NEFMC's Swept Area Seabed Impact Model:
A tool for evaluating the adverse effects of fishing on Essential Fish Habitat

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July 10, 2009

The Magnuson-Stevens Act and Essential Fish Habitat

NEFMC is developing an omnibus FMP amendment to address MSA EFH requirements:

Phase 1:

- Describe and identify EFH for every fishery (this is interpreted as species and life stage in final rule)
- List the major prey species for the species in the FMU and discuss their location
- Identify non-fishing activities that may adversely affect EFH

Phase 2

- **Minimize to the extent practicable the adverse impacts of fishing on EFH**

EFH Final Rule and adverse effects

"<u>Adverse effect</u> means any impact that reduces quality and/or quantity of EFH"

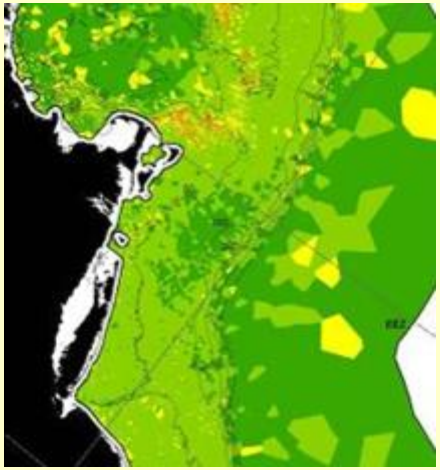
"Councils must act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing activity adversely affects EFH in a manner that is more than minimal and not temporary in nature."

"Adverse effects to EFH may result from actions occurring within EFH <u>or outside of EFH</u> and may include site specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions."

NE Council objectives for Omnibus Amendment related to the adverse effects of fishing on EFH:

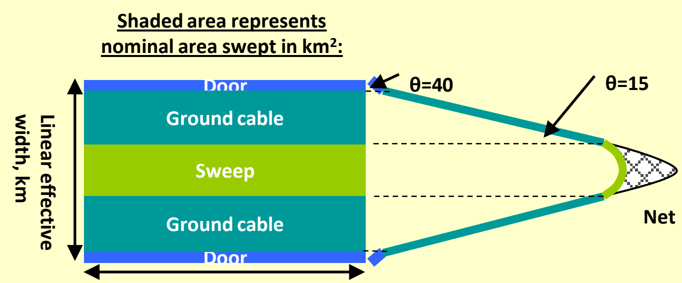
- Identify all major fishing threats to the EFH of those species managed by the Council
- Identify and implement mechanisms to protect, conserve, and enhance the EFH of those species managed by the Council to the extent practicable.
- Define measurable thresholds for achieving the requirements to minimize adverse impacts to the extent practicable
- Integrate and optimize measures to minimize the adverse impacts to EFH across all Council managed FMPs

How might we accomplish these objectives?



			Gear type (Generic trawl)	
			Substrate (Mud)	
Feature type	*Feature*	*Gear effects*	*Studies documenting gear-substrate-feature interaction (high energy)*	*Studies docume interaction (lov*
Geological	Featureless	resuspension, compression, geochem	35, 88, 92, 211, 236, 334, 408, 409, 599	88, 211, 277, 2
Geological	Biogenic depressions	filling	11, 35, 408, 409	11, 101, 336
Geological	Biogenic burrows	filling, crushing	334, 408, 409	101, 313, 336
Geological	Special-case biogenic burrows	filling, crushing	none	none
Geological	Bedforms	smoothing	11, 35, 211, 236, 408, 409	11, 211, 414
Geological	Shell debris	burying, crushing, displacing	11	11, 101
Biological	Hydroids	breaking, crushing, dislodging, displacing	11, 34, 228, 368, 408, 409	11, 368
Biological	Anemones, burrowing	breaking, crushing, dislodging, displacing	228	none
Biological	Sea pens	breaking, crushing, dislodging, displacing	228	101, 164
Biological	Epifaunal bivalve mollusks	breaking, crushing, dislodging, displacing	21, 34, 368, 408, 409	89, 203, 368

$$SASI = \sum_{\substack{e=1\\ s=1}}^{\substack{5\\2}} \left[\left[\sum_{\substack{i=1\\ k=1}}^{\substack{\infty\\9}} \left(\sum_{j=1}^{\infty} (w * c)_j * d \right)_{k,i} \right] * \left(\omega_{h_1} + \omega_{h_2} \right) \right]_{s,e}$$



There's the easy way, and then there's the **Swept Area Seabed Impact (SASI) model.**

The Swept Area Seabed Impact (SASI) model is designed to:

1. Allow the Council to compare the impacts of different fisheries and gear types using a common currency (area swept), and
2. Provide insight into
   a) which areas are most likely to be vulnerable to adverse effects from fishing
   b) how adverse effects from fishing have changed/are changing over time

SASI = Area Swept (A) * Vulnerability (Ω)

A = the area impacted by a unit of fishing effort times the proportion of the gear in contact with the bottom during normal operation

Ω = a factor adjustment that accounts for the nature of the impact of a particular fishing gear on a particular habitat component

The Swept Area Seabed Impact model

$$SASI = \sum_{\substack{e=1\\s=1}}^{\substack{5\\2}} \left[\left[\sum_{\substack{i=1\\k=1}}^{\substack{\infty\\9}} \left(\sum_{j=1}^{\infty} (w * c)_j * d \right)_{k,i} \right] * \left[(\omega_{h_1} + \omega_{h_2}) \right] \right]_{s,e}$$

5 substrates
2 energy environments

9 gear types

A

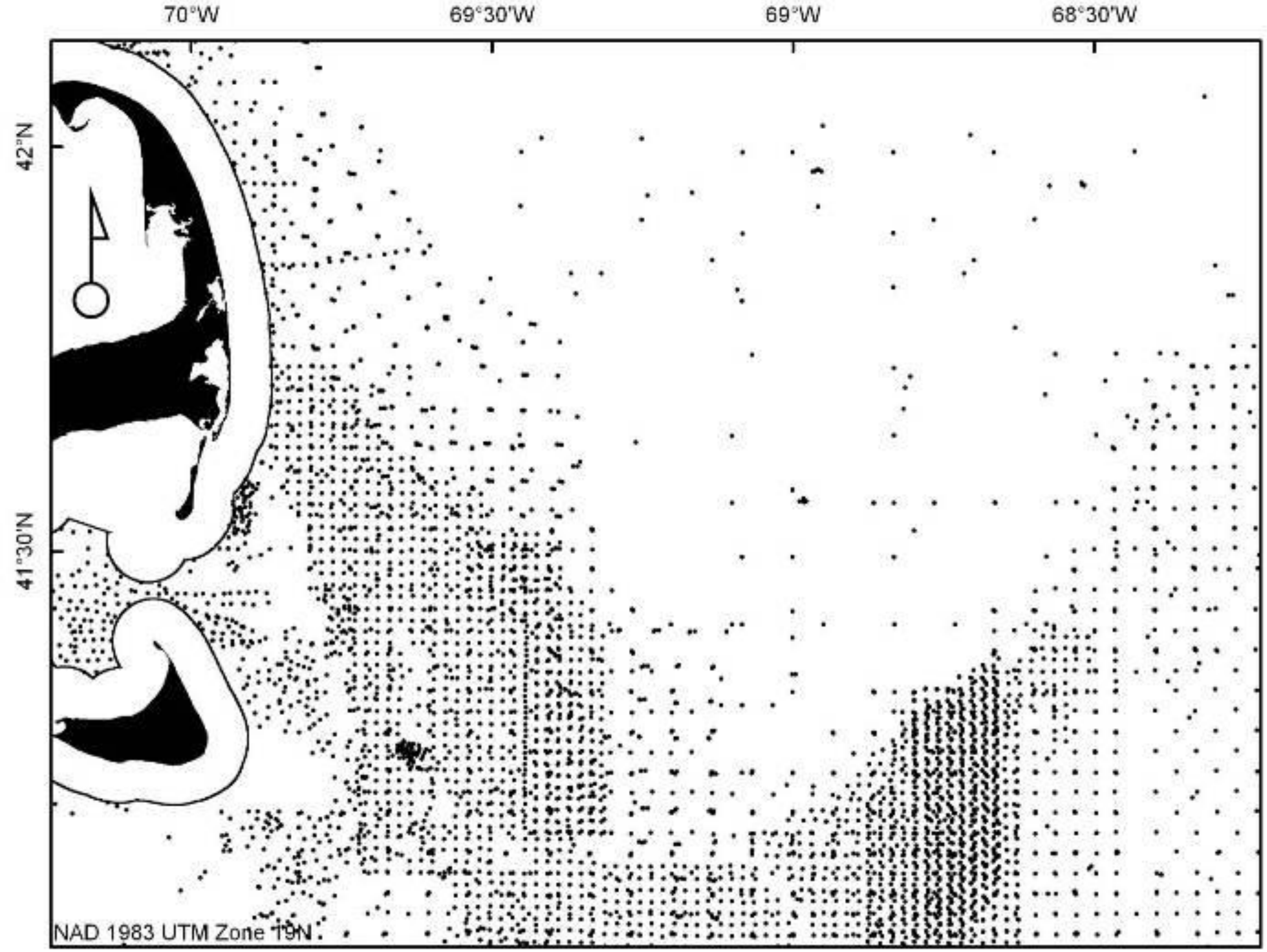
Area swept,
adjusted for contact
of gear component
(*j*) with seabed

Ω

Vulnerability of
habitat to gear type

Creating the model grid

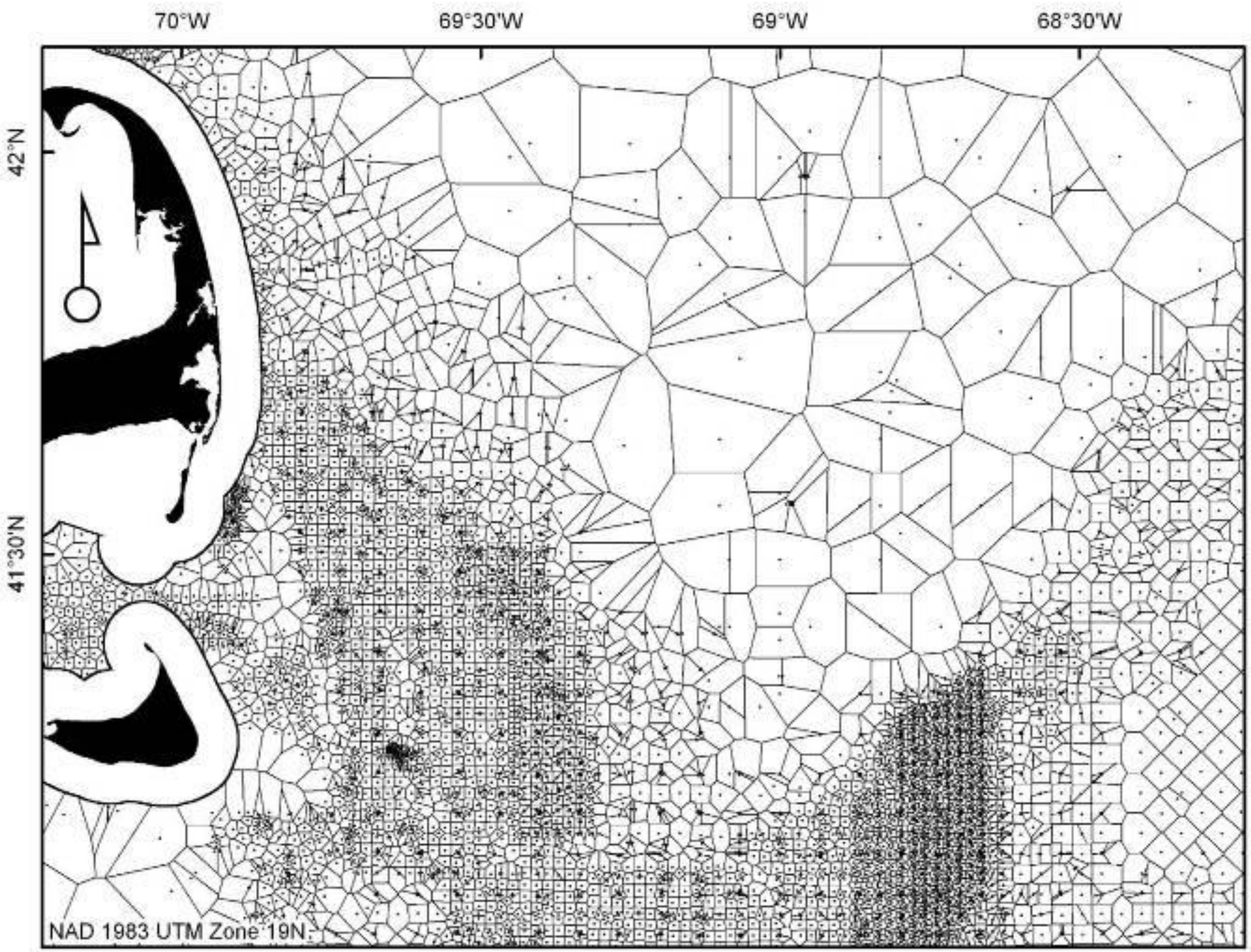
Model grid – x,y substrate data



Two data sets:

SMAST video survey and usSEABED.

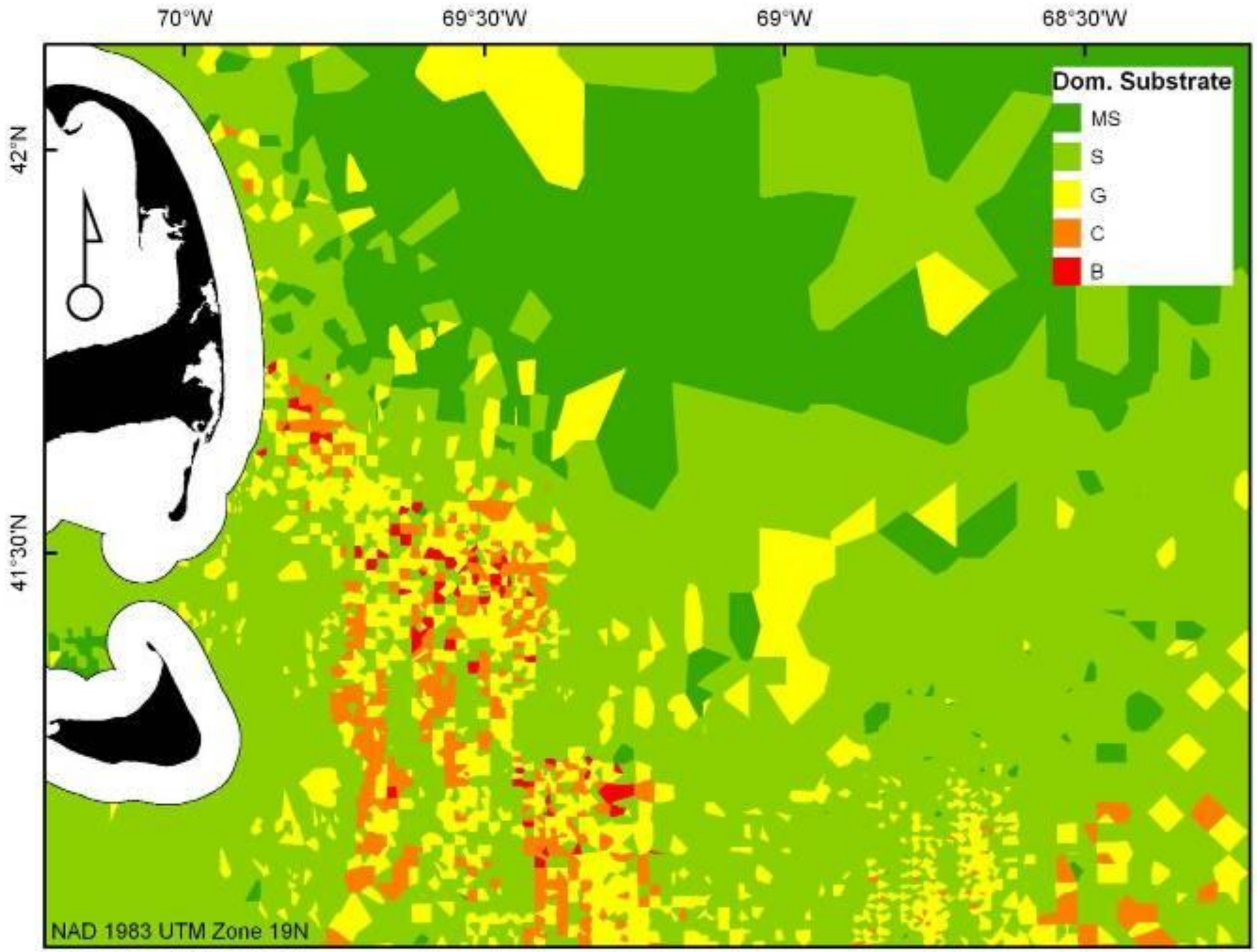
Model grid – draw Voronoi cells

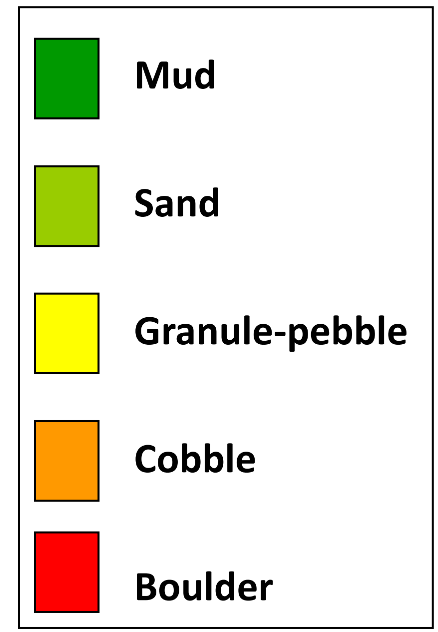


*Voronoi tessellations allow the size of the grid cell to vary in proportion to the density of data available**

*Each polygon is convex, and defined by the perpendicular bisectors of lines drawn between geological data points such that each polygon bounds the region closest to that data point relative to all others (Thiessen and Alter 1911, Gold 1991, Okabe et al. 1992, Legendre and Legendre 1998)

Cells colored by dominant substrate*





**Based on Wentworth scale*

Energy regimes

Variations in the flow of water over the seabed creates a habitat's energy environment

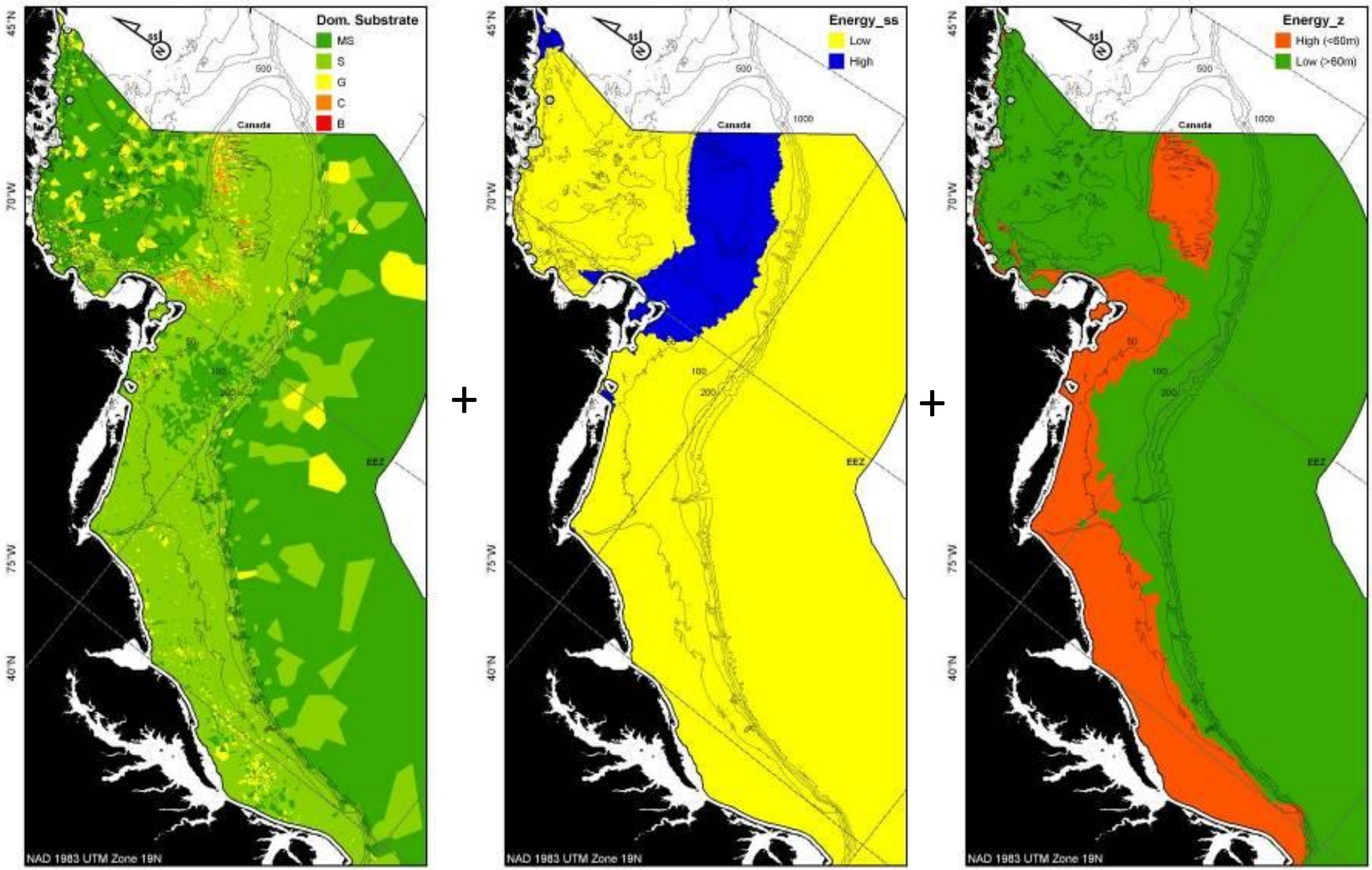
Energy environment affects the:

- nature of fishing gear impacts
- susceptibility of habitats to fishing gears
- rates of recovery

In the SASI model, energy is defined as high or low, based on a combination of critical shear stress and depth.

Habitat =

Substrate + Energy – shear stress* + Energy – depth*



*High energy based on either criteria indicates high energy cell

Parameterizing SASI:

Estimating A

Contact-adjusted area swept (A)

A is the sum of the linear effective width of the gear components (e.g. otter boards, sweep, cables) multiplied by the distance the gear travels and the proportion of the gear in contact with the bottom during normal operation (c).

To calculate A, we combine:

Contact patch	(w*d)	*empirically derived from observer, VTR and VMS data*
Contact index	(c)	*categorically specified by gear type*

Gear component-specific models were developed for the following gear types:

Trawl	Groundfish, Scallop
	Shrimp
	Squid
	Raised footrope
Dredge	Scallop
	Surf clam/Ocean quahog
Trap	Lobster, Deep sea red crab
Fixed	Longline
	Sink gillnet

Calculating area swept:
trawl gear example

Cont. adj. area swept (m^2) = $d_t[(2 \cdot w_o \cdot c_o) + (2 \cdot w_c \cdot c_c) + (w_s \cdot c_s)]$

d_t = distance towed in one tow (m)

w_o = effective width of otter board (m), which equals otter board length (m)·sin (α_o), where α_o = angle of attack

c_o = contact index, otter board

w_c = effective width of ground cables (m)

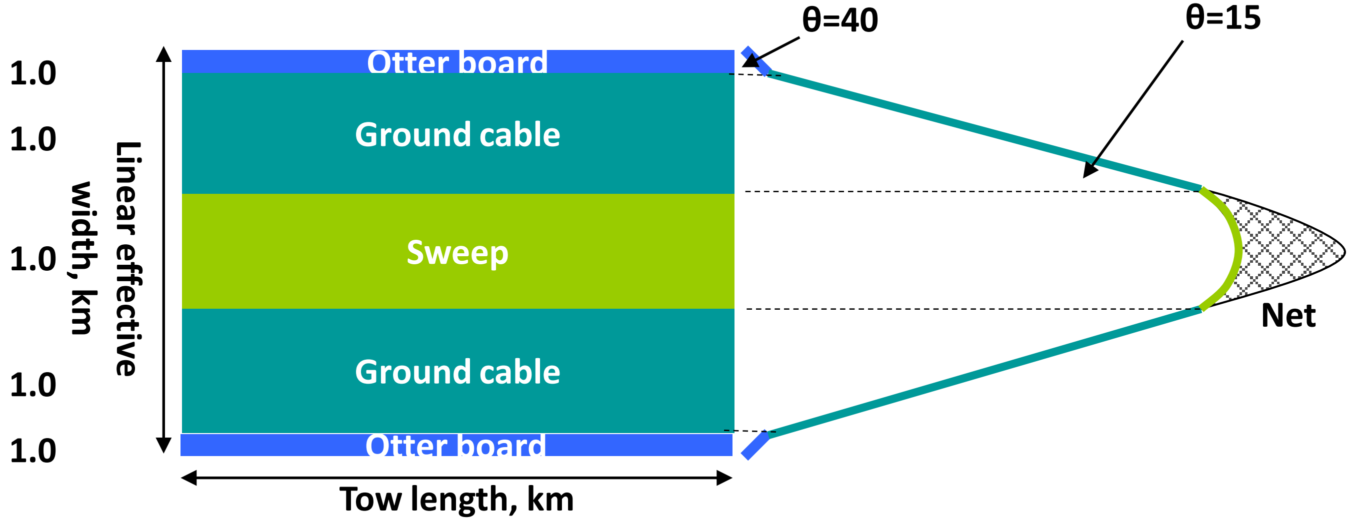
c_c = contact index, ground cables, which equals ground cable length (m) ·sin(α_c), where α_c = angle of attack

w_s = effective width of sweep (m)

c_s = contact index, sweep

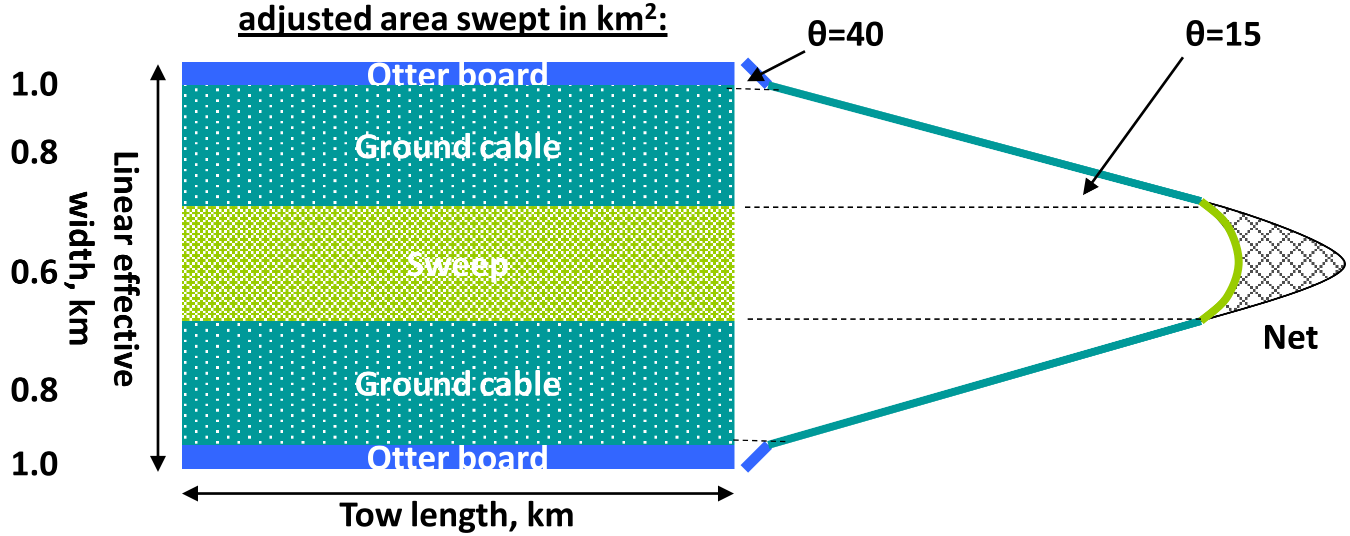
Shaded area represents nominal area swept in km²:

Contact index is held constant at 1.0:

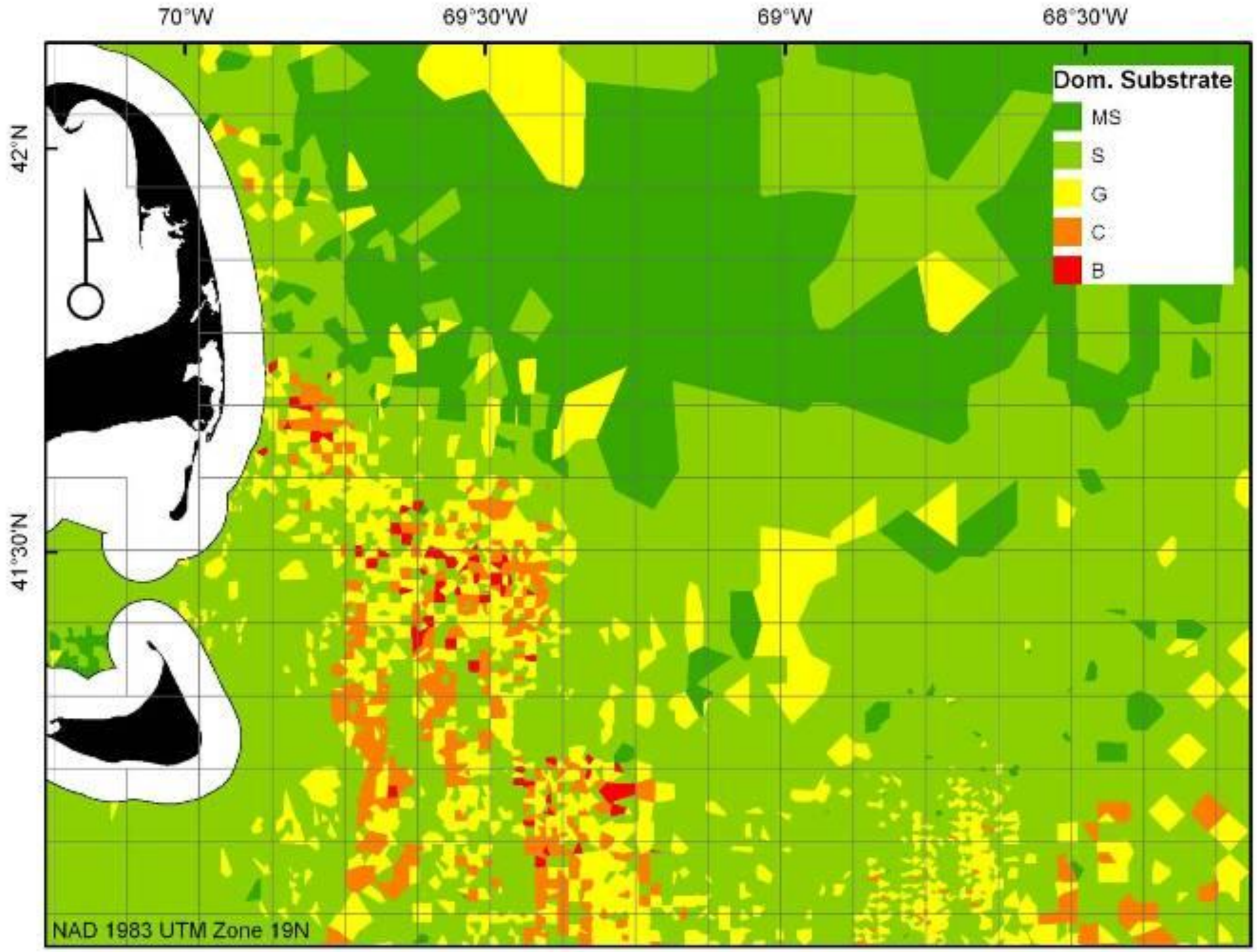


Shaded area represents contact-adjusted area swept in km²:

Contact index is allowed to vary by gear component:



Contact adjusted area swept is assigned to the appropriate 10 km^2 grid



Parameterizing SASI:

Estimating Ω

Vulnerability (Ω)

Ω is a combination of the effects of a fishing gear on the functional value provided by a unit of habitat (*susceptibility*), and the recovery in functional value that unit of habitat will experience after the gear effect has passed (*recovery*)

$$\Omega = f\text{(susceptibility, recovery)}$$

where susceptibility and recovery may vary across:

- Gear types
- Substrates
- Energy environments
- Habitat features

Habitat components and features

Geological

Biogenic burrows, Biogenic depressions, Special-case biogenic burrows, Bedforms, Featureless mud and sand, Gravel pavement, Scattered gravel, Piled cobbles/boulders, Shell debris → Matrices → Ω

Biological

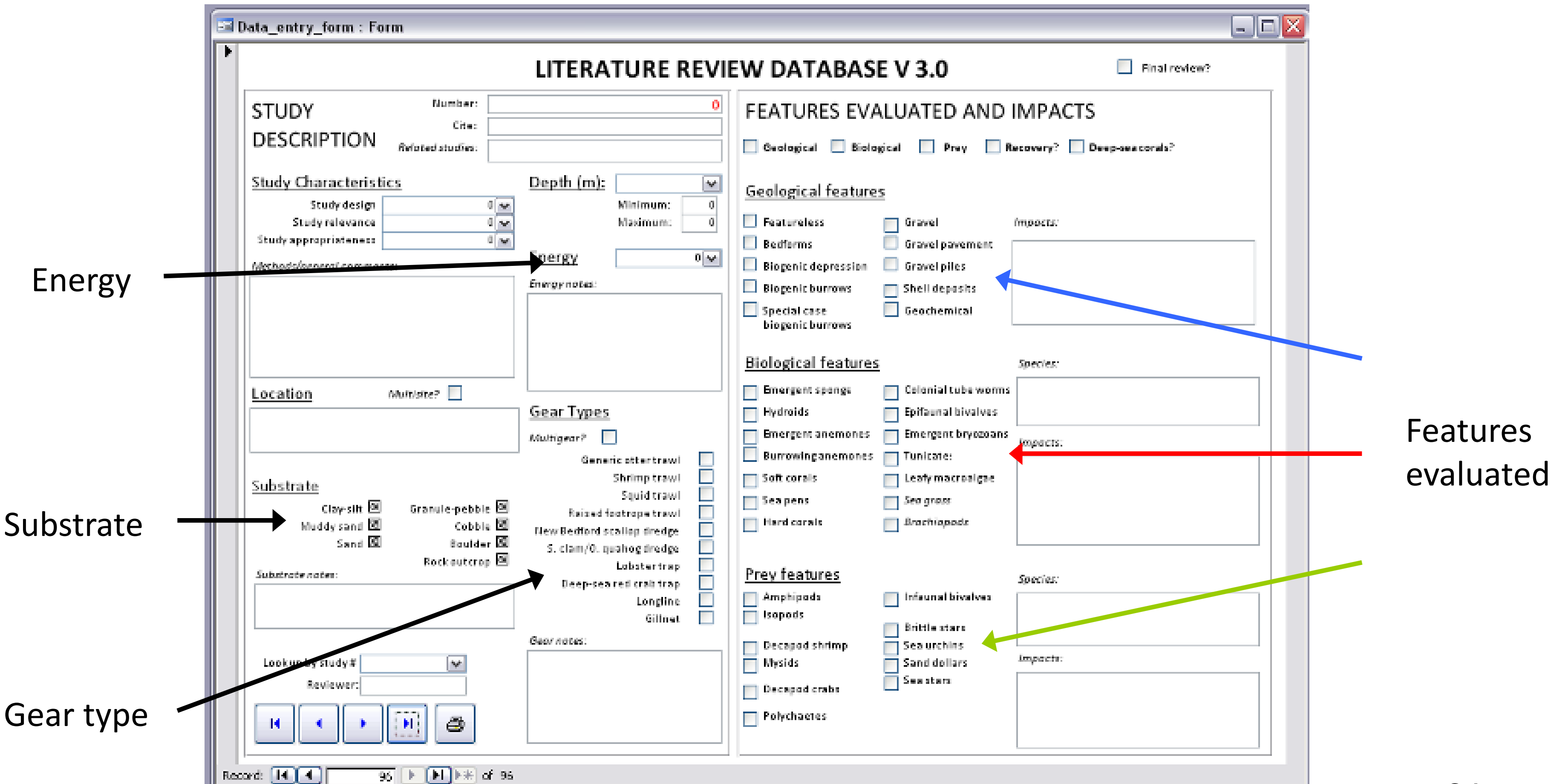
Sponges, Hydroids, Anemones, Burrowing anemones, Soft corals/gorgonians, Hard corals, Colonial tube worms, Epifaunal bivalves, Bryozoans, Ascidians, Macroalgae → Matrices → Ω

Prey

Amphipods/isopods, Polychaete worms, Decapod shrimp, Decapod crabs, Infaunal bivalves, Echinoderms → Matrices

Literature review

Comprehensive evaluation of 96 studies, selected for use based on relevance to regional habitats and gears



Infer features to habitats by substrate and energy

Example: geological

	Mud		***Sand***		***Granule-pebble***		***Cobble***		***Boulder***	
Feature	***High***	***Low***	***High***	***Low***	***High***	***Low***	***High***	***Low***	***High***	***Low***
Featureless	■	■		■						
Biogenic depressions	■	■	■	■						
Biogenic burrows	■	■	■	■						
Special case biogenic burrows	■	■								
Bedforms	■		■							
Scattered gravel					■	■	■	■	■	■
Gravel pavement					■		■			
Gravel piles							■	■	■	■
Shell debris	■	■	■	■	■	■	■	■	■	■

Sample matrix – generic trawl gear/mud

Gear type (Generic trawl)								
Substrate (Mud)								
Feature type	*Feature*	*Gear effects*	*Studies documenting gear-substrate-feature interaction (high energy)*	*Studies documenting gear-substrate-feature interaction (low energy)*	S_{avg}	$R_{high\ energy}$	$R_{low\ energy}$	*Notes*
Geological	Featureless	resuspension, compression, geochemical	35, 88, 92, 211, 236, 334, 408, 409, 599	88, 211, 277, 283, 313, 320, 335, 336, 372, 414				
Geological	Biogenic depressions	filling	11, 35, 408, 409	11, 101, 336				
Geological	Biogenic burrows	filling, crushing	334, 408, 409	101, 313, 336				
Geological	Special-case biogenic burrows	filling, crushing	none	none				
Geological	Bedforms	smoothing	11, 35, 211, 236, 408, 409	11, 211, 414			n/a	
Geological	Shell debris	burying, crushing, displacing	11	11, 101				
Biological	Hydroids	breaking, crushing, dislodging, displacing	11, 34, 228, 368, 408, 409	11, 368				
Biological	Anemones, burrowing	breaking, crushing, dislodging, displacing	228	none				
Biological	Sea pens	breaking, crushing, dislodging, displacing	228	101, 164				
Biological	Epifaunal bivalve mollusks	breaking, crushing, dislodging, displacing	21, 34, 368, 408, 409	89, 203, 368				
Prey	Amphipods	breaking, crushing, dislodging, displacing	34, 211, 228, 292, 334, 408, 409, 599, 658	89, 90, 211, 320				
Prey	Decapod shrimp	breaking, crushing, dislodging, displacing	11, 211, 292, 368, 409, 599, 658	11, 89, 90, 164, 211, 335, 368				
Prey	Decapod crabs	breaking, crushing, dislodging, displacing	21, 211, 292, 368, 408, 409	24, 89, 90, 164, 211, 368				
Prey	Polychaetes	breaking, crushing, dislodging, displacing	34, 88, 211, 228, 292, 334, 368, 408, 409, 599, 658	88, 89, 90, 101, 203, 211, 320, 335, 336, 368, 372				
Prey	Infaunal bivalve mollusks	breaking, crushing, dislodging, displacing	21, 34, 88, 211, 228, 292, 334, 368, 408, 409, 599, 658	88, 89, 90, 101, 203, 211, 320, 335, 368, 372, 414				
Prey	Echinoderms	breaking, crushing, dislodging, displacing	21, 228, 292, 368, 408, 409, 658	24, 89, 90, 101, 164, 335, 368, 414				

Metrics for (S) and (R)

Susceptibility values

Code	*Description*	*Quantitative*
0	None	0
1	Low	>0 - 25%
2	Medium	25 - 50%
3	High	> 50%

Recovery values

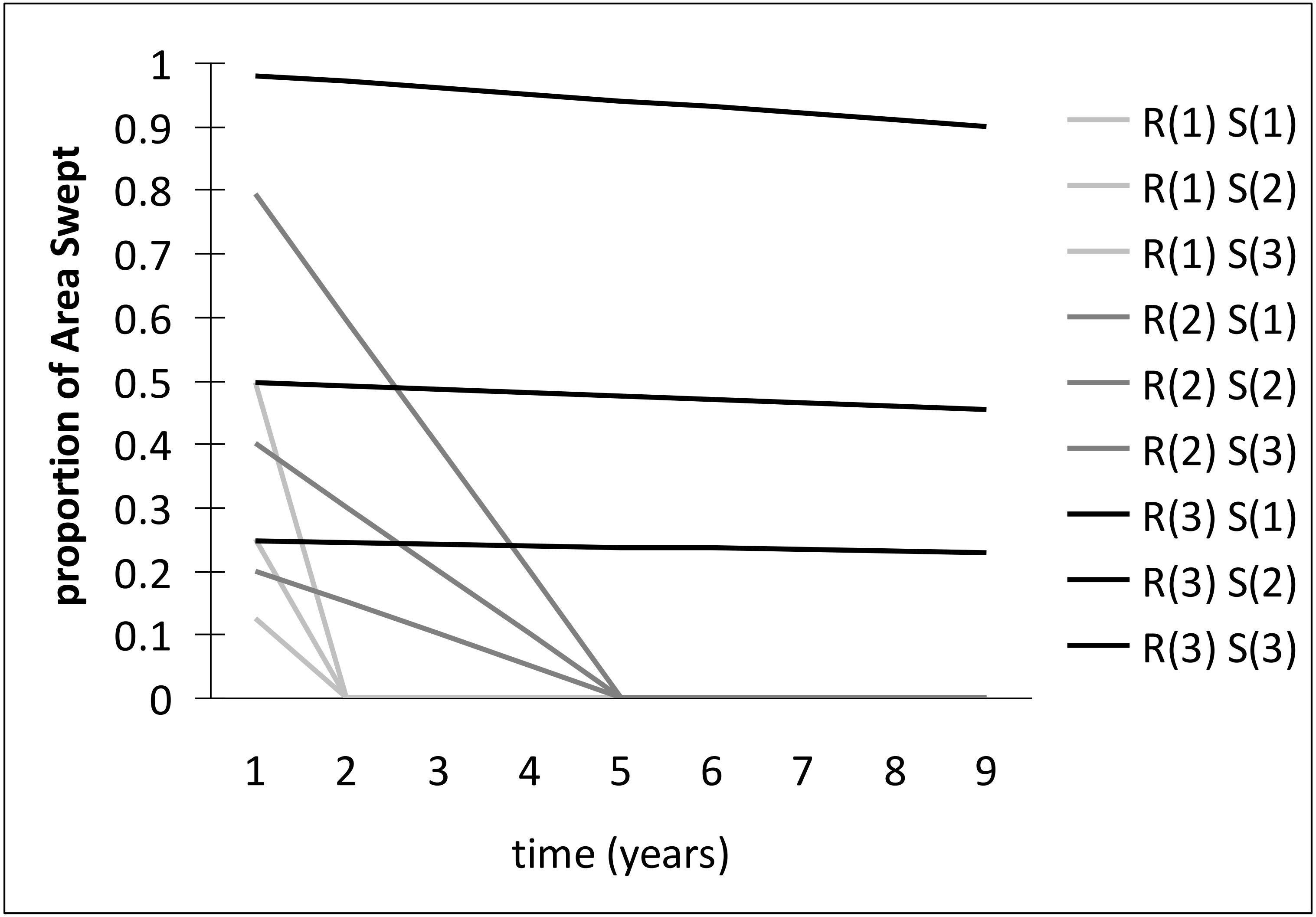
Code	*Description*	*Quantitative*
0	Fast	< 1 year
1	Moderate	1 – 2 years
2	Slow	2 – 5 years
3	Very slow	> 5 years

Combining S and R to generate Ω

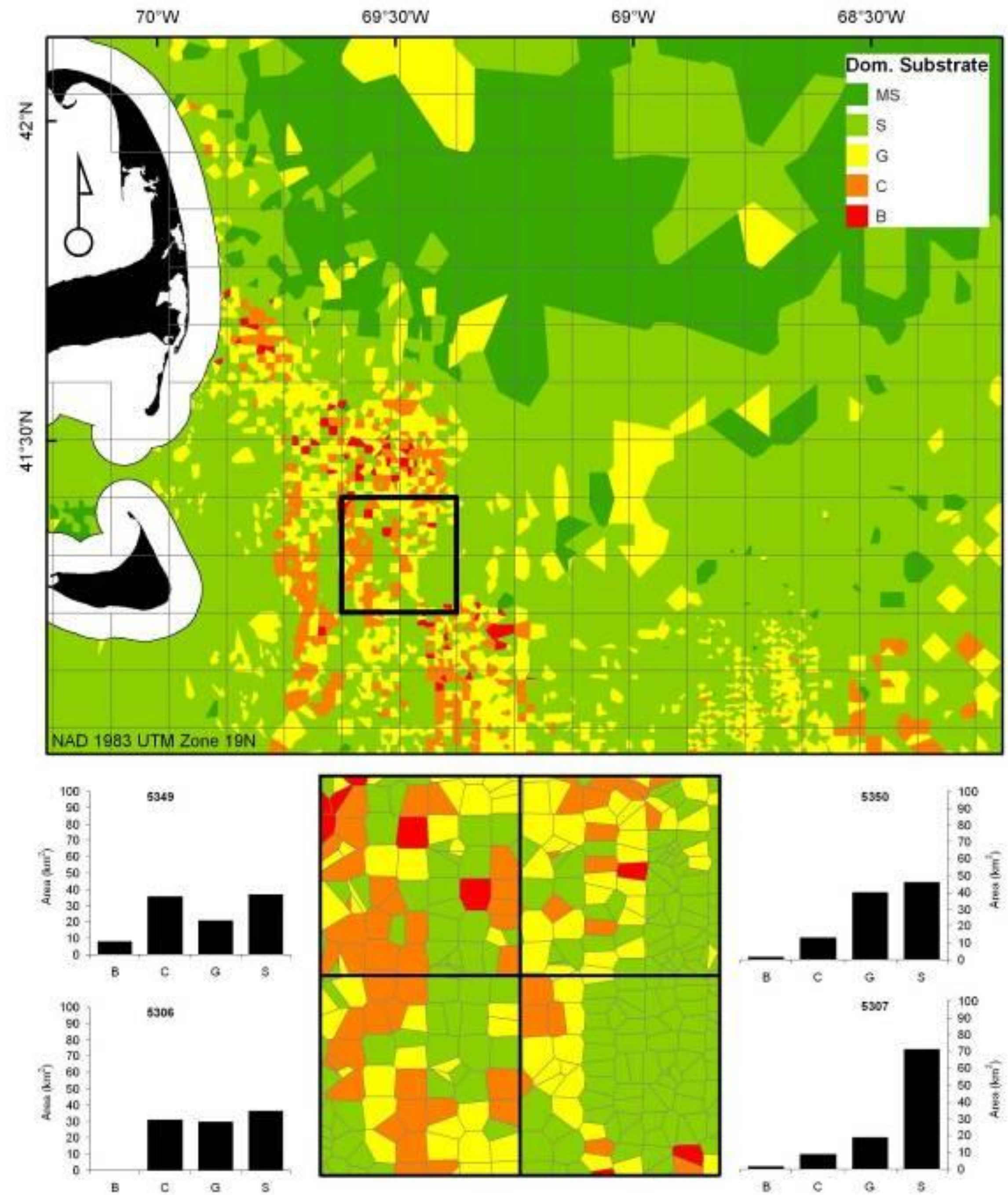
Ω is modeled as a linear decay function, based on the (S) and (R) metric definitions, where the:

- (S) value determines the initial reduction in contact-adjusted area swept (i.e. the resulting "adverse effect")
- (R) value determines the duration of that effect

Decay of area swept over time



Proportion of Voronoi cells in 10 km^2 grid with dominant substrate:



Preliminary model outputs

(based on geological feature matrix scores only)

- Geological features were weighted according to their assumed relative abundance

- Area swept and other statistics are shown for each year separately

- These results combine S and R values into a single sensitivity parameter, rather than using decay function for R

- The decay function will allow for accumulation of fishing effort over time, eliminating need to run model over discrete time steps

Trawl gear component dimensions (m), 1996-2008

groundfish trawl

YEAR	nom. otter board	contact-adj ott board	nom. ground cables	contact-adj gr cables	nom. sweep	contact-adj sweep	nom. gear width	contact-adj gear width
1996	2.0	2.0	38.5	36.5	18.1	16.3	58.6	54.8
1997	2.0	2.0	38.3	36.4	17.9	16.1	58.2	54.5
1998	2.0	2.0	38.2	36.3	17.7	15.9	57.9	54.2
1999	2.0	2.0	38.3	36.4	17.8	16.0	58.1	54.4
2000	2.0	2.0	38.2	36.3	18.0	16.2	58.2	54.5
2001	2.0	2.0	37.9	36.0	17.5	15.8	57.4	53.8
2002	2.0	2.0	37.8	35.9	17.3	15.6	57.1	53.5
2003	2.0	2.0	37.9	36.0	17.5	15.7	57.4	53.7
2004	2.0	2.0	38.2	36.3	17.8	16.0	57.9	54.3
2005	2.0	2.0	38.6	36.7	18.1	16.3	58.7	55.0
2006	2.0	2.0	38.6	36.6	18.2	16.4	58.8	55.1
2007	2.0	2.0	38.5	36.6	18.2	16.4	58.7	55.0
2008	2.0	2.0	38.5	36.6	18.2	16.4	58.8	55.0

raised

YEAR	nom. otter board	contact-adj ott board	nom. ground cables	contact-adj gr cables	nom. sweep	contact-adj sweep	nom. gear width	contact-adj gear width
1996	.	.	.	.	.	.	.	.
1997	.	.	.	.	.	.	.	.
1998	.	.	.	.	.	.	.	.
1999	.	.	.	.	.	.	.	.
2000	.	.	.	.	.	.	.	.
2001	.	.	.	.	.	.	.	.
2002	.	.	.	.	.	.	.	.
2003	2.0	2.0	37.8	35.9	17.7	0.9	57.5	38.8
2004	2.0	2.0	37.0	35.2	17.1	0.9	56.2	38.0
2005	1.9	1.9	36.6	34.8	16.0	0.8	54.5	37.5
2006	2.0	2.0	38.5	36.6	18.2	0.9	58.7	39.5
2007	1.9	1.9	36.0	34.2	15.5	0.8	53.4	36.9
2008	1.9	1.9	36.4	34.6	16.1	0.8	54.4	37.3

shrimp

YEAR	nom. otter board	contact-adj ott board	nom. ground cables	contact-adj gr cables	nom. sweep	contact-adj sweep	nom. gear width	contact-adj gear width
1996	1.9	1.9	14.2	12.8	15.7	14.9	31.8	29.6
1997	1.9	1.9	14.2	12.8	16.0	15.2	32.2	30.0
1998	1.9	1.9	14.2	12.8	15.8	15.0	32.0	29.7
1999	1.9	1.9	14.2	12.8	16.1	15.3	32.2	30.0
2000	2.0	2.0	14.2	12.8	16.5	15.7	32.7	30.4
2001	1.9	1.9	14.2	12.8	16.2	15.4	32.3	30.1
2002	2.0	2.0	14.2	12.8	17.6	16.7	33.7	31.5
2003	1.9	1.9	14.2	12.8	16.0	15.2	32.1	29.9
2004	1.9	1.9	14.2	12.8	15.9	15.1	32.1	29.8
2005	1.9	1.9	14.2	12.8	15.7	14.9	31.8	29.6
2006	2.0	2.0	14.2	12.8	16.6	15.7	32.7	30.5
2007	2.0	2.0	14.2	12.8	16.9	16.0	33.0	30.8
2008	2.0	2.0	14.2	12.8	17.7	16.8	33.9	31.6

squid

YEAR	nom. otter board	contact-adj ott board	nom. ground cables	contact-adj gr cables	nom. sweep	contact-adj sweep	nom. gear width	contact-adj gear width
1996	2.1	2.1	40.4	38.4	20.6	10.3	63.1	50.8
1997	2.1	2.1	39.9	37.9	20.1	10.1	62.2	50.1
1998	2.1	2.1	40.6	38.5	20.9	10.5	63.6	51.1
1999	2.1	2.1	39.6	37.6	19.9	9.9	61.5	49.6
2000	2.1	2.1	39.5	37.5	19.6	9.8	61.2	49.4
2001	2.1	2.1	39.6	37.6	20.0	10.0	61.8	49.8
2002	2.1	2.1	39.6	37.6	19.9	10.0	61.6	49.7
2003	2.1	2.1	40.5	38.5	20.9	10.4	63.5	51.0
2004	2.1	2.1	40.1	38.1	20.5	10.2	62.6	50.4
2005	2.2	2.2	41.4	39.3	21.7	10.9	65.3	52.3
2006	2.1	2.1	40.8	38.8	20.9	10.5	63.9	51.4
2007	2.1	2.1	39.9	37.9	20.6	10.3	62.6	50.3
2008	2.1	2.1	39.5	37.5	19.7	9.8	61.2	49.4

Trawl gear component dimensions (m), all years summary

	nom. otter board		***contact-adj ott board***		***nom. ground cables***		***contact-adj gr cables***	
	mean	*st. dev.*	*mean*	*st. dev.*	*mean*	*st. dev.*	*mean*	*st. dev.*
Gear Type								
otter	2.01	*0.2*	2.01	*0.2*	38.25	*4.28*	36.34	*4.07*
raised	1.96	*0.15*	1.96	*0.15*	36.89	*3.41*	35.05	*3.24*
shrimp	1.94	*0.14*	1.94	*0.14*	14.2	*0*	12.78	*0*
squid	2.11	*0.25*	2.11	*0.25*	40.01	*4.21*	38.01	*4*

	nom. sweep		***contact-adj sweep***		***nom. gear width***		***contact-adj gear width***	
	mean	*st. dev.*	*mean*	*st. dev.*	*mean*	*st. dev.*	*mean*	*st. dev.*
Gear Type								
otter	17.84	*4.92*	16.06	*4.43*	58.11	*9.05*	54.42	*8.37*
raised	16.61	*3.68*	0.83	*0.18*	55.46	*7.07*	37.83	*3.55*
shrimp	16.19	*3.39*	15.38	*3.22*	32.33	*3.53*	30.1	*3.36*
squid	20.3	*6.09*	10.15	*3.04*	62.41	*10.17*	50.27	*7.03*

Trawl fishing effort, 1996-2008

	otter						raised					
	soak time per tow		*# hauls*		*hours fished per trip*		*soak time per tow*		*# hauls*		*hours fished per trip*	
	mean	*st dev*	mean	*st dev*	mean	*st dev*	mean	*st dev*	mean	*st dev*	mean	*st dev*
YEAR												
1996	2.68	*1.62*	7.55	*9.9*	22.44	*35.53*	.	.	.	.	.	.
1997	2.66	*3.26*	6.73	*8.88*	19.5	*31.53*	.	.	.	.	.	.
1998	2.64	*1.88*	6.47	*8.85*	19.01	*31.09*	.	.	.	.	.	.
1999	2.63	*1.62*	6.52	*8.73*	19.47	*31.92*	.	.	.	.	.	.
2000	2.59	*1.51*	6.19	*8.7*	18.28	*30.48*	.	.	.	.	.	.
2001	2.37	*1.08*	6.52	*8.95*	16.93	*27.1*	.	.	.	.	.	.
2002	2.16	*0.8*	5.97	*8.4*	13.92	*22.26*	.	.	.	.	.	.
2003	2.16	*0.77*	5.82	*7.91*	13.4	*20.78*	1.88	*0.32*	4.48	*2.86*	8.36	*5.4*
2004	2.16	*0.8*	5.6	*7.69*	12.88	*20.31*	1.8	*0.39*	4.64	*2.36*	8.19	*4.49*
2005	2.14	*0.81*	5.47	*7.16*	12.64	*20.33*	1.96	*0.43*	3.26	*2.15*	6.36	*4.28*
2006	2.1	*0.8*	5.58	*6.77*	12.67	*19.3*	2.1	*0.29*	4.18	*2.35*	8.85	*5.1*
2007	2.07	*0.72*	5.54	*7.15*	12.42	*19.31*	2.11	*0.57*	3.43	*4.1*	7.23	*10.66*
2008	2.05	*0.67*	5.37	*7*	12.02	*19.09*	1.76	*0.32*	3.52	*1.38*	6.09	*2.51*

	shrimp						squid					
	soak time per tow		*# hauls*		*hours fished per trip*		*soak time per tow*		*# hauls*		*hours fished per trip*	
	mean	*st dev*	mean	*st dev*	mean	*st dev*	mean	*st dev*	mean	*st dev*	mean	*st dev*
YEAR												
1996	2.42	*0.87*	3.85	*3.97*	9.45	*11.02*	2.42	*0.88*	9.92	*8.65*	24.45	*23.19*
1997	2.54	*0.93*	4.22	*4.49*	11.35	*15.01*	2.35	*0.82*	8.91	*7.9*	22.08	*22.38*
1998	2.5	*0.93*	4.37	*4.76*	11.4	*14.7*	2.6	*0.88*	9.67	*9.37*	26.29	*26.93*
1999	2.56	*0.99*	6.18	*7.93*	15.52	*20.6*	2.45	*0.89*	9.13	*9.19*	24.52	*27.97*
2000	2.44	*1.06*	6.38	*8.05*	17.05	*24.2*	2.36	*0.94*	6.14	*7.17*	16.12	*23.21*
2001	2.46	*0.85*	5.37	*6.88*	12.58	*16.36*	2.33	*0.75*	7.34	*7.09*	17.67	*20.14*
2002	2.24	*0.62*	8.67	*8.13*	19.97	*20.94*	2.23	*0.59*	7.26	*6.85*	16.56	*18.17*
2003	2.19	*0.46*	4.69	*5.36*	10.36	*12.83*	2.27	*0.65*	8.81	*7.17*	20.86	*21.77*
2004	2.08	*0.43*	5.15	*5.62*	10.89	*13.2*	2.18	*0.59*	7.89	*6.78*	17.71	*18.22*
2005	2.12	*0.42*	3.68	*4.48*	7.77	*11.44*	2.2	*0.66*	9	*7.9*	20.9	*20.78*
2006	1.96	*0.41*	4.74	*6*	9.68	*14.23*	2.14	*0.55*	8.53	*7.37*	19.05	*18.81*
2007	2.07	*0.46*	5.86	*5.93*	12.76	*15.22*	2.17	*0.65*	8.16	*7.93*	19	*22.28*
2008	2.03	*0.47*	5.94	*6.2*	12.51	*15.16*	2.14	*0.62*	7.8	*7.49*	17.37	*19.18*

Contact-adjusted area swept (km^2), all trawl components combined, 1996-2008

	Trawl gears *contact-adj as per tow*							
	otter		**raised**		**shrimp**		**squid**	
	mean	*st dev*	mean	*st dev*	mean	*st dev*	mean	*st dev*
YEAR								
1996	7.64	*13.08*	.	.	1.62	*2.16*	7.46	*7.98*
1997	6.63	*11.66*	.	.	1.98	*2.92*	6.66	*7.62*
1998	6.46	*11.41*	.	.	1.99	*2.82*	8.11	*9.15*
1999	6.73	*11.89*	.	.	2.78	*4*	7.54	*9.74*
2000	6.28	*11.24*	.	.	3.21	*4.76*	4.85	*8.03*
2001	5.79	*10.11*	.	.	2.28	*3.21*	5.28	*6.79*
2002	4.7	*8.32*	.	.	3.74	*4.09*	4.88	*6.01*
2003	4.57	*7.74*	1.86	*1.34*	1.81	*2.42*	6.27	*7.16*
2004	4.45	*7.63*	1.77	*1.05*	1.93	*2.58*	5.24	*5.84*
2005	4.37	*7.65*	1.36	*1*	1.34	*2.47*	6.44	*6.73*
2006	4.41	*7.32*	2.02	*1.3*	1.78	*2.96*	5.78	*6.18*
2007	4.42	*7.4*	1.54	*2.52*	2.38	*3.12*	5.92	*7.59*
2008	4.06	*7.13*	1.28	*0.62*	2.39	*3.95*	5.12	*6.27*

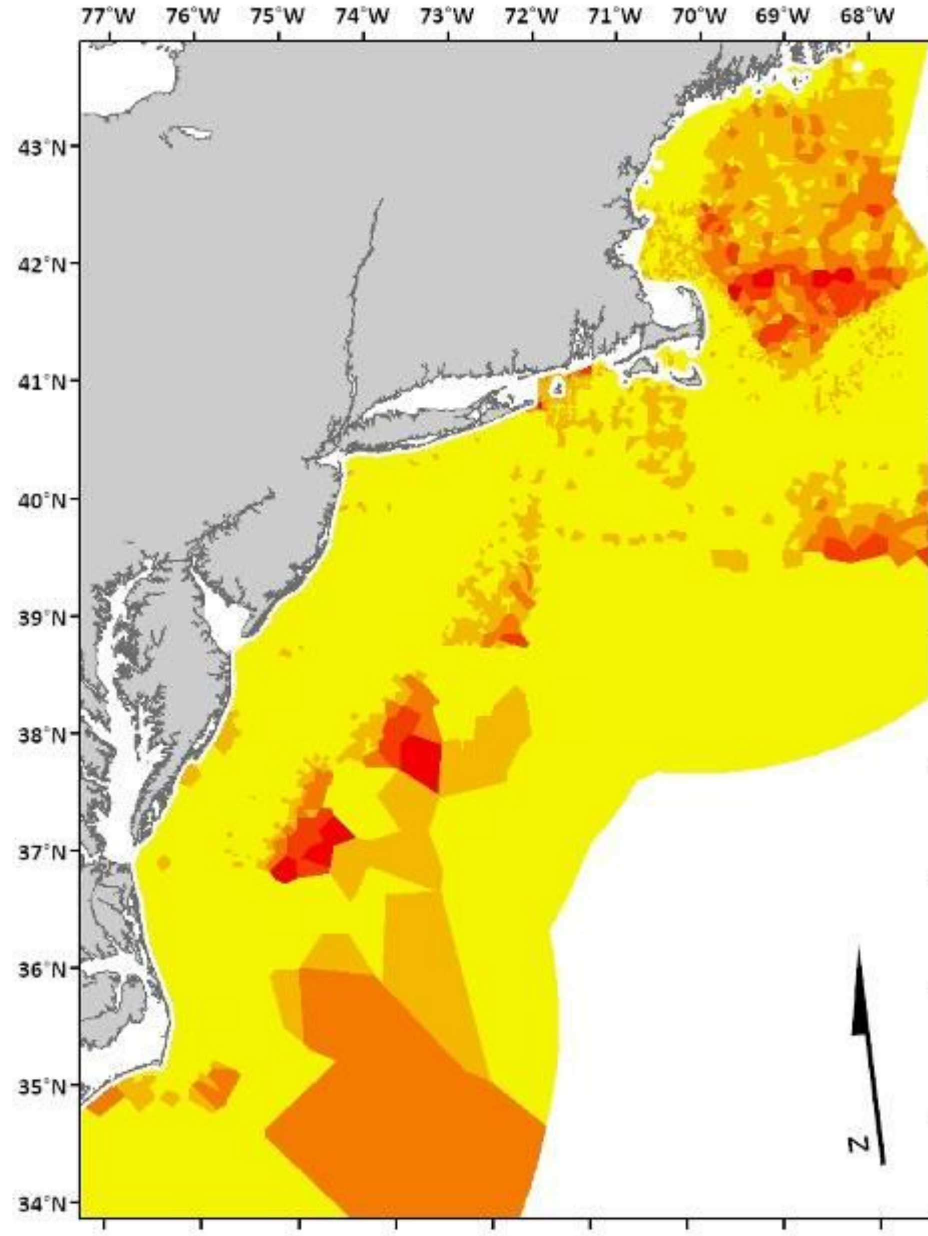
All trawl types:

Contact-adjusted area swept (km^2) and sensitivity-adjusted area swept (km^2), all trawl components combined, 1996-2008

	otter				raised			
YEAR	*Contact-Adj AS*	*SASI*	*Hrs Fished*	*Revenue*	*Contact-Adj AS*	*SASI*	*Hrs Fished*	*Revenue*
1996	262,942	81,391	776,356	216,459,098	.	.	.	.
1997	215,306	66,555	638,477	193,989,081	.	.	.	.
1998	214,624	66,202	640,978	198,158,696	.	.	.	.
1999	209,143	64,153	618,855	194,896,871	.	.	.	.
2000	194,060	59,509	578,182	197,701,861	.	.	.	.
2001	179,879	54,934	537,527	216,617,059	.	.	.	.
2002	145,842	44,488	437,245	198,434,650	.	.	.	.
2003	134,846	40,909	406,426	195,158,814	298	71	1,337	375,679
2004	132,984	40,034	398,154	199,378,042	301	71	1,393	448,170
2005	136,723	41,459	408,356	184,972,601	150	36	699	187,404
2006	119,442	36,231	355,245	149,940,774	214	51	939	315,490
2007	105,878	32,118	312,696	142,795,329	314	76	1,476	387,663
2008	89,396	27,147	263,359	129,272,828	313	75	1,492	406,684

	shrimp				squid			
YEAR	*Contact-Adj AS*	*SASI*	*Hrs Fished*	*Revenue*	*Contact-Adj AS*	*SASI*	*Hrs Fished*	*Revenue*
1996	15,461	4,465	91,254	18,659,817	10,281	2,446	33,631	14,971,035
1997	16,061	4,605	93,253	18,165,981	14,755	3,595	48,813	13,035,570
1998	9,345	2,716	55,370	10,220,056	17,643	4,218	56,892	23,877,756
1999	9,297	2,537	52,803	9,345,435	21,208	5,093	68,669	18,977,654
2000	11,758	3,114	65,405	14,040,666	13,906	3,328	45,613	17,762,064
2001	8,046	2,184	45,798	7,210,668	11,198	2,681	36,953	12,425,800
2002	5,684	1,445	30,742	6,358,600	12,403	2,980	41,359	14,667,915
2003	3,656	1,012	21,255	4,459,827	8,339	1,969	27,427	12,349,556
2004	4,056	1,117	23,399	3,416,174	8,246	1,956	27,490	18,281,947
2005	2,722	816	16,574	2,795,557	8,870	2,095	28,848	18,041,481
2006	2,889	803	16,263	3,273,999	12,133	2,916	39,845	16,978,920
2007	6,313	1,686	34,794	9,419,157	8,912	2,079	28,745	19,211,399
2008	7,033	1,867	38,046	9,269,063	10,186	2,414	33,930	9,749,980

2006 generic otter trawl, SASI units



Alternative development

- Maps and matrices will provide the public, habitat oversight committee and Council with an objective tool for assessing adverse effects
- Gear-specific representations of susceptibility and recovery provide the committee and Council insight into which areas are most likely to be vulnerable to adverse effects from fishing
- Realized fishing effort (SASI) provides insight into how these effects have changed/are changing over time

Impacts analysis

SASI allows the PDT to quantify management alternative-specific changes in seabed impacts:

- Area-based fishing restrictions *(mapping hypothetical future fishing effort)*
- Gear modifications *(altering SASI contact and sensitivity indices)*
- Effort reductions (*changes in SASI from specified baseline)*

Summary

This approach creates an objective, iterative model with a set of consistent metrics for analyzing and comparing adverse impacts to habitats across:

- All FMP documents
- Each FMP's Amendment and Framework documents

Additional Slides

Model Assumptions

1. Fishing gear impact is constant within a tow
2. There is constant impact along the entire length of a gear component
3. The impact of each gear component is cumulative
4. A gear component has the same impact on the epibethos and infauna irrespective of its size, length, weight, design and rigging, unless it translates into a reduced contact index
5. Seabed topography and composition are consistent within a tow
6. The abundance of habitat features within a tow is uniform
7. Otter board angle of attack is constant during a tow
8. Ground cables are straight along their entire length
9. Seabed contact (contact index) is consistent for a given gear type
10. The effect of towing speed on seabed contact is accommodated by (d)
11. The impact of multiple tows is linear and additive
12. Substrates do not vary with time

Scallop dredge components, 1996-2008

	# dredges		total width of dredges	
	mean	*st dev*	*mean*	*st dev*
YEAR				
1996	1.529	*0.558*	5.725	*3.882*
1997	1.409	*0.557*	5.012	*3.437*
1998	1.485	*0.551*	5.513	*3.5*
1999	1.576	*0.526*	5.95	*3.351*
2000	1.599	*0.5*	6.484	*4.805*
2001	1.456	*0.499*	5.255	*3.275*
2002	1.417	*0.493*	5.018	*3.252*
2003	1.409	*0.492*	5.03	*3.265*
2004	1.384	*0.486*	4.856	*2.916*
2005	1.262	*0.44*	4.158	*2.266*
2006	1.274	*0.446*	4.218	*2.184*
2007	1.398	*0.489*	4.755	*2.291*
2008	1.436	*0.496*	4.958	*2.355*

Scallop dredge fishing effort, 1996-2008

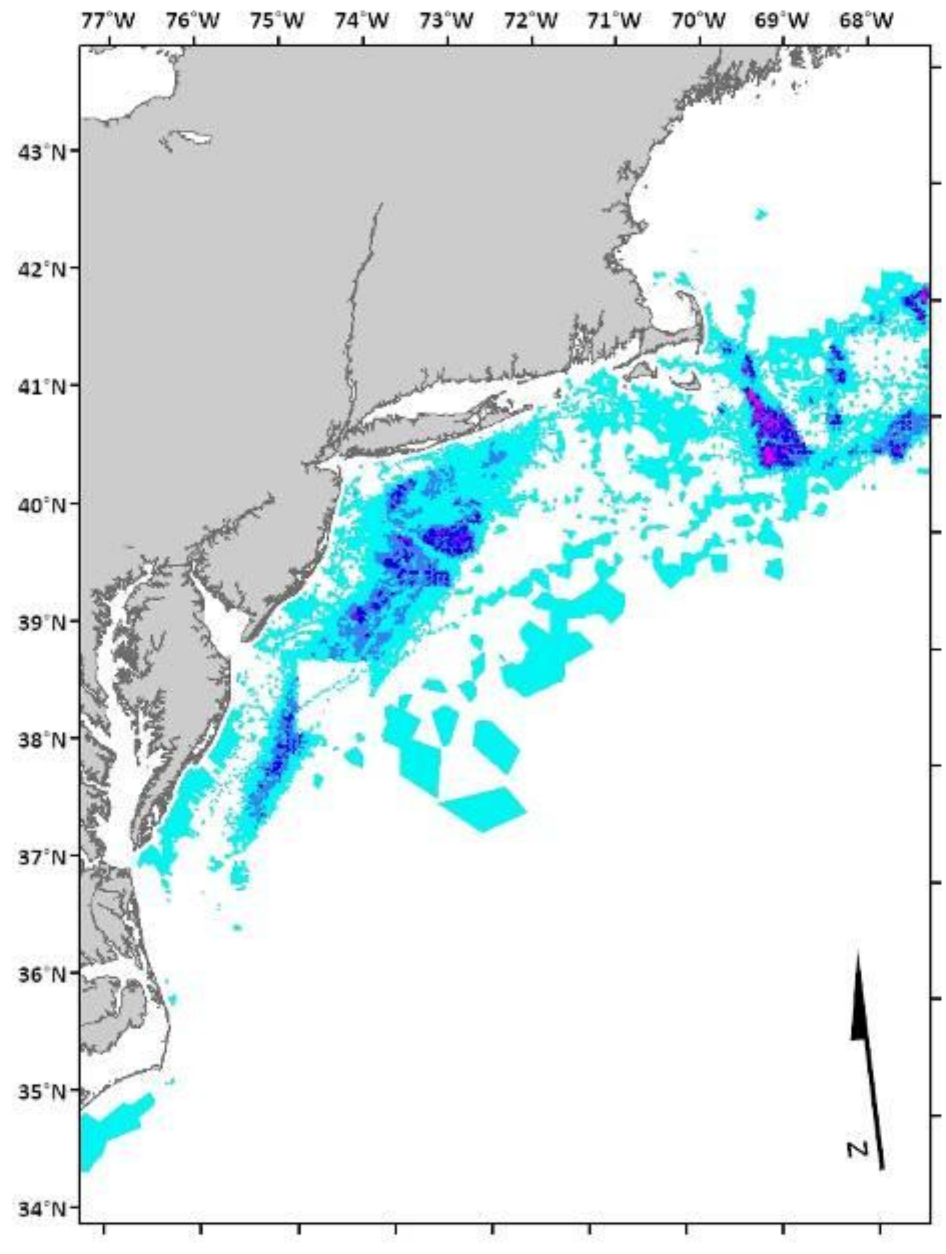
	soak time per tow		***# hauls***		***hours fished per trip***		***contact-adj as per trip***	
	mean	*st dev*	*mean*	*st dev*	*mean*	*st dev*	*mean*	*st dev*
YEAR								
1996	0.69	*0.37*	80.6	*68.8*	66.9	*70.12*	4.29	*5.33*
1997	0.67	*0.33*	65.69	*67.38*	53.18	*65.47*	3.28	*4.72*
1998	0.7	*0.34*	67.97	*65.99*	55.82	*64.27*	3.59	*4.75*
1999	0.79	*0.36*	61.83	*62.47*	55.06	*65.23*	3.59	*4.78*
2000	0.77	*0.36*	61.62	*63.61*	55.6	*68.4*	4.02	*7.11*
2001	0.98	*0.29*	46.67	*56.58*	47.98	*62.39*	3.01	*4.89*
2002	1.11	*0.13*	49.54	*58.96*	54.62	*65.69*	3.34	*5.16*
2003	1.11	*0.15*	47.92	*57.92*	52.87	*64.44*	3.22	*5*
2004	1.14	*0.12*	37.22	*49.49*	42.49	*56.6*	2.45	*4.07*
2005	1.17	*0.11*	23.31	*38.73*	27.2	*45.33*	1.4	*3.18*
2006	1.15	*0.08*	23.9	*36.04*	27.42	*41.31*	1.34	*2.88*
2007	1.15	*0.06*	26.1	*39.71*	29.92	*45.66*	1.54	*3.08*
2008	1.17	*0.11*	26.05	*40.73*	30.26	*47.23*	1.65	*3.28*

<u>Scallop dredge</u>:

Contact-adjusted area swept (km²) and sensitivity-adjusted area swept (km²), 1996-2008

	scallop dredge			
	Contact-Adj AS	***SASI***	***Hrs Fished***	***Revenue***
YEAR				
1996	22,247	**7,722**	347,088	130,185,159
1997	19,049	**6,580**	309,652	115,443,677
1998	19,456	**6,680**	300,829	90,748,622
1999	17,521	**5,963**	268,482	142,215,120
2000	19,640	**6,765**	269,897	182,154,484
2001	22,966	**7,958**	363,680	211,025,075
2002	26,664	**9,261**	432,596	241,434,870
2003	27,426	**9,486**	445,106	270,272,440
2004	26,850	**9,283**	464,583	355,171,867
2005	25,955	**8,999**	505,530	447,479,279
2006	27,796	**9,532**	568,617	372,825,135
2007	26,847	**9,295**	518,436	356,069,878
2008	20,902	**7,218**	382,019	291,777,637

2006 limited entry scallop dredge, nominal area swept



EFH Final Rule and adverse effects

"Loss of prey may be an adverse effect on EFH…

…actions that reduce the availability of a major prey species, either through direct harm or capture, or through adverse impacts to the prey species' habitat … may be considered adverse effects on EFH if such actions reduce the quality of EFH"

Trawls and scallop dredges:

Contact-adjusted area swept (km^2) and sensitivity-adjusted area swept (km^2), 1996-2008

	Total			
	Contact-Adj AS	***SASI***	***Hrs Fished***	***Revenue***
YEAR				
1996	310,931	**94,010**	1,248,329	380,275,109
1997	265,171	**79,241**	1,090,195	340,634,309
1998	261,068	**77,693**	1,054,069	323,005,130
1999	257,169	**75,489**	1,008,809	365,435,080
2000	239,364	**70,702**	959,097	411,659,075
2001	222,089	**66,012**	983,958	447,278,602
2002	190,593	**56,299**	941,942	460,896,035
2003	174,565	**52,009**	901,551	482,616,316
2004	172,437	**51,102**	915,019	576,696,200
2005	174,420	**51,961**	960,007	653,476,322
2006	162,474	**48,179**	980,909	543,334,318
2007	148,264	**43,929**	896,147	527,883,426
2008	127,830	**37,612**	718,846	440,476,192