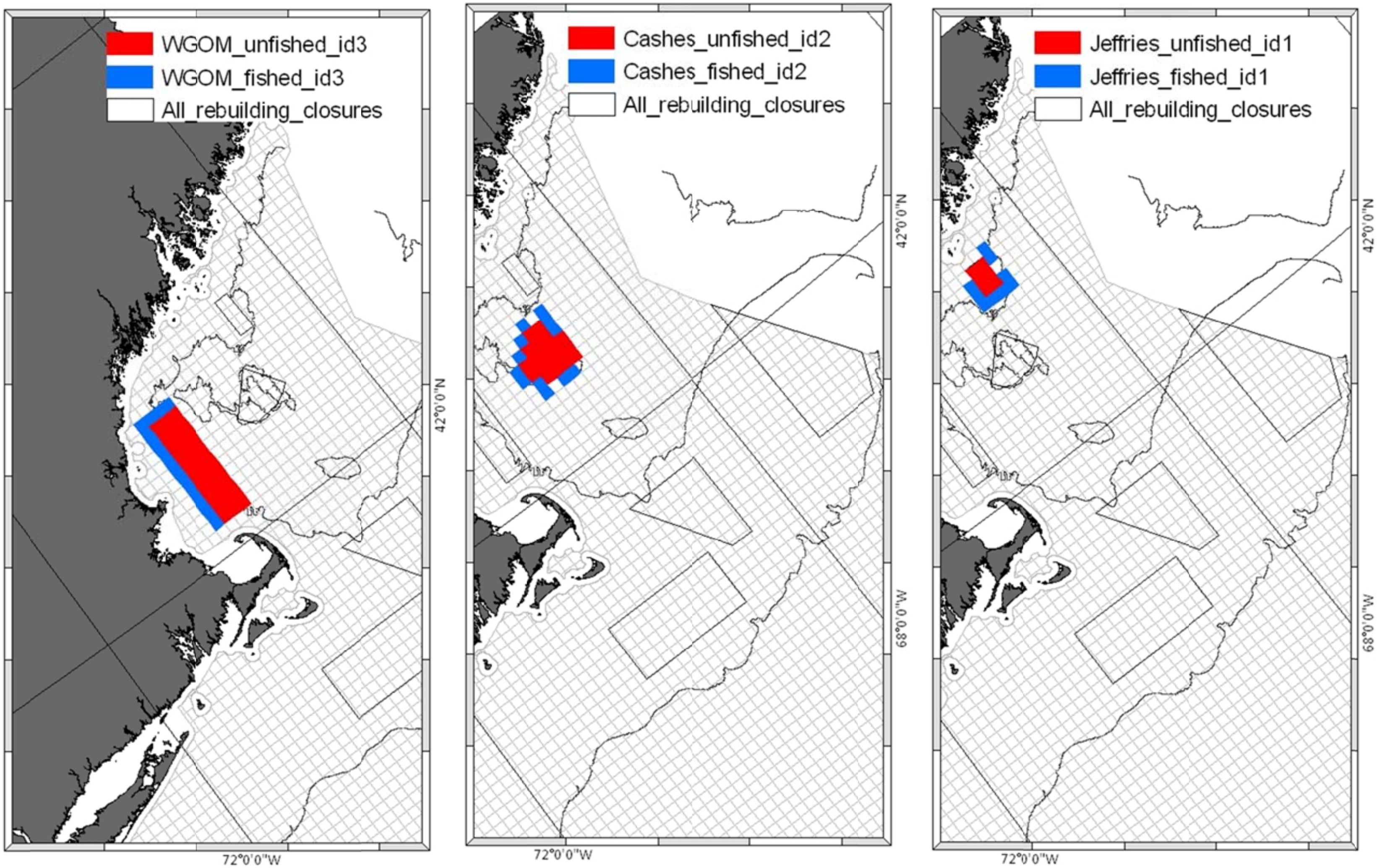

Table 6 – Average percent difference in Z∞ between fished and unfished parcels, by gear type. Negative values (shown in bold type) indicate greater vulnerability for the unfished areas relative to their proximate fished areas, while positive values indicate lesser vulnerability for the unfished areas relative to their proximate fished areas.

Average % difference in Z∞	Generic otter trawl	Shrimp trawl	Squid trawl	Raised footrope trawl	Limited access scallop dredge	General category scallop dredge	Hydraulic clam dredge	Gillnet	Longline	Pot/Trap
Cashes	**-3.56%**	**-3.56%**	**-3.56%**	**-3.56%**	**-1.62%**	**-1.62%**	0.93%	**-1.01%**	**-0.83%**	0.25%
Closed Area 1 East	0.16%	0.16%	0.16%	0.16%	**-2.94%**	**-2.94%**	**-2.25%**	**-3.76%**	**-4.68%**	**-2.99%**
Closed Area 1 North	4.83%	4.83%	4.83%	4.83%	3.17%	3.17%	9.68%	0.96%	1.15%	2.82%
Closed Area 1 West	5.35%	5.35%	5.35%	5.35%	4.48%	4.48%	1.63%	3.84%	3.97%	3.28%
Closed Area 2 Central	**-0.67%**	**-0.67%**	**-0.67%**	**-0.67%**	**-0.87%**	**-0.87%**	1.38%	0.59%	**-0.02%**	-0.60%
Closed Area 2 North	4.65%	4.65%	4.65%	4.65%	3.77%	3.77%	7.28%	1.56%	1.44%	3.75%
Closed Area 2 South	2.05%	2.05%	2.05%	2.05%	1.96%	1.96%	7.22%	1.12%	1.53%	1.28%
Jeffries	3.25%	3.25%	3.25%	3.25%	2.85%	2.85%	**-6.81%**	5.05%	4.98%	7.29%
NLCA East	11.80%	11.80%	11.80%	11.80%	4.21%	4.21%	1.87%	3.47%	3.93%	3.18%
NLCA West	**-2.01%**	**-2.01%**	**-2.01%**	**-2.01%**	**-3.26%**	**-3.26%**	0.03%	0.11%	**-0.17%**	5.14%
WGOM	**-2.30%**	**-2.30%**	**-2.30%**	**-2.30%**	**-3.97%**	**-3.97%**	**-2.59%**	**-1.39%**	**-1.27%**	0.11%

Results for closure removal options

This model estimates the potential change in adverse effects from fishing on fish habitat after a regulatory fishing area opening. The point of the analysis was to demonstrate whether or not aggregate adverse effects would increase or decrease after an area opening, given existing profit to adverse effect relationships in the vicinity of the potential opening and reasonable assumptions about how those relationships would translate onto newly opened fishing grounds.

The results for each model run are summarized in the tables on the following pages (Table 7 through Table 17). The Z_{net} values shown in the first two columns represent the sum across all grid cells in both the fished and unfished areas within each parcel. The 'before opening' column indicates total, global Z_{net} when fishing was only occurring in the 'fished' area (blue areas in the figures), while the 'after opening' column indicates the total, global Z_{net} across all cells when fishing was redistributed (given the assumptions described in the previous sections) into both the fished and unfished (blue and red) areas. In both cases, a larger (more positive) value of Z_{net} indicates a greater magnitude of adverse effects (remember that in the earlier table of Z_{∞} values, more adverse values are more negative). Thus, negative values in the rightmost 'Average % change in Z_{net}' columns indicate that Z_{net}/adverse effects <u>decrease</u> if the area is opened to that gear type. Because the various parcels are of different sizes, when comparing between parcels (e.g. CA1 East vs. Cashes Ledge), it is important to use the percentage change column. Note that the Z_{net} values represent an average across the years 1996-2009.

In summary, we find that for nearly all area and gear type combinations, opening existing closed areas to fishing is predicted to decrease aggregate adverse effects. For mobile bottom tending gears, which comprise nearly 99% of all adverse effects in our region, allowing fishing in almost any portion of the area closures on Georges Bank is estimated to substantially decrease total adverse effects from fishing. Closures in the Gulf of Maine appear to also decrease aggregate adverse effects, but the magnitude of these reductions is substantially smaller.

Note that the parameters used to estimate both catch rate and total effort increases for potential fishing inside closed areas may easily be adjusted either up or down based on feedback from the Committee and public, and additional time may allow for calibration of these parameters based on empirical data from special access programs, etc. **However, so long as there is agreement that, if areas are opened, catch rates and effort levels for most fisheries are likely to be higher inside these areas than outside, the direction of change in aggregate adverse effect for these various opening scenarios as summarized below will not change**.

Table 7 – Cashes Ledge Closure, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	1,055.0	-	0.0%
Gillnet	61.4	55.2	(6.2)	-10.0%
Limited access scallop dredge	13,659.5	13,660.3	0.8	0.0%
Longline	122.2	122.2	-	0.0%
Generic otter trawl	125,932.9	119,639.2	(6,293.7)	-5.0%
Pot/Trap	345.4	345.2	(0.2)	-0.1%
Raised footrope trawl	165.0	165.0	-	0.0%
Shrimp trawl	5,390.3	1,232.1	(4,158.2)	-77.1%
Squid trawl	12,150.2	12,150.2	-	0.0%

Table 8 – Closed Area 1 East, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	779.1	(275.9)	-26.2%
Gillnet	61.4	54.7	(6.7)	-10.9%
Limited access scallop dredge	13,659.5	11,719.8	(1,939.7)	-14.2%
Longline	122.2	63.0	(59.2)	-48.4%
Generic otter trawl	125,932.9	110,319.5	(15,613.4)	-12.4%
Pot/Trap	345.4	345.2	(0.2)	-0.1%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	5,390.3		0.0%
Squid trawl	12,150.2	12,150.2		0.0%

Table 9 – Closed Area 1 North, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	1,055.1	0.1	0.0%
Gillnet	61.4	59.0	(2.4)	-4.0%
Limited access scallop dredge	3,659.5	13,647.9	(11.6)	-0.1%
Longline	122.2	82.6	(39.6)	-32.4%
Generic otter trawl	125,932.9	117,598.2	(8,334.7)	-6.6%
Pot/Trap	345.4	340.7	(4.7)	-1.4%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	5,390.3		0.0%
Squid trawl	12,150.2	12,150.2		0.0%

Table 10 – Closed Area 1 West, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	787.7	(267.3)	-25.3%
Gillnet	61.4	52.9	(8.5)	-13.8%
Limited access scallop dredge	13,659.5	11,380.1	(2,279.4)	-16.7%
Longline	122.2	24.7	(97.5)	-79.8%
Generic otter trawl	125,932.9	108,994.3	(16,938.6)	-13.5%
Pot/Trap	345.4	339.1	(6.3)	-1.8%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	5,390.3		0.0%
Squid trawl	12,150.2	12,150.2		0.0%

Table 11 – Closed Area 2 Central, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	1,055.0		0.0%
Gillnet	61.4	61.4		0.0%
Limited access scallop dredge	13,659.5	13,633.5	(26.0)	-0.2%
Longline	122.2	122.2		0.0%
Generic otter trawl	125,932.9	99,443.6	(26,489.3)	-21.0%
Pot/Trap	345.4	237.2	(108.3)	-31.3%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	5,390.3		0.0%
Squid trawl	12,150.2	12,150.2		0.0%

Table 12 – Closed Area 2 North, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	1,055.0		0.0%
Gillnet	61.4	51.0	(10.4)	-17.0%
Limited access scallop dredge	13,659.5	11,428.7	(2,230.7)	-16.3%
Longline	122.2	(1.7)	(123.8)	-101.0%
Generic otter trawl	125,932.9	110,050.9	(15,882.0)	-12.6%
Pot/Trap	345.4	335.1	(10.3)	-3.0%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	5,390.3		0.0%
Squid trawl	12,150.2	12,150.2		0.0%

Table 13 – Closed Area 2 South, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	1,055.0		0.0%
Gillnet	61.4	61.4		0.0%
Limited access scallop dredge	13,659.5	10,841.0	(2,818.5)	-20.6%
Longline	122.2	122.2		0.0%
Generic otter trawl	125,932.9	108,509.0	(17,423.9)	-13.8%
Pot/Trap	345.4	345.4		0.0%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	5,390.3		0.0%
Squid trawl	12,150.2	12,150.2		0.0%

Table 14 – Jeffries Bank Closed Area, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	1,055.0		0.0%
Gillnet	61.4	59.8	(1.6)	-2.6%
Limited access scallop dredge	13,659.5	13,659.5		0.0%
Longline	122.2	123.5	1.4	1.1%
Generic otter trawl	125,932.9	125,130.0	(802.9)	-0.6%
Pot/Trap	345.4	342.1	(3.4)	-1.0%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	4,090.8	(1,299.5)	-24.1%
Squid trawl	12,150.2	12,150.2		0.0%

Table 15 – Nantucket Lightship Closed Area East, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	920.6	(134.4)	-12.7%
Gillnet	61.4	61.4		0.0%
Limited access scallop dredge	13,659.5	11,562.3	(2,097.2)	-15.4%
Longline	122.2	28.9	(93.3)	-76.4%
Generic otter trawl	125,932.9	115,499.4	(10,433.5)	-8.3%
Pot/Trap	345.4	275.2	(70.3)	-20.3%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	5,390.3		0.0%
Squid trawl	12,150.2	12,150.2		0.0%

Table 16 – Nantucket Lightship Closed Area West, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	1,055.0		0.0%
Gillnet	61.4	37.2	(24.2)	-39.5%
Limited access scallop dredge	13,659.5	13,618.1	(41.4)	-0.3%
Longline	122.2	49.0	(73.1)	-59.9%
Generic otter trawl	125,932.9	108,100.5	(17,832.4)	-14.2%
Pot/Trap	345.4	222.3	(123.1)	-35.6%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	5,390.3		0.0%
Squid trawl	12,150.2	12,150.2		0.0%

Table 17 – Western Gulf of Maine Closed Area, change in Z_{net} after opening, holding profits constant (data from 1996-2009 VTR)

Gear	Sum of Z_{net} before opening	Sum of Z_{net} after opening	Change in Z_{net}	% change in Z_{net}
General category scallop dredge	1,055.0	676.1	(378.9)	-35.9%
Gillnet	61.4	56.8	(4.6)	-7.4%
Limited access scallop dredge	13,659.5	12,713.5	(945.9)	-6.9%
Longline	122.2	65.7	(56.5)	-46.2%
Generic otter trawl	125,932.9	125,604.3	(328.6)	-0.3%
Pot/Trap	345.4	341.3	(4.1)	-1.2%
Raised footrope trawl	165.0	165.0		0.0%
Shrimp trawl	5,390.3	1,463.7	(3,926.6)	-72.8%
Squid trawl	12,150.2	12,150.2		0.0%

3.0 Impacts analysis methods for additional closure options

Similar to the methods used for estimating the potential impacts of regulatory openings of habitat closed areas, we use Z_{net} and e to estimate the potential changes in adverse effects resulting from closing additional areas to fishing. To more accurately reflect current fishing practices we use parcel level mean profit and Z_{net} data from 2007 – 2009 only. For each closure scenario, we simply sum the amount of profit and Z_{net} that is found inside the proposed closure area, redistribute the 'missing' profits proportional to the observed spatial distribution of fishing effort, assign the corresponding Z_{net} estimate to the profits now generated outside the proposed area closure, and calculate the change in aggregate Z_{net}. Unlike the area opening analysis, no assumptions are made here regarding catch rates and profits for the redistributed fishing effort post-closure. Redistributed fishing effort will almost always result in lower profits and proportionally higher Z_{net}, and for this reason the estimates provided in this analysis are highly likely to overstate reductions in aggregate Z_{net}. Data for only the Georges Bank and Gulf of Maine regions are used to better reflect where displaced effort will likely fish. We focused our efforts for these analyses on the two most affected gear types – generic otter trawl and limited access scallop dredge.

Results for additional closure options

Area closure options for Cluster's 5 and 6 appear to potentially affect between $5-7.5 million of profits for these two gear types, representing less than 5% of their total aggregate profits from the Georges Bank and Gulf of Maine regions (see "profit at risk" in the tables below). However, the redistribution of these profits is estimated to have relatively minimal effects on aggregate Z^{net}. As with all adverse effects options, the largest net gains are to be had by regulating the otter trawl gear type, with Z^{net} reductions on the order of 1,000 km^2 for Cluster's 5 and 6. Closure of Cluster 5 is estimated to slightly increase adverse effects for the limited entry scallop dredge fishery. Cluster 7 is estimated to have the smallest impact, both on industry profits and adverse effects minimization.

Table 18 – Closure option for Cluster 5 (Georges Shoal), change in Z_{net} (2007-2009 VTR, profits in 1,000 dollars)

Gear	Pre-closure profit	Profit at risk	Pre-closure Z_{net}	Closure Z_{net}	% reduction in Z_{net}
Generic otter trawl	$57,076	$2,921	37,816	36,946	2.3%
Limited access scallop dredge	$105,998	$4,483	6,526	6,592	-1.0%

Table 19 – Closure option for Cluster 6 (Great South Channel), change in Z^{net} (2007-2009 VTR, profits in 1,000 dollars)

Gear	Pre-closure profit	Profit at risk	Pre-closure Z_{net}	Closure Z_{net}	% reduction in Z_{net}
Generic otter trawl	$57,076	$1,996	37,816	36,695	3.0%
Limited access scallop dredge	$105,998	$3,048	6,526	6,071	7.0%

Table 20 – Closure option for Cluster 7 (Brown's Ledge), change in Z^{net} (2007-2009 VTR, profits in 1,000 dollars)

Gear	Pre-closure profit	Profit at risk	Pre-closure Z_{net}	Closure Z_{net}	% reduction in Z_{net}
Generic otter trawl	$57,076	$310	37,816	37,862	-0.1%
Limited access scallop dredge	$105,998	$-	6,526	6,526	0.0%