EFH Species Descriptions

EFH Levels within EFH Regulation (50 CFR Part 600)

Level 1 - *Distribution data are available* for some or all portions of the geographic range of the species.

Level 2 - *Habitat-related densities* of the species are available

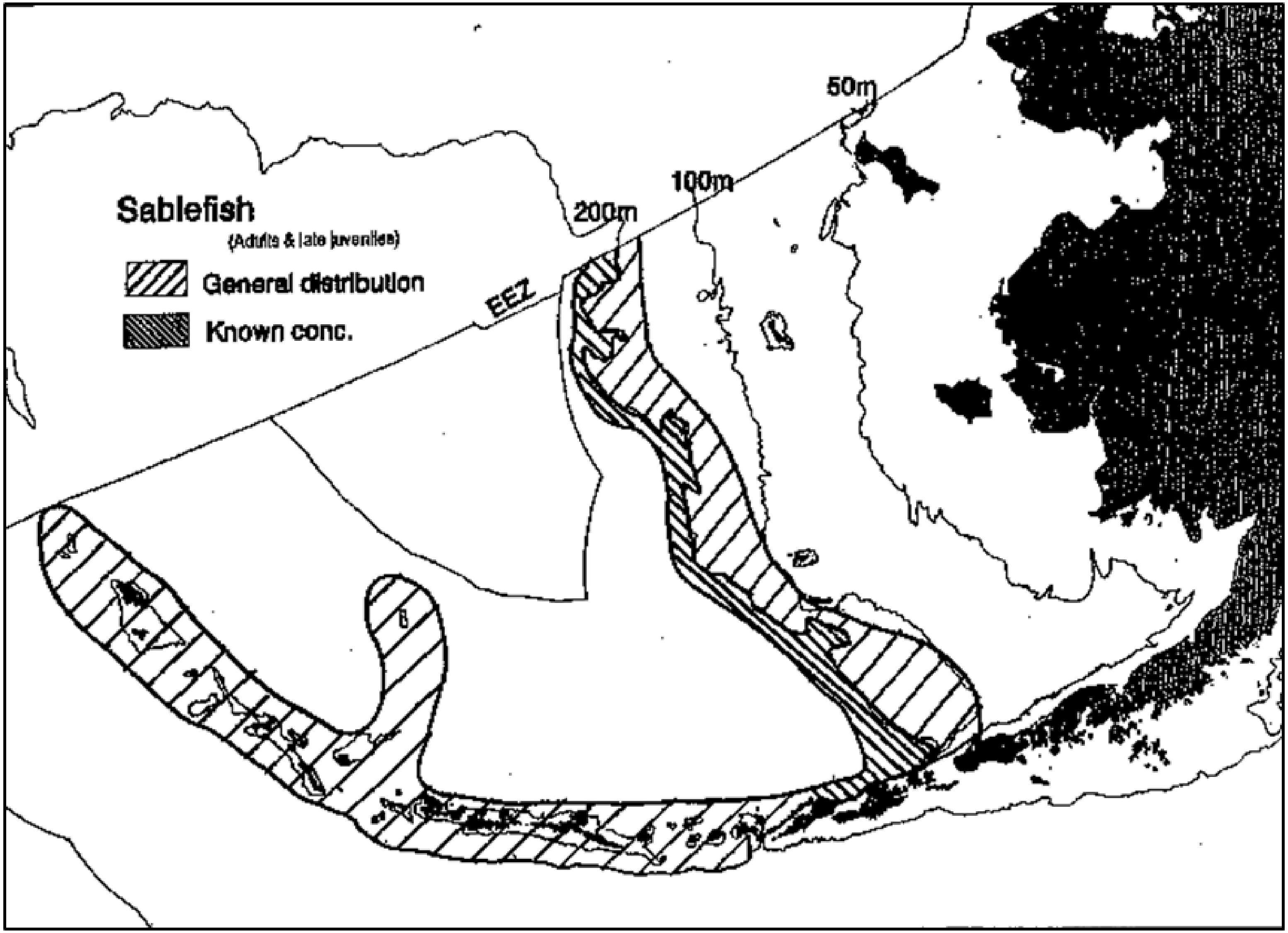
Level 3 - *Growth, reproduction, or survival rates* within habitats are available.

Level 4 - *Production rates* by habitat are available.

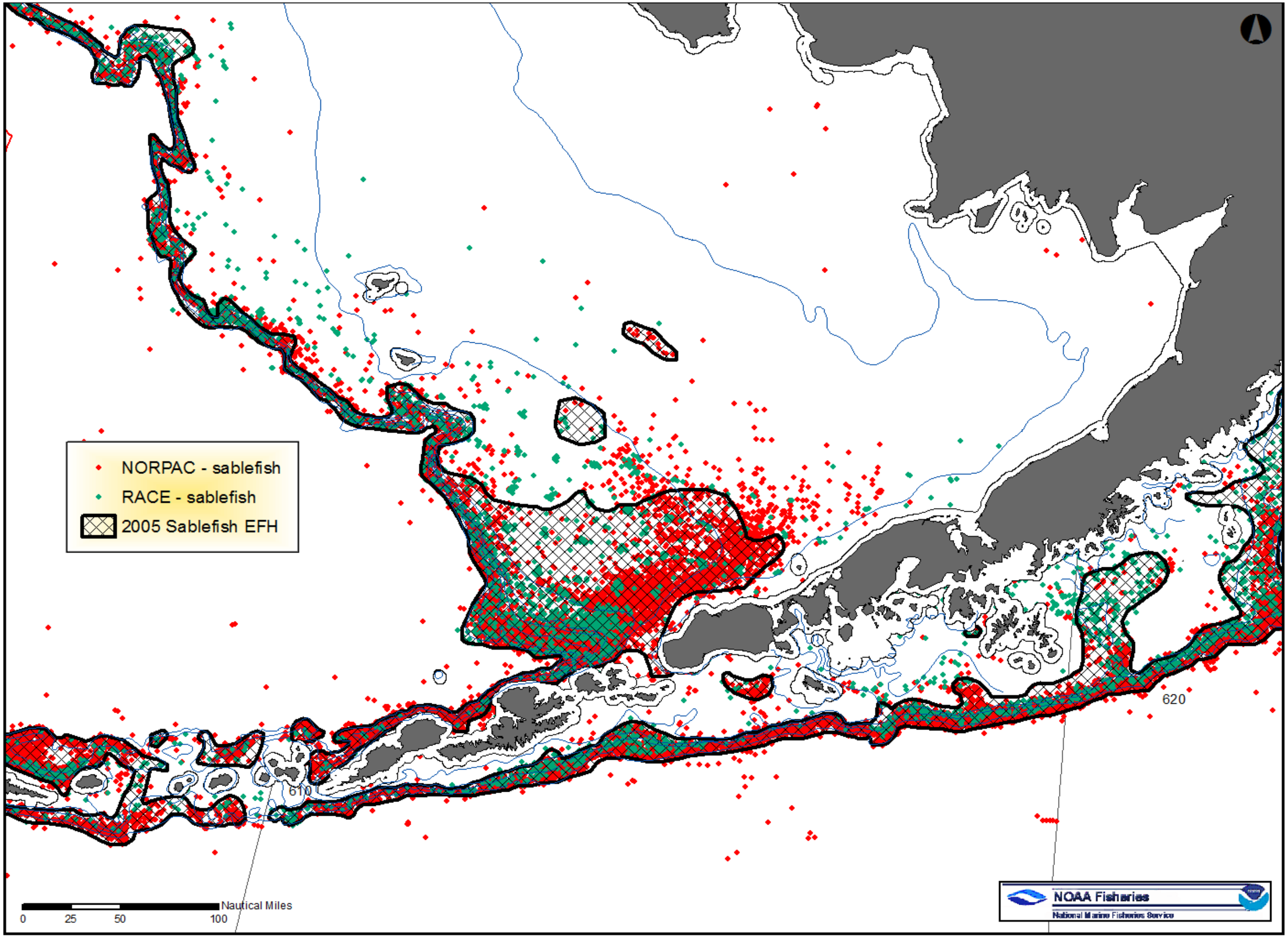
- 600.815 (a)(1)(**ii**)(B). FMPs must demonstrate that the **best scientific information available was used in the description and identification of EFH**, consistent with National Standard 2.

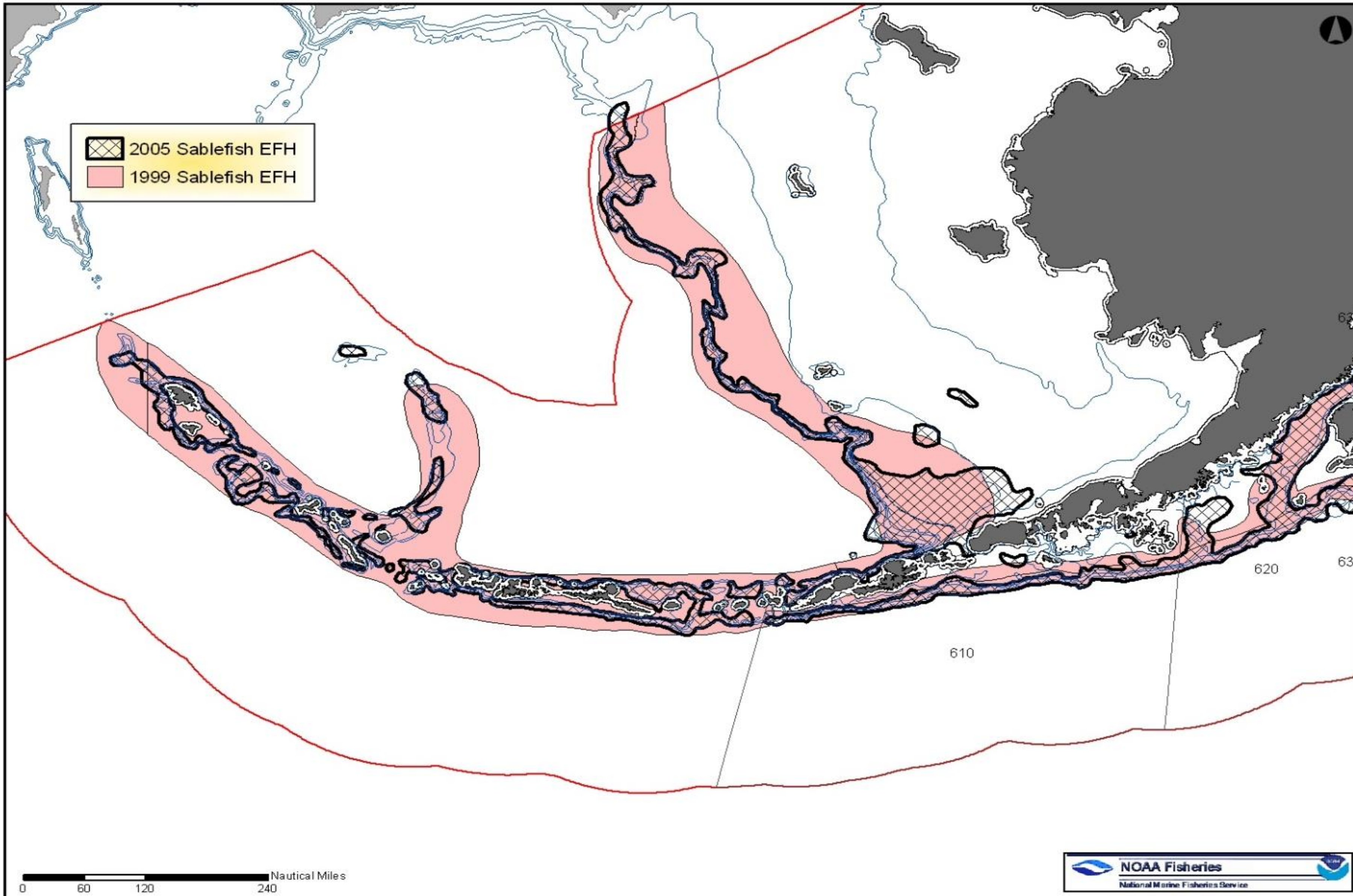
- 600.815 (a)(1)(**iii**)(B). Councils should **strive to describe habitat based on the highest level of detail (i.e., Level 4**). If there is no information on a given species or life stage, and habitat usage cannot be inferred from other means, such as information on a similar species or another life stage, EFH should not be designated.

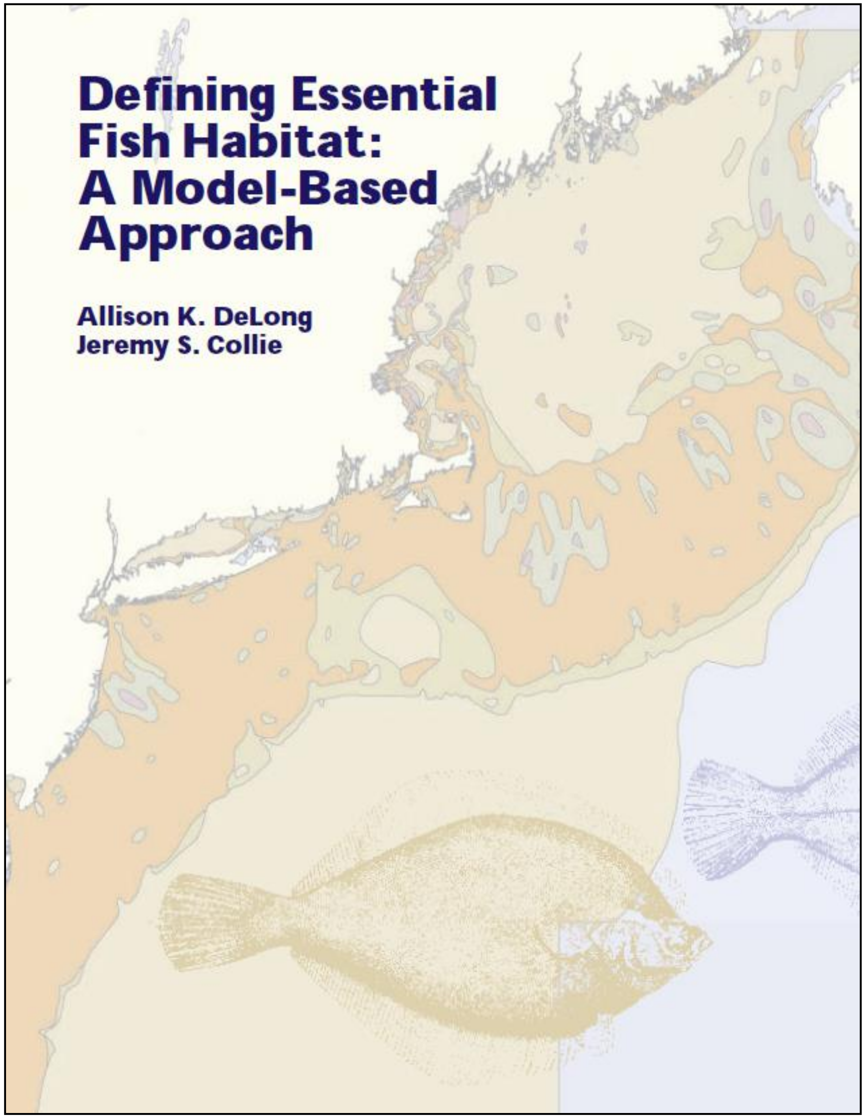
Sablefish EFH, 1999



Sablefish EFH, 2005/2010




2005 Sablefish EFH
1999 Sablefish EFH
630
620
630
610
Nautical Miles
0
60
120
240
NOAA Fisheries
National Marine Fisheries Service



NOAA Technical Memorandum NMFS-AFSC-236

A Refined Description of Essential Fish Habitat for Pacific Salmon Within the U.S. Exclusive Economic Zone in Alaska

by
K. Echave, M. Eagleton, E. Farley, and J. Orsi

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

June 2012

Science, Service, Stewardship

Distribution modeling for deep-sea corals and sponges in Alaska

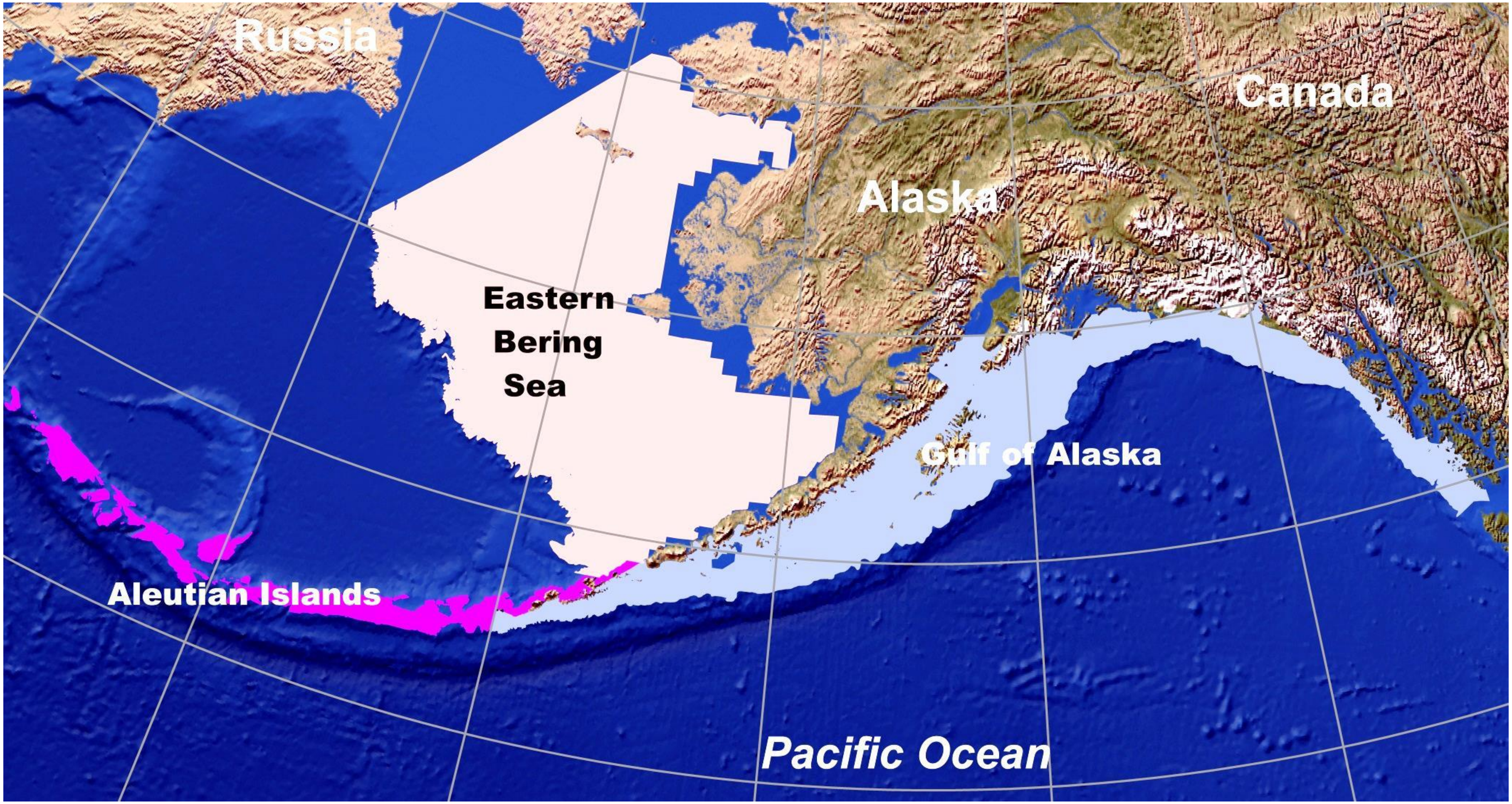
Chris Rooper, Mark Zimmermann, Mike Sigler and Jerry Hoff

- Objectives:

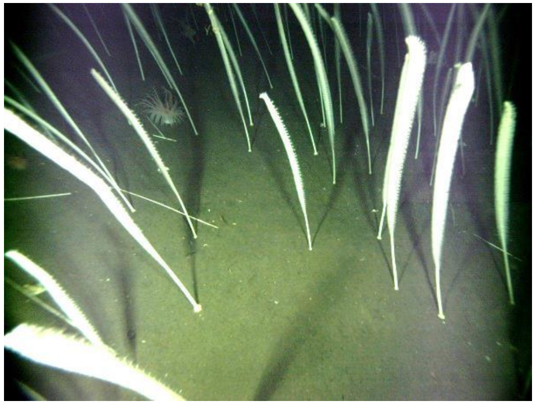
  – Move EFH Descriptions from Level 0 (no information) and Level 1 (presence information) to Level 1 & Level 2 (density information by habitat)

  – Standardized and repeatable method

Data, Regions, Surveys, and Sampling Areas



Approach– EFH Definitions in Alaska



- Uses species distribution modeling tuned to available data

- Divisions by season (Fall, Winter, Spring)

- Divisions by life history stage
  (egg, larvae, pelagic juvenile
  settled juvenile, adult)

- Funded by Alaska Regional Office

Aleutian Islands (n = 30)

Species
Alaska skate (*Bathyraja parmifera*)
Aleutian skate (*Bathyraja aleutica*)
Arrowtooth flounder (*Atheresthes stomias*)
Atka mackerel (*Pleurogrammus monopterygius*)
Bering skate (*Bathyraja interrupta*)
Bigmouth sculpin (*Hemitripterus bolini*)
Blackspotted rockfish (*Sebastes melanostictus*)
Dark rockfish (*Sebastes ciliatus*)
Dover sole (*Microstomus pacificus*)
Dusky rockfish (*Sebastes variabilis*)
Flathead sole (*Hippoglossoides elassodon*)
Golden king crab (*Lithodes aequispinus*)
Great sculpin (*Myoxocephalus polyacanthocephalus*)
Greenland turbot (*Reinhardtius hippoglossoides*)
Harlequin rockfish (*Sebastes variegatus*)
Kamchatka flounder (*Atheresthes evermanni*)
Mud skate (*Bathyraja taranetzi*)
Northern rock sole (*Lepidopsetta polyxystra*)
Northern rockfish (*Sebastes polyspinis*)
Octopus sp. (*Octopus dofleini*)
Pacific cod (*Gadus macrocephalus*)
Pacific ocean perch (*Sebastes alutus*)
Pollock (*Gadus chalcogramma*)
Rex sole (*Glyptocephalus zachirus*)
Rougheye rockfish (*Sebastes aleutianus*)
Sablefish (*Anoplopoma fimbria*)
Shortraker rockfish (*Sebastes borealis*)
Shortspine thornyhead (*Sebastolobus alascanus*)
Southern rock sole (*Lepidopsetta bilineata*)
Yellow Irish lord (*Hemilepidotus jordani*)

Eastern Bering Sea (n = 34)

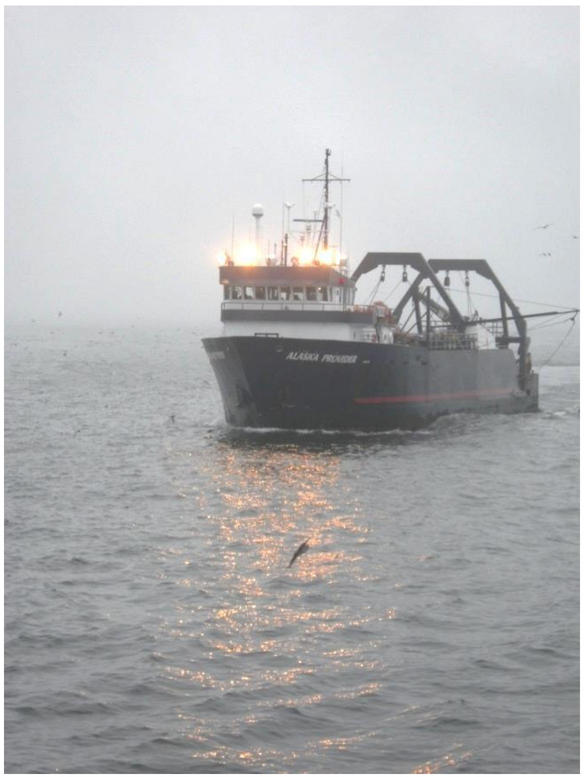
Species
Alaska plaice (*Pleuronectes quadrituberculatus*)
Alaska skate (*Bathyraja parmifera*)
Aleutian skate (*Bathyraja aleutica*)
Arrowtooth flounder (*Atheresthes stomias*)
Atka mackerel (*Pleurogrammus monopterygius*)
Bering skate (*Bathyraja interrupta*)
Bigmouth sculpin (*Hemitripterus bolini*)
Snow crab (*Chionoecetes opilio*)
Blackspotted rockfish (*Sebastes melanostictus*)
Tanner crab (*Chionoecetes bairdi*)
Red king crab (*Paralithodes camtschaticus*)
Blue king crab (*Paralithodes platypus*)
Dover sole (*Microstomus pacificus*)
Dusky rockfish (*Sebastes variabilis*)
Flathead sole (*Hippoglossoides elassodon*)
Great sculpin (*Myoxocephalus polyacanthocephalus*)
Greenland turbot (*Reinhardtius hippoglossoides*)
Kamchatka flounder (*Atheresthes evermanni*)
Longspine thornyhead (*Sebastolobus altivelis*)
Mud skate (*Bathyraja taranetzi*)
Northern rock sole (*Lepidopsetta polyxystra*)
Northern rockfish (*Sebastes polyspinis*)
Octopus sp. (*Octopus dofleini*)
Pacific cod (*Gadus macrocephalus*)
Pacific ocean perch (*Sebastes alutus*)
Pollock (*Gadus chalcogramma*)
Rex sole (*Glyptocephalus zachirus*)
Rougheye rockfish (*Sebastes aleutianus*)
Sablefish (*Anoplopoma fimbria*)
Shortraker rockfish (*Sebastes borealis*)
Shortspine thornyhead (*Sebastolobus alascanus*)
Southern rock sole (*Lepidopsetta bilineata*)
Yellow Irish lord (*Hemilepidotus jordani*)
Yellowfin sole (*Limanda aspera*)

Gulf of Alaska (n = 46)

Species
Alaska plaice (*Pleuronectes quadrituberculatus*)
Alaska skate (*Bathyraja parmifera*)
Aleutian skate (*Bathyraja aleutica*)
Arrowtooth flounder (*Atheresthes stomias*)
Atka mackerel (*Pleurogrammus monopterygius*)
Bering skate (*Bathyraja interrupta*)
Bigmouth sculpin (*Hemitripterus bolini*)
Black rockfish (*Sebastes melanops*)
Blackspotted rockfish (*Sebastes melanostictus*)
Canary rockfish (*Sebastes pinniger*)
Dark rockfish (*Sebastes ciliatus*)
Darkblotched rockfish (*Sebastes crameri*)
Dover sole (*Microstomus pacificus*)
Dusky rockfish (*Sebastes variabilis*)
Flathead sole (*Hippoglossoides elassodon*)
Great sculpin (*Myoxocephalus polyacanthocephalus*)
Greenstriped rockfish (Sebastes elongatus)
Harlequin rockfish (*Sebastes variegatus*)
Kamchatka flounder (*Atheresthes evermanni*)
Longspine thornyhead (*Sebastolobus altivelis*)
Mud skate (*Bathyraja taranetzi*)
Northern rock sole (*Lepidopsetta polyxystra*)
Northern rockfish (*Sebastes polyspinis*)
Octopus sp. (*Octopus dofleini*)
Pacific cod (*Gadus macrocephalus*)
Pacific ocean perch (*Sebastes alutus*)
Pollock (*Gadus chalcogramma*)
Pygmy rockfish (*Sebastes wilsoni*)
Quillback rockfish (*Sebastes maliger*)
Redbanded rockfish (*Sebastes babcocki*)
Redstripe rockfish (*Sebastes proriger*)
Rex sole (*Glyptocephalus zachirus*)
Rosethorn rockfish (*Sebastes helvomaculatus*)
Rougheye rockfish (*Sebastes aleutianus*)
Sablefish (*Anoplopoma fimbria*)
Sharpchin rockfish (*Sebastes zacentrus*)
Shortraker rockfish (*Sebastes borealis*)
Shortspine thornyhead (*Sebastolobus alascanus*)
Silvergray rockfish (*Sebastes brevispinis*)
Southern rock sole (*Lepidopsetta bilineata*)
Splitnose rockfish (*Sebastes diploproa*)
Widow rockfish (*Sebastes entomelas*)
Yellow Irish lord (*Hemilepidotus jordani*)
Yelloweye rockfish (*Sebastes ruberrimus*)
Yellowfin sole (*Limanda aspera*)
Yellowtail rockfish (*Sebastes flavidus*)

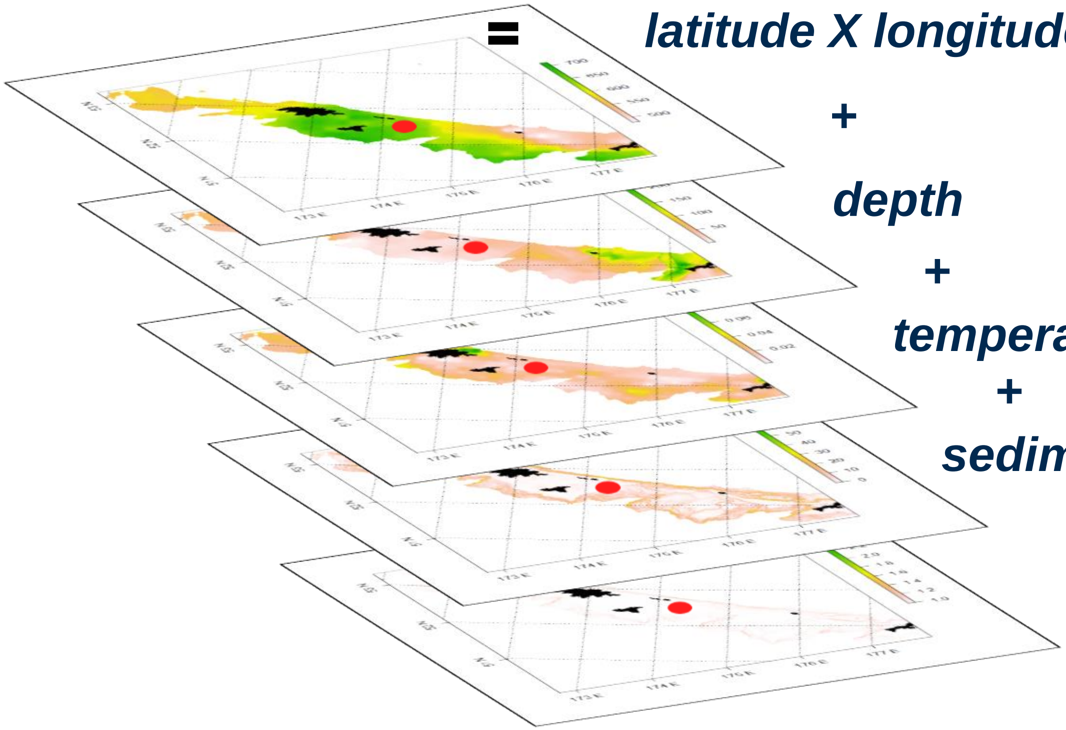
> 400 combinations to model

Dependent data



- Bottom trawl surveys (1982-2014)
  - CPUE (GAM, hurdle GAM, Maxent)
  - Adults
  - Settled juveniles
  - Summer only
- EcoFOCI data (1994-2015)
  - Presence only (MaxEnt)
  - Eggs
  - Larvae
  - Pelagic juveniles
  - All seasons
- Catch in areas database (2005-2013)
  - Presence only (MaxEnt)
  - Fall, winter, spring
  - Adults only

Method Part I. Term Selection & Model Fitting (GAM)



= ***latitude X longitude***

+

depth

+

temperature

+

sediment size

+

slope

Method Part II. Generalized Additive Modeling

$$y = s(latitude, longitude) + s(depth) + s(temperature) + s(slope) + s(tide)$$
$$+ s(current) + s(ocean\_color) + s(grain\_size) + \varepsilon$$

Details:

Dismo package for MaxEnt

MGCV package for GAM

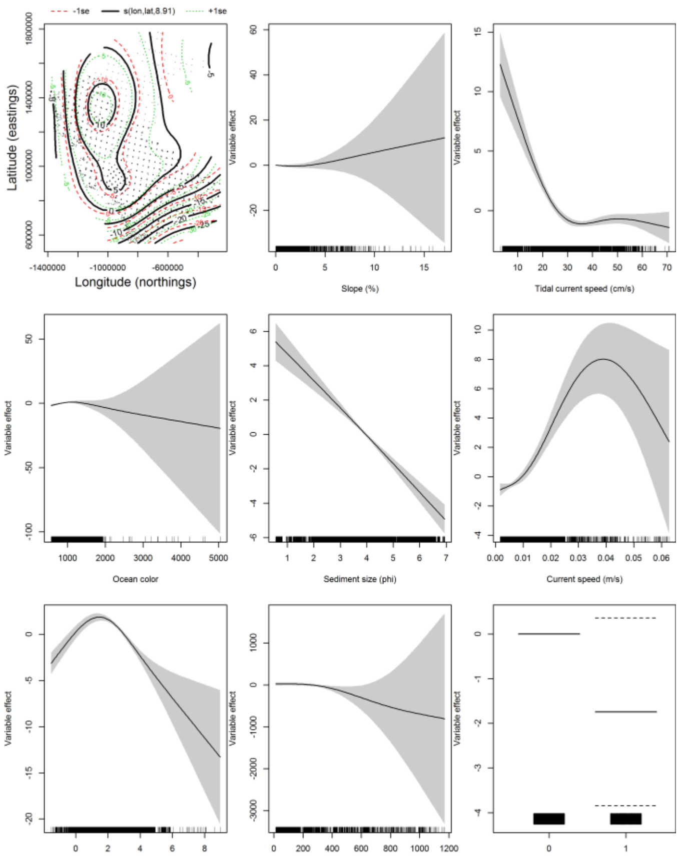
Presence-absence = Binomial distribution

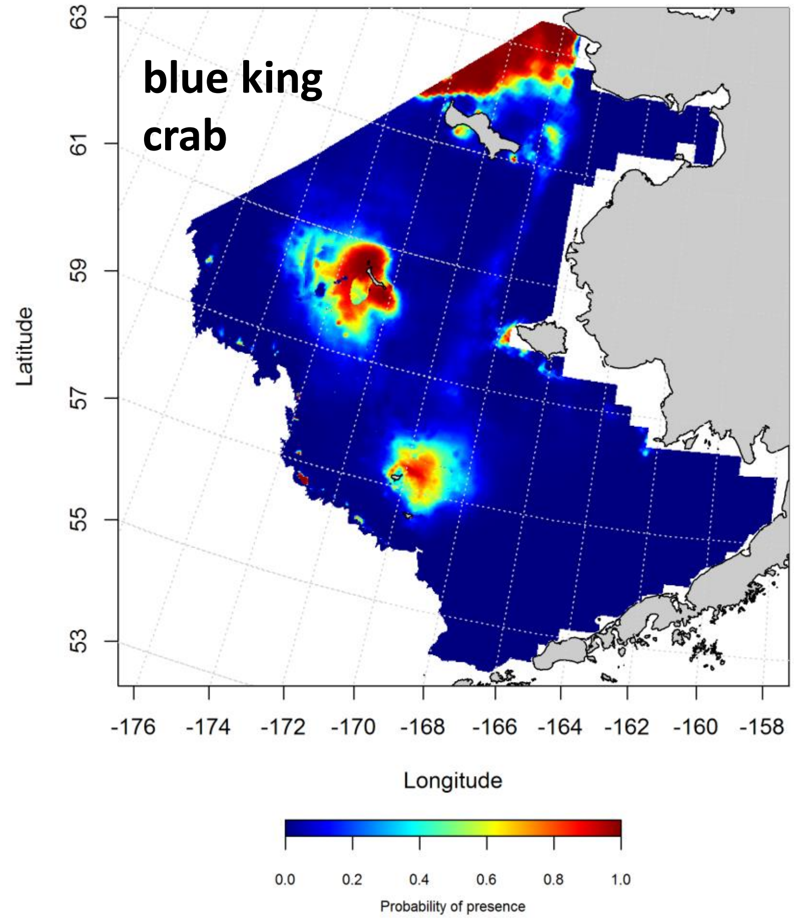
CPUE = 4^{th} root transformation

k = 30 for bivariate term, 4 for univariate terms

Prediction

~ (longitude X latitude) + depth + temperature + sediment size + slope

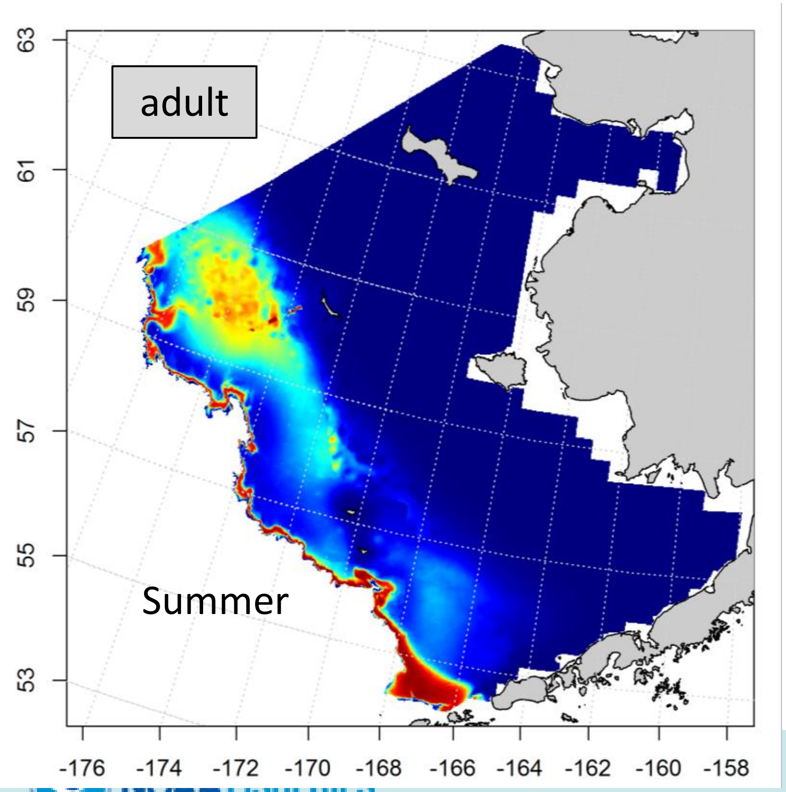




Kamchatka flounder

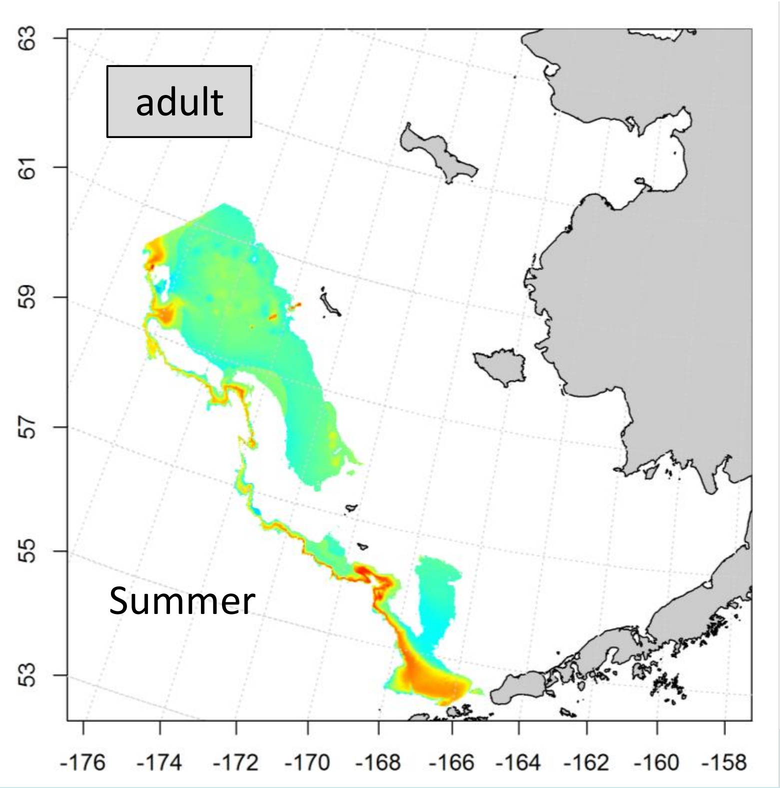
bottom trawl surveys: hurdle GAM

presence-absence | **conditional abundance**



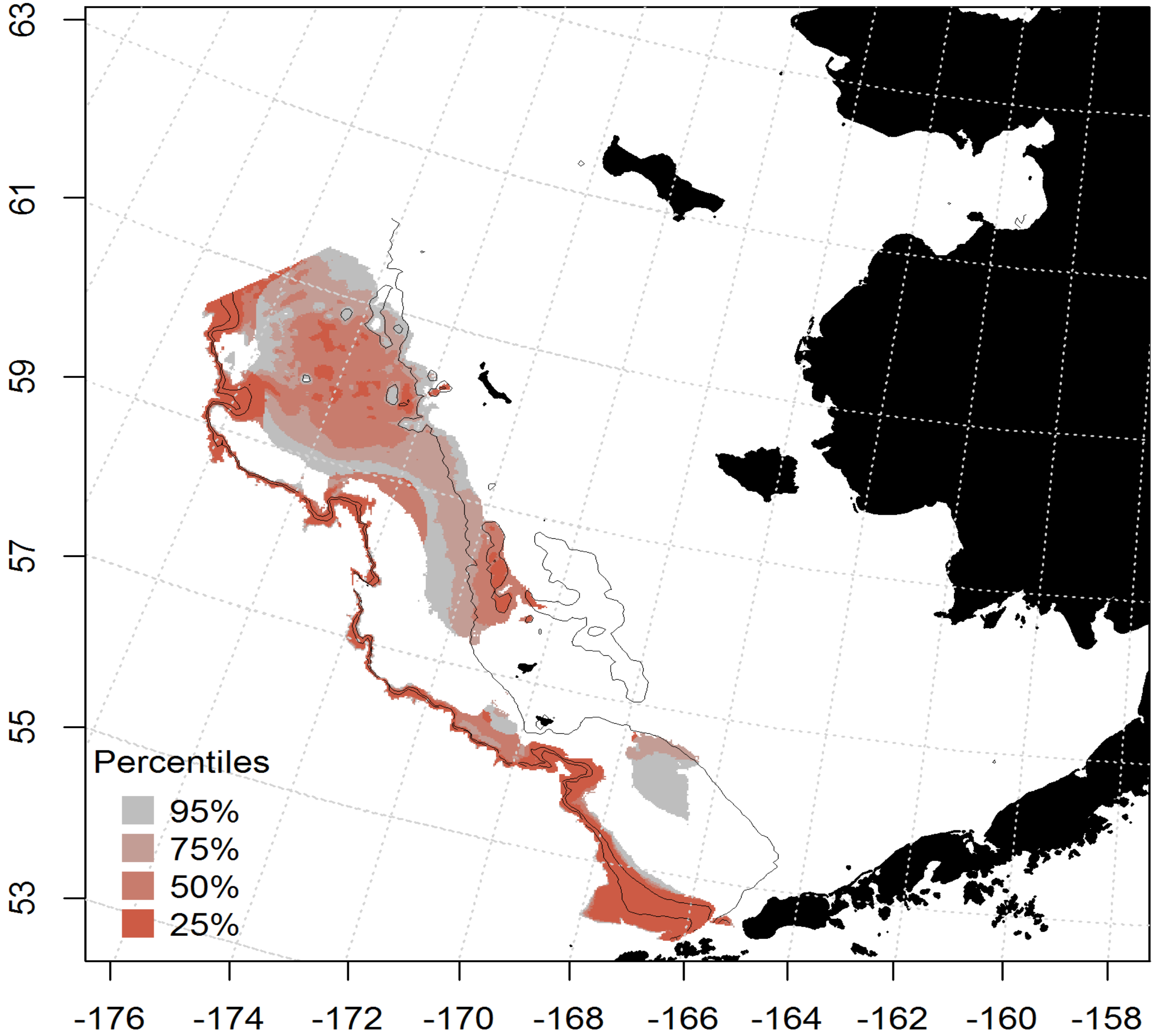
threshold

p > 0.39



EFH - Kamchatka flounder

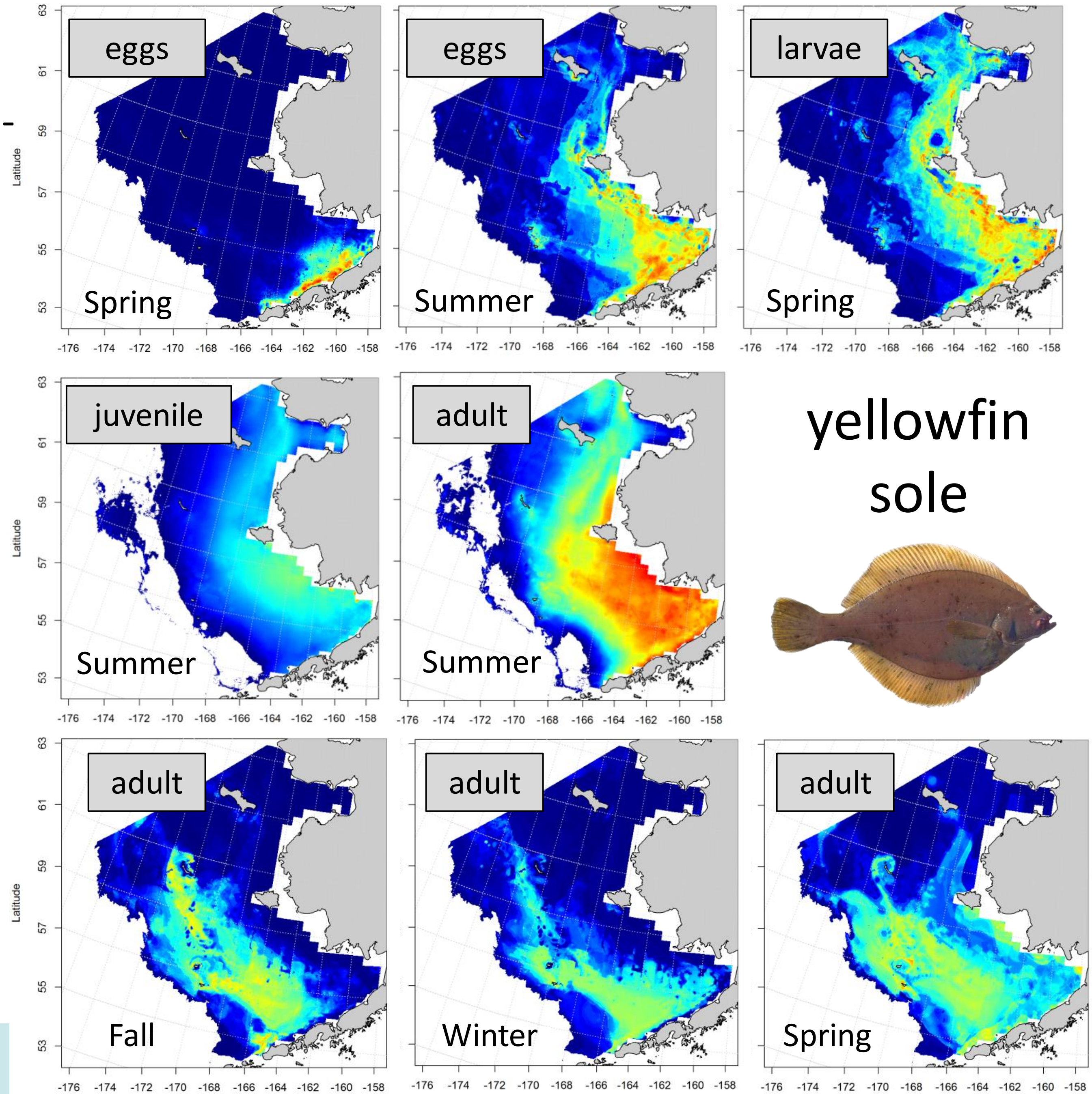
Groundfish survey



ichthyoplankton survey - MaxEnt - presence only (probability)

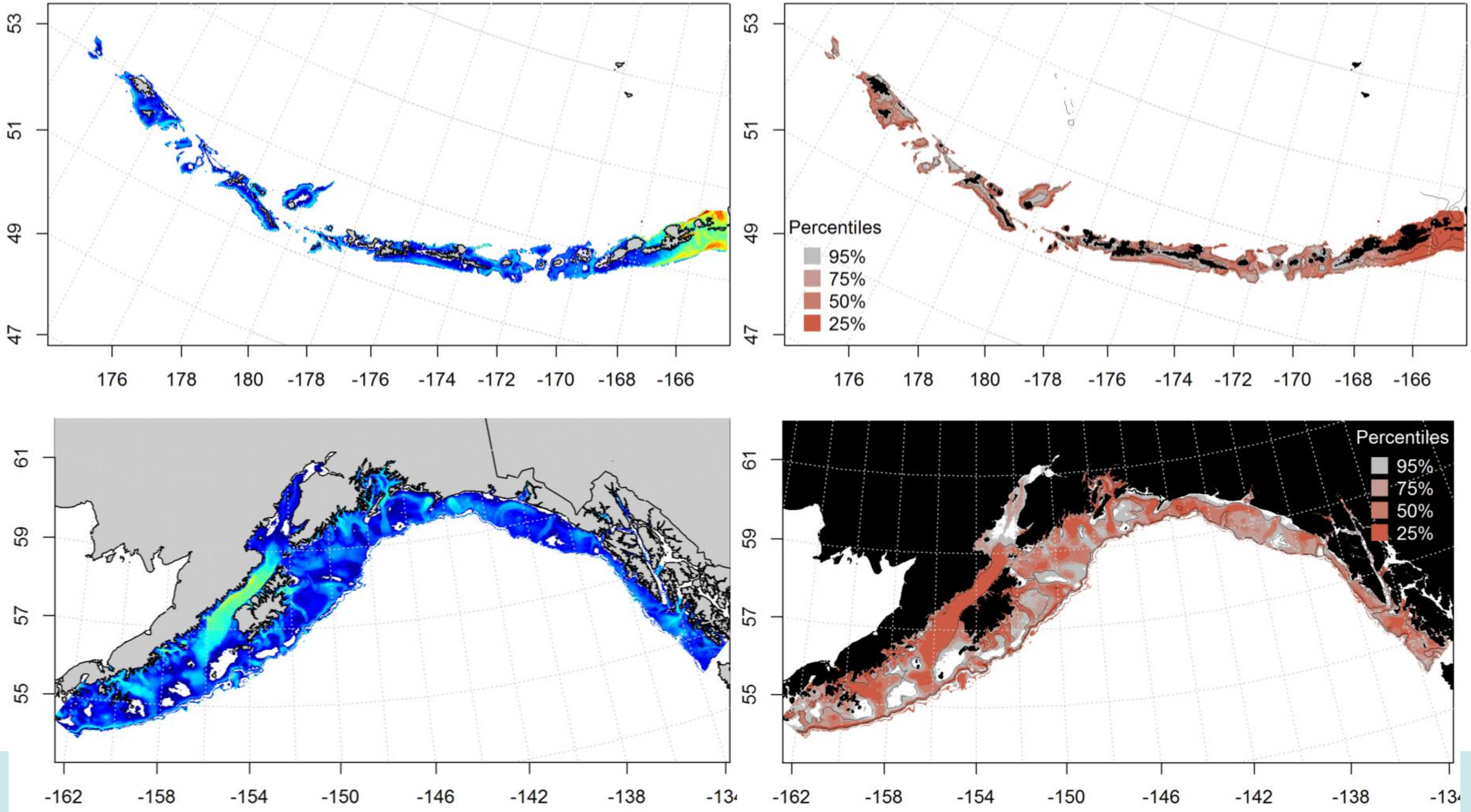
bottom trawl survey - GAM - abundance

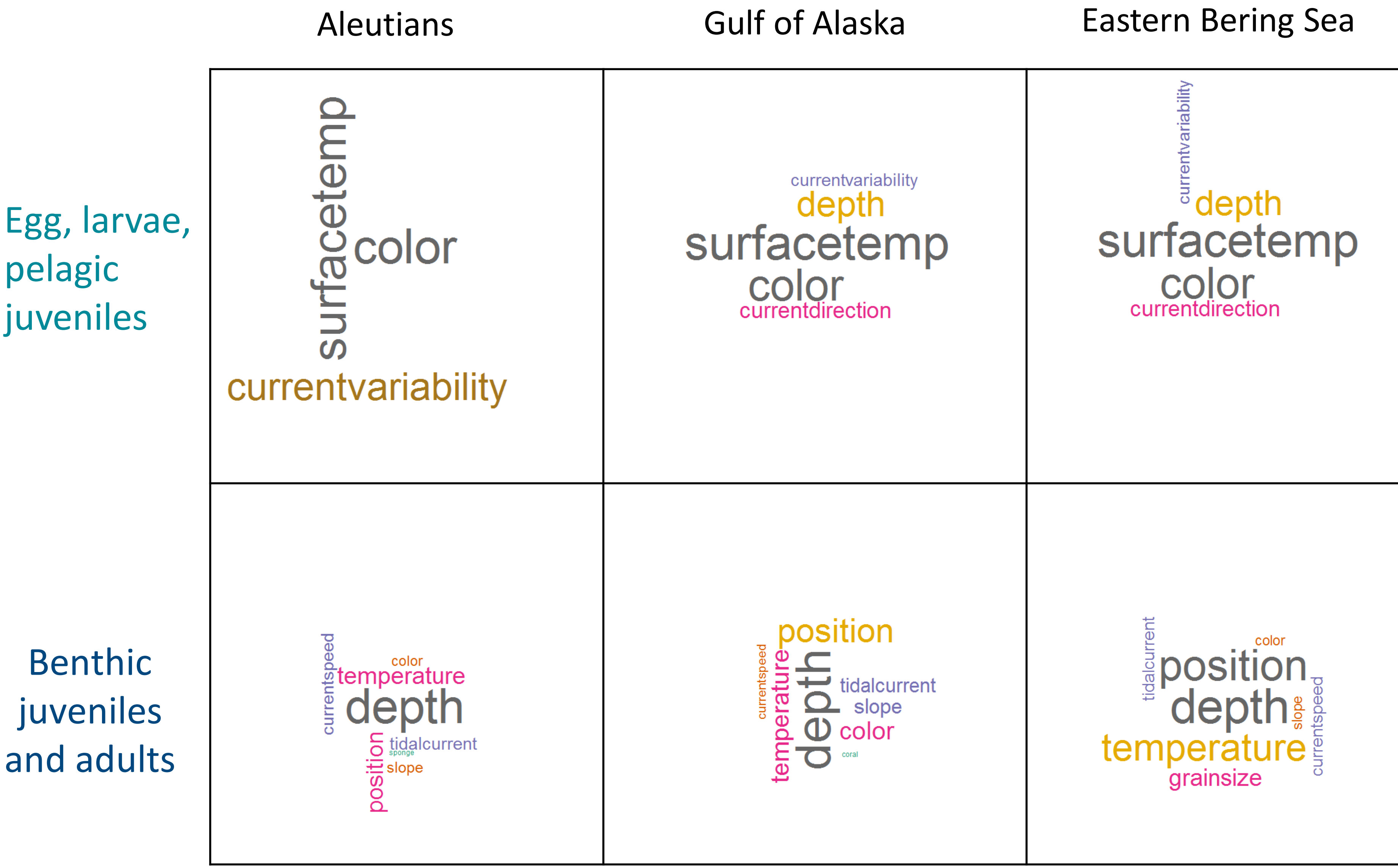
observer catch - MaxEnt - presence only (probability)



AI and GOA too!

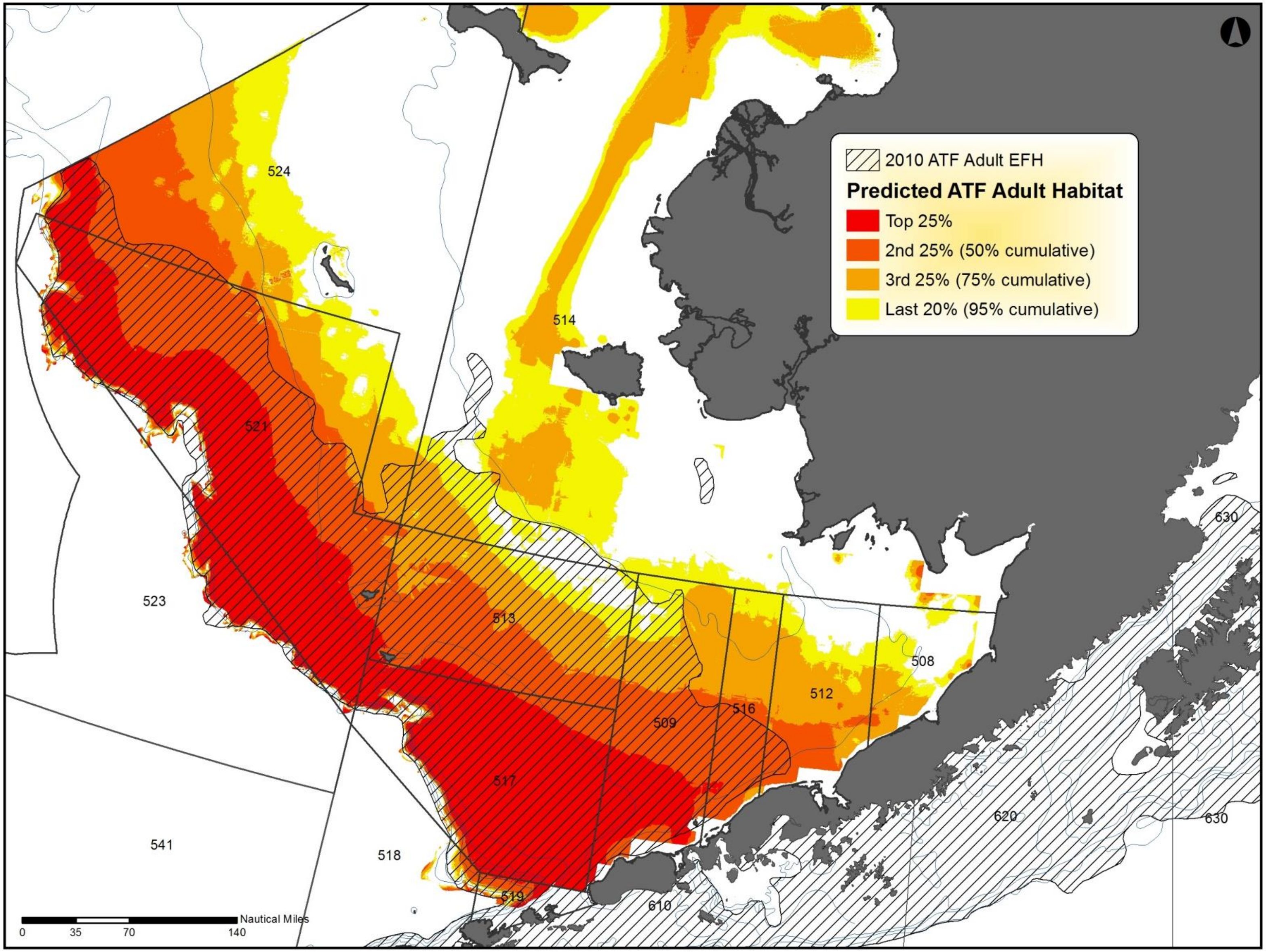
walleye pollock





Aleutians
Gulf of Alaska
Eastern Bering Sea
Egg, larvae, pelagic juveniles
surfacetemp
color
currentvariability
currentvariability
depth
surfacetemp
color
currentdirection
currentvariability
depth
surfacetemp
color
currentdirection
Benthic juveniles and adults
currentspeed
color
temperature
depth
position
tidalcurrent
sponge
slope
position
currentspeed
temperature
depth
tidalcurrent
slope
color
coral
tidalcurrent
color
position
depth
slope
currentspeed
temperature
grainsize

New EFH Descriptions

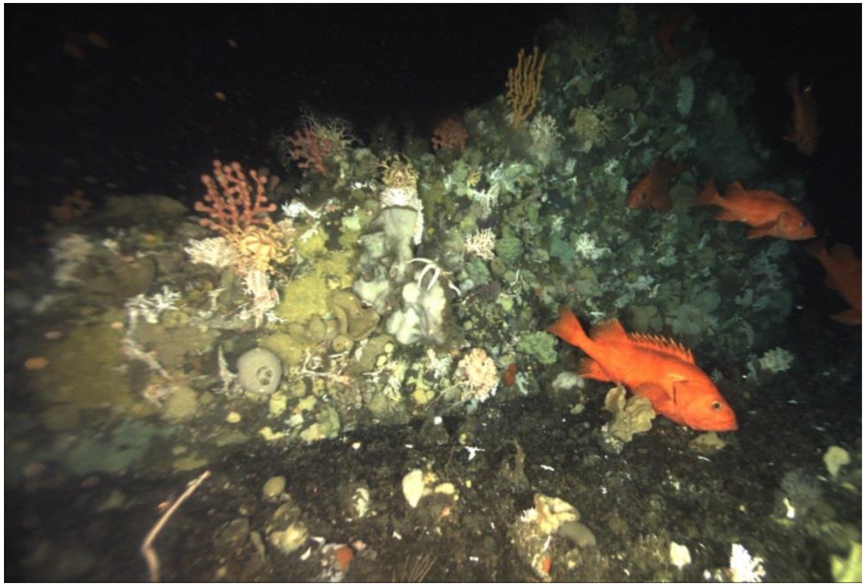


Caveats (there are many)

- Fishery-dependent and ichthyoplankton data are effort dependent
- Results are large-scale, decadal, regional
- Don't include results from previous studies
- Untrawlable regions not considered

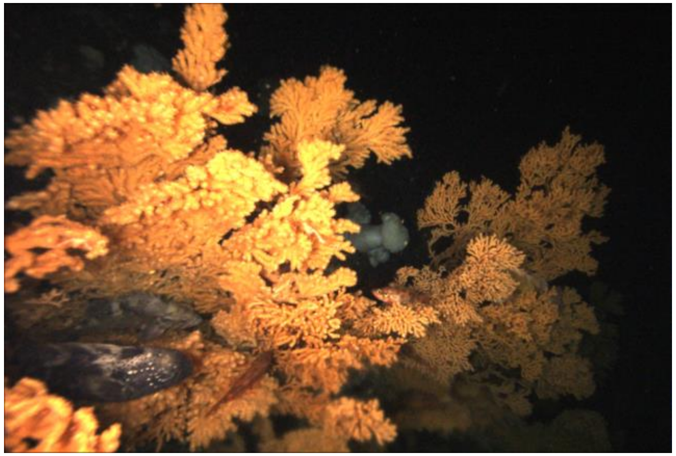
Advantages:

- EFH definitions directly linked to habitat attributes
- Cohesive maps aid spatial planning
- Relatively easy to update with new data



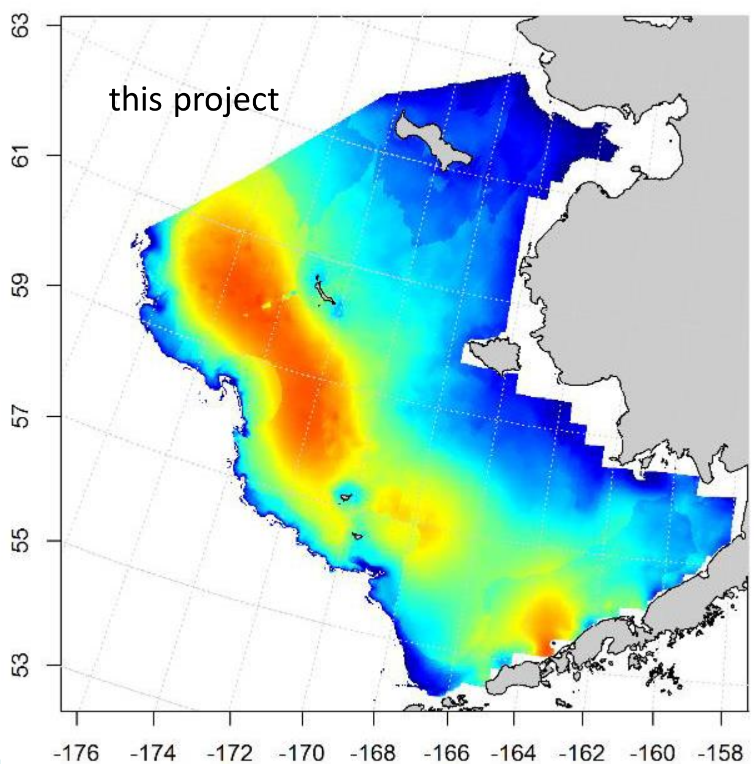
Future Work

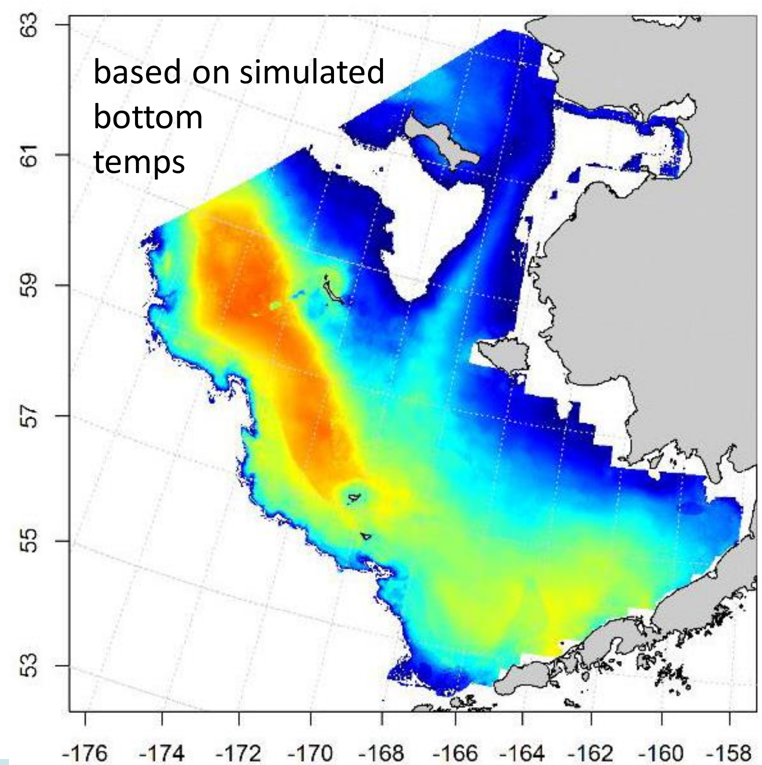
- Stock assessor review (1500 pages)
- Automation!
- Additional modeling methods
- Combine with other habitat studies to more fully integrated EFH reporting
- Temporal changes in habitat



Distribution and abundance under changing scenarios

walleye pollock distribution





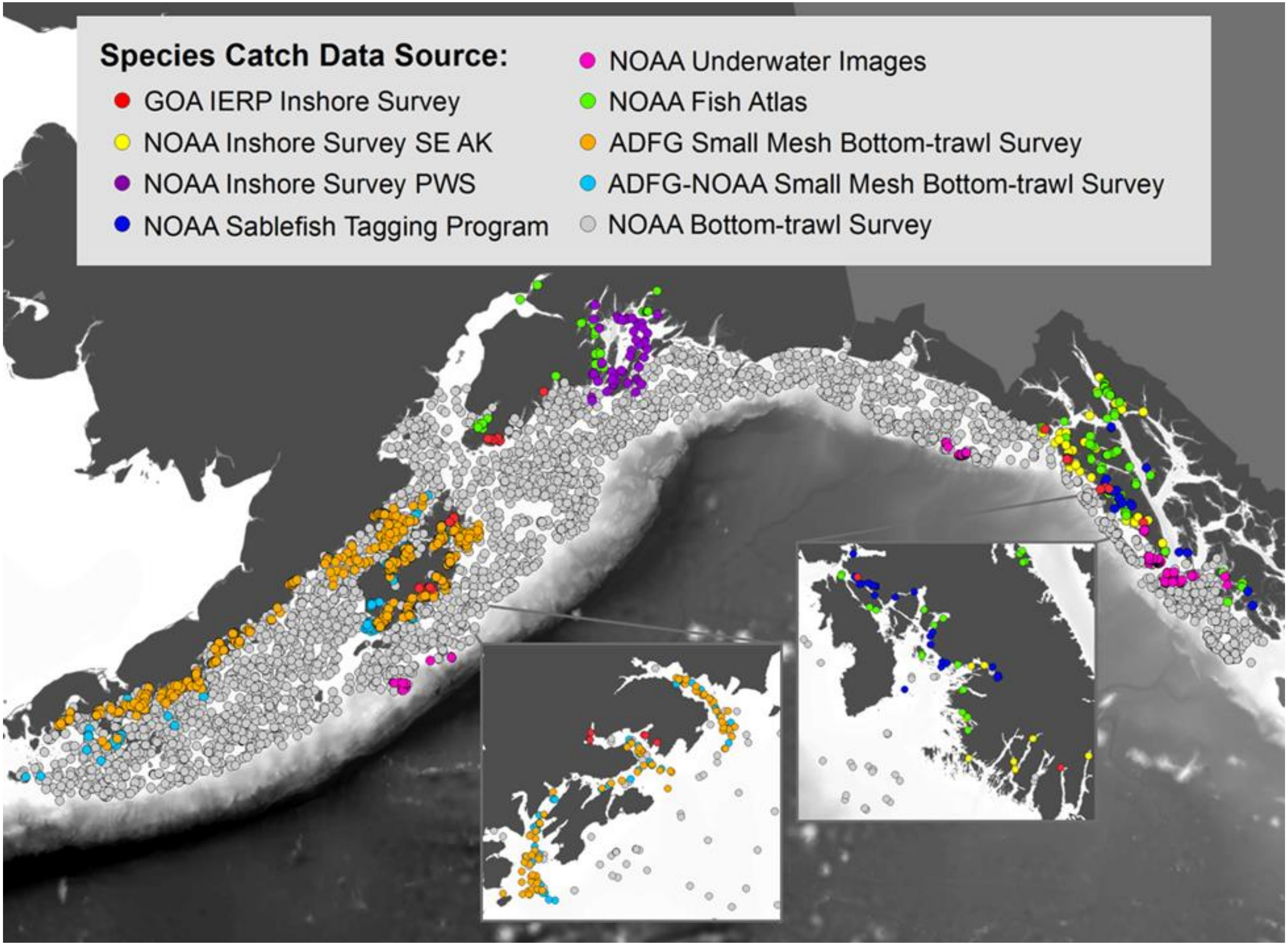
Habitat Metrics Presence-only Models

Improving base model EFH definitions for Gulf of Alaska groundfish species using combined species distribution models with high-resolution regional habitat metrics (Pirtle et al. EFH Project 2015-04);

- Seafloor Terrain: depth, slope, aspect, curvature, bathymetric position index (BPI)
- Structural Invertebrates: coral, sponge, and whip presence
- Biophysical: bottom temperature, bottom current speed, tidal current speed, primary and secondary production
- Next Steps: rockiness surface from sediment and substrate features and *other* seafloor data

Table 1: FMP groundfish species and demersal life stages for the GOA region, where a presence-only habitat suitability model was developed. Life stage breaks are provided between stages (mm fork length and mm total length for skates).

Species	Early juveniles	Late juveniles	Adults
Sablefish *Anoplopoma fimbria*	≤ 399	400-550	> 550
Walleye pollock *Gadus chalcogrammus*	≤ 140	141-370	> 370
Pacific cod *Gadus macrocephalus*	≤ 150	151-420	> 420
Northern rock sole *Lepidopsetta polyxystra*	≤ 140	141-300	> 300
Flathead sole *Hippoglossoides elassodon*	≤ 140	141-290	> 290
Arrowtooth flounder *Atheresthes stomias*	≤ 160	161-350	>350
Pacific ocean perch *Sebastes alutus*	≤ 200	201-250	> 250
Sharpchin rockfish *Sebastes zacentrus*	-	≤ 250	> 250
Shortspine thornyhead *Sebastolobus alaskanus*	-	≤ 210	> 210
Longnose skate *Raja rhina*	-	≤ 1020	> 1020
Big skate *Raja binoculata*	-	≤ 1250	> 1250


Species Catch Data Source:
GOA IERP Inshore Survey
NOAA Inshore Survey SE AK
NOAA Inshore Survey PWS
NOAA Sablefish Tagging Program
NOAA Underwater Images
NOAA Fish Atlas
ADFG Small Mesh Bottom-trawl Survey
ADFG-NOAA Small Mesh Bottom-trawl Survey
NOAA Bottom-trawl Survey

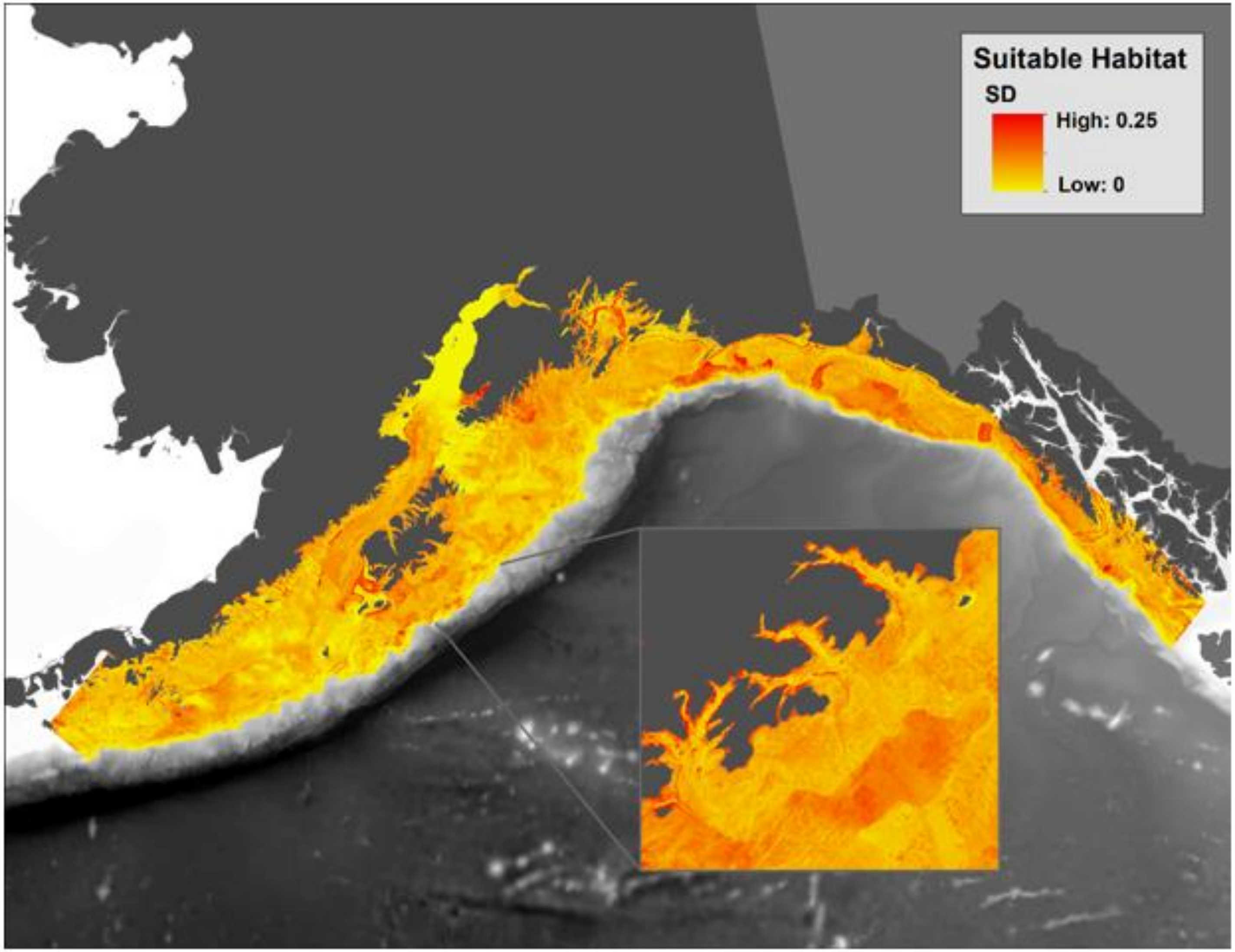


Figure 6: Sablefish demersal early juvenile stage (150-399 mm) habitat suitability model (MaxEnt HSM). Standard deviation of the mean probability of suitable habitat is shown on a continuous scale, where higher values are red and lower values are yellow, with inset of the continental shelf and bays near south Kodiak Island.

Appendix B
Evaluation of Fishing Activities that May Adversely Affect Essential Fish Habitat

Prepared by

National Marine Fisheries Service

April 2005

The Long-term Effect Index: The estimated percentage by which a habitat feature would be reduced from a hypothetical unfished abundance, if recent intensity and distribution of fishing effort were continued over a long enough term to achieve equilibrium

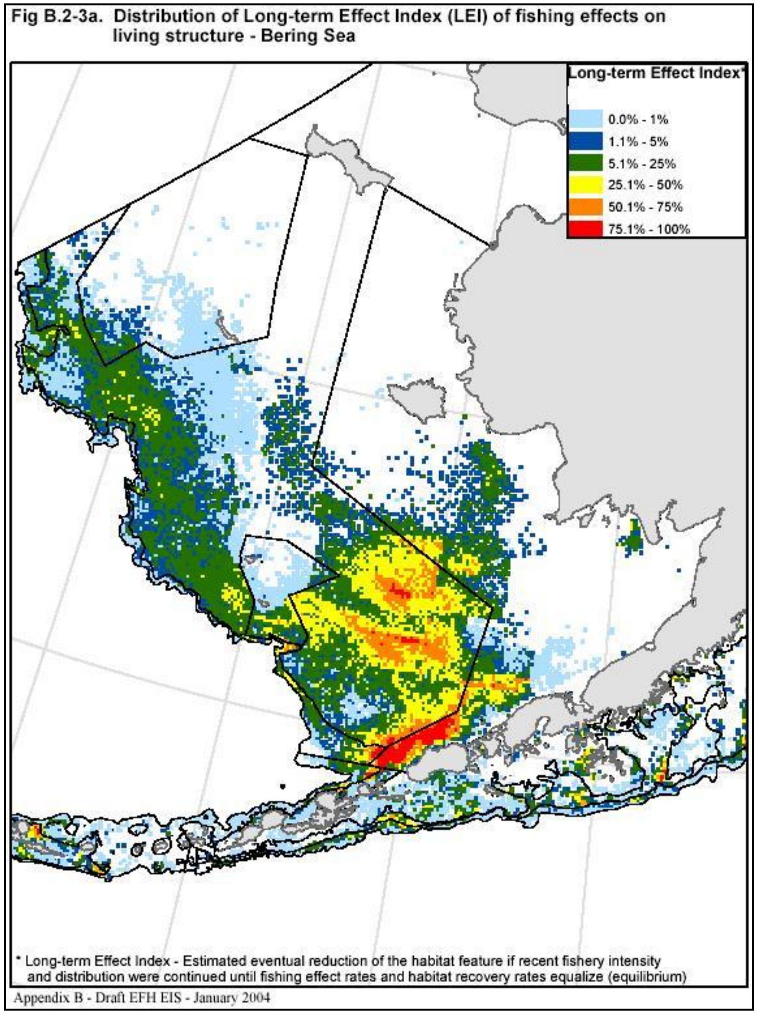
Inputs

- Fishing intensity and distribution
- Sensitivity of habitat features
- Recovery rates of habitat features
- Habitat distribution

- Advantages
    - Repeatable;
    - Incorporates EFH Habitat Description and Habitat Information;
    - Habitats sensitive to disturbance are measured;
    - Highlights areas of data gaps and inadequacies;
    - Future research direction

- Disadvantages
    - Appearance that detailed information is available to assess impacts;
    - MMST threshold stood out as primary measure when in fact other stock information was available in the assessment;
    - Text clearly details inadequacies; projections depict more than is actually known;
    - Model may be used out of context

Living Structure Habitat



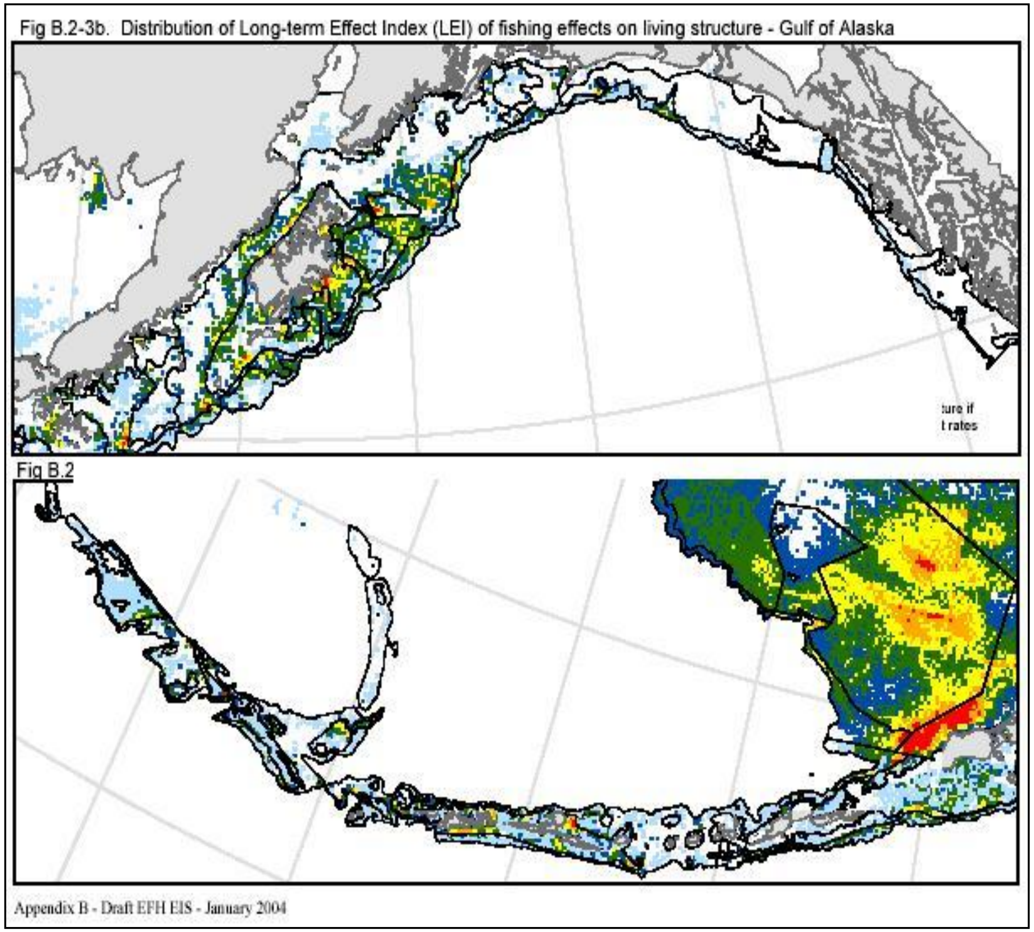


Table B.2-9. Long-term Effect Indices (LEI* in % reduction) for Fishing Effects on Benthic Habitat Features of Alaska Marine Waters by Habitat Type (low and high LEIs in parentheses)

Habitat	Soft Substrates (mud - gravel)									Hard Substrates (pebble - rock)				
		Bering Sea			Aleutians			Gulf of Alaska		Aleutians			Gulf of Alaska	
Features	Sand	Sand/Mud	Mud	Slope	Shallow	Deep	Shallow	Deep Shelf	Slope	Shallow	Deep	Shallow	Deep Shelf	Slope
Infauna Prey	0 (0-1)	2 (0-4)	0 (0-0)	3 (1-7)	0 (0-1)	1 (0-2)	0 (0-1)	1 (0-1)	1 (0-2)	0 (0-1)	0 (0-0)	1 (0-1)	0 (0-1)	0 (0-1)
Epifauna Prey	0 (0-1)	2 (0-3)	0 (0-0)	3 (0-6)	0 (0-1)	1 (0-2)	0 (0-0)	0 (0-1)	0 (0-1)	1 (0-1)	0 (0-0)	1 (0-1)	1 (0-1)	1 (0-1)
Living Structure	4 (1-6)	11 (3-19)	0 (0-1)	11 (4-19)	4 (1-7)	3 (1-4)	3 (1-5)	3 (1-6)	4 (0-7)	7 (3-17)	2 (1-7)	5 (2-10)	6 (3-13)	9 (4-21)
Non-living Structure	0 (0-1)	1 (0-3)	0 (0-0)	4 (1-7)	1 (0-1)	0 (0-0)	0 (0-1)	0 (0-1)	0 (0-1)	5 (5-11)	2 (1-4)	3 (1-7)	4 (2-9)	5 (2-14)
Hard Coral	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16 (11-20)	6 (4-9)	10 (8-12)	13 (10-16)	20 (14-25)

* LEI - Estimated eventual reduction in a class of habitat feature if recent fishing intensity and distribution were continued until fishing effect rates and habitat recovery rates equalized (equilibrium).

New England Fishery Management Council
[illegible] Water Street | Newburyport, Massachusetts [illegible] | Phone [illegible] | Fax [illegible]
John Pappalardo, *Chairman* | Paul J. Howard, *Executive Director*

ESSENTIAL FISH HABITAT (EFH) OMNIBUS AMENDMENT

"THE SWEPT AREA SEABED IMPACT (SASI) APPROACH: A TOOL FOR ANALYZING THE EFFECTS OF FISHING ON ESSENTIAL FISH HABITAT"

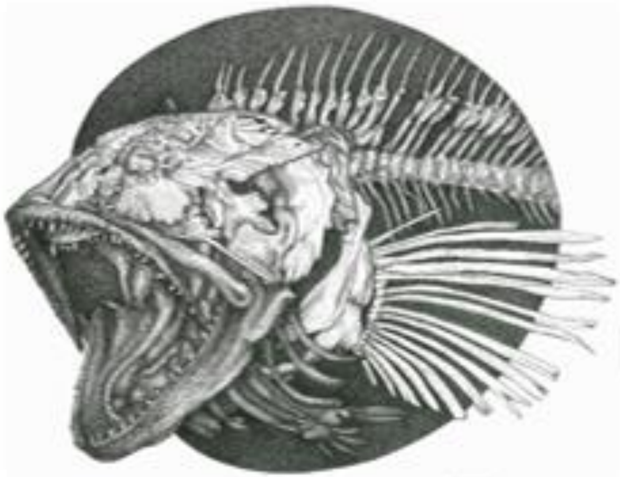
April 2014 SSC Comments

"A second technical subgroup will re-examine the Fujioka-Rose Long-term Evaluation of Fishing Effects Index (LEI) model and will review potential utility of a Swept Area Seabed Impact (SASI) model. The SASI model was developed for application for implementation by the New England Fishery Management Council. Dr. Harris has experience in applying SASI in New England. The LEI model will be migrated from Matlab to R software, streamlined, and some new features may be added based on the SASI review. Habitat-specific applications of an improved fishing effects model will take advantage of finer-scale information on catches owing to VMS, the Catch-in-Areas database, and improved geospatial habitat data."

1. Prepare a one-page "cheat sheet" that compares the advantages and disadvantages of the LEI and SASI models.

2. Compare outcomes from the "old" and "new" versions of the LEI model. For instance, when and where has scoring changed?

Examination of the Fujioka fishing effects model: model formulation, implementation, and interpretation



The Fisheries, Aquatic Science, & Technology (FAST) Laboratory

at

Alaska Pacific University

Director - *Brad Harris, Ph.D.*

Quantitative Ecologist - *Suresh Sethi, Ph.D.*

Coastal Geographer - *Chris Maio, Ph.D.*

Fishery Scientist and Conservation Engineer - *Craig Rose, Ph.D.*

Geostatistical Analyst - *Scott Smeltz, M.Sc.*

Laboratory Manager - *Sarah Webster*

NOAA FISHERIES

Draft Recommendations from White Paper

1. Use updated substrate distribution data
2. Use updated commercial fishing effort, including Catch-in-Areas database and VMS
3. Develop R code to implement the time-varying fishing effort version of the Fujioka fishing impacts model
4. Reflect uncertainty in habitat feature sensitivity and recovery parameters
5. Develop functional or empirical models to allow simulation of management alternatives and changes to commercial fishing gear

SSC request for model modifications:

- Discrete time (like SASI)
- Incorporate literature review from SASI
- Track fishing effects over time with monthly time step

Fishing Effects model background

Long-term effects index (LEI) - Fujioka 2006

$$LEI = \frac{I}{I+\rho}$$

Continuous time framework

Swept Area Seabed Impacts (SASI) - NEFMC 2011

$$Z_{t+1} = Z_t + X_t - Y_t$$

Susceptibility and Recovery dynamics from literature

Annual Time Step

Fishing Effects model (FE)

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

Discrete time framework

Monthly Time Step

LITERATURE REVIEW DATABASE V 3.0

☑ Final review?

STUDY DESCRIPTION

Number: 408

Cite: Mirarchi and CR Environmental 2003

Related studies: 409

Study Characteristics

Study design: 2

Study relevance: 4

Study appropriateness: 2

Methods/general comments:

Evaluated imm effects of 6 replicate tows in 2 lanes at 2 locations, one heavily and one lightly trawled (HT/LT) locations), with controls, using SS sonar, grab samples, benthic dredge, and video cameras.

Depth (m): 0-50m

Minimum: 36

Maximum: 48

Energy: 4

Energy notes:

inferred based on shallow depth

Location

Multisite? ☐

Gulf of Maine, MA coast

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:

Smooth bottom (flatfish) trawl: 350 kg doors, 2.5 in rubber cookies on ground cables/bridles, sweep 0.5 in chain with continuous string of 6 in cookies

Substrate

- ☐ Clay-silt
- ☑ Muddy sand
- ☑ Sand
- ☐ Granule-pebble
- ☐ Cobble
- ☐ Boulder
- ☐ Rock outcrop

Substrate notes:

HT - muddy sand; LT - sand

Look up by study #

Reviewer: Bachman/Stevenson

FEATURES EVALUATED AND IMPACTS

☑ Geological ☑ Biological ☑ Prey ☐ Recovery? ☐ Deep-sea corals?

Geological features

- ☑ Featureless
- ☑ Bedforms
- ☑ Biogenic depressions
- ☑ Biogenic burrows
- ☐ Special case biogenic burrows
- ☐ Gravel
- ☐ Gravel pavement
- ☐ Gravel piles
- ☐ Shell deposits
- ☐ Geochemical

Impacts:

Doors created furrows/ridges in seabed (6" in mud, 2-3" in sand), smoothed seafloor, exposed worm tubes, reduced grain size in trawl and control lanes (resuspension by trawl); physical impacts of trawling less visible at shallower/sandy site

Biological features

- ☑ Emergent sponges
- ☑ 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:

Sea stars and sand dollars most abundant epifauna, Cancer crabs at HT site, scallops at LT site

Impacts:

Fish and inverts (eg Cancer crabs) less numerous imm after trawling, differences not obvious 4-18 hrs later

Prey features

- ☑ Amphipods
- ☐ Isopods
- ☐ Decapod shrimp
- ☐ Mysids
- ☑ Decapod crabs
- ☑ Polychaetes
- ☑ Infaunal bivalves
- ☐ Brittle stars
- ☐ Sea urchins
- ☑ Sand dollars
- ☑ Sea stars

Species:

Polychaete Prionospio steenstrupi common in mud, amphipod Unicola inermis in sand -

Impacts:

No difference in infaunal density, richness, or species composition between treatment and control lanes after exp tows at either location

NOAA FISHERIES

Literature Review Database information

- 3 separate NEFMC SSC reviews
- Independent peer review 2011
- Grabowski et al 2014. Assessing the Vulnerability of Marine Benthos to Fishing Gear Impacts. *Reviews in Fisheries Science & Aquaculture* 22:142-155
- New England Fishery Management Council (NEFMC) 2011. The Swept Area Seabed Impact (SASI) approach: a tool for analyzing the effects of fishing on essential fish habitat. New England Fishery Management Council report. Newburyport, MA.

Alaska-specific literature currently included in Literature Review database

Stone, R. P. (2006). "Coral habitat in the Aleutian Islands of Alaska: depth distribution, finescale species association, and fisheries interactions." Coral Reefs **25**(2): 229-238. **(Ref#353)** *internal-pdf://353_Stone_2006-0230588673/353_Stone_2006.pdf*

Stone, R. P., M. M. Masuda and P. W. Malecha (2005). Effects of Bottom Trawling on Soft-Sediment Epibenthic Communities in the Gulf of Alaska. Benthic Habitats and the Effects of Fishing: American Fisheries Society Symposium 41. P. W. Barnes and J. P. Thomas. Bethesda, MD, American Fisheries Society**:** 461-475. **(Ref#355)** *internal-pdf://355_Stone_etal_2005-2919427585/355_Stone_etal_2005.pdf*

McConnaughey, R. A., K. L. Mier and C. B. Dew (2000). "An examination of chronic trawling effects on soft-bottom benthos of the eastern Bering Sea." ICES J. Mar. Sci. **57**(5): 1377-1388. **(Ref#238)** *internal-pdf://238_McConnaughey_etal_2000-1124486146/238_McConnaughey_etal_2000.pdf*

McConnaughey, R. A. and K. R. Smith (2000). "Associations between flatfish abundance and surficial sediments in the eastern Bering Sea." Canadian Journal of Fisheries and Aquatic Sciences **57**(12): 2410-2419. **(Ref#237)** *internal-pdf://237_McConnaughey_Smith_2000-1752844801/237_McConnaughey_Smith_2000.pdf*

McConnaughey, R. A., S. E. Syrjala and C. B. Dew (2005). Effects of Chronic Bottom Trawling on the Size Structure of Soft-Bottom Benthic Invertebrates. Benthic Habitats and the Effects of Fishing: American Fisheries Society Symposium 41. P. W. Barnes and J. P. Thomas. Bethesda, MD, American Fisheries Society**:** 425-437. **(Ref#239)** *internal-pdf://239_McConnaughey_etal_2005-0637692673/239_McConnaughey_etal_2005.pdf*

Stoner, A. W., C. L. Ryer and R. A. McConnaughey (2005). Ecological Consequences of Lost Habitat Structure for Commercially Significant Flatfishes: Habitat Choice and Vulnerability to Predators. **(Ref#357)**

Freese, J. L. (2001). "Trawl-induced Damage to Sponges Observed From a Research Submersible." Mar. Fish. Rev. **63**(3): 7-13. **(Ref#110)** *internal-pdf://110_Freese_2001-4192454913/110_Freese_2001.pdf*

Freese, L., P. J. Auster, J. Heifetz, et al. (1999). "Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska." Mar. Ecol. Prog. Ser.: Vol. 182, p. **(Ref#111)** *internal-pdf://111_Freese_etal_1999-3201981697/111_Freese_etal_1999.pdf*

Fujioka, J. T. (2006). "A model for evaluating fishing impacts on habitat and comparing fishing closure strategies." Canadian journal of fisheries and aquatic sciences/Journal canadien des sciences halieutiques et aquatiques **63**(10): 2330-2342. **(Ref#114)** *internal-pdf://114_Fujioka_2005-0805663745/114_Fujioka_2005.pdf*

Brooke, S. and R. Stone (2007). "Reproduction of deep-water Hydrocorals (family Stylasteridae) from the Aleutian Islands, Alaska." Bulletin of Marine Science **81**(3): 519-532. **(Ref#539)** *internal-pdf://539_Brooke_Stone_2007-0685702912/539_Brooke_Stone_2007.pdf*

Classification of Habitat Features

Infauna Prey - clams, polychaetes

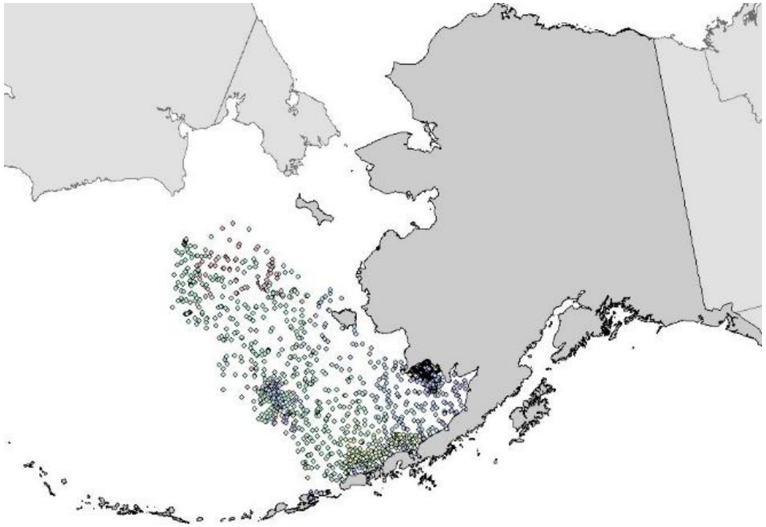
Epifauna Prey - brittle stars, amphipods

Non-living Structure - sand waves, rocks

Living Structure - Anemones, sponges, coral

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
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

Sediment



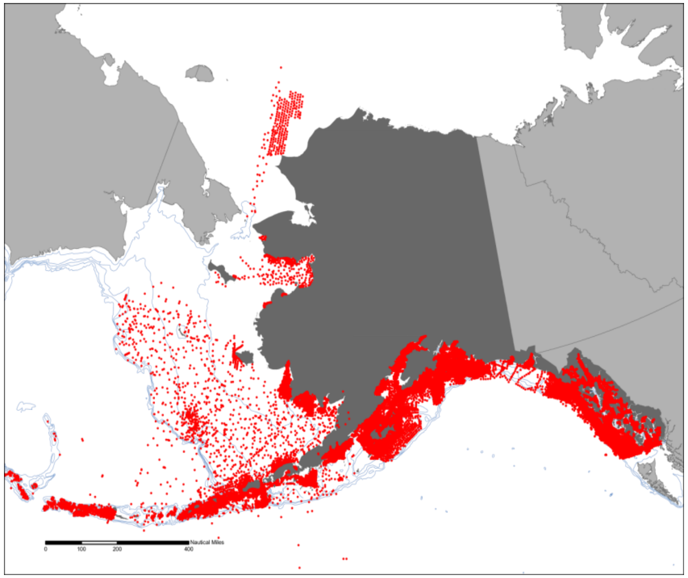
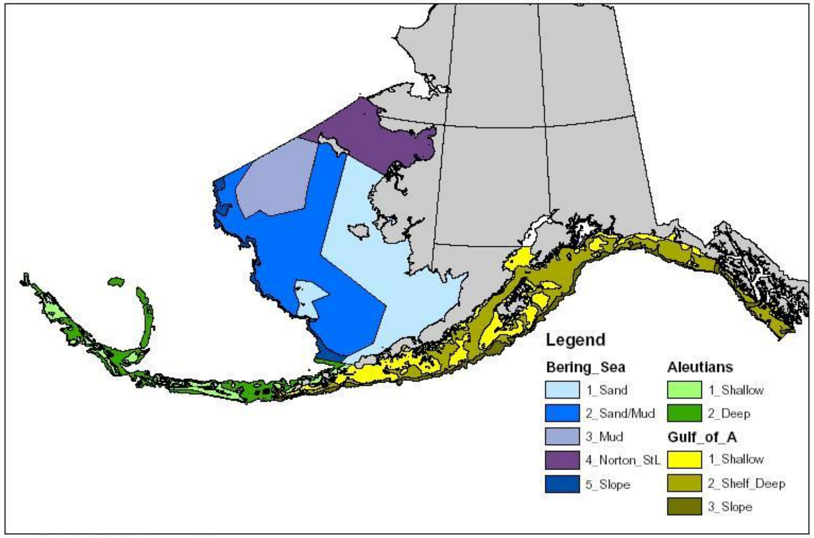


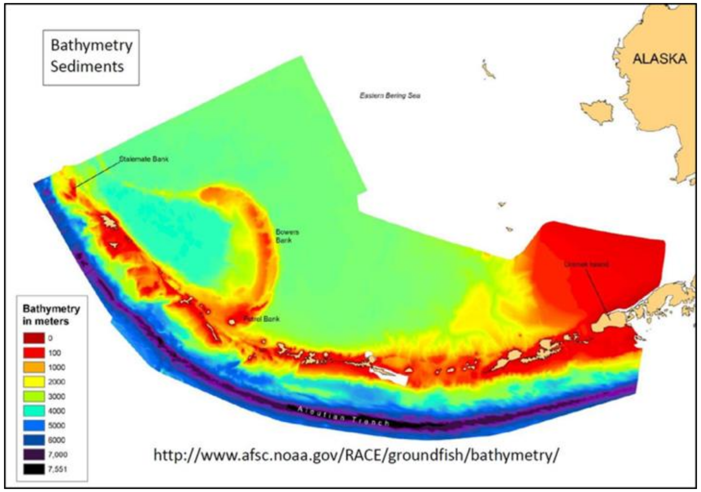
Figure B.2-1 Habitats Used for Evaluation of Fishing Activities



Appendix B - Draft EFH EIS - January 2004

230,000+ points with 6,000+ sediment descriptions coded into 5 sediment classes:

Mud
Sand
Granule/Pebble
Cobble
Boulder



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)

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

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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

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

Evaluate Susceptibility & Recovery matrices

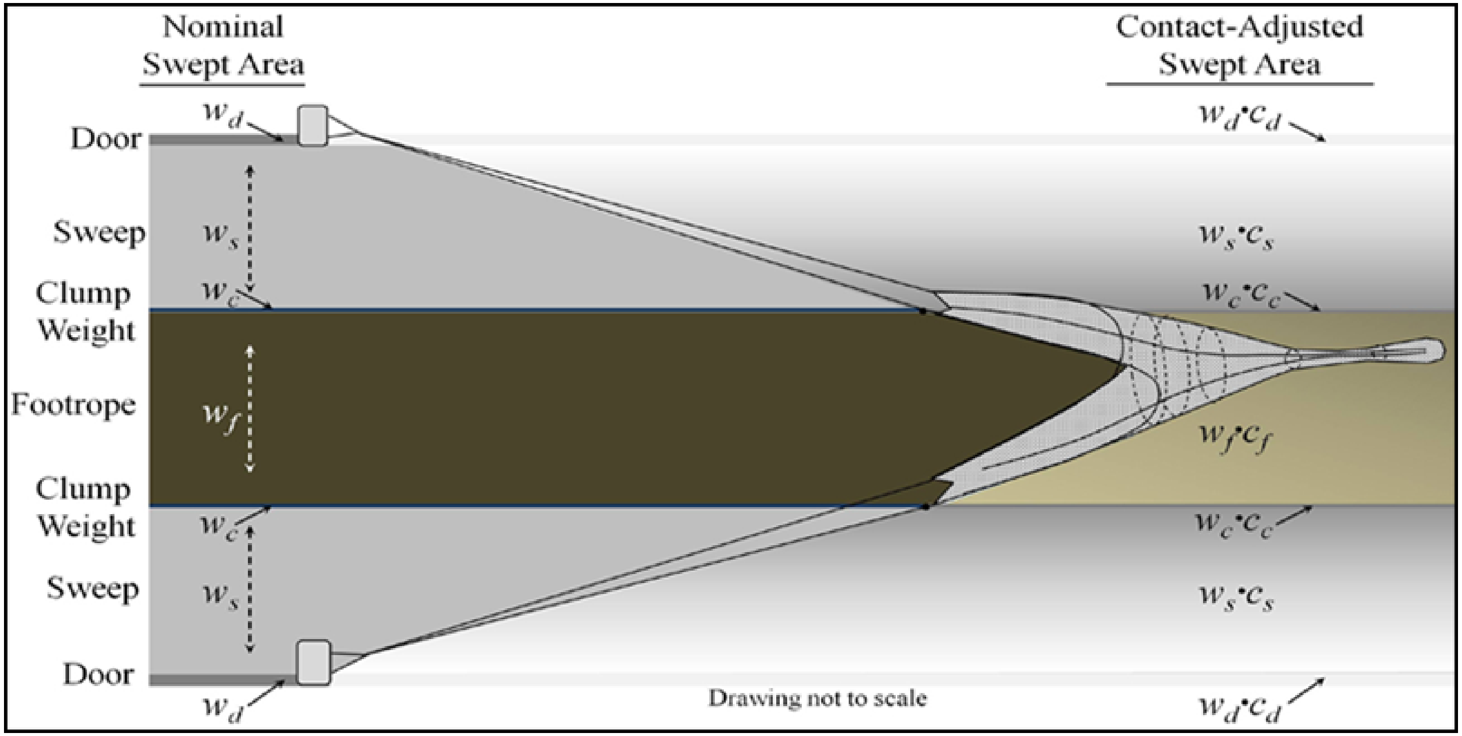
Susceptibility & Recovery can be estimated for each gear/feature interaction

Gear: Trawl							
Substrate: Mud							
Feature name and class – G (Geological) or B (Biological)	**Gear effects**	**Literature high**	**Literature low**	**S High**	**S Low**	**R High**	**R Low**
Biogenic burrows (G)	filling, crushing	334, 408, 409	97, 101, 313, 333, 336, 407	2	2	0	0
Biogenic depressions (G)	filling	236, 408, 409	101, 247, 336	2	2	0	0
Sediments, surface (G)	re-suspension, compression, geochemical	88, 92, 211, 236, 330, 334, 406, 408, 409, 599	88, 97, 211, 247, 277, 283, 313, 320, 333, 335, 336, 338, 372, 407, 414	3	3	0	0
Amphipods, tube-dwelling (B) – see note	crushing	34, 113, 119, 211, 228, 292, 334, 408, 409, 599, 658	89, 80, 97, 113, 149, 320, 575	1	1	0	0
Anemones, cerianthid burrowing (B)	breaking, crushing, dislodging, displacing	none	none	2	2	2	2
Corals, sea pens (B)	breaking, crushing, dislodging, displacing	none	101, 164	2	2	2	2
Hydroids (B)	breaking, crushing, dislodging, displacing	408, 409	368	1	1	1	1
Mollusks, epifaunal bivalve, *Modiolus modiolus* (B)	breaking, crushing, dislodging, displacing	21, 34, 368, 408, 409	89, 203, 360, 368	2	2	3	3

Impact dynamics

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

Impact = (Nominal area swept) X **(**Contact adjustment) X (Susceptibility)

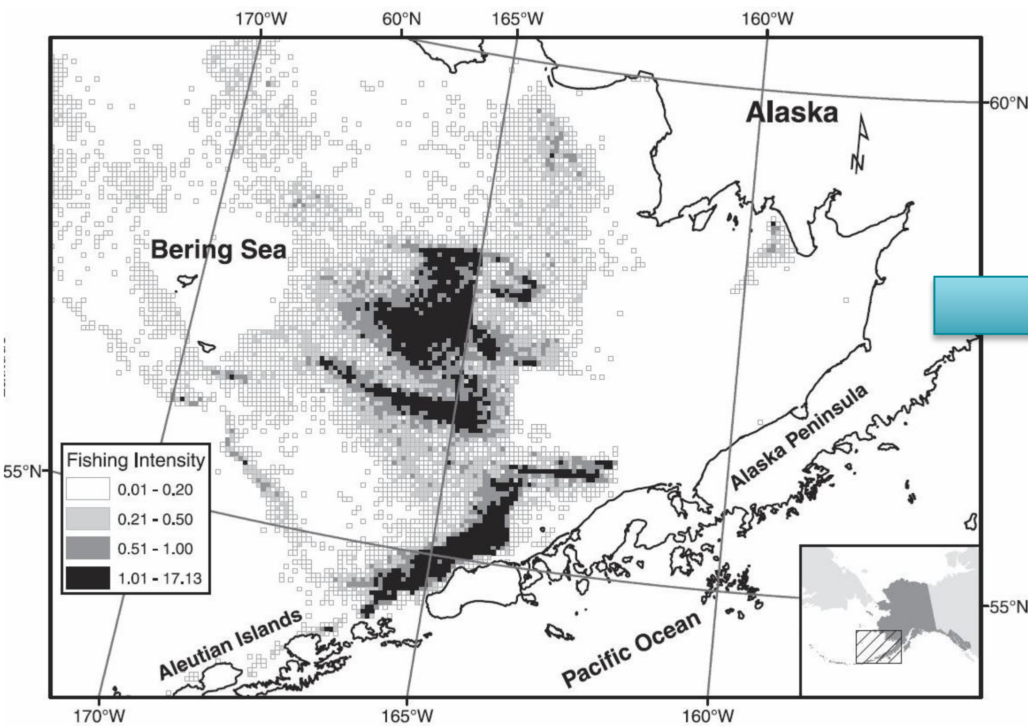


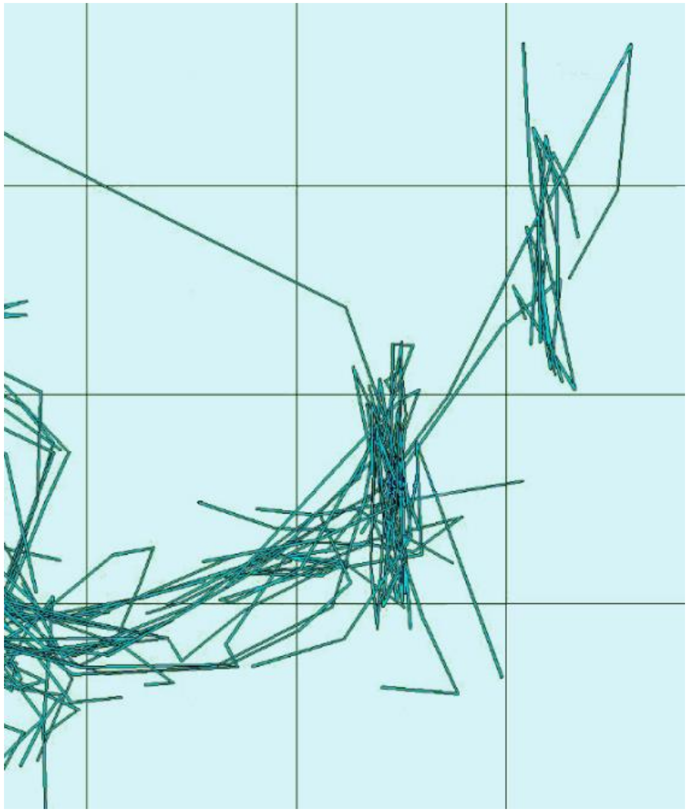
Nominal Area Swept & Contact Adjustment

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, all others	125-151	A	60-90	87
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	A	<60	75
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	B	≥90	115

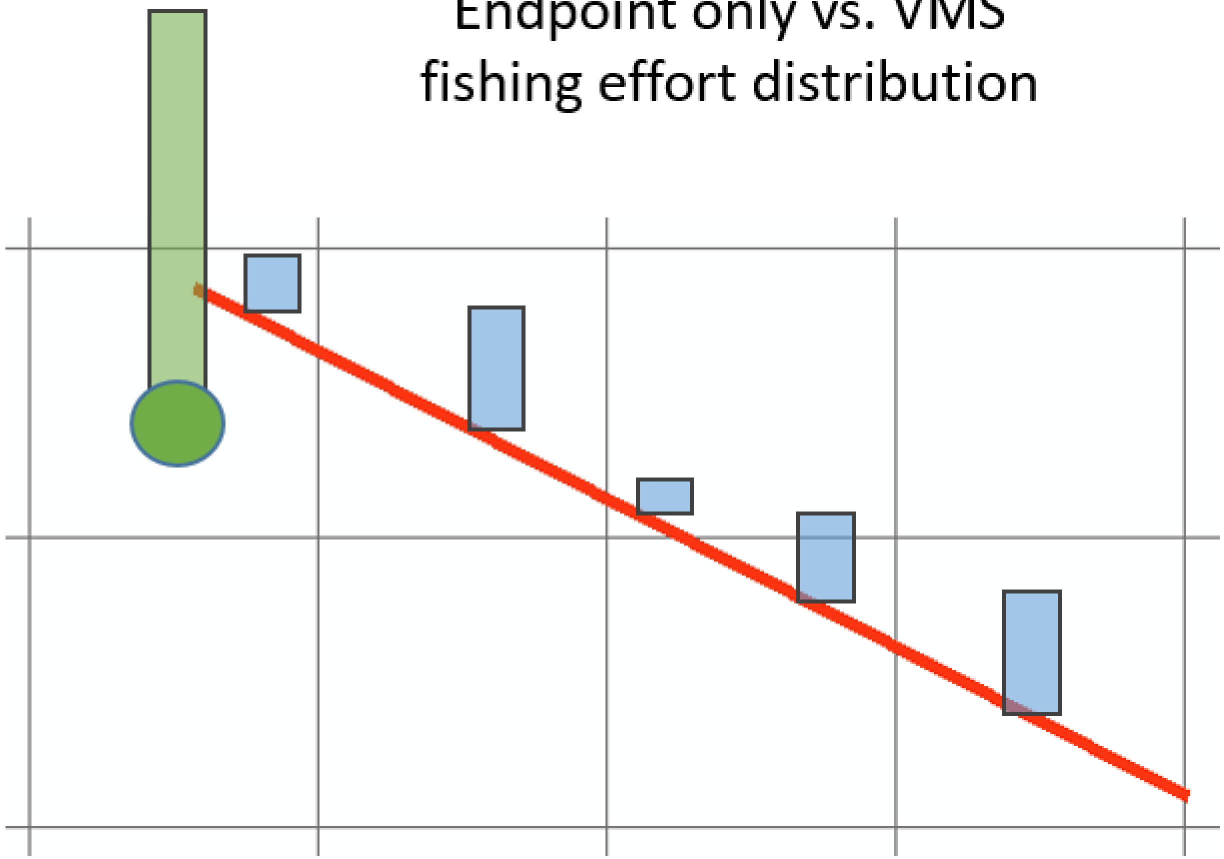
Impact = (Nominal area swept) X (Contact adjustment) X (Susceptibility)

Increasing spatial resolution & accounting for overlapping fishing impacts





Endpoint only vs. VMS fishing effort distribution



Swept area calculation

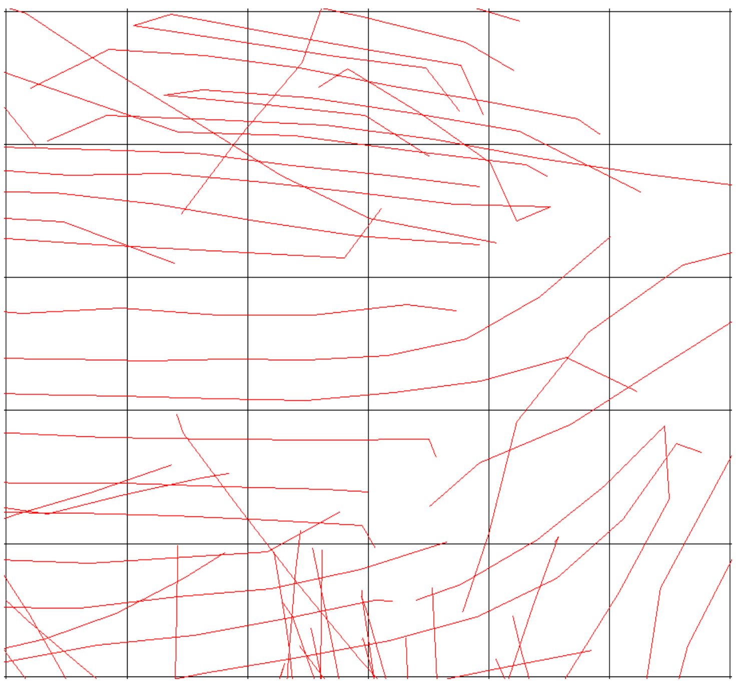
LEI model

FE model

Nominal Area Swept

VMS Catch-in-Areas database

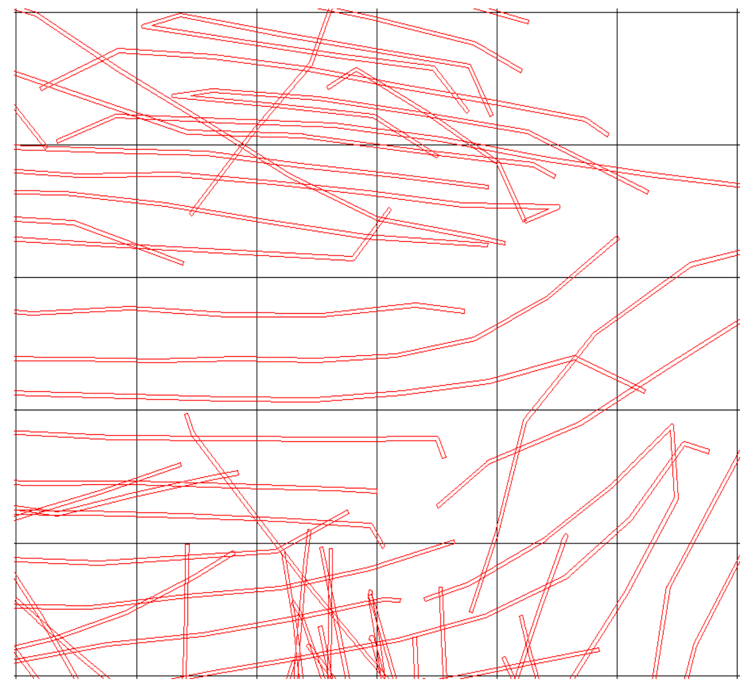
Impact = (Nominal area swept**)** X (Contact adjustment) X (Susceptibility)

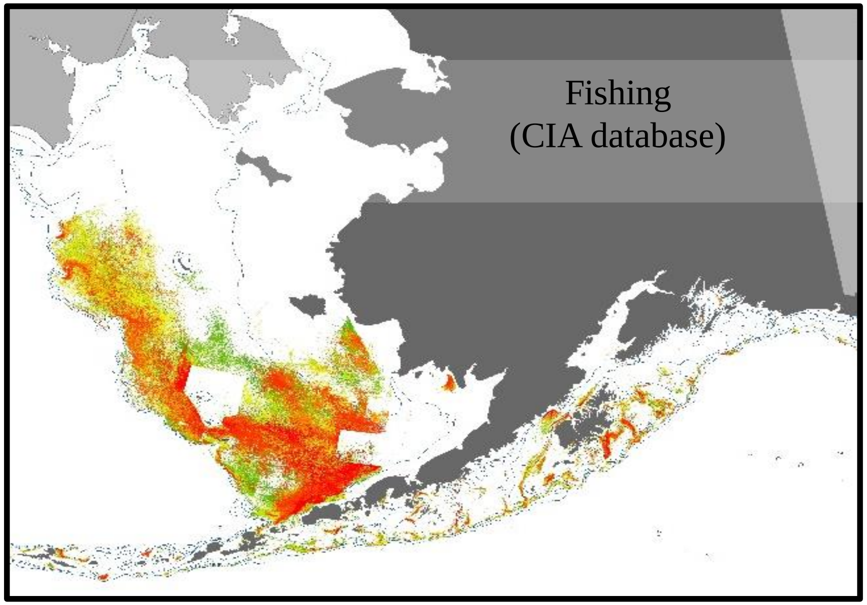


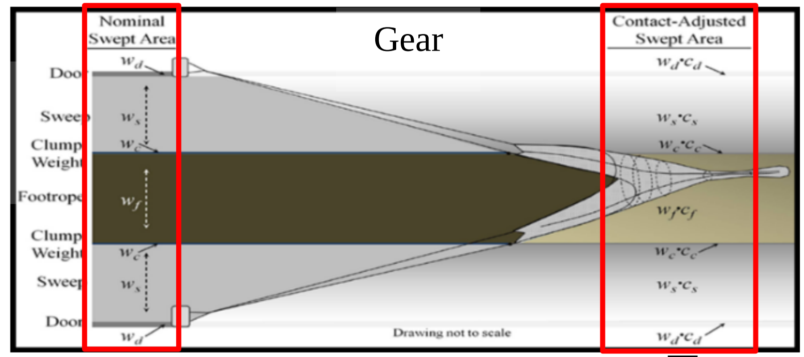
Catch-in-area database (CIA)

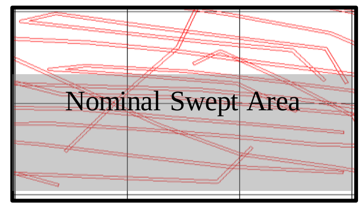
Buffered by

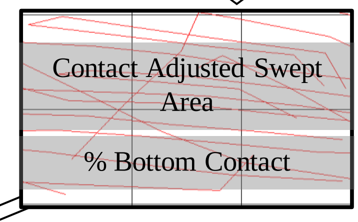
gear width

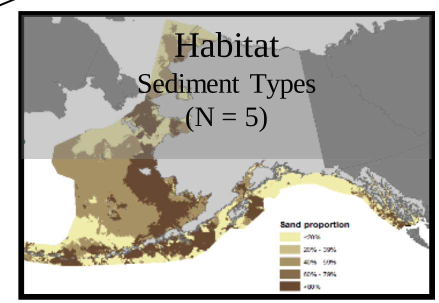


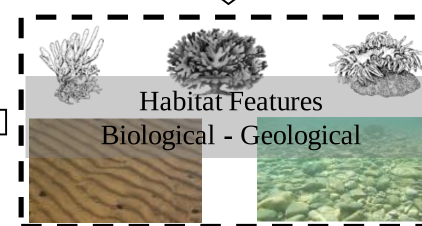












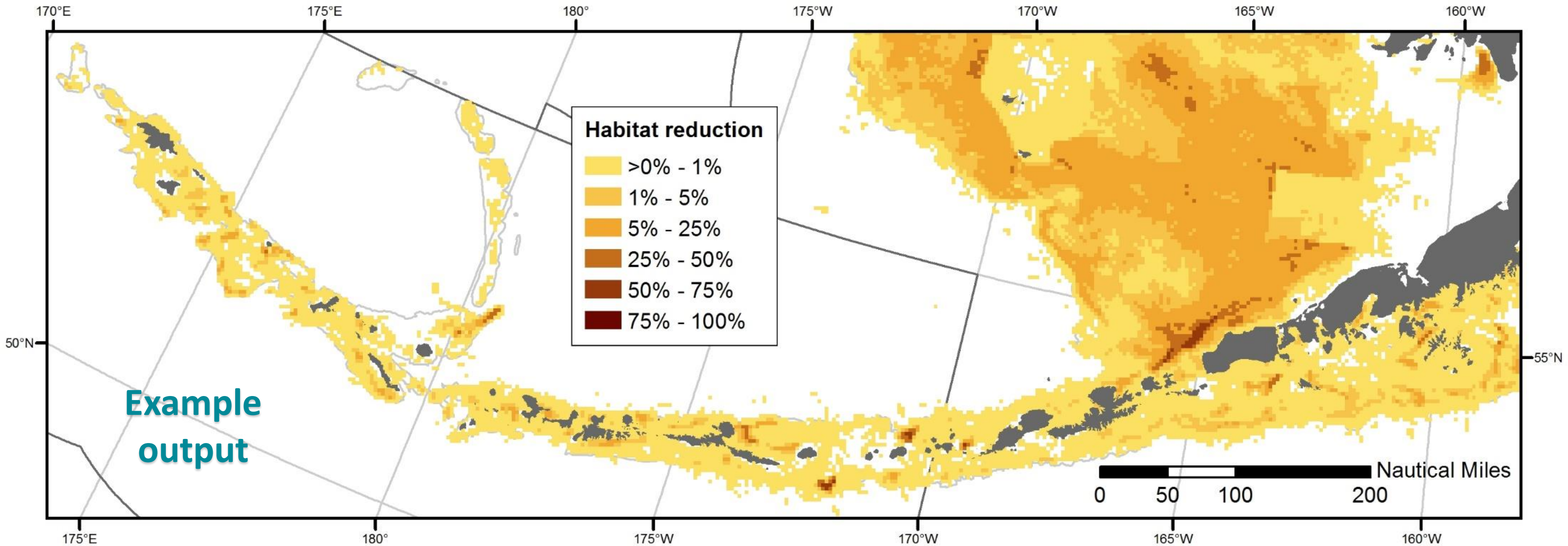
Susceptibility
Adjusted Swept Area (per month)

Recovery Time (months)

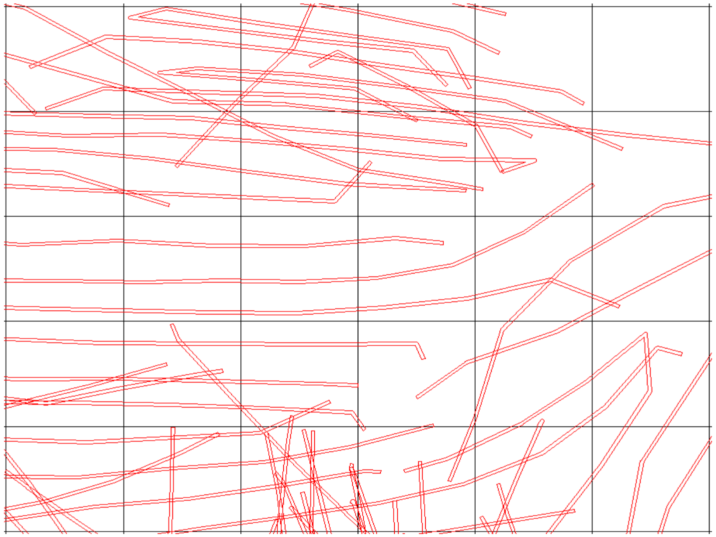
Fishing Effects

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

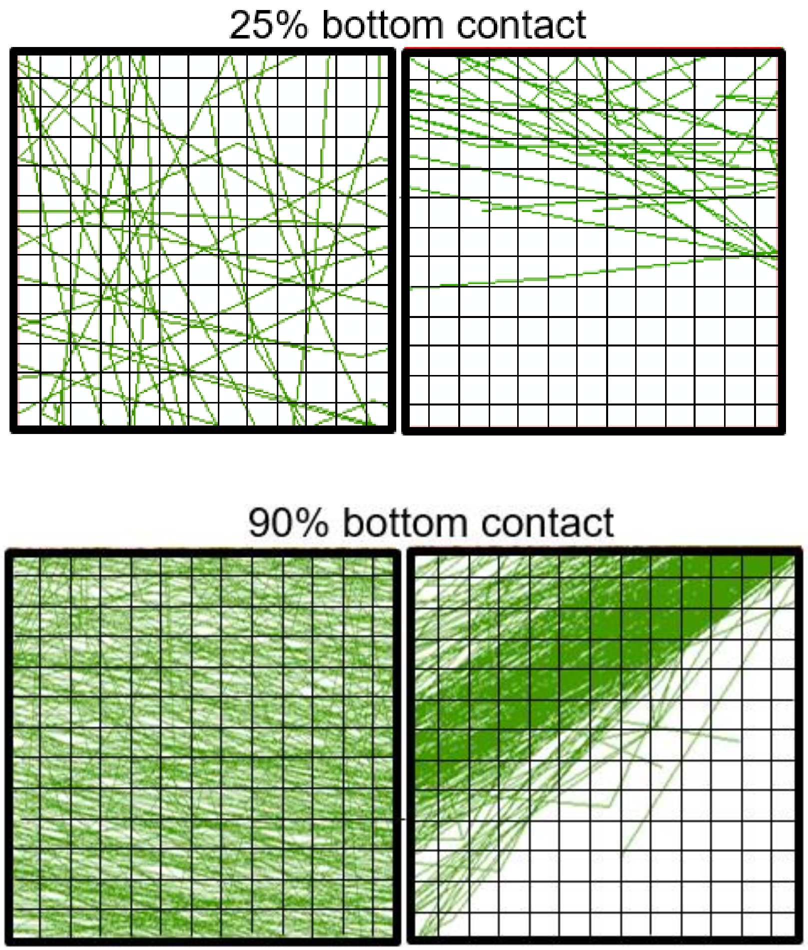
H: habitat undisturbed from fishing
h: habitat disturbed from fishing
I': monthly impact rate
ρ': monthly recovery rate

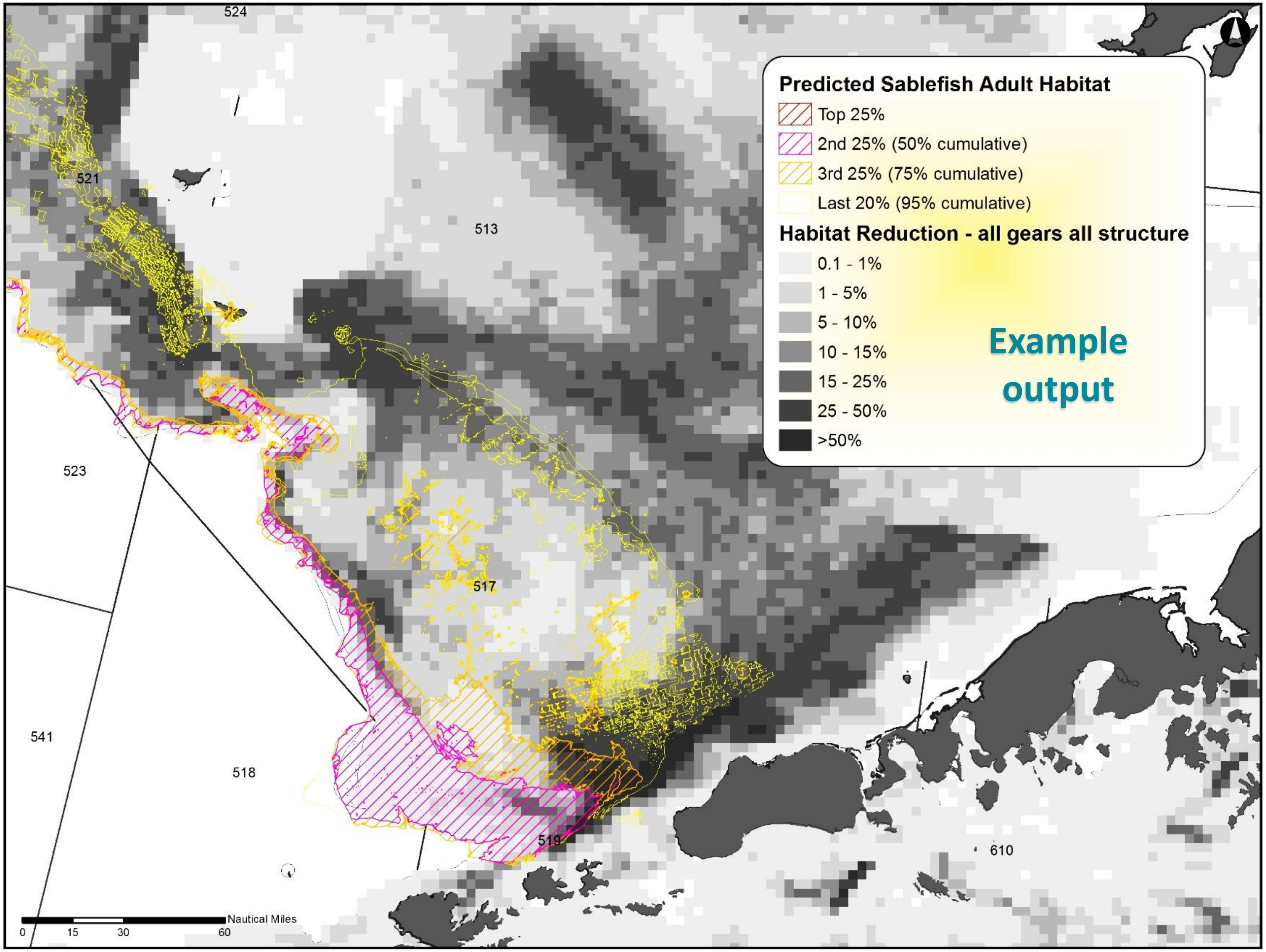


170°E
175°E
180°
175°W
170°W
165°W
160°W
50°N
55°N
175°E
180°
175°W
170°W
165°W
160°W
Habitat reduction
>0% - 1%
1% - 5%
5% - 25%
25% - 50%
50% - 75%
75% - 100%
Nautical Miles
0
50
100
200
Example output



Catch-in-area database (CIA)




Predicted Sablefish Adult Habitat
Top 25%
2nd 25% (50% cumulative)
3rd 25% (75% cumulative)
Last 20% (95% cumulative)
Habitat Reduction - all gears all structure
0.1 - 1%
1 - 5%
5 - 10%
10 - 15%
15 - 25%
25 - 50%
>50%
Example output
524
521
513
523
517
541
518
519
610
Nautical Miles
0 15 30 60

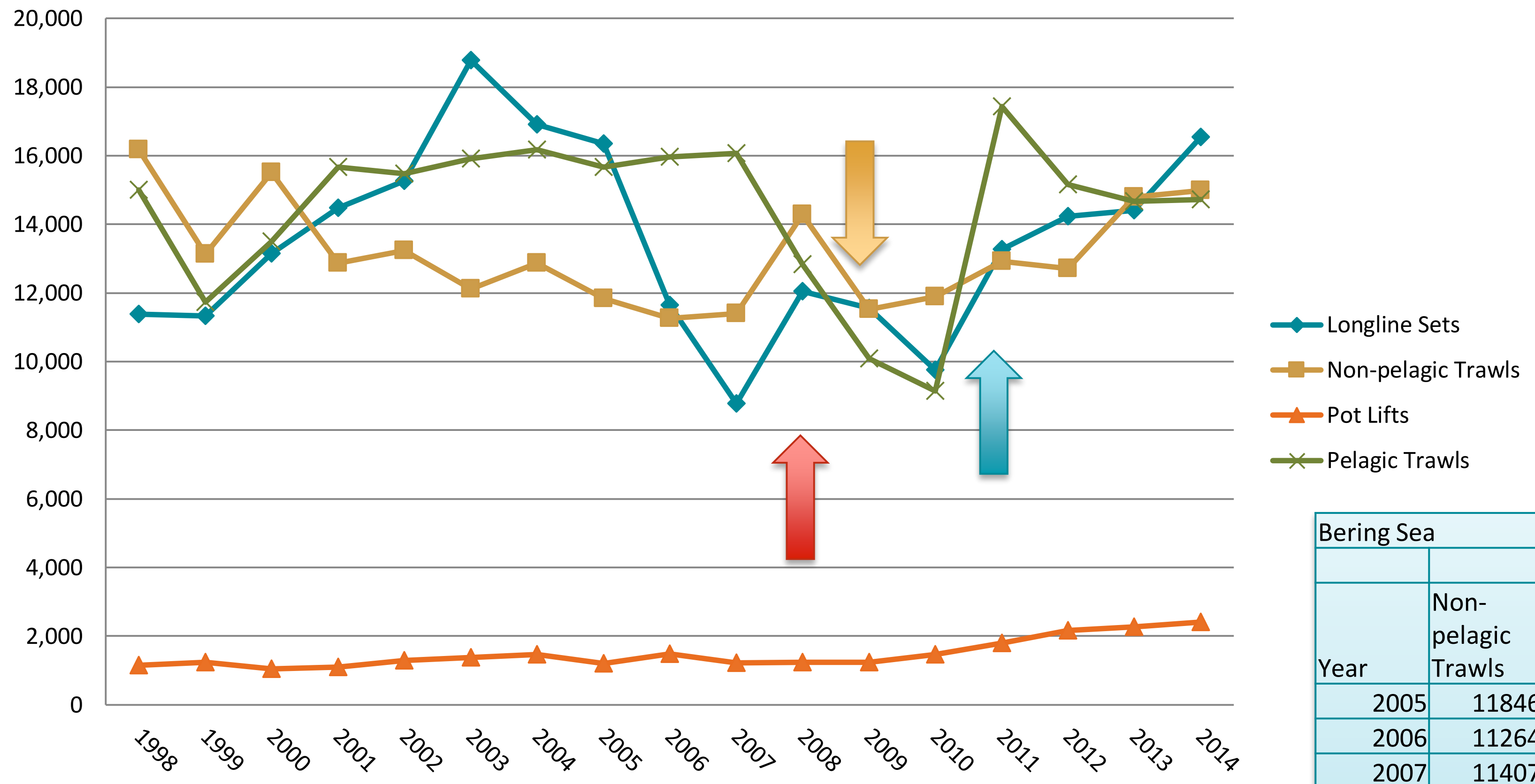
Habitat Reduction by species life stage (GAM/MaxEnt + FE model)

	AI	BS	GOA
Adult - Summer	2.7	9.1	1.8
Adult - Fall		10.6	1.8
Adult - Spring	3.4	11.2	1.7
Adult - Winter		9.5	1.7
Juvenile	2.8	8.9	1.7

Example output

Habitat Reduction, all gears

Example output

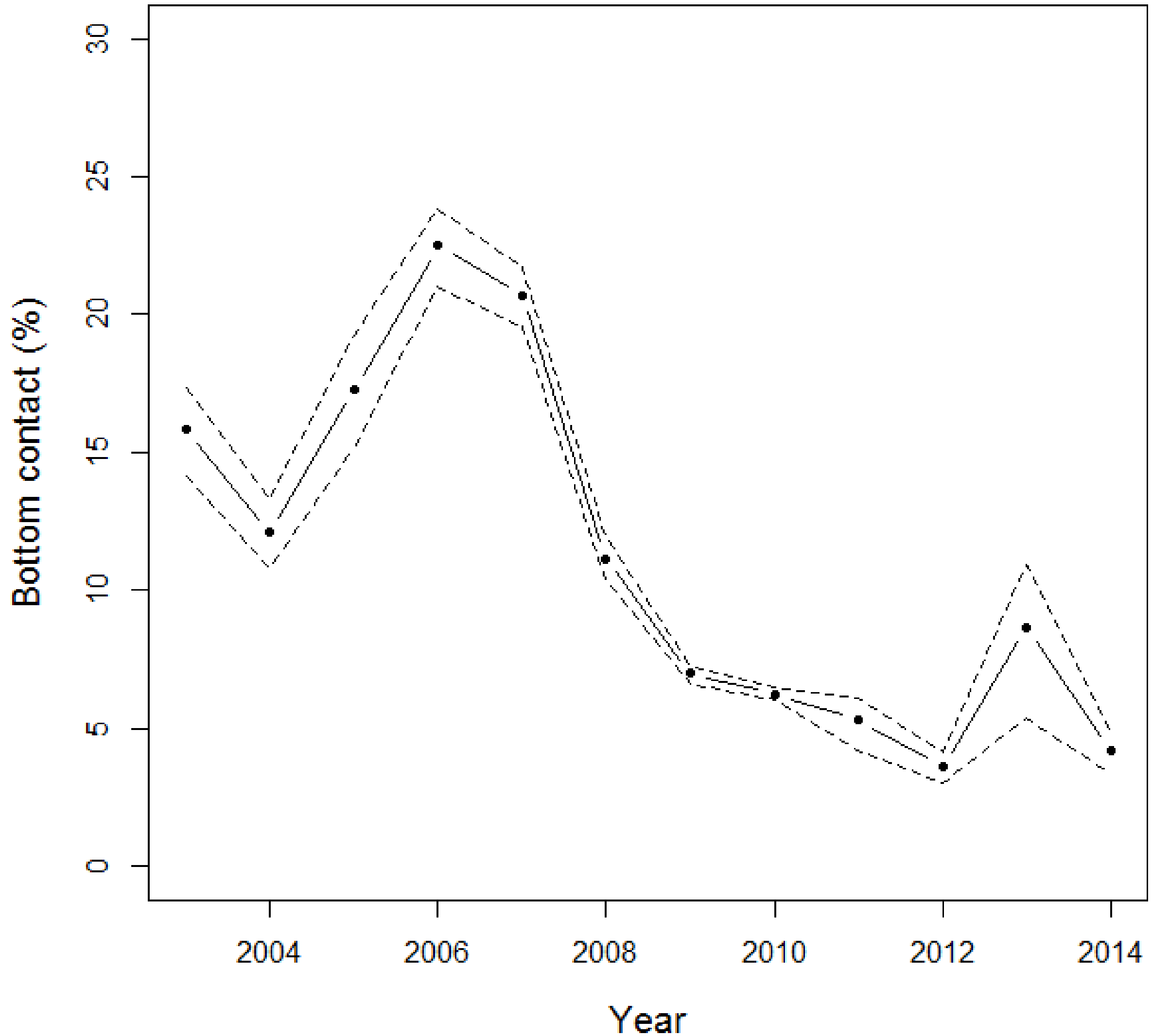


Bering Sea		
Year	Non-pelagic Trawls	Pelagic Trawls
2005	11846	15674
2006	11264	15968
2007	11407	16074
2008	14287	12837
2009	11527	10092
2010	11896	9143
2011	12928	17439
2012	12720	15159
2013	14800	14669
2014	14982	14718
Grand Total	223579	245268
AVERAGE	12765.7	14177.3

Habitat Reduction, NPT in the Bering Sea

Example output

Seabed Contact Sensitivity Analysis



1. The FE model is cast in a discrete time framework.

2. The FE model implements monthly tracking of fishing impacts and habitat disturbance.

3. The FE model draws on the VMS-enabled Catch in Areas (CIA) database to use the best available spatial data of fishing locations.

4. The FE model incorporates the extensive literature review conducted by the New England Fisheries Management Council (NEFMC 2011) to estimate susceptibility and recovery dynamics.

5. The FE model can incorporate model-based EFH species descriptions

```r
#Fishing impacts (I')
I.prime_a = array(NA, dim = c(nYears, nSubAnnual, nGrid, nSubst))

for(y in 1:nYears){
  for(m in 1:nSubAnnual){
    q_m = suscept.f()  # Get new susceptibility table for each month
    I_m = F_a[y,m,,] %*% q_m
    I.prime_a[y,m,,] = 1-exp(-I_m)
  }
}



# Recovery (rho')
tau_m = read.csv("R_input_tables\\Recovery_table.csv")


tau_m = tau_m[,subst_types] # Make sure sediments are in correct order

recovery.f = function(){
    for(column in 1:ncol(tau_m)){
      tau_m[tau_m[,column] %in% 0, column] =
        runif(sum(tau_m[,column] %in% 0), min = 0, max = 1)

      tau_m[tau_m[,column] %in% 1, column] =
        runif(sum(tau_m[,column] %in% 1), min = 1, max = 2)

      tau_m[tau_m[,column] %in% 2, column] =
        runif(sum(tau_m[,column] %in% 2), min = 2, max = 5)

      tau_m[tau_m[,column] %in% 3, column] =
        runif(sum(tau_m[,column] %in% 3), min = 5, max = 10)
    }

    tau_v = colMeans(tau_m, na.rm=T) # Average recovery over all habitat features
```

Future Work

Model validation

Incorporate variability into model outputs.

Incorporate non-fishing effects as impacts or covariate on recovery.

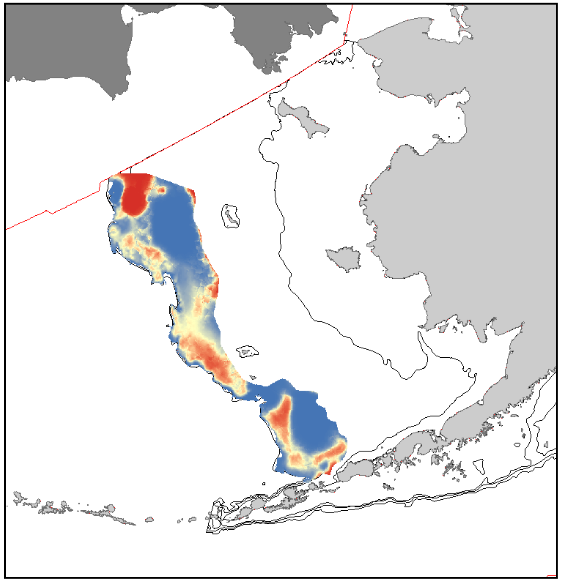
Environmental/seasonal covariates on recovery.

Successional processes - current FE model has two states (impacted and un-impacted). $H \rightarrow h_1 \rightarrow h_2 \rightarrow h_3 \rightarrow H$

Test use of habitat GAMs to replace sediment-based categorization

Efficacy of Marine Protected Areas & Management Actions

GAM modeling of sea whip presence



Rooper et al. 2015

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