Assessment of the Effects of Fishing on Essential Fish Habitat in Alaska for the 2022 5-year Review

John V. Olson, Habitat Conservation Division, NMFS Alaska Region, Anchorage, AK
T. Scott Smeltz, Alaska Pacific University
Steve Lewis, Sustainable Fisheries Division, NMFS Alaska Region, Juneau AK

1. Overview of Fishing Effects model
2. Review of methodology to evaluate the effects of fishing on EFH
3. Updates for the 2022 EFH 5-year Review
4. Input from the SSC on this process

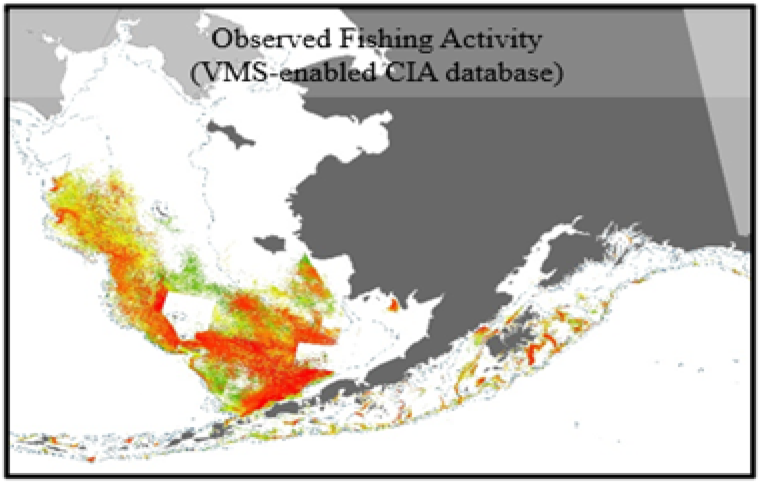
Fishing Effects (FE) Model

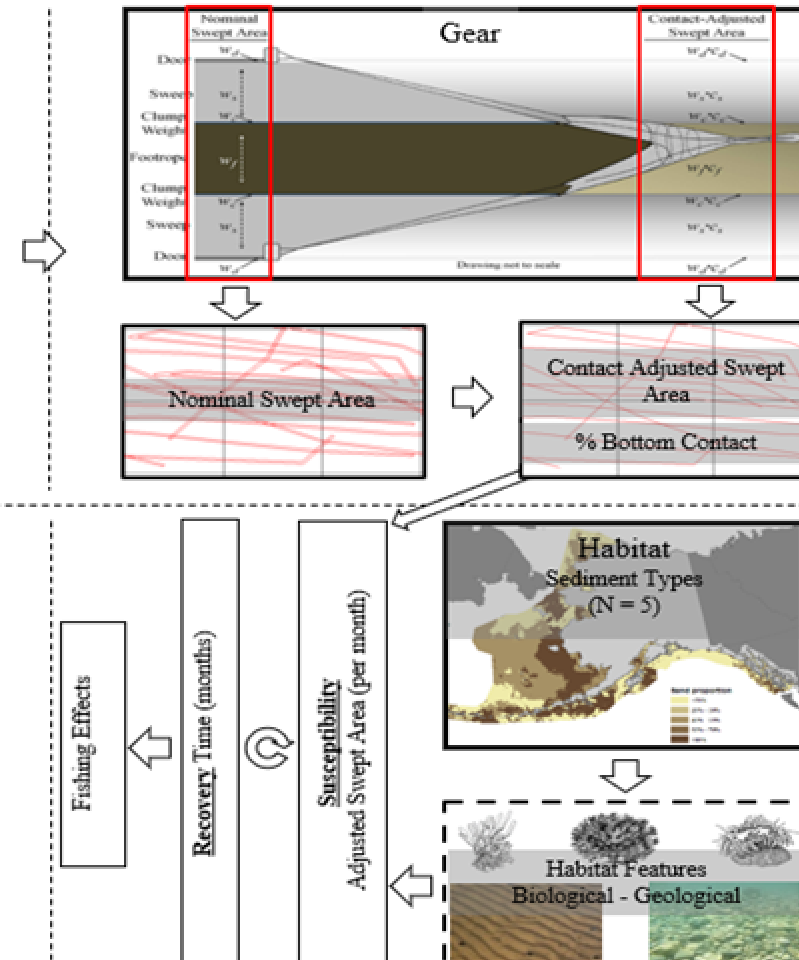
During the 2017 EFH 5-year review, the SSC requested several updates to the Long-term Effects Index (LEI) model to make the input parameters more intuitive and to draw on the best available data. In response to their requests, the Fishing Effects (FE) model was developed.

It is based on interaction between habitat impact and recovery, which depend on the amount of fishing effort, the types of gear used, habitat sensitivity, and substrate.

- The FE model is cast in a discrete-time framework.
- The FE model implements sub-annual (monthly) tracking of fishing impacts and feature recovery.
- The FE model draws on spatially explicit vessel monitoring system (VMS) data to determine fishing locations.
- The FE model incorporates an extensive, global literature review and vulnerability assessment from Grabowski et al. (2014) to estimate habitat susceptibility and recovery dynamics.

Fishing Effects Model Overview

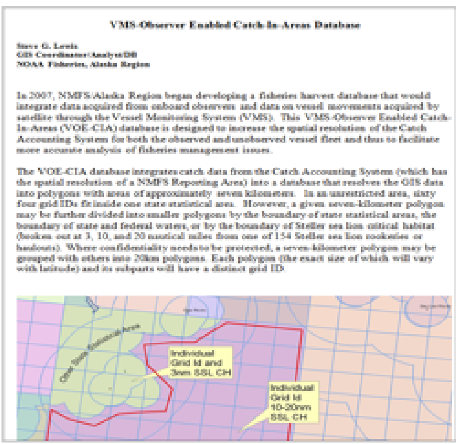




$$H_{t+1} = H_t(1 - I'_t) + h_t \rho'_t$$

H: habitat undisturbed from fishing
h: habitat disturbed from fishing
I': monthly impact rate
ρ': monthly recovery rate

VMS & Defining Fishing Gear Footprint

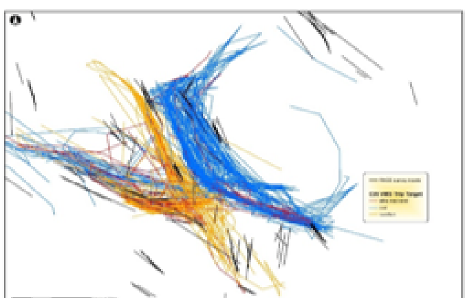


VMS-Observer Enabled Catch-In-Areas Database

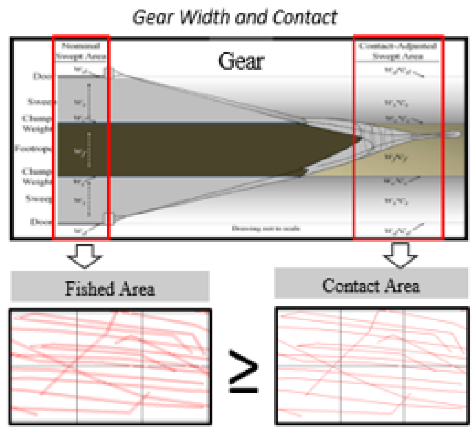
Steve G. Lewis
GIS Coordinator/Analyst/DB
NOAA Fisheries, Alaska Region

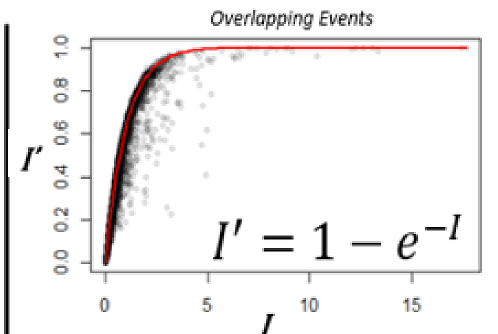
In 2007, NMFS/Alaska Region began developing a fisheries harvest database that would integrate data acquired from onboard observers and data on vessel movements acquired by satellite through the Vessel Monitoring System (VMS). This VMS-Observer Enabled Catch-In-Areas (VOE-CIA) database is designed to increase the spatial resolution of the Catch Accounting System for both the observed and unobserved vessel fleet and thus to facilitate more accurate analysis of fisheries management issues.

The VOE-CIA database integrates catch data from the Catch Accounting System (which has the spatial resolution of a NMFS Reporting Area) into a database that resolves the GIS data into polygons with areas of approximately seven kilometers. In an unrestricted area, sixty four grid IDs fit inside one state statistical area. However, a given seven-kilometer polygon may be further divided into smaller polygons by the boundary of state statistical areas, the boundary of state and federal waters, or by the boundary of Steller sea lion critical habitat (broken out at 3, 10, and 20 nautical miles from one of 154 Steller sea lion rookeries or haulouts). Where confidentiality needs to be protected, a seven-kilometer polygon may be grouped with others into 20km polygons. Each polygon (the exact size of which will vary with latitude) and its subparts will have a distinct grid ID.



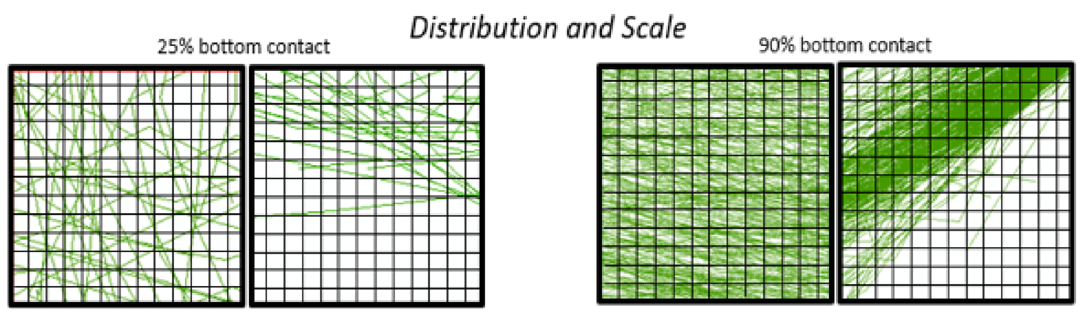
Defining Fishing Gear Footprint





I = Sum contact area / grid cell area (25km^2)

I' = Bottom contact proportion



Gear Descriptions & Contact Adjustment

67 individual gear descriptions

Fishery	Vessel type	Area	Gear	Target1	Target2	Vessel Length (ft)	Season	Depth Range (fath.)	Nom Width (m)
GOA Pollock Pelagic Trawl Sand Point	CV	GOA	PTR	P	all others	<75			50
GOA Pollock Pelagic Trawl	CV	GOA	PTR	P	all (but K, S)	≥75			75
GOA Slope Rockfish Pelagic Trawl	CV	GOA	PTR	K	S	≥75			75
GOA Slope Rockfish Pelagic Trawl	CP	GOA	PTR	K	W	all			100
GOA PCod Bottom Trawl Inshore	CV	GOA	NPT	C	B, P	≥75			90
GOA Deepwater Flatfish Bottom Trawl	CV	GOA	NPT	D	W, X	≥75			90
GOA Shallowwater Flatfish Bottom Trawl	CV	GOA	NPT	H	all others	≥75			90
GOA PCod Bottom Trawl Sand Point	CV	GOA	NPT	C	all others	<75			55
GOA Deepwater Flatfish Bottom Trawl CP	CP	GOA	NPT	D, W	X	all			193
GOA Shallowwater Flatfish/Cod Bottom Trawl CP	CP	GOA	NPT	H, C	L, all others	all			193
GOA Slope Rockfish Bottom Trawl CP	CP	GOA	NPT	K	S	all			75
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	A	≥90	62
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	A	60-90	58
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	A	<60	50
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	B	≥90	77
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	B	60-90	73
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	B	<60	64
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	A	≥90	93
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, [illegible]	[illegible]	[illegible]	[illegible]	[illegible]

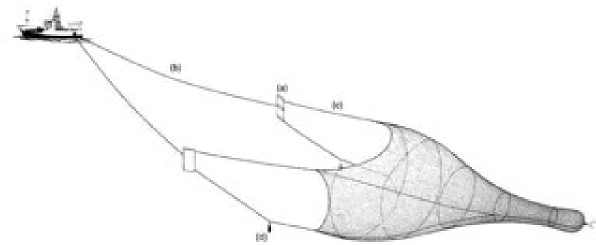
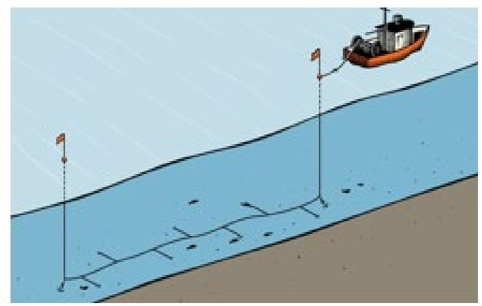


Figure 10. Single boat pelagic trawl



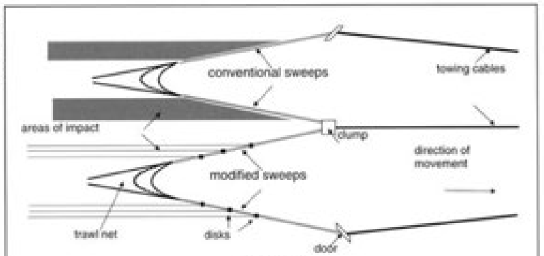
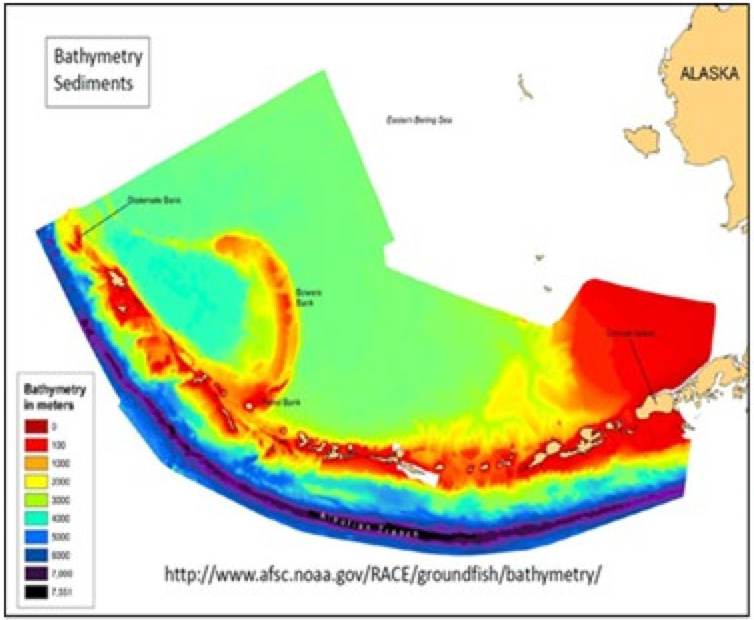
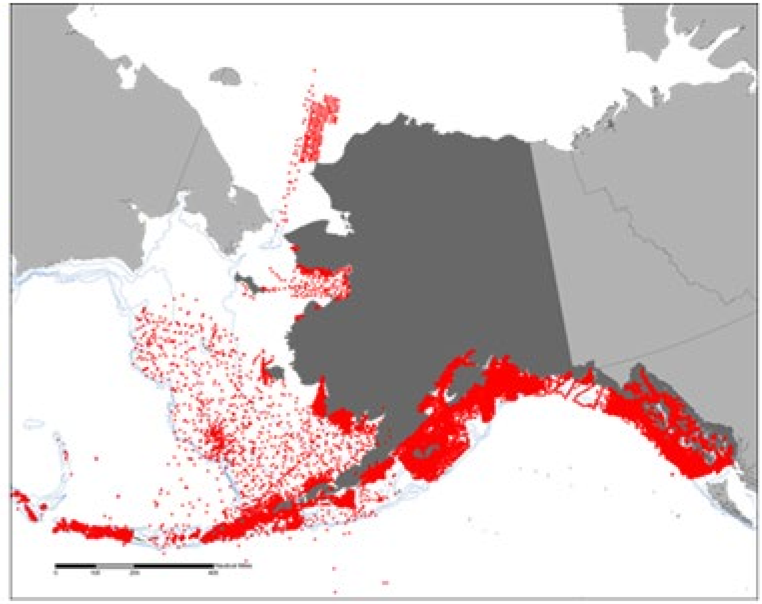
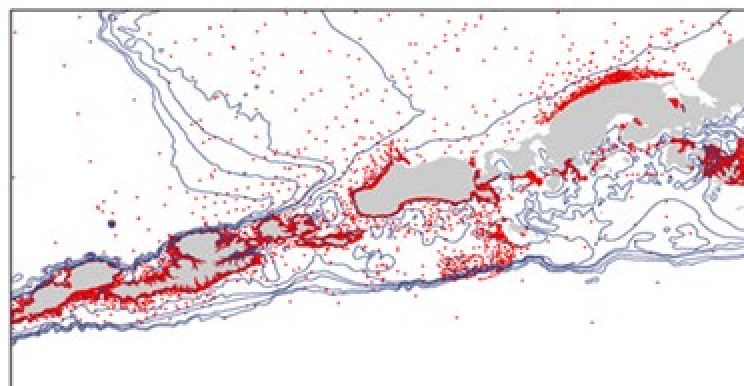


Figure 1
Diagram of the twin trawl system, complete with sweeps (conventional and modified), towed simultaneously behind a vessel and used to test whether raised trawl sweeps reduce flatfish herding. Actual total width was approximately 250 m. Shaded areas represent the area of contact with the seafloor.

Habitat Types







250,000+ points with 6,000+ sediment descriptions coded into 5 sediment classes: Mud, Sand, Granule/Pebble, Cobble, Boulder

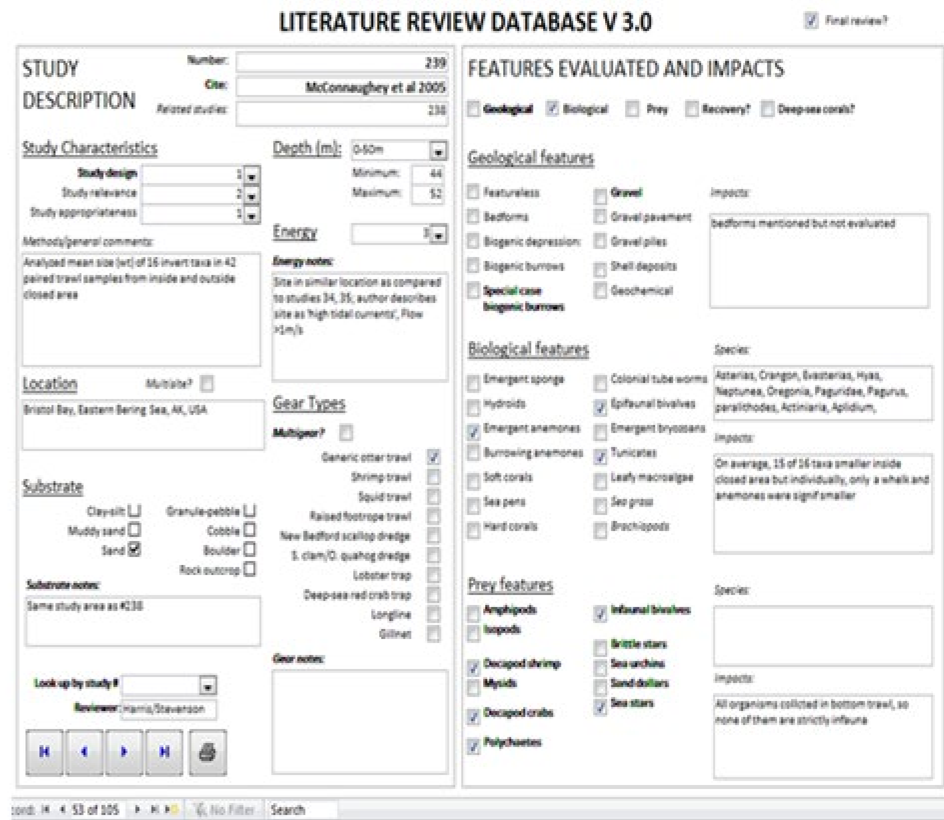
Review of Susceptibility & Recovery parameters

Assessing the Vulnerability of Marine Benthos to Fishing Gear Impacts

JONATHAN H. GRABOWSKI,[1] MICHELLE BACHMAN,[2] CHAD DEMAREST,[3] STEVE EAYRS,[4] BRADLEY P. HARRIS,[5] VINCENT MALKOSKI,[6] DAVID PACKER,[7] and DAVID STEVENSON[8]

[1]Marine Science Center, Northeastern University, Nahant, Massachusetts, USA
[2]New England Fishery Management Council, Newburyport, Massachusetts, USA
[3]NOAA/NMFS Northeast Fisheries Science Center, Woods Hole, Massachusetts, USA
[4]Gulf of Maine Research Institute, Portland, Maine, USA
[5]Department of Environmental Science, Alaska Pacific University, Anchorage, Alaska, USA
[6]Massachusetts Division of Marine Fisheries, New Bedford, Massachusetts, USA
[7]NOAA National Marine Fisheries Service, Highlands, New Jersey, USA
[8]NOAA Northeast Regional Office, Gloucester, Massachusetts, USA

"develop a framework for generating and organizing quantitative susceptibility (based on percent loss of structural habitat from a single interaction with the gear) and recovery (i.e., the time required for recovery of lost structure) parameters for each biological (e.g., sponges, ascidians, mollusks) and geological (e.g., mud burrows, sand ripples, cobble, and boulder piles) feature common to the following five substrates: mud, sand, granule–pebble, cobble, and boulder"



LITERATURE REVIEW DATABASE V 3.0

Final review?

STUDY DESCRIPTION
Number: 239
Cite: McConnaughey et al 2005
Related studies: 238

Study Characteristics
Study design: 1
Study relevance: 2
Study appropriateness: 1
Methods/general comments: Analyzed mean size (wt) of 16 invert taxa in 42 paired trawl samples from inside and outside closed area

Depth (m): 0-50m
Minimum: 44
Maximum: 52

Energy: 3
Energy notes: Site in similar location as compared to studies 34, 35; author describes site as 'high tidal currents', Flow >1m/s

Location
Multisite?
Bristol Bay, Eastern Bering Sea, AK, USA

Gear Types
Multigear?
Generic otter trawl
Shrimp trawl
Squid trawl
Raised footrope trawl
New Bedford scallop dredge
S. clam/O. quahog dredge
Lobster trap
Deep-sea red crab trap
Longline
Gillnet
Gear notes:

Substrate
Clay-silt
Muddy sand
Sand
Granule-pebble
Cobble
Boulder
Rock outcrop
Substrate notes: Same study area as #238

Look up by study #
Reviewer: Harris/Stevenson

FEATURES EVALUATED AND IMPACTS
Geological
Biological
Prey
Recovery?
Deep-sea corals?

Geological features
Featureless
Bedforms
Biogenic depression
Biogenic burrows
Special case biogenic burrows
Gravel
Gravel pavement
Gravel piles
Shell deposits
Geochemical
Impacts: bedforms mentioned but not evaluated

Biological features
Emergent sponge
Hydroids
Emergent anemones
Burrowing anemones
Soft corals
Sea pens
Hard corals
Colonial tube worms
Epifaunal bivalves
Emergent bryozoans
Tunicates
Leafy macroalgae
Sea grass
Brachiopods
Species: Asterias, Crangon, Evasterias, Hyas, Neptunea, Oregonia, Paguridae, Pagurus, paralithodes, Actiniaria, Aplidium,
Impacts: On average, 15 of 16 taxa smaller inside closed area but individually, only a whelk and anemones were signif smaller

Prey features
Amphipods
Isopods
Decapod shrimp
Mysids
Decapod crabs
Polychaetes
Infaunal bivalves
Brittle stars
Sea urchins
Sand dollars
Sea stars
Species:
Impacts: All organisms collected in bottom trawl, so none of them are strictly infauna

Record: 53 of 105 No Filter Search

Grabowski, J. H., M. Bachman, C. Demarest, S. Eayrs, B. P. Harris, V. Malkoski, D. Packer, and D. Stevenson. 2014. Assessing the vulnerability of marine benthos to fishing gear impacts. Reviews in Fisheries Science & Aquaculture 22:142-155.

Susceptibility & Recovery of Habitat Features

14 biological and 12 geological literature-based habitat feature categories combined into 5 sediment types (mud, sand, pebble/granule, cobble, & boulder

G	Bedforms
G	Biogenic burrows
G	Biogenic depressions
G	Boulder, piled
G	Boulder, scattered, in sand
G	Cobble, pavement
G	Cobble, piled
G	Cobble, scattered in sand
G	Granule-pebble, pavement
G	Granule-pebble, scattered, in sand
G	Sediments, suface/subsurface
G	Shell deposits

B	Amphipods, tube-dwelling
B	Anemones, actinarian
B	Anemones, cerianthid burrowing
B	Ascidians
B	Brachiopods
B	Bryozoans
B	Corals, sea pens
B	Hydroids
B	Macroalgae
B	Mollusks, epifaunal bivalve, *Modiolus modiolus*
B	Mollusks, epifaunal bivalve, *Placopecten magellanicus*
B	Polychaetes, *Filograna implexa*
B	Polychaetes, other tube-dwelling
B	Sponges

Susceptibility code	Susceptibility
0	0 – 10%
1	10 – 25%
2	25 – 50%
3	>50%

Susceptibility

Feature Class	Feature	Mud	Sand	Gran-Peb	Cobble	Boulder
G	Bedforms		2			
G	Biogenic burrows	2	2			
G	Biogenic depressions	2	2			
G	Boulder, piled					2
G	Boulder, scattered, in sand					0
G	Cobble, pavement				1	
G	Cobble, piled				3	
G	Cobble, scattered in sand				1	
G	Granule-pebble, pavement			1		
G	Granule-pebble, scattered, in sand			1		
G	Sediments, suface/subsurface	2	2			
G	Shell deposits		1	1		
B	Amphipods, tube-dwelling	1	1			
B	Anemones, actinarian			2	2	2
B	Anemones, cerianthid burrowing	2	2	2		
B	Ascidians		2	2	2	2
B	Brachiopods			2	2	2
B	Bryozoans			1	1	1
B	Corals, sea pens	2	2			
B	Hydroids	1	1	1	1	1
B	Macroalgae			1	1	1
B	Mollusks, epifaunal bivalve, *Modiolus modiolus*	1	1	2	2	2
B	Mollusks, epifaunal bivalve, *Placopecten magellanicus*		2	1	1	
B	Polychaetes, *Filograna implexa*		2	2	2	2
B	Polychaetes, other tube-dwelling			2	2	2
B	Sponges		2	2	2	2

Adapted from the SASI model (NEFMC, 2011)

Recovery code	τ
0	<1 year
1	1 – 2 years
2	2 – 5 years
3	>5 years

Recovery

Feature Class	Features	Mud	Sand	Gran-Peb	Cobble	Boulder
G	Bedforms		0			
G	Biogenic burrows	0	0			
G	Biogenic depressions	0	0			
G	Boulder, piled					3
G	Boulder, scattered, in sand					0
G	Cobble, pavement				0	
G	Cobble, piled				3	
G	Cobble, scattered in sand				0	
G	Granule-pebble, pavement			0		
G	Granule-pebble, scattered, in sand			2		
G	Sediments, suface/subsurface	0	0			
G	Shell deposits		2	2		
B	Amphipods, tube-dwelling	0	0			
B	Anemones, actinarian			2	2	2
B	Anemones, cerianthid burrowing	2	2	2		
B	Ascidians		1	1	1	1
B	Brachiopods			2	2	2
B	Bryozoans			1	1	1
B	Corals, sea pens	2	2			
B	Hydroids	1	1	1	1	1
B	Macroalgae			1	1	1
B	Mollusks, epifaunal bivalve, *Modiolus modiolus*	3	3	3	3	3
B	Mollusks, epifaunal bivalve, *Placopecten magellanicus*		2	2	2	
B	Polychaetes, *Filograna implexa*		2	2	2	2
B	Polychaetes, other tube-dwelling			1	1	1
B	Sponges		2	2	2	2

Adapted from the SASI model (NEFMC, 2011)
Recovery codes: 0: < 1 year; 1: 1–2 years; 2: 2–5 years; 3: >5 years
Blank spaces are habitat features not associated with the given sediment class
G is Geological features and B is Biological features

Inclusion of long-lived species on deep and rocky habitats

At the October 2016 Council Meeting, the SSC supported the use of the FE model as a tool for assessing the effects of fishing on EFH but raised concern that the longest recovery time incorporated into the model (10 years) may not capture the recovery needed for long-lived species, in particular, hard corals that live on rocky substrate at deep depths.

To address these concerns, we added a deep and rocky substrate habitat category. (>300m, cobble & boulder habitat created new Deep/Rocky habitat type, based on Stone 2006)

Table 1. Recovery table including Deep/Rocky habitat category

Feature Class	Features	Mud	Sand	Gran-Peb	Cobble	Boulder	Deep/Rocky
B	Bryozoans			1	1	1	1
B	Corals, sea pens	2	2				
B	Hydroids	1	1	1	1	1	1
B	Polychaetes, other tube-dwelling			1	1	1	1
B	Sponges		2	2	2	2	2
B	Long-lived species						4

Recovery codes: 0: < 1 year; 1: 1 – 2 years; 2: 2 – 5 years; 3: 5 – 10 years; 4: 10 – 50 years

Blank spaces are habitat features not associated with the given sediment class

G = Geological features; B = Biological features

Inclusion of long-lived species on deep and rocky habitats

The FE model uses an exponential decay curve to estimate the proportion of habitat that recover each time step (ρ') from the average time to recovery (τ) using the following equation,

$$\rho' = 1 - \exp\left(\frac{-1}{\tau}\right) \quad (1)$$

The proportion undisturbed habitat in each time step (H_t) is calculate from the disturbed habitat (h_t) multiplied by ρ' plus the proportion of H_t that is not impacted $(1 - I')$,

$$H_{t+1} = h_t\rho' + H_t(1 - I') \quad (2)$$

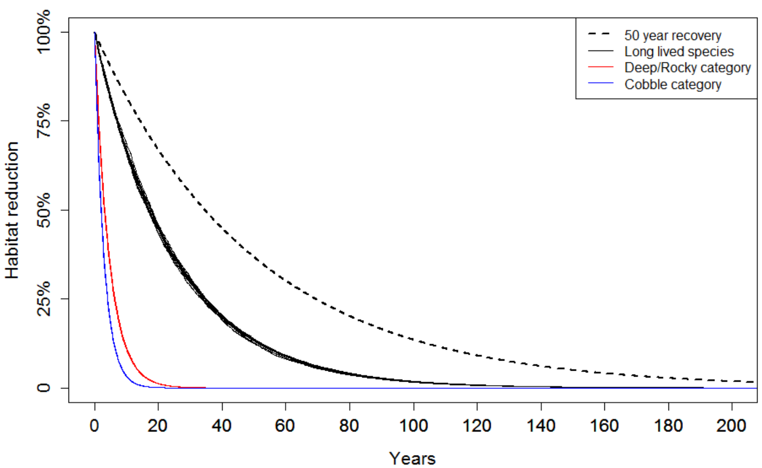
The dynamics of various recovery parameters can be explored by considering a scenario that begins with a completely disturbed habitat ($h_0 = 1$) and involves no future impacts using the following equation,

$$h_t = (1 - \rho')^t \quad (3)$$

Although the FE model uses a monthly time step, t can be modeled in years to simplify interpretation. Figure A1 shows the recovery curve from Eq. 3 using various values and ranges for τ. Combing Eq. 1 and Eq. 2 and rearranging, we get,

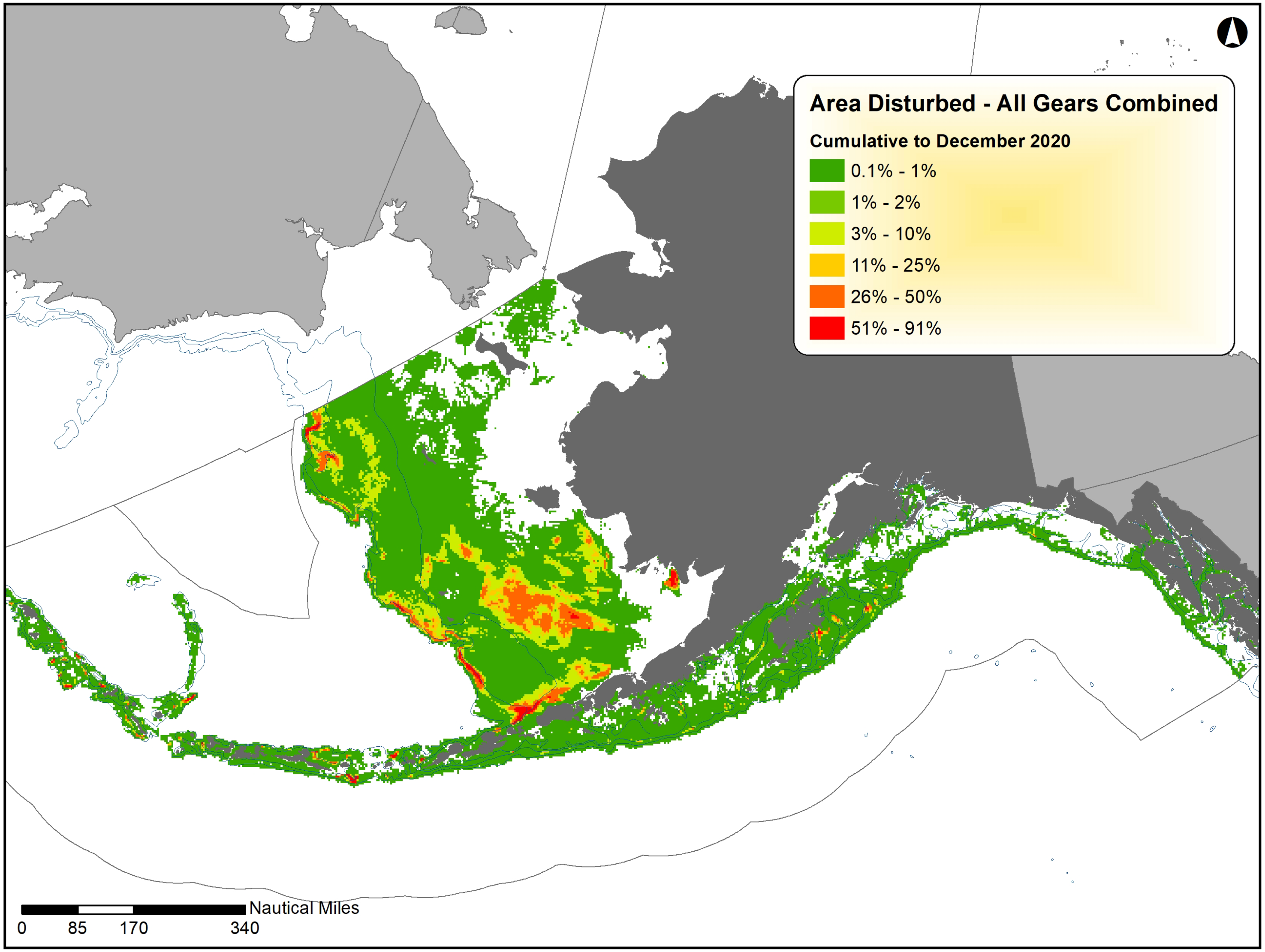
$$\tau = -\frac{t}{\ln(h_t)} \quad (4)$$

Eq. 4 allows us to back calculate a recovery parameter, τ, if we have a known expectation for the proportion of a habitat remaining disturbed (h_t) after a certain number of years (t). For example, if we expect that 150 years following a complete disturbance, 5% of the habitat would still not have recovered, we can use Eq. 4 to calculate $\tau = -\frac{150}{\ln(0.05)} \approx 50$ years.

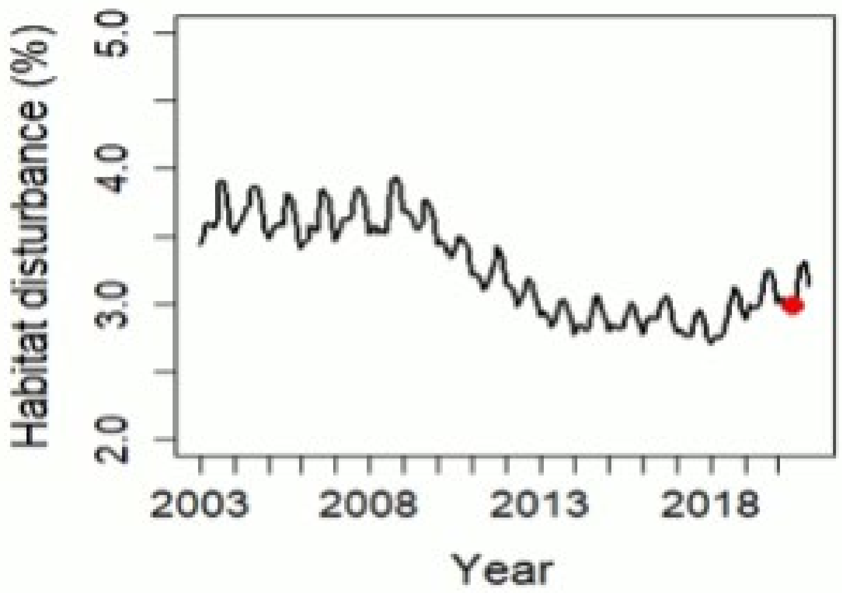


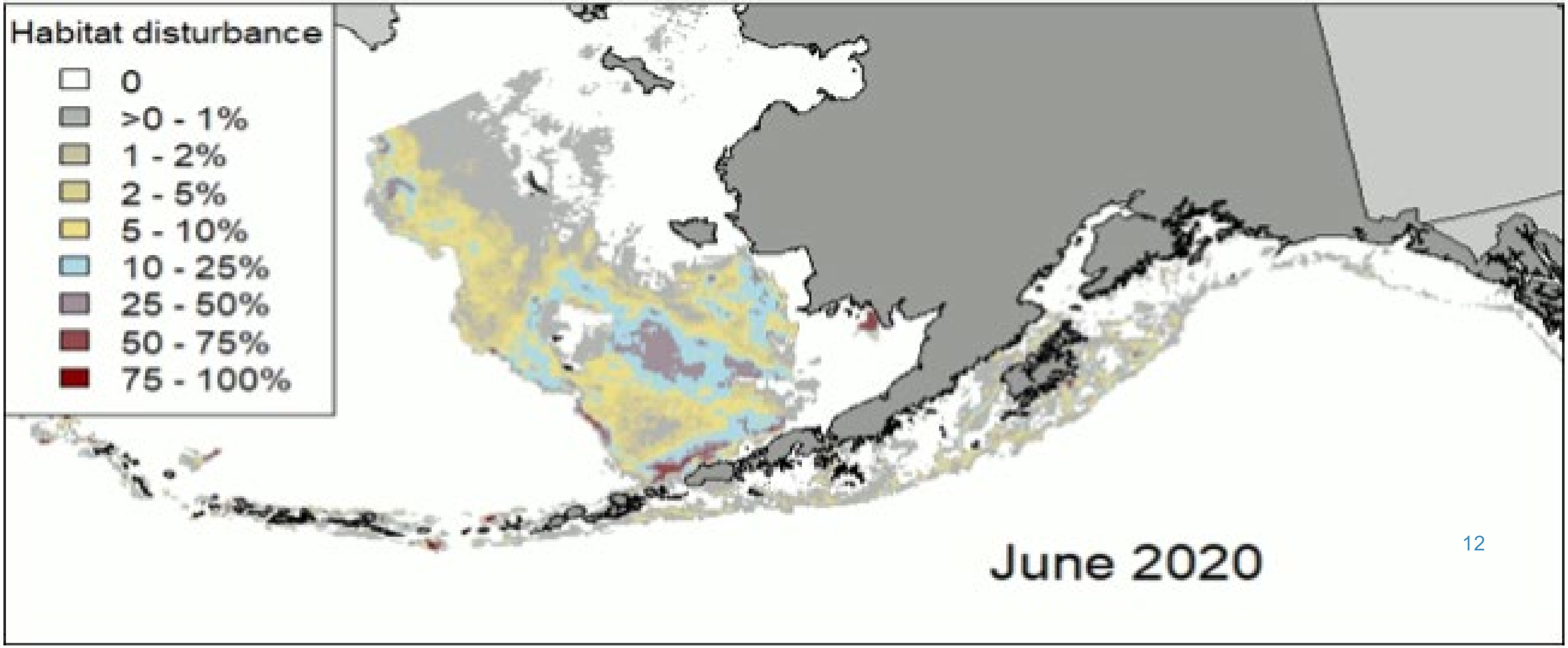
The 50-year recovery (dashed black line) represents the upper limit of recovery in the model. The long-lived species curves (solid black lines) represent 10 runs, randomly sampling from a 10 – 50 year recovery range. The Deep/Rocky curves (solid red lines) represent 10 runs averaging over the full suite of habitat features in the Deep/Rocky habitat category (from Table 1). The Cobble curves (solid blue lines) represent 10 run averaging over the full suite of habitat features in the Cobble habitat category.

FE Output – Habitat Disturbance



Habitat Disturbance, all gears



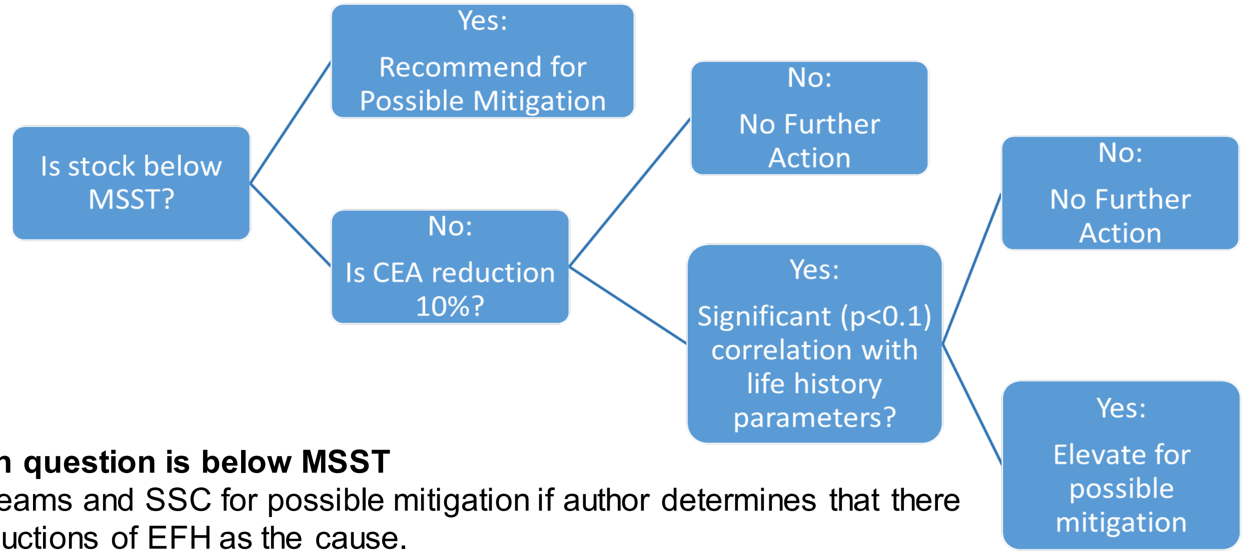


Hierarchical Impact Analysis Framework

"The proposed methods outline a hierarchical impact analysis framework that utilizes the availability of time varying estimates of fisheries effects. This framework provides an evidence-based impact assessment to assess the potential effects of fishing on EFH for crab and groundfish resources. The goal of the framework is to assess whether there is a fishing effect on EFH that is more than minimal and produces significant and temporary impact(s) on the growth-to-maturity, spawning success, breeding success, and/or feeding success of species managed by the NPFMC. The improved analytical products allow analysts to evaluate linkages between time trends in fishing effects on EFH and independently determined time trends in size-at-age, recruitment, spawning distributions and feeding distributions. It will be important to develop a mechanistic tie between the effect on EFH and the impact on the fish. "

SSC Meeting, October 2016

Stock Author Review Process (2016)



The steps of the analysis are:

1. **Determine whether the stock in question is below MSST**
   - If Yes, provide report to Plan Teams and SSC for possible mitigation if author determines that there is a plausible connection to reductions of EFH as the cause.
   - If No: Move on to step 2

2. **Determine whether 10% of the CEA is affected by commercial fishing (**the predicted 50 percent quantile threshold of suitable habitat of summer abundance as defined in the species distribution models)
   - If yes: Move on to step 3
   - If no: No further action required (additional analysis is appreciated, move on to step 3)

3. **Evaluate correlations between CEA habitat reduction and life history indices**
   - If significant at $p<0.1$: provide written report for Plan Teams and SSC
   - If not significant: No further action required

4. **Provide recommendations for EFH research activities and priorities for your species**

5. **Provide a written report for distribution to the appropriate Plan Teams, SSC, and Council.**

Stock Author Review

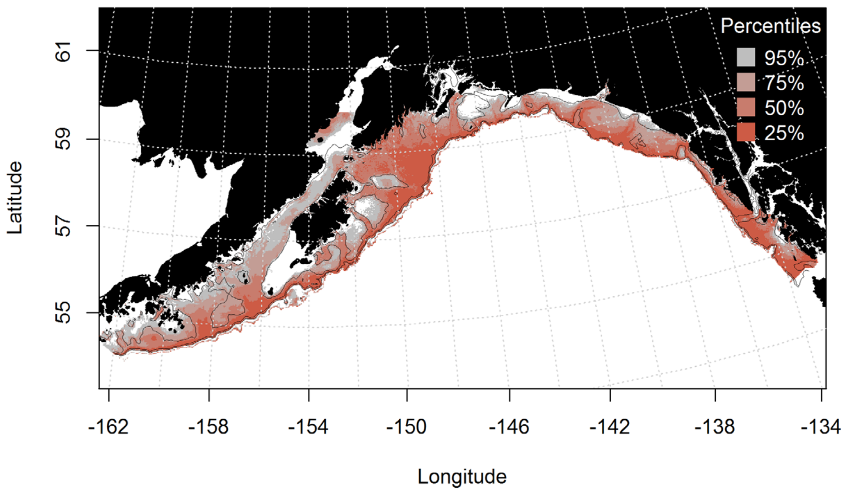
"The purpose of this criterion is not to determine whether any correlation is statistically significant, but rather to provide an objective threshold to ensure that a "hard look" has been taken for each species, as appropriate. Because multiple parameters will be examined for correlation to habitat reduction, it is possible that spurious significant ($p > 0.1$) correlations will be found. Whenever significant correlations are found, the expert judgement and opinion of the stock assessment authors will be important to determine whether there is a plausible connection to reductions in EFH as the cause, or if the result is spurious. If stock assessment authors determine that the correlation between the impacts to the CEA and life history parameter(s) suggest a stock effect, then they will raise that potential impact to the attention of the Plan Teams, SSC, and Council."

Methods to evaluate the effects of fishing on Essential Fish Habitat Proposal from the SSC subcommittee. December 2016

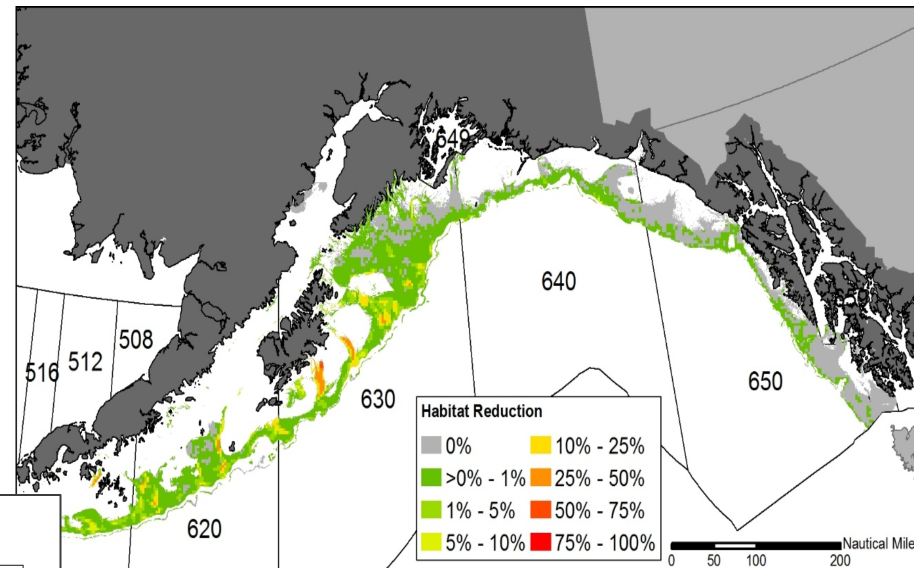
Subcommittee members: Liz Chilton, Bob Foy, Brandee Gerke, Anne Hallowed, Brad Harris, Dan Ito, Sandra Lowe, John Olson, Steve MacLean

2017 Stock Author Review – Pacific Ocean Perch

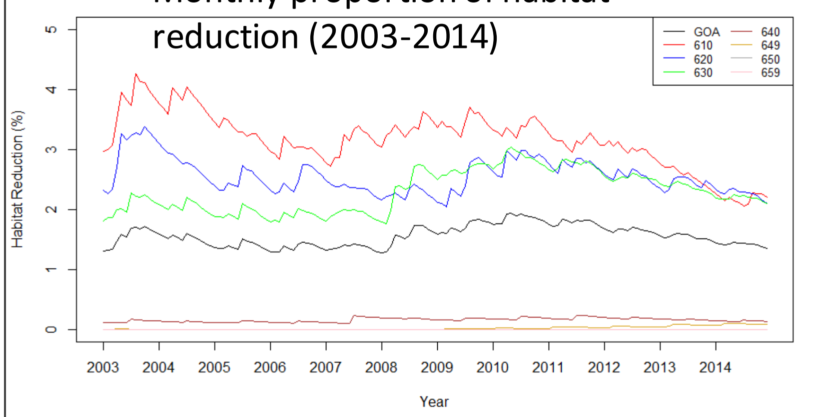
Core EFH (CEA) area defined as 50% cumulative distribution



Proportion of habitat reduction (November 2016)



Monthly proportion of habitat reduction (2003-2014)

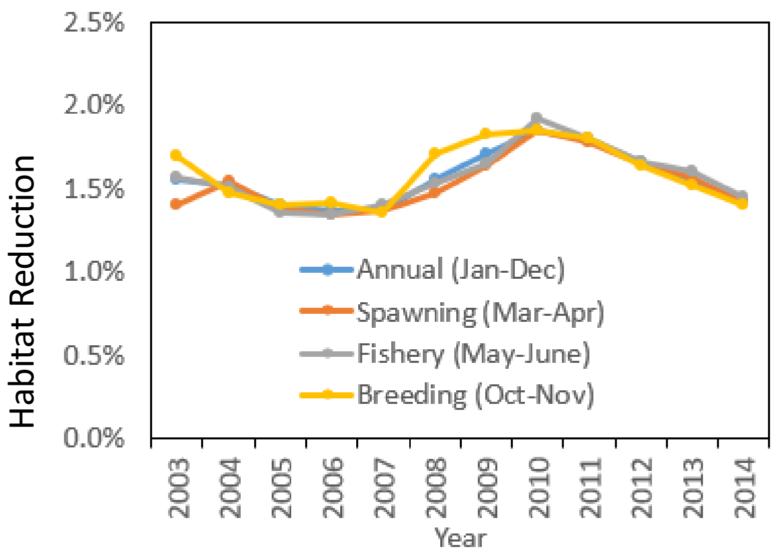


No area exceeds 5% habitat reduction

2017 Stock Author Review – Pacific Ocean Perch

Correlations: POP

- No *p*-values > 0.1



		ρ	*p*-value
Average size-at-age	age-3	-0.49	0.33
	age-4	-0.25	0.63
	age-5	-0.56	0.24
	age-6	-0.58	0.23
	age-7	-0.20	0.71
	age-8	-0.71	0.11
	age-9	-0.25	0.63
	age-10	-0.60	0.21
	age-11	0.02	0.97
	age-12	-0.40	0.43
	age-13	-0.38	0.46
	age-14	0.42	0.41
	age-15	-0.14	0.79
LVB params	L_∞	0.56	0.33
	κ	-0.64	0.24
	t_0	-0.64	0.24
SAFE output	Spawning biomass	0.43	0.17
	Total biomass	0.37	0.24
	Recruitment	0.33	0.30

Conclusion of 2017 EFH 5-year Review

In April 2017, the SSC and Council concurred with species-specific EFH fishing effects reviews conducted by stock assessment authors that no stocks needed mitigation review, and that the effects of fishing on the EFH of fisheries species managed by the NPFMC are minimal and temporary (NPFMC 2017).

At the conclusion of the 2017 EFH 5-year Review, the SSC provided several recommendations related to the Fishing Effects (FE) model. In response:

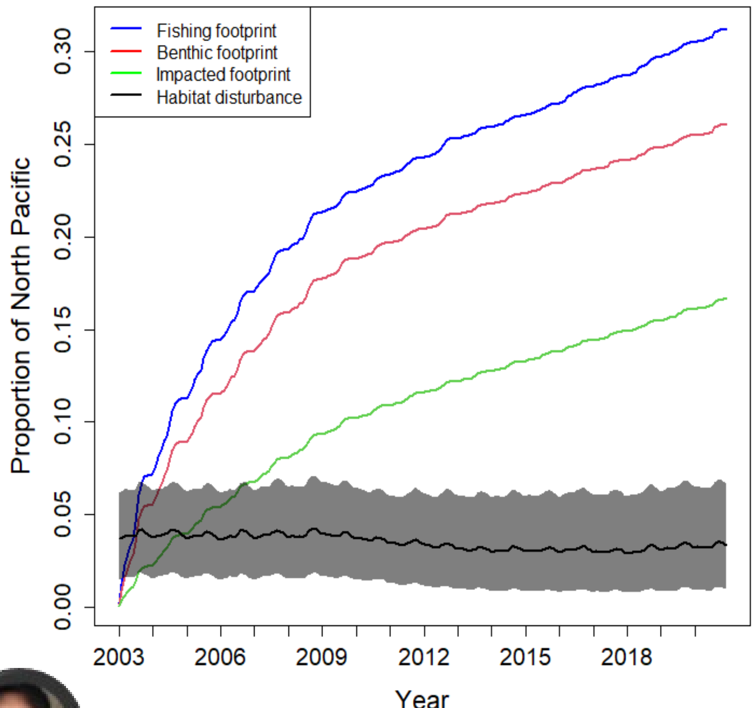
- Output from the FE model is included as an indicator (habitat disturbed) in yearly Ecosystem Status Reports
- Smeltz, T.S., Harris, B., Olson, J., and Sethi, S. 2019. A seascape-scale habitat model to support management of fishing impacts on benthic ecosystems. Canadian Journal of Fisheries and Aquatic Sciences, 76(10): 1836-1844.
- A sensitivity analysis is included in the discussion paper
- Core EFH (CEA) maps will be available to the public
- Updated gear descriptions, gear impact, and recovery parameters

Sensitivity Analysis

Model outputs for low/high habitat disturbance parameter scenarios and restricted (no recovery) models

Model version	Dec 2020 model estimate (% of North Pacific)
Habitat disturbance (lower – upper bound)	3.4% (1.0% - 6.7%)
Fishing footprint	31%
Benthic footprint	26%
Impact footprint	17%

Model outputs for habitat disturbance and each of the restricted models (no recovery). The grey band shows the bounds of habitat disturbance with all parameters fixed to their highest or lower values.



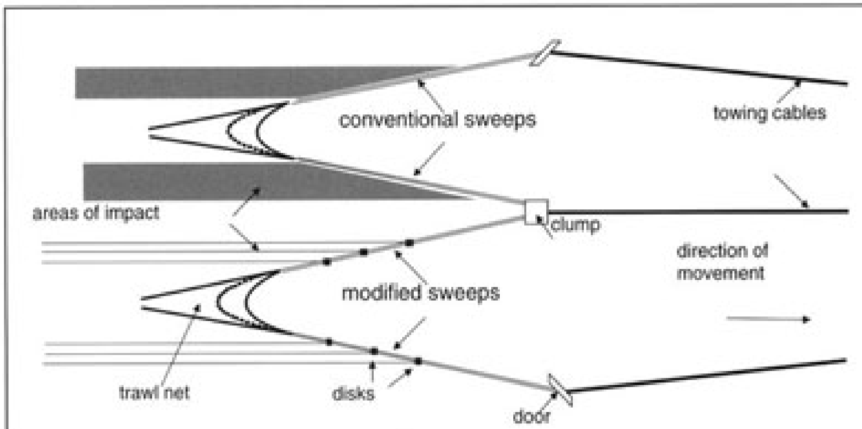


Figure 1

Diagram of the twin trawl system, complete with sweeps (conventional and modified), towed simultaneously behind a vessel and used to test whether raised trawl sweeps reduce flatfish herding. Actual total width was approximately 250 m. Shaded areas represent the area of contact with the seafloor.

Responses to SSC Comments for 2022 EFH 5-year Review

1. **Run the old dataset with old parameters and new parameters to see how they contrast. Then run new data with new parameters.**
   - Section 3.4, “FE model code”, figure 6

2. **Consider 2017 SSC minutes concerning the use of averages or alternatives for estimation of susceptibility and recovery.**
   - Section 3.6, “Feature averaging”

3. **Explain why sediment type must continue to be used as a proxy for habitat susceptibility and recovery rates.**
   - Sections 3.2, “Habitat categorization” and 3.3, “Susceptibility and recovery”

4. **Isolate how the new 2022 parameters affect results**
   - Section 3.4, “FE model code”

5. **Description of updated data inputs (including those to the catch in area database), new data sets not previously considered, and any methodological changes to the model or treatment of input data.**
   - Section 3.1, “Fishing intensity”

6. **Consider including a few key examples of overlays of updated 2022 SDMs and FE model results for species that are informative – say ones with large differences.**
   - Section 4.2, “Example 2022 FE model output with 2017/2022 SDMs”

7. **Describe whether the EFH Team plans to use the evidence-based approach for evaluation of impacts on spawning, feeding, growth to maturity used in 2017 to evaluate impacts and provide a timeline for completion of this analysis.**
   - Section 2.5.1, “Hierarchical impact assessment methods”, Section 4.1 “Thresholds”

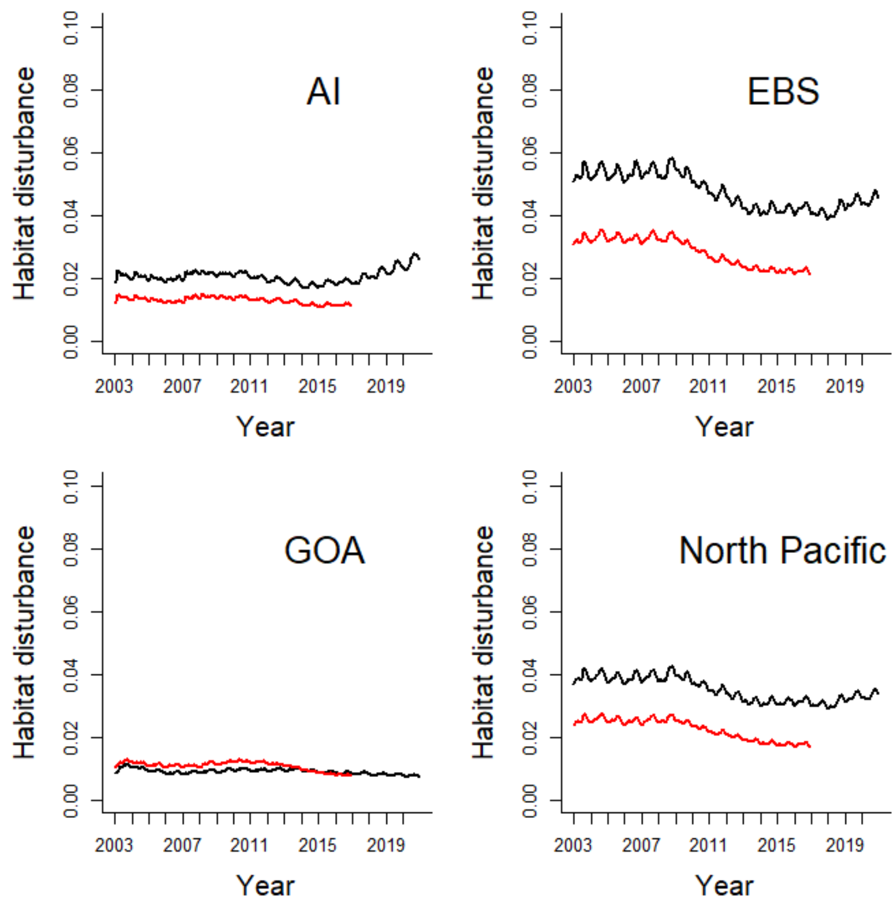
Run the old dataset with old parameters and new parameters to see how they contrast. Then run new data with new parameters

Since 2017, the model code has undergone various updates and improvements with an aim toward flexibility and efficiency.

An error in the 2017 model code transposed the susceptibility for trawl and longline gears. Because susceptibility is generally higher for trawls than longlines, impacts from trawls were underestimated and longlines overestimated.

Because the total footprint of trawling throughout the North Pacific is much greater than the footprint of longlines, the net effect of this error resulted in an underestimate of habitat disturbance, with the largest difference evident in the Bering Sea.

The differences between the outputs are due to the correction made to properly attribute susceptibility to trawl and longline, as well as updates to the Gear Table parameters.



Comparison of 2017 FE output (red lines) and 2022 FE model output (black lines) among subregions and the North Pacific at large

Consider 2017 SSC minutes concerning the use of averages or alternatives for estimation of susceptibility and recovery (and sediment as a proxy)

Global analysis of depletion and recovery of seabed biota after bottom trawling disturbance

Jan Geert Hiddink,[a,1] Simon Jennings,[b,c,2] Marija Sciberras,[a] Claire L. Szostek,[a] Kathryn M. Hughes,[a] Nick Ellis,[d] Adriaan D. Rijnsdorp,[e,1] Robert A. McConnaughey,[f] Tessa Mazor,[d] Ray Hilborn,[g] Jeremy S. Collie,[h] C. Roland Pitcher,[d] Ricardo O. Amoroso,[i] Ana M. Parma,[i] Petri Suuronen,[j] and Michel J. Kaiser[a]

▸ Author information ▸ Copyright and License information Disclaimer

Table 4. Habitat areas and trawled areas (km^2) by base 2 categories of trawl swept-area ratio (area trawled/grid-cell area): total area; area of sediment-habitat types; total swept area; and estimates of trawl footprints (which account for overlapping trawls) assuming trawling is uniform at 0·01° or randomly distributed within 0·01° grid cells

		Habitat area					Trawl footprint	
Swept-area ratio	Total area	Mud	Muddy-Sand	Sand	Gravel	Swept area	Uniform	Random
0	1760	34	244	892	590	0	0	0
>0–0·03125	454	9	94	234	117	9	9	8
0·0625	126	1	32	66	26	11	11	11
0·125	152	2	57	66	26	28	28	25
0·25	210	0	79	95	36	74	74	62
0·5	222	2	42	136	41	160	160	113
1	307	6	100	151	50	451	307	233
2	216	0	42	121	53	590	216	200
>4	88	0	8	53	28	481	88	88
Totals	3535	55	698	1815	967	1803	892	740

Pitcher et al 2017
Hiddink et al 2020
Rijnsdorp et al 2020
Pitcher et al 2022

"Selective effects linked to trawling history are likely to be strongest for long-lived sessile epifauna that build biogenic reefs, such as sponges and corals. The estimates of r and T presented here are applicable to invertebrate communities living in sedimentary habitats but not biogenic habitats, because no studies of trawling impacts on biogenic habitats met the rigorous selection criteria imposed by the systematic review."

Pitcher et al 2022. Trawl impacts on the relative status of biotic communities of seabed sedimentary habitats in 24 regions worldwide.

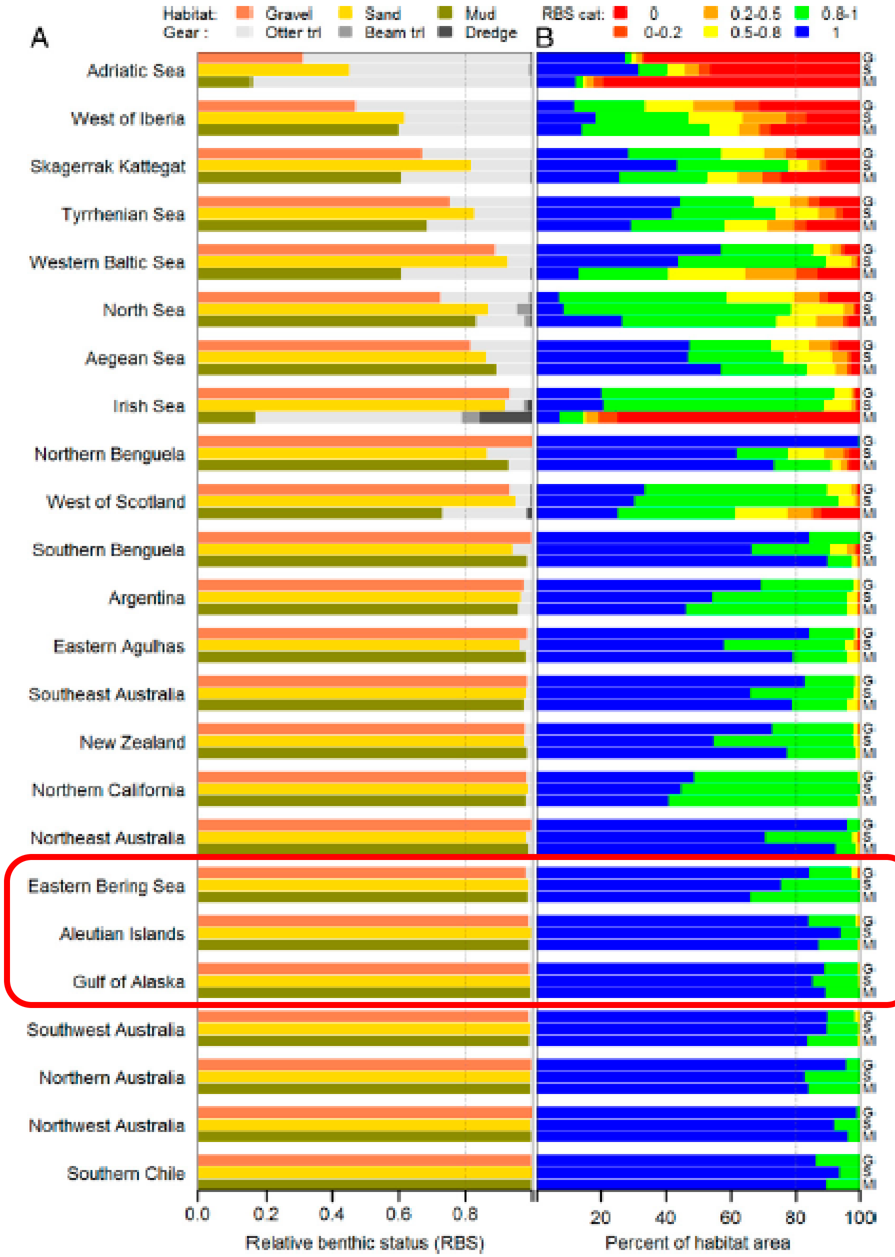
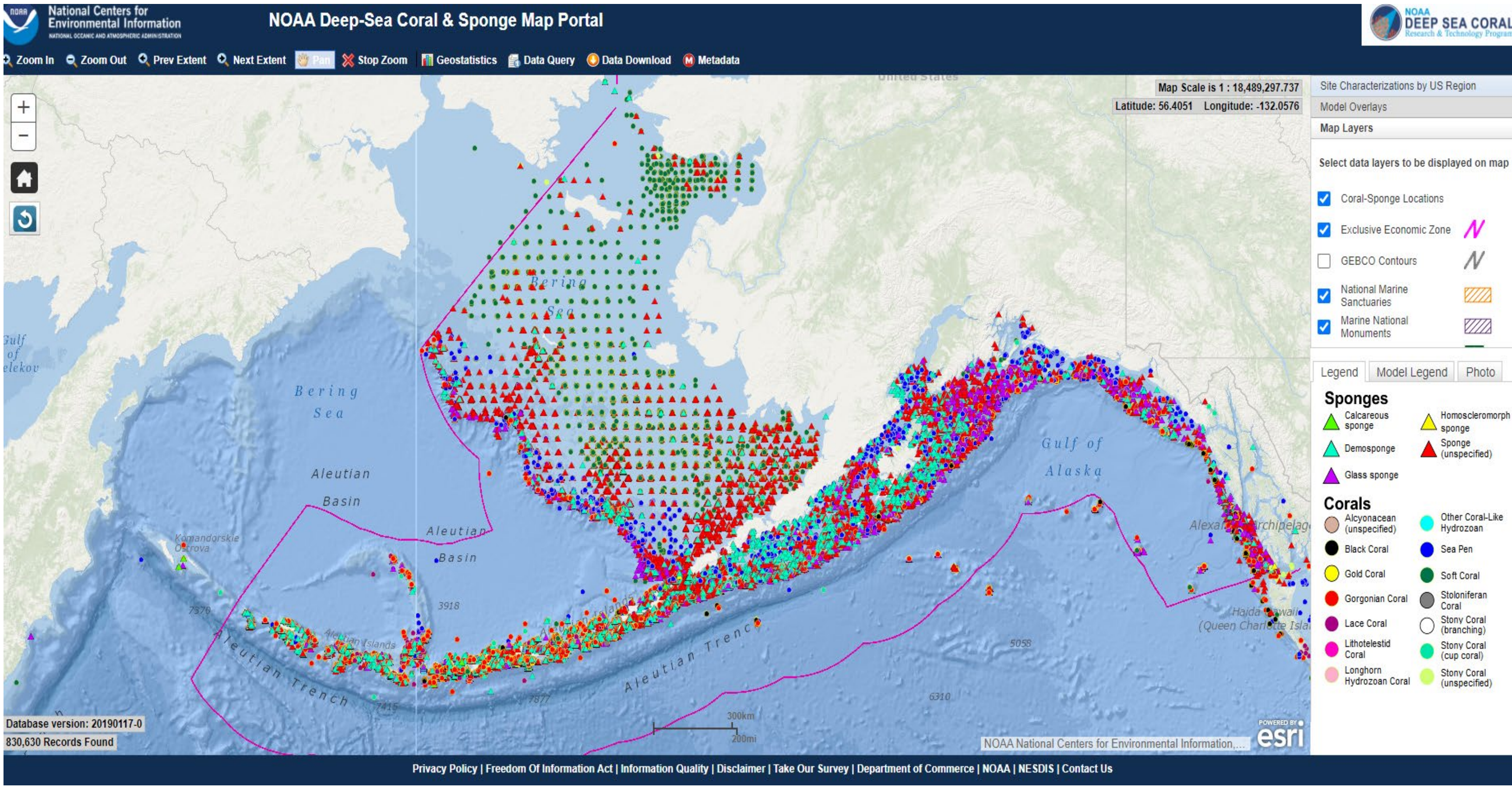


Fig. 3. Bar plots of (*A*) average RBS for gravel, sand, and mud (G, S, and M; colored bars) habitats within regions, and reduction of RBS (=1 − RBS) because of cumulative impacts of different trawl gear types (stacked gray bars); (*B*) percentage area of each regional habitat in six RBS category intervals. Vertical dotted line indicates RBS = 0.8 in *A* and 80% of regional habitat area in *B*.

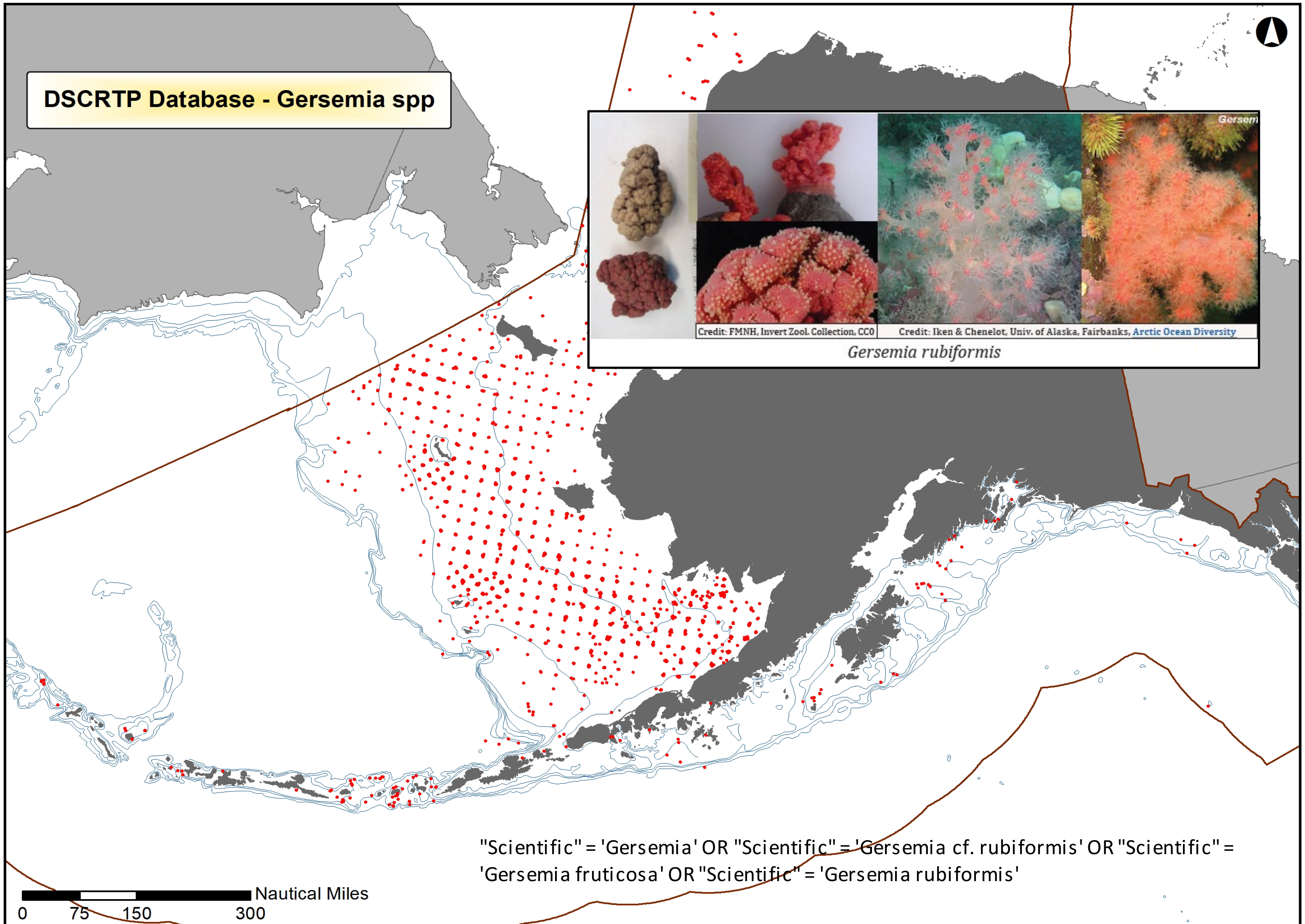
DSCRTP Data Portal



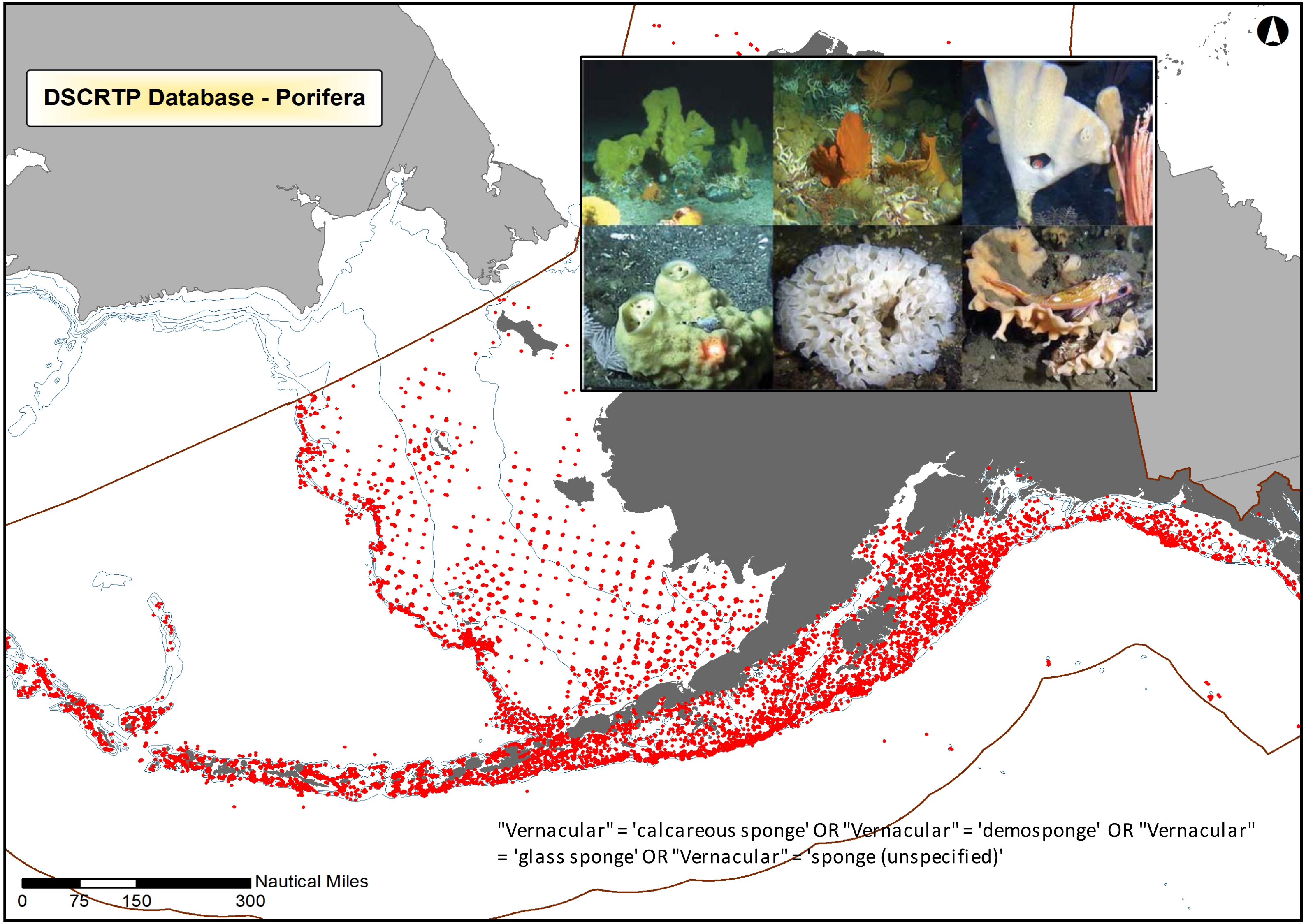
https://www.ncei.noaa.gov/maps/deep-sea-corals/mapSites.htm

Wilborn, R.E., Goddard, P., Wilborn, M.M. II (illus.), Best, M., and Rooper, C.N.. 2021. Field Guide to Corals of British Columbia, Canada, Alaska, USA, and the eastern North Pacific Ocean (Anthozoa: Octocorallia and Hexacorallia) (Hydrozoa: Anthoathecata). A complete compilation of coral identifications for the eastern North Pacific Ocean. Can. Tech. Rep. Fish. Aquat. Sci. 3433: xi + 123 p.

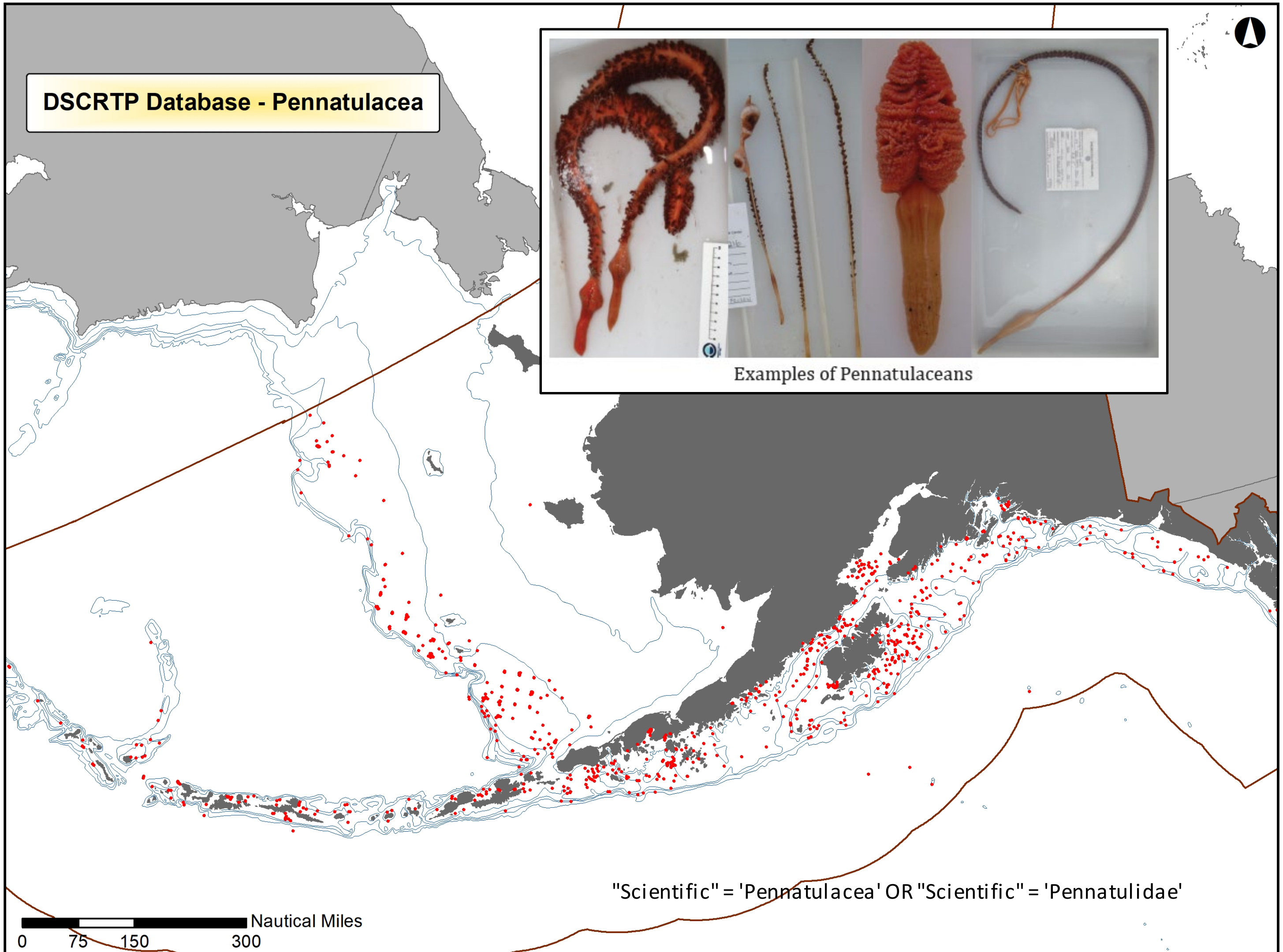
DSCRTP Data Portal – Gersemia



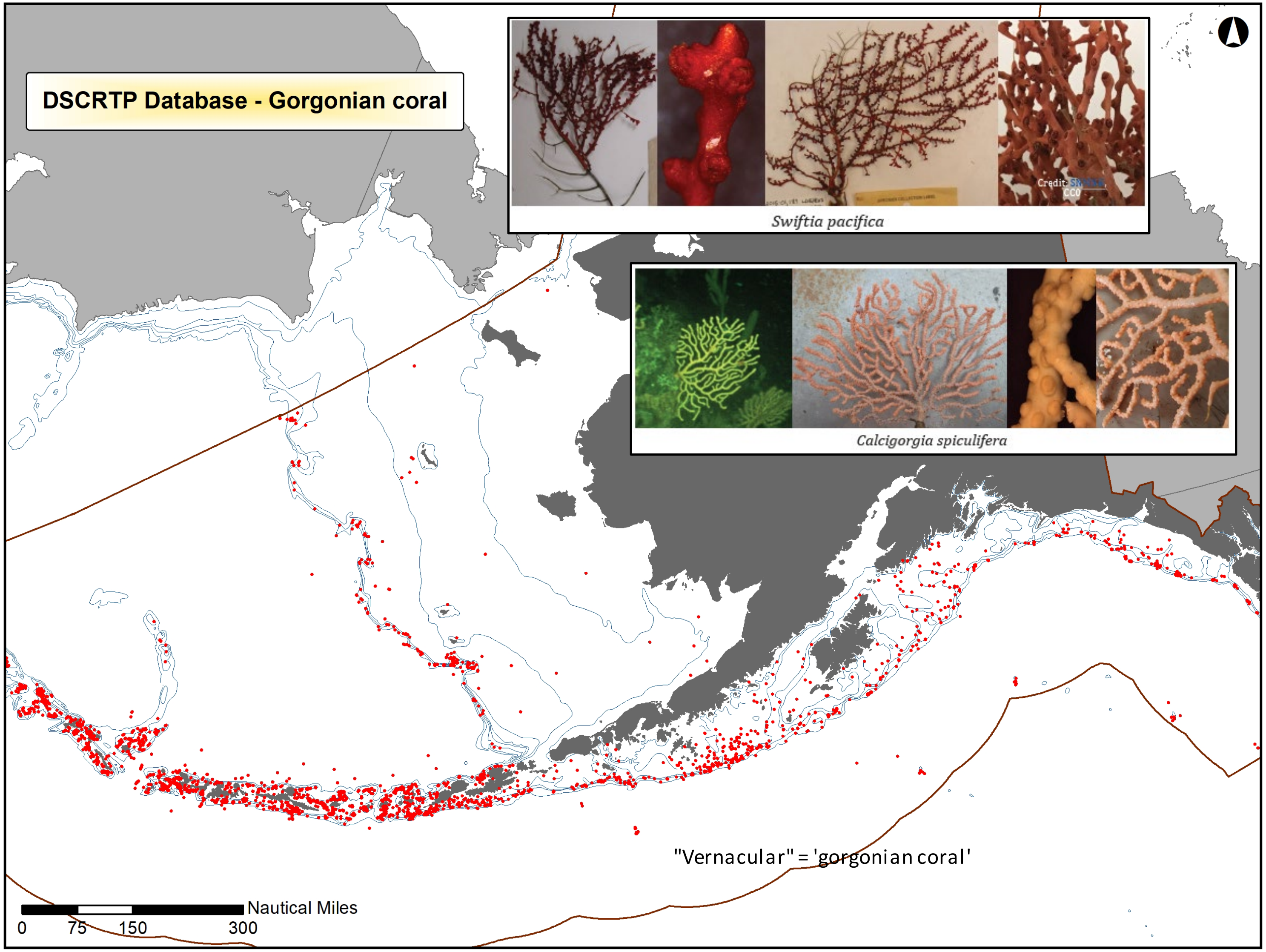
DSCRTP Data Portal – Sponges



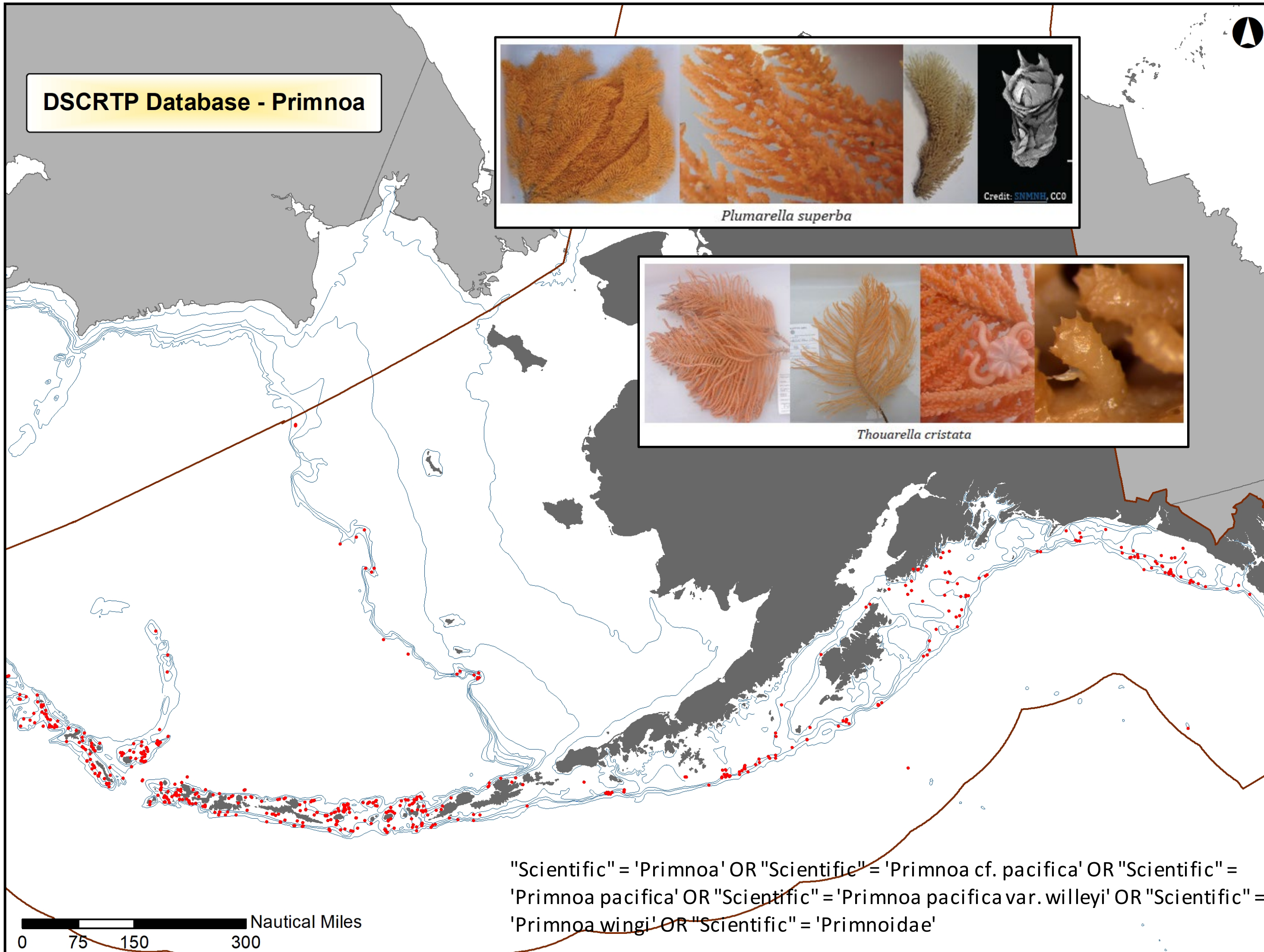
DSCRTP Data Portal - Pennatulacea



DSCRTP Data Portal – Gorgonian corals



DSCRTP Data Portal – Primnoa



Description of updated data inputs (including those to the catch in area database), new data sets not previously considered, and any methodological changes to the model or treatment of input data.

Catch-in-areas data through 2020.

Updated longline, pot, & GOA pelagic rockfish trawl gear parameters

- Longline footprint – Welsford et al 2014
- Pot footprint – Doherty et al 2017
- GOA pelagic rockfish trawl

Exploratory analyses using unobserved fishing lines in the CIA

- Unobserved VMS records based on trips rather than individual events (7-18% CIA)
- Almost 50% of *minutes fished* or *line length* in entire VMS dataset
- Discussions with SFD staff ongoing.

Alaska Coral and Sponge Initiative 2020-2024

- *GOA coral & sponge validation cruise scheduled for 2022*
- *"Incorporate Coral and Sponge Covariates into FE model"*

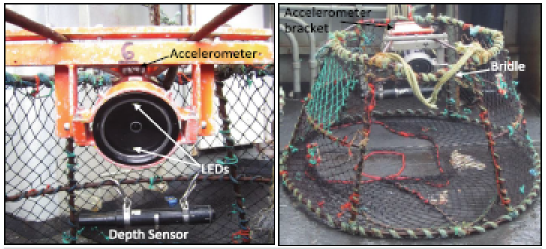
Fishing Effects Model Northeast Region 2020

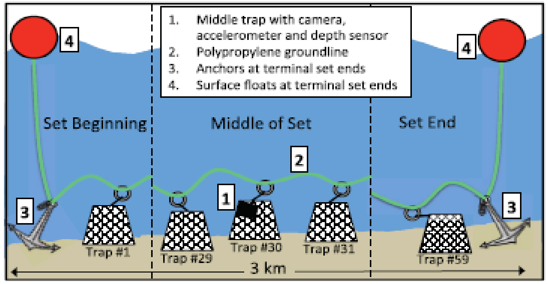
- *Vulnerability assessment and literature review were updated*
- *Proposal to Develop a National Fishing Effects Database to support Fishery Management Councils Essential Fish Habitat Reviews (NEFMC, MAFMC, GARFO, AKRO, NPFMC)*

Longline and pot gear parameters

Using autonomous video to estimate the bottom-contact area of longline trap gear and presence–absence of sensitive benthic habitat[1]

Beau Doherty, Samuel D.N. Johnson, and Sean P. Cox





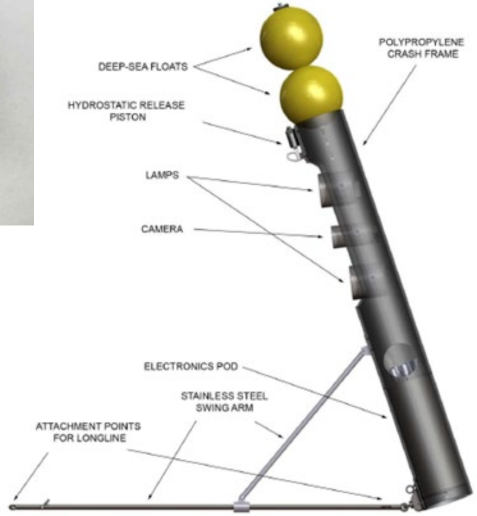
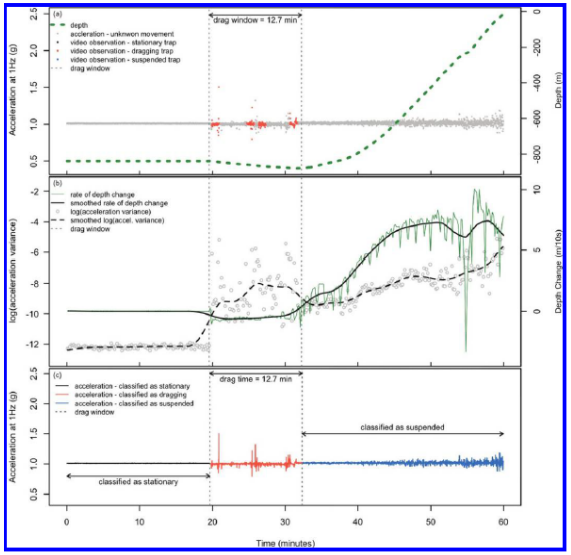


Figure A4.2. Benthic Impacts Camera System (BICS) mounted in the longline crash frame. The narrow cylindrical shape of the longline housing allows it to be deployed through a narrow shooting window, the stainless steel swing arm on the left side is attached to the longline and folds open after deployment (as shown). The floats keep the unit upright and filming down the longline during fishing and retrieval.



VMS - GOA unobserved fishing by gear & target

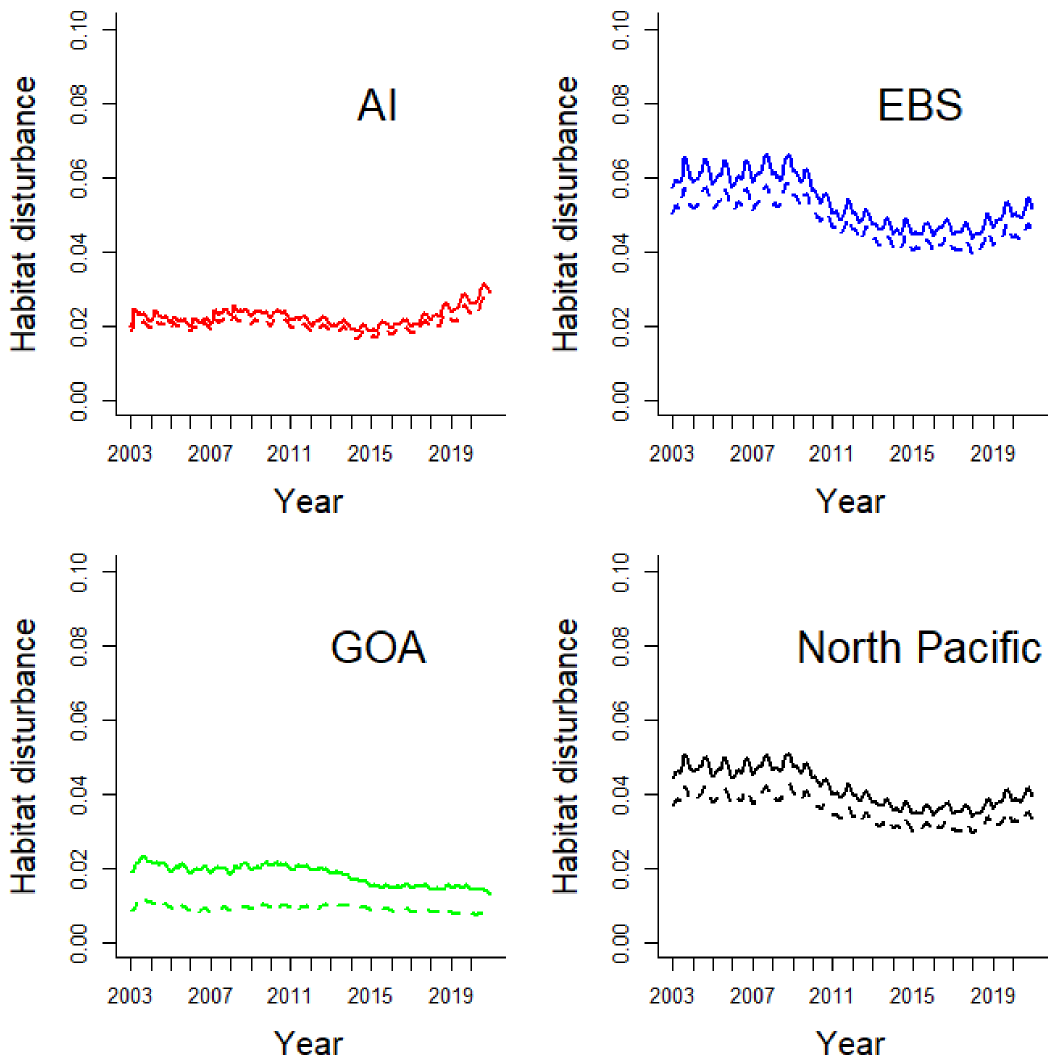
Catch-in-Areas Database 2003-2020

(for vessels with active VMS)

Target	Unobs Events	Obs Events	% unobs
Non-pelagic Trawl			
Atka mackerel	3	28	10%
Pollock - bottom	985	1,096	47%
Pacific cod	2,293	4,810	32%
Deep water flatfish	34	141	19%
Shallow water flat	1,330	5,298	20%
Rockfish	387	19,172	2%
Flathead sole	316	1,306	19%
Other species	46	154	23%
Pollock - midwater	189	149	56%
Sablefish	10	1,615	1%
Arrowtooth	2,368	12,141	16%
Rex sole	589	2,930	17%
Pelagic Trawl			
Pollock - bottom	2,011	1,933	51%
Pacific cod	23	87	21%
Shallow water flat	7	40	15%
Rockfish	67	3,149	2%
Flathead sole	1	5	17%
Other species	0	2	0%
Pollock - midwater	10,009	8,124	55%
Sablefish	0	88	0%
Arrowtooth	7	26	21%
Rex sole	0	2	0%

Target	Unobs Events	Obs Events	% unobs
Hook and Line			
Pacific cod	9,592	12,188	44%
Halibut	5,239	8,996	37%
Rockfish	25	47	35%
Other species	84	28	75%
Sablefish	3,538	17,300	17%
Arrowtooth	0	59	0%
Pot			
Pollock - bottom	3	0	100%
Pacific cod	16,527	4,380	79%
Halibut	13	11	54%
Other species	15	1	94%
Sablefish	945	1,321	42%

Incorporating unobserved VMS into FE



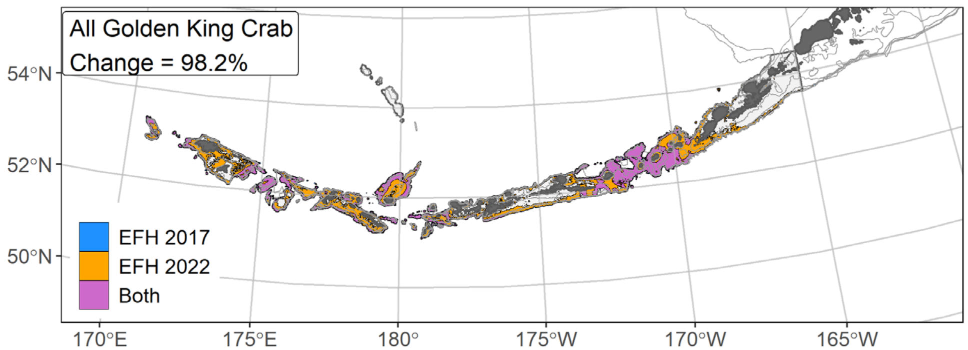
EXPLORATORY!!

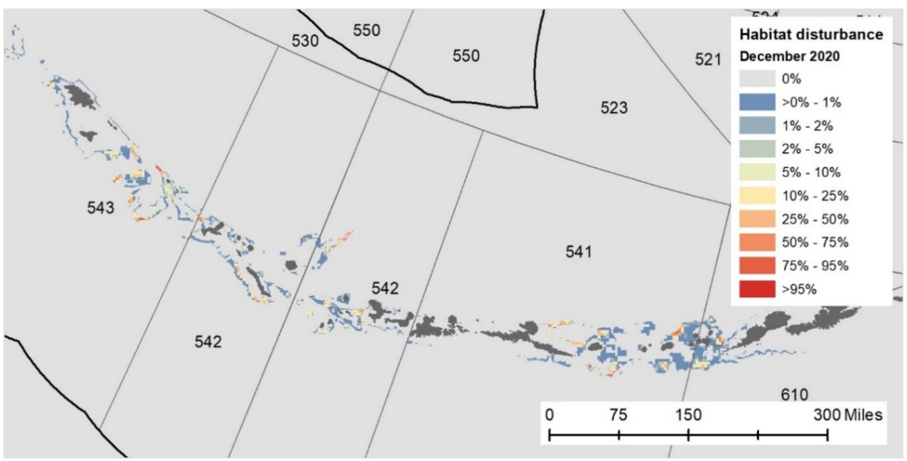
Solid line – obs + unobs
Dashed line – obs only

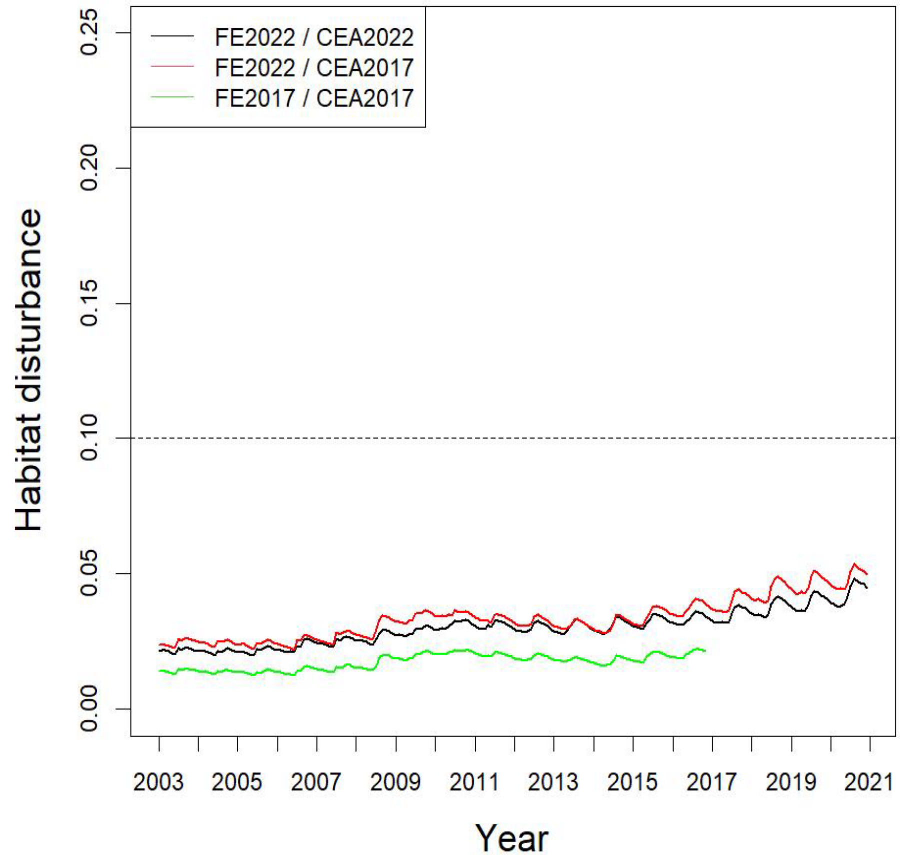
Consider including a few key examples of overlays of updated 2022 SDMs and FE model results for species that are informative – say ones with large differences.

- ***Aleutian Islands Golden king crab (98% larger)***
- ***Bering Sea Arrowtooth flounder (15% smaller)***
- ***Gulf of Alaska Pacific cod (4% smaller)***

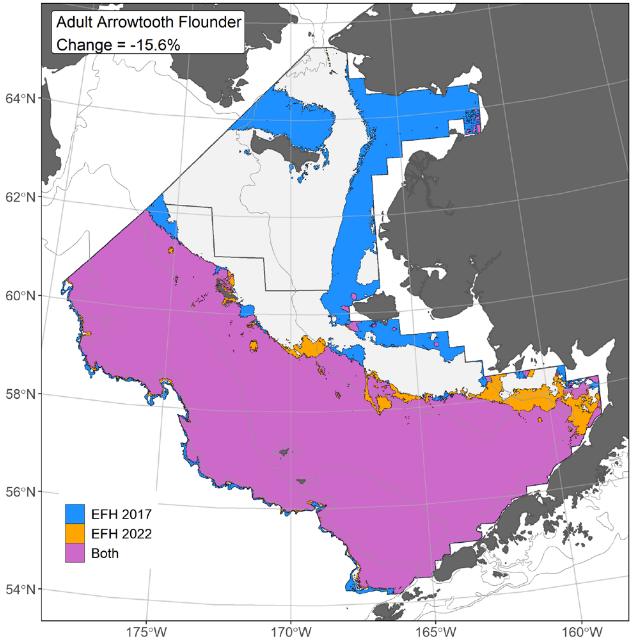
2022 Examples – Aleutian Islands Golden king crab

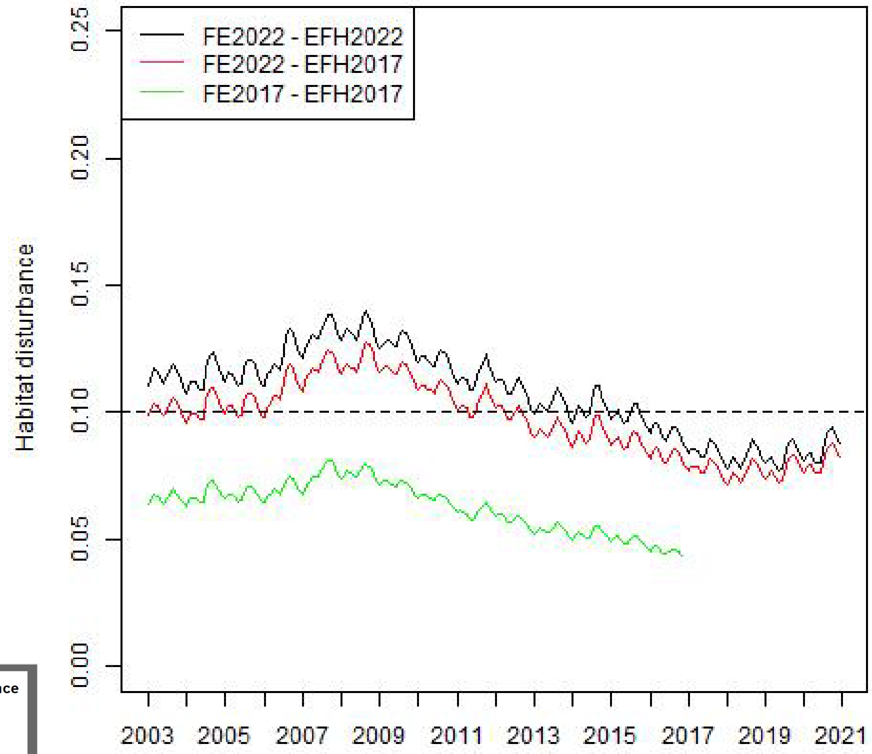


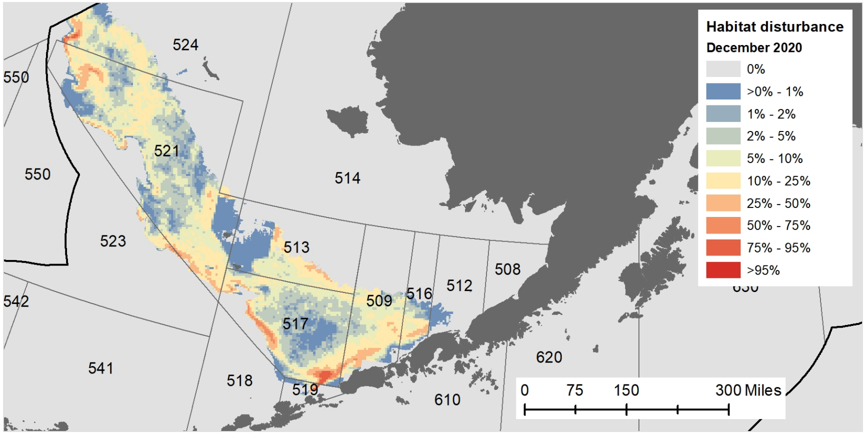




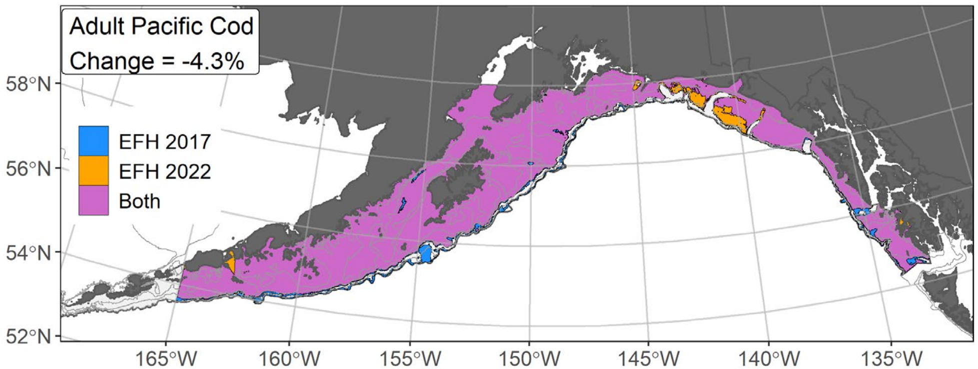
2022 Examples – Bering Sea Arrowtooth Flounder

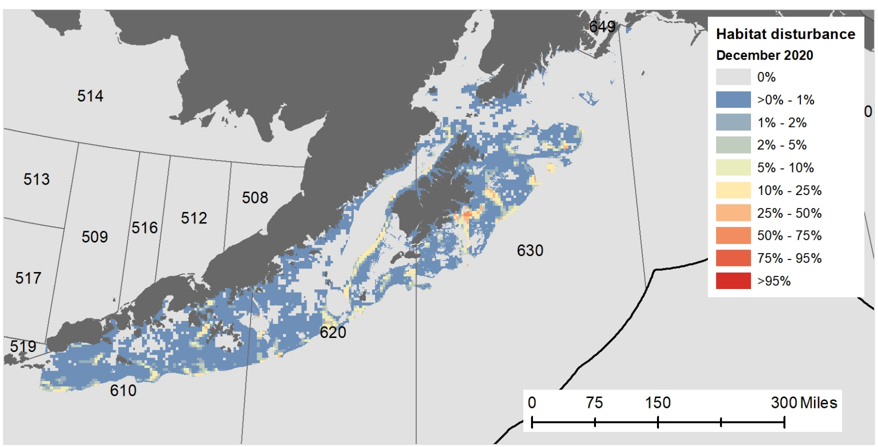


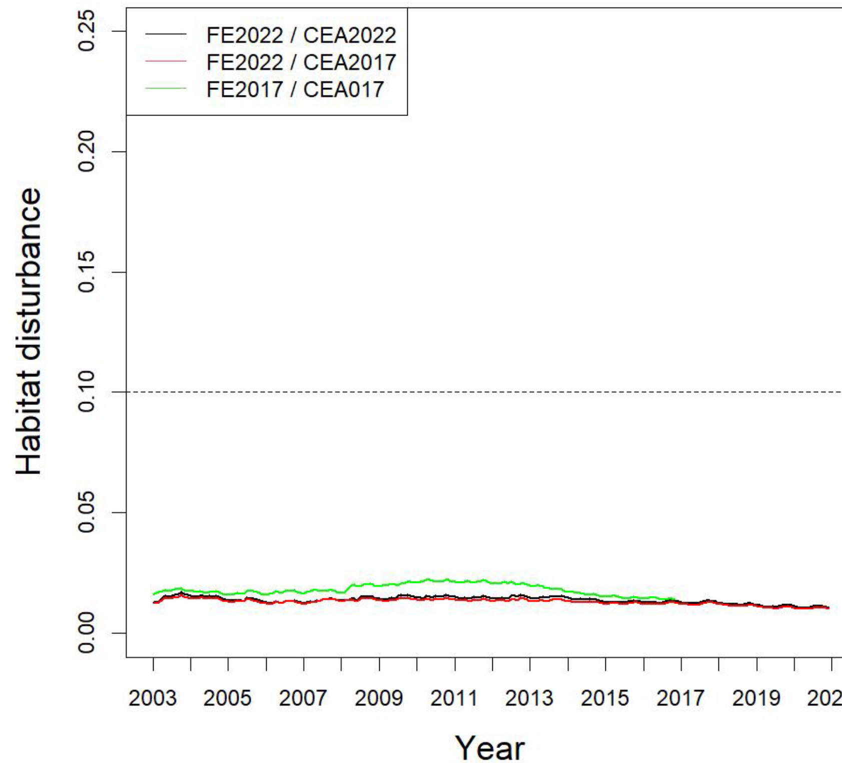




2022 Examples – Gulf of Alaska Pacific cod







Describe whether the EFH Team plans to use the evidence-based approach for evaluation of impacts on spawning, feeding, growth to maturity used in 2017 to evaluate impacts and provide a timeline for completion of this analysis.

1. ***Should assessments be based on regional boundaries for the stock or species?***
2. ***Is the 50% Core EFH (CEA) threshold the right one?***
3. ***Continue the 10% habitat reduction threshold?***
4. ***Is p-value of 0.1 reasonable?***

Questions for the SSC

- Questions on the updates to FE?
- Input on the methods/thresholds to evaluate the effects of fishing developed for the 2017 EFH 5-year review?
- Potential timeline for stock author review – Spring 2022 for a June 2022 SSC presentation.

Questions that may be outside the scope of the Effects of Fishing analysis

- Separating habitat issues from bycatch or unobserved mortality issues
- Efficacy of closed areas

Additional slides

Equation to convert mean recovery ($\bar{\tau}$) to 5% - 95% recovery (τ^*):

$$\tau^* = \bar{\tau}\,[\log(1 - 0.05) - \log(1 - 0.95)]$$

$\bar{\tau}$ (mean recovery)	τ^* (5% - 95% recovery)
1 year	2.9 years
2 years	5.9 years
5 years	14.7 years
10 years	29.4 years
50 years	147.2 years

Feature averaging

During previous NPFMC meetings, both the SSC and public testimony expressed interest in a clearer explanation of feature averaging. To illustrate and clarify, we provide this example:

The Fishing Effects model computes the amount recovery each time step based on one of five sediment-based habitat types. To calculate an average recovery time for each sediment class, a recovery time (τ, in years) was first randomly selected for each habitat feature based on its score for that sediment. The mean of these recovery times was then calculated over all habitat features associated with the sediment class. The inverse of this averaged recovery time was then used in the following equation to convert the time to recovery into a proportional recovery (ρ) for each time step, $\rho=1-e-1/\tau$

In practice, τ is multiplied by twelve before conversion to ρ to convert it to months, which is the time step of the FE model. This process was repeated for each grid cell at a monthly time step. The following example illustrates feature averaging for mud and deep/rocky sediments.
Simplified table of recovery scores

Recovery codes:
0: < 1 year
1: 1 - 2 years
2: 2 - 5 years
3: 5 - 10 years
4: 10 – 50 years

Habitat feature	Mud	Sand	Deep/rocky
Biogenic depression	0	0	
Anemones, cerianthid burrowing	2	2	
Mollusks, epifaunal bivalve, Modiolus modiolus	3	3	3
Long-lived species			4

Feature averaging 2

To calculate monthly recovery on mud in one grid cell for one specific time step:

Habitat feature	Mud score (range)	Random selection from range (τ)
Biogenic depression	0 (0 -1 years)	0.3 years
Anemones, ceriantid burrowing	2 (2 – 5 years)	4.1 years
Mollusks, epifaunal bivalve, *Modiolus modiolus*	3 (5 – 10 year)	6.3 years
Long-lived species	Not present	
		mean = 3.57 years

$$\tau = 3.57\ years = 42.8\ months$$
$$\tilde{p} = 1 - e^{-\frac{1}{42.8}} = 0.023 = 2.3\%$$

Thus, on the proportion of mud sediment within this grid cell and time step, 2.3% of the disturbed habitat would recover (i.e. convert to an undisturbed state in the model) for the next time step.

To calculate monthly recovery on deep/rocky sediment in one grid cell for one specific time step using the simplified table:

Habitat feature	Deep/rocky score (range)	Random selection from range (τ)
Biogenic depression	Not present	
Anemones, ceriantid burrowing	Not present	
Mollusks, epifaunal bivalve, *Modiolus modiolus*	3 (5 – 10)	5.1 years
Long-lived species	4 (10 -50)	39.8 years
		mean = 22.5 years

$$\tau = 22.5\ years = 270\ months$$
$$\tilde{p} = 1 - e^{-1/270} = 0.0037 = 0.37\%$$

Thus, on the proportion of deep/rocky sediment within this grid cell and time step, 0.37% of the disturbed habitat would recover (i.e. convert to an undisturbed state in the model) for the next time step.

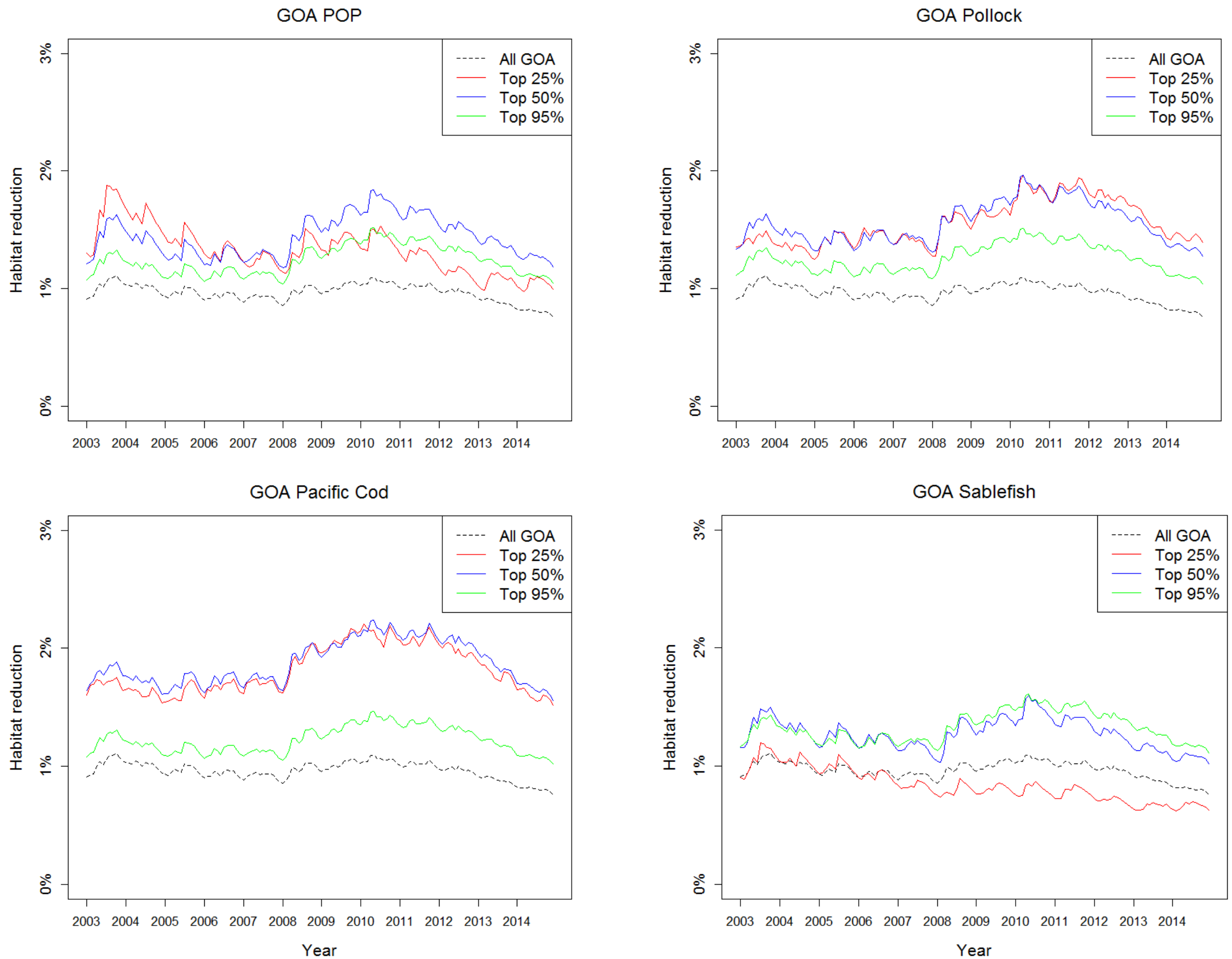
Future application and research needs

"To date, there has been very little effort in any region to develop objective criteria to assess the effects of fishing on EFH, or to consider how those habitat impacts affect fishery stocks. The FE model that was developed for the 2016 review of EFH at the Council was a continuation and modification of the Swept Area Seafloor Impact (SASI) model developed for the New England Fishery Management Council.

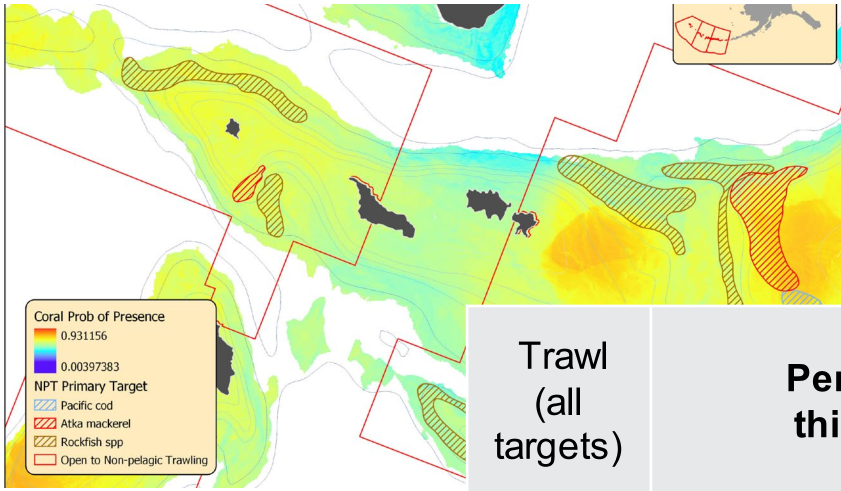
Similarly, the Fishing Effects subcommittee felt that the methods and criteria developed for the Council could be applied in other areas of the world, with appropriate modifications to address their local concerns and species. The subcommittee recognized that data limitations remain, particularly links between specific habitat impacts and population level effects on fish stocks. In order to continue development of these methods and criteria to evaluate the impacts of fishing on EFH, the subcommittee recommends that research should continue to better elucidate those linkages."

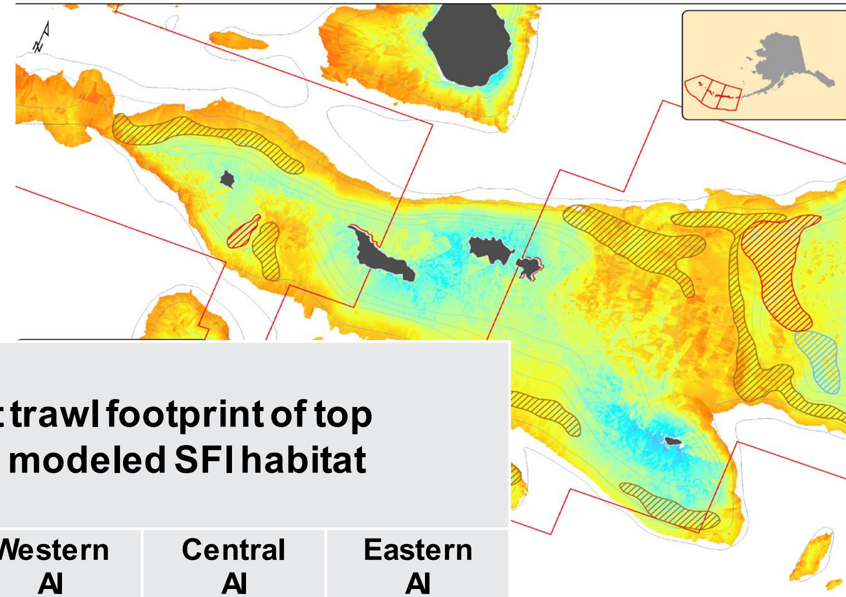
Methods to evaluate the effects of fishing on Essential Fish Habitat Proposal from the SSC subcommittee. December 2016

50% threshold

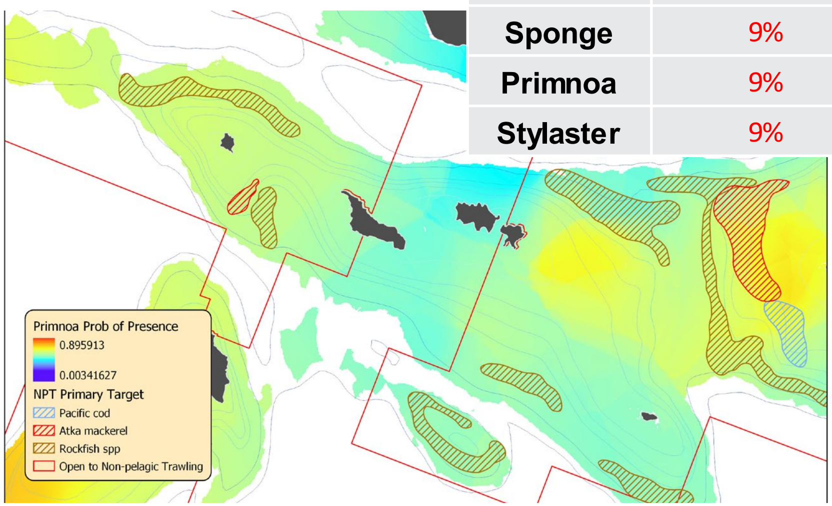


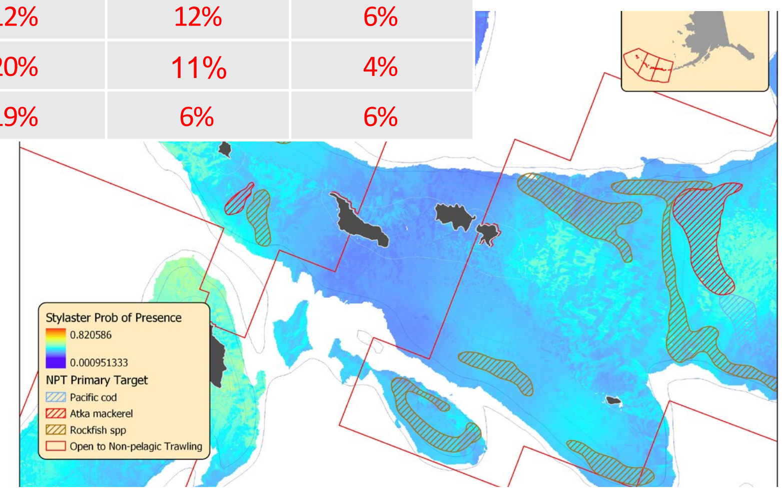
Preliminary Results – Summary





Trawl (all targets)	Percent trawl footprint of top third of modeled SFI habitat			
	Entire AI	**Western AI**	**Central AI**	**Eastern AI**
Coral	9%	19%	11%	4%
Sponge	9%	12%	12%	6%
Primnoa	9%	20%	11%	4%
Stylaster	9%	19%	6%	6%





Survey Trawl Locations & Coral Model Output