Science, Service, Stewardship

Factors affecting the large scale distribution of deep sea corals and sponges in the Alaskan ecosystems of the North Pacific Ocean

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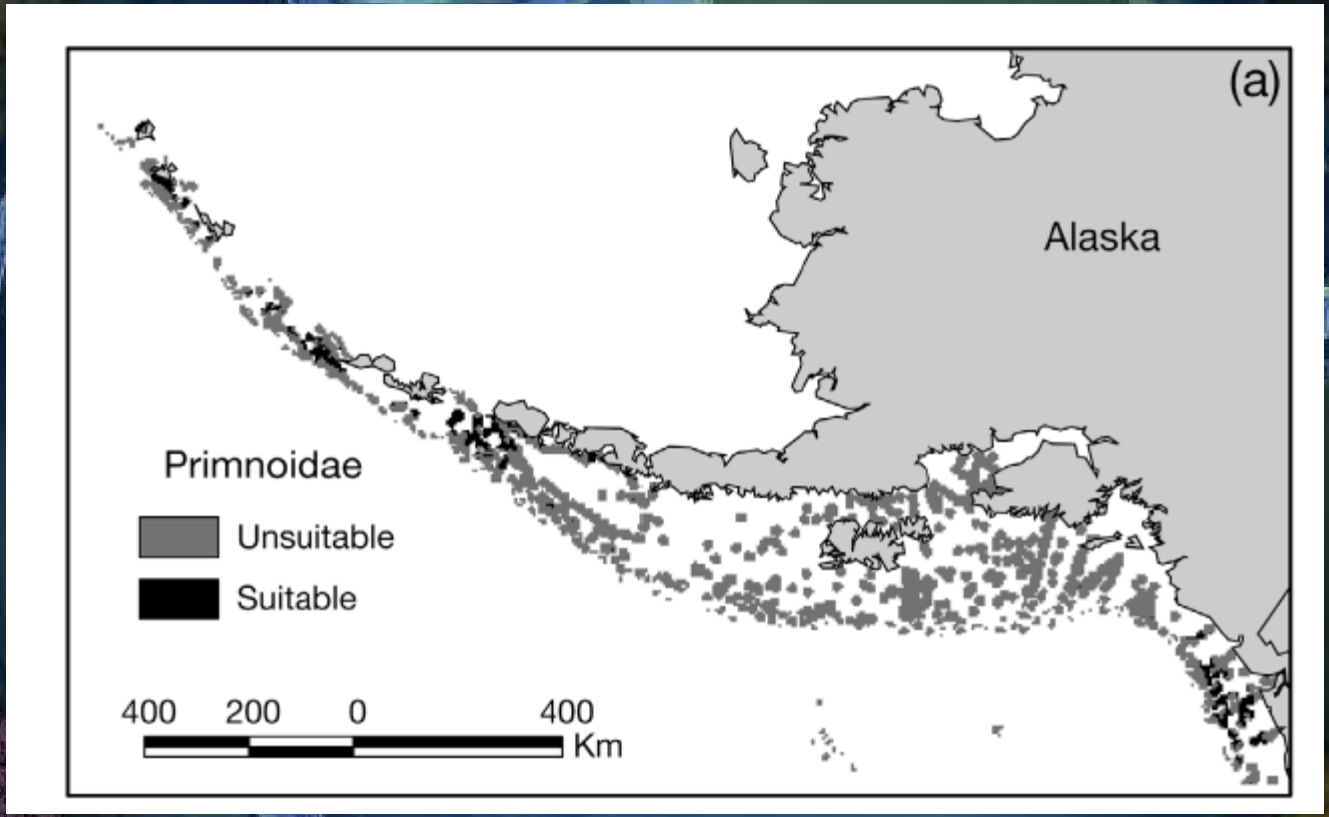
Outline

- Large-scale modeling studies
  - Basin-wide (literature)
- Regional-scale modeling studies
  - Alaska
- Transect-scale studies
  - Alaska
- Caveats
- Summary
- Future directions

Basin-scale modeling that include Alaska

- Bryan and Metaxas 2007 (Gorgonians) – ENFA
  —Temperature, Slope, Current and Chlorophyll *a*

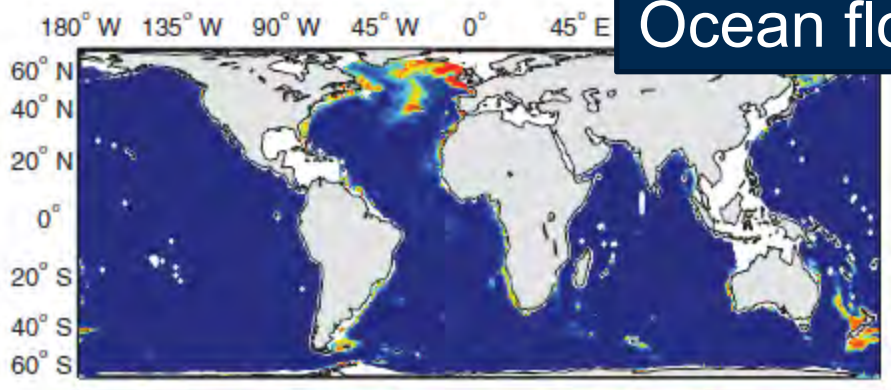


Bryan TL, Metaxas A (2007) Predicting suitable habitat for deep-water gorgonian corals on the Atlantic and Pacific Continental Margins of North America. Mar Ecol Prog Ser 330: 113−126

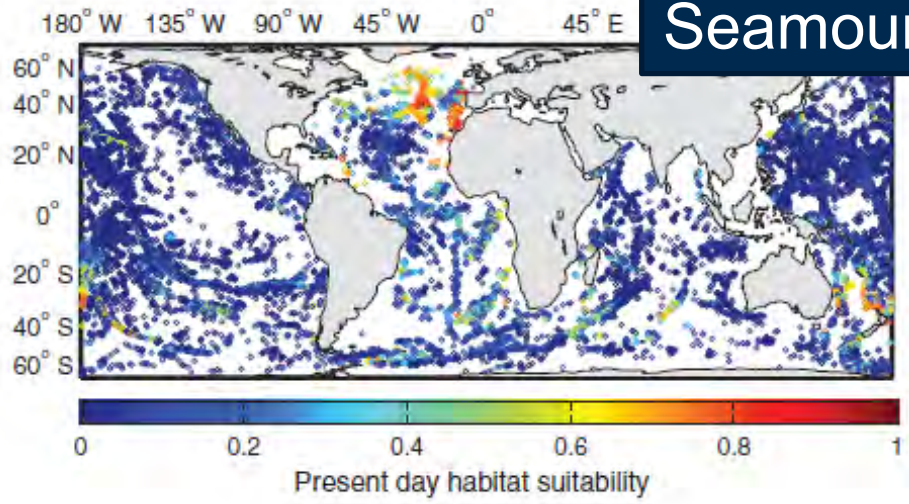
Basin-scale modeling that include Alaska

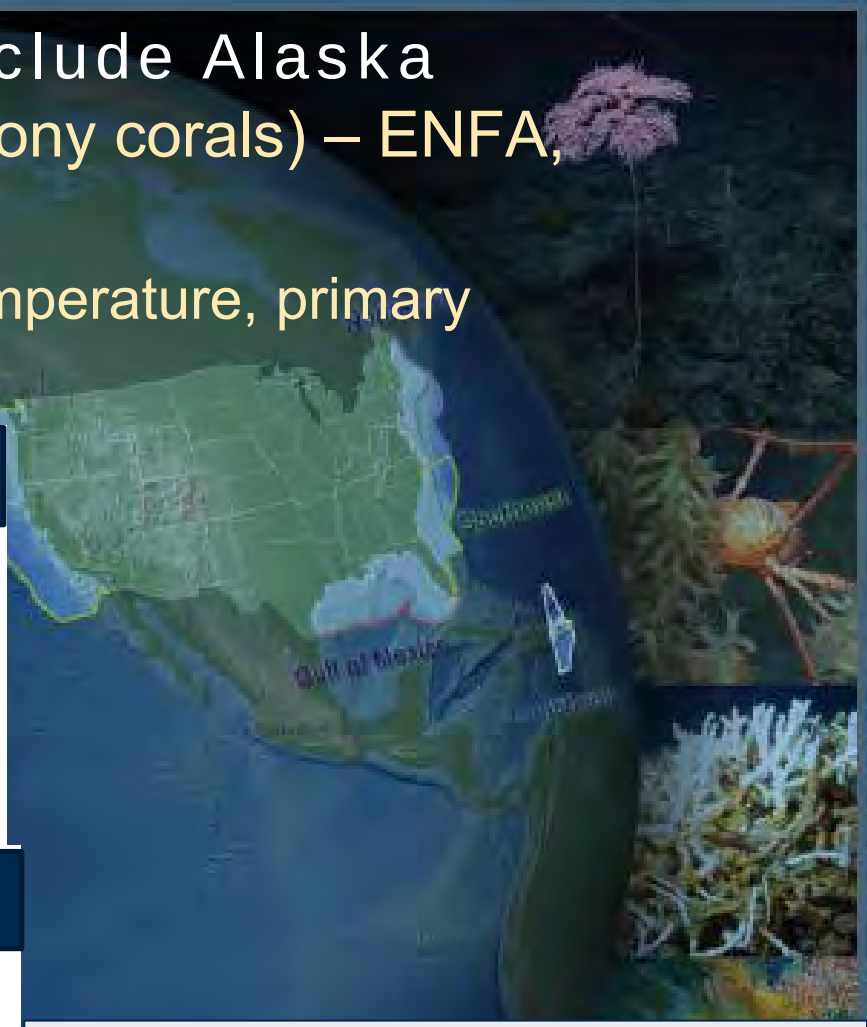
- Tittensor et al. 2009, 2010 (Stony corals) – ENFA, MaxEnt
  - —Aragonite saturation, DIC, temperature, primary productivity, Oxygen

Ocean floor



Seamounts



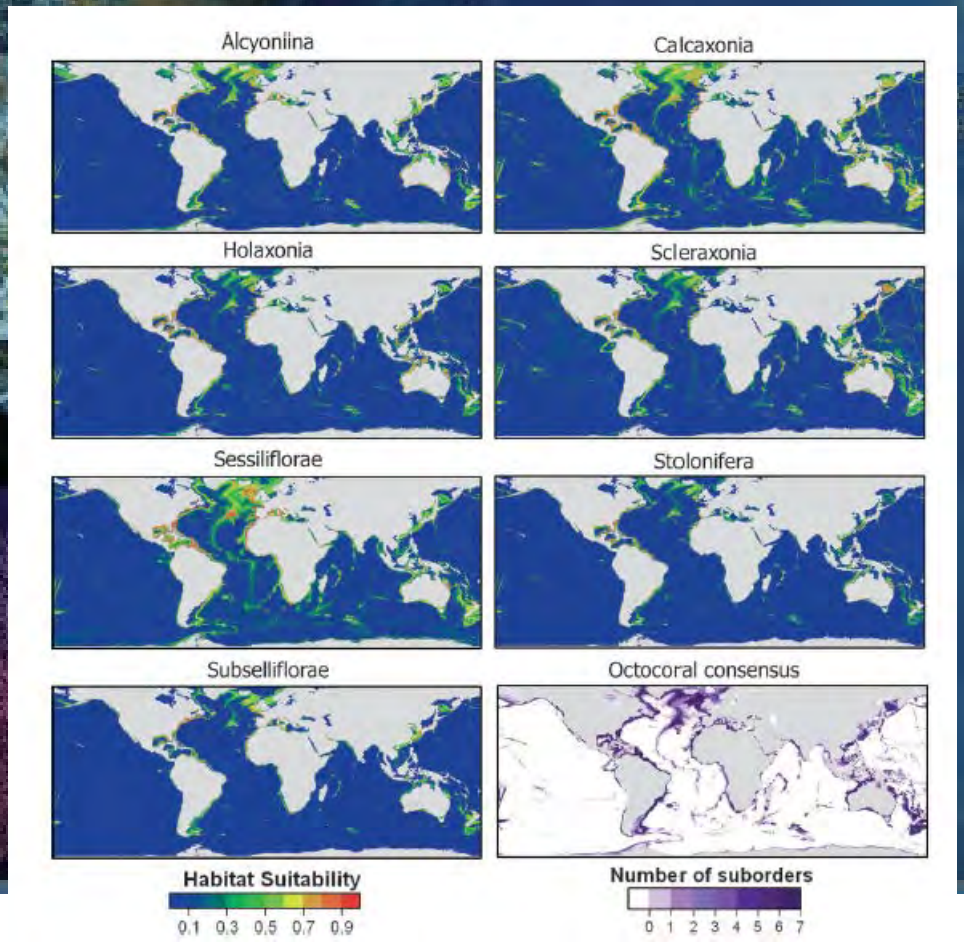


Tittensor D.P., Baco-Taylor A.R., Brewin P., Clark M.R., Consalvey M., Hall-Spencer J., Rowden A.A., Schlacher T., Stocks K., Rogers A.D. (2009) Predicting global habitat suitability for stony corals on seamounts. J Biogeogr,36, 1111–1128.

Tittensor DP, Baco AR, Hall-Spencer JM, Orr JC, Rogers CAD (2010) Seamounts as refugia from ocean acidification for cold-water stony corals. Mar Ecol 31: 212−225

Basin-scale modeling that include Alaska

- Yesson et al. 2012 (Octocorals) – MaxEnt
  - —Calcite saturation*, Slope, Productivity, Temperature, Salinity



Yesson C, Taylor ML, Tittensor DP, Davies AJ and others (2012) Global habitat suitability of cold-water octocorals. J Biogeogr 39: 1278−1292

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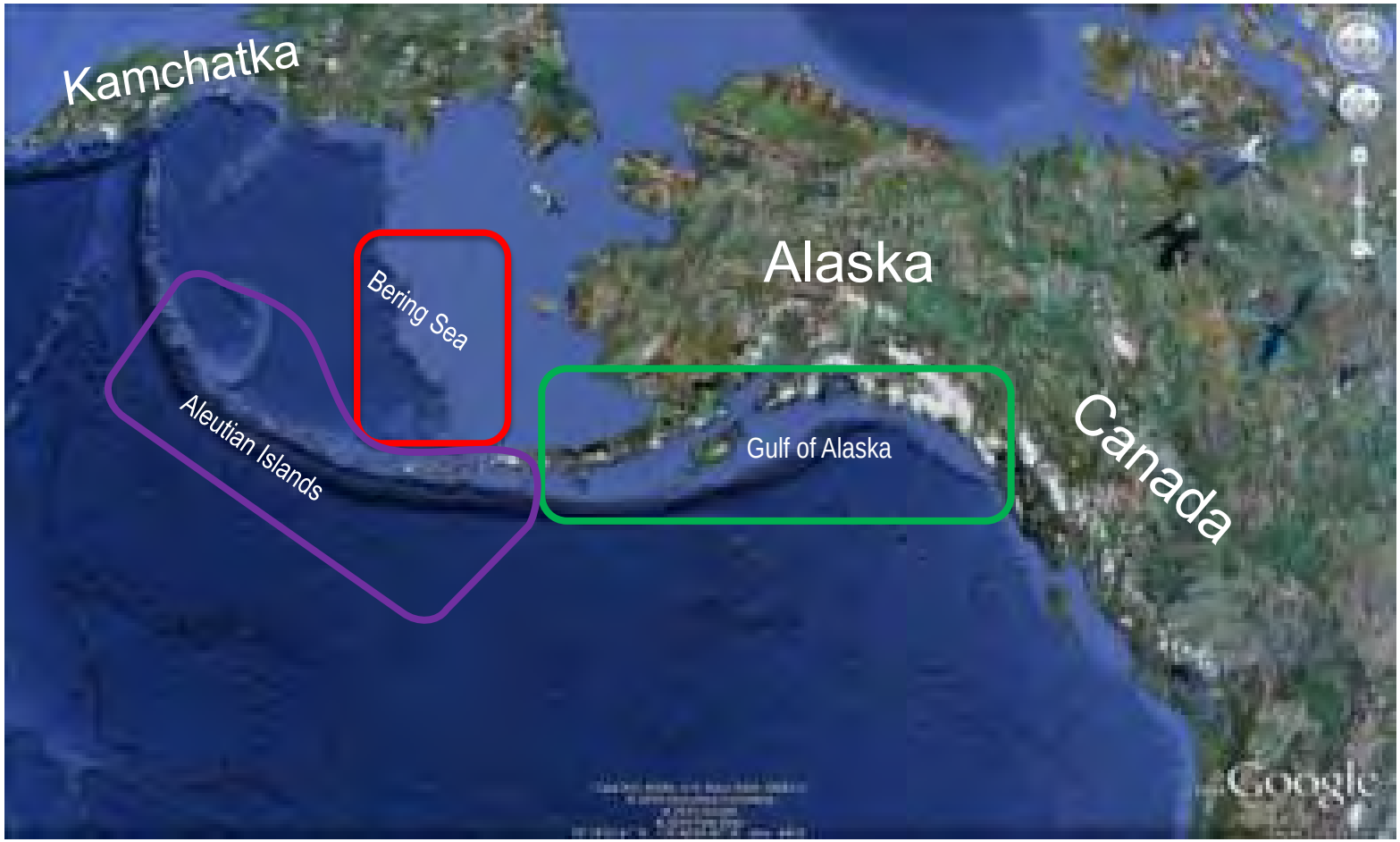
Regional-scale modeling



Objectives for 3 Alaska Large Marine Ecosystems

- Predict presence or absence of sponge and coral
- Predict abundance of sponge and coral

Dependent Data:

Bottom trawl survey catch 1991–2014 (EBS, AI & GOA)

Validation (either by year AI-2012 or random sample)

Flavors:

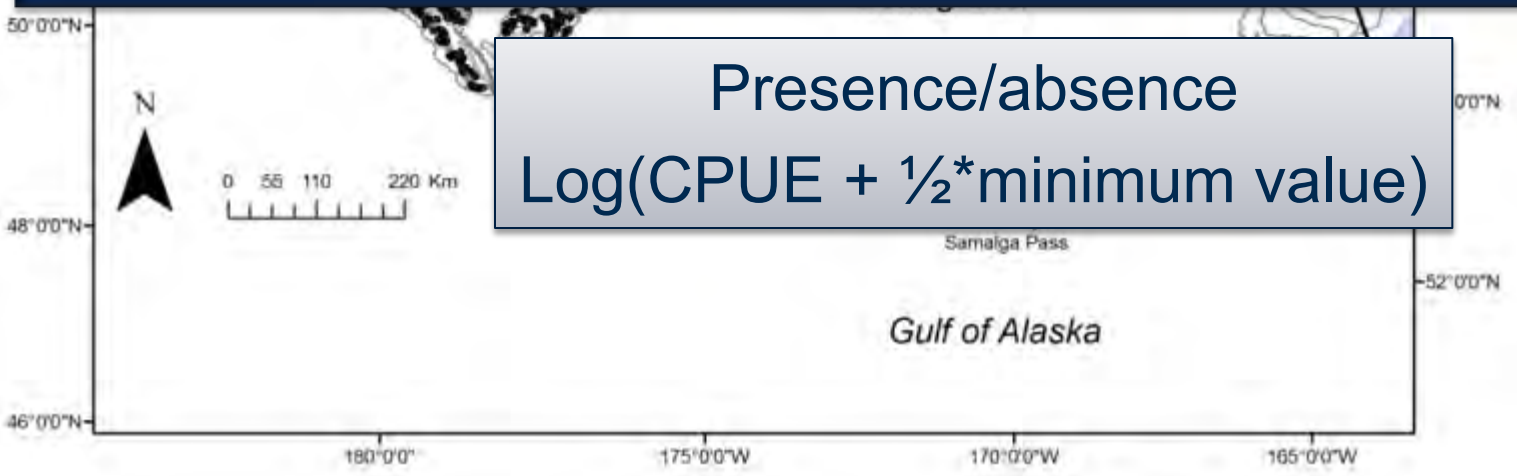
Upright sponges (vase, branching, monolithic, etc.)

“Hard” coral (Primnoidae, Stylasteridae, Plexauridae, Paragorgidae, Acanthogorgiidae, Cladopathidae, Isididae)

Primnoidae

Stylasteridae

Coral Diversity

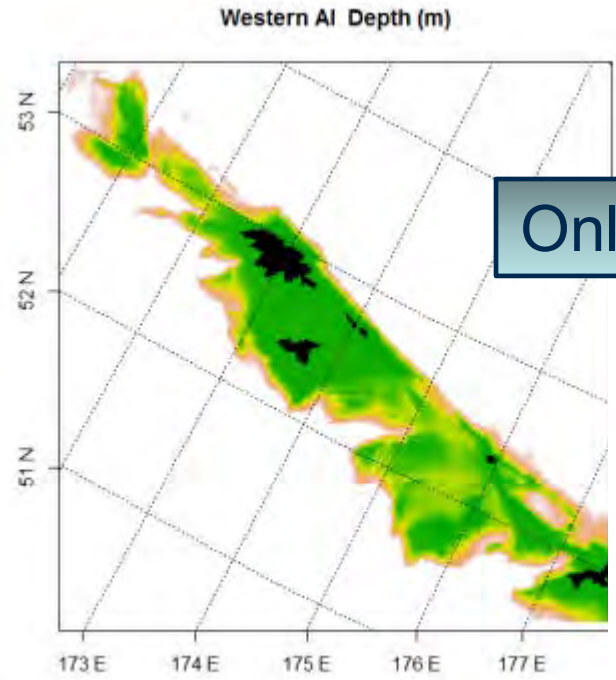


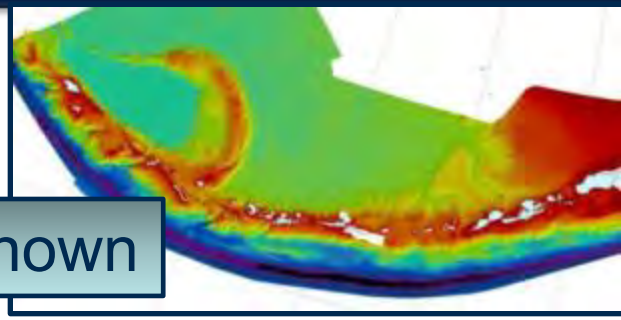
Presence/absence

Log(CPUE + ½*minimum value)

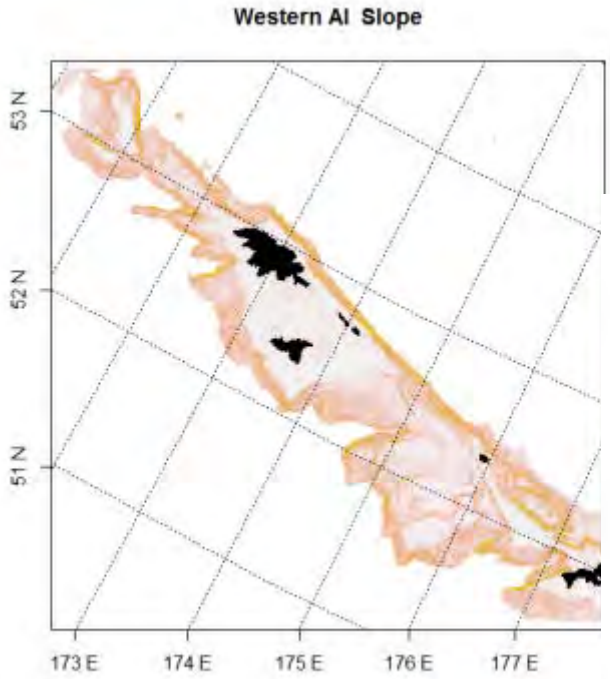
Independent Data:

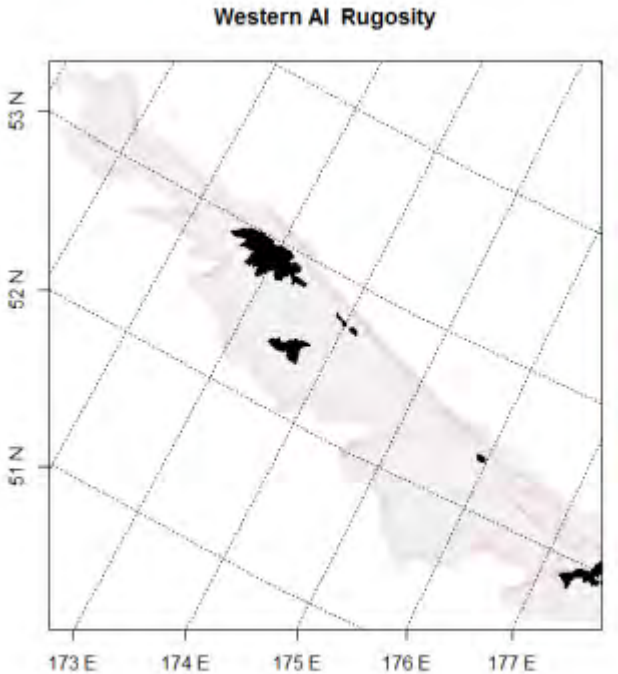
Seafloor characteristics based on Zimmermann et al. bathymetry compilation





Only western Aleutians is shown





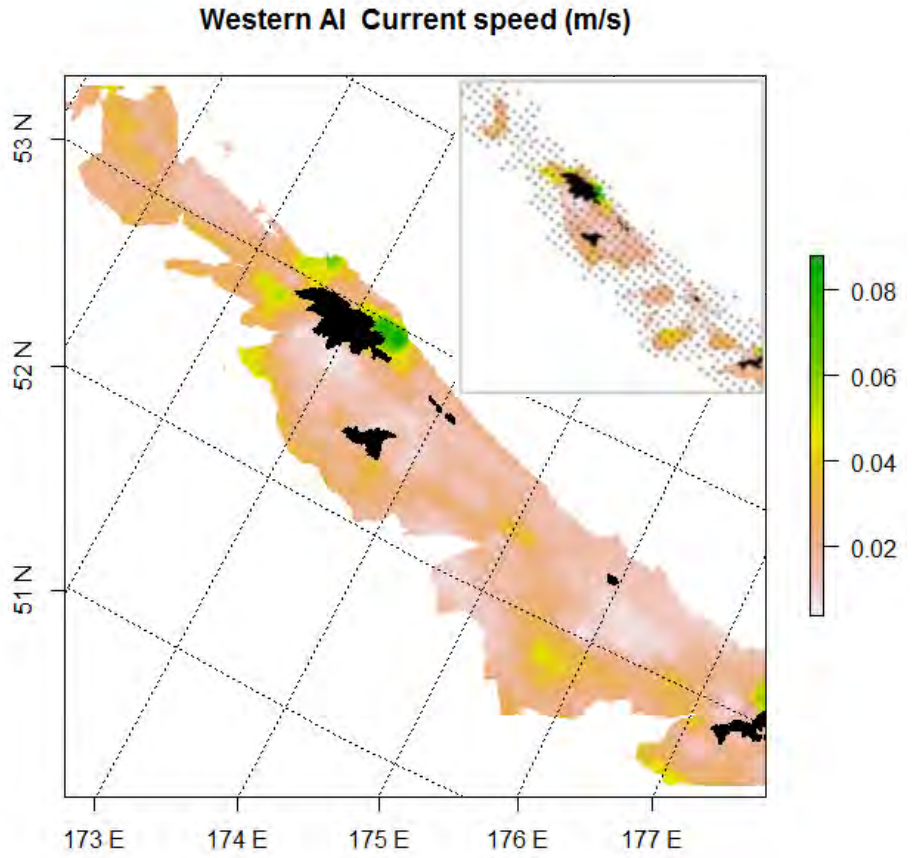
R software

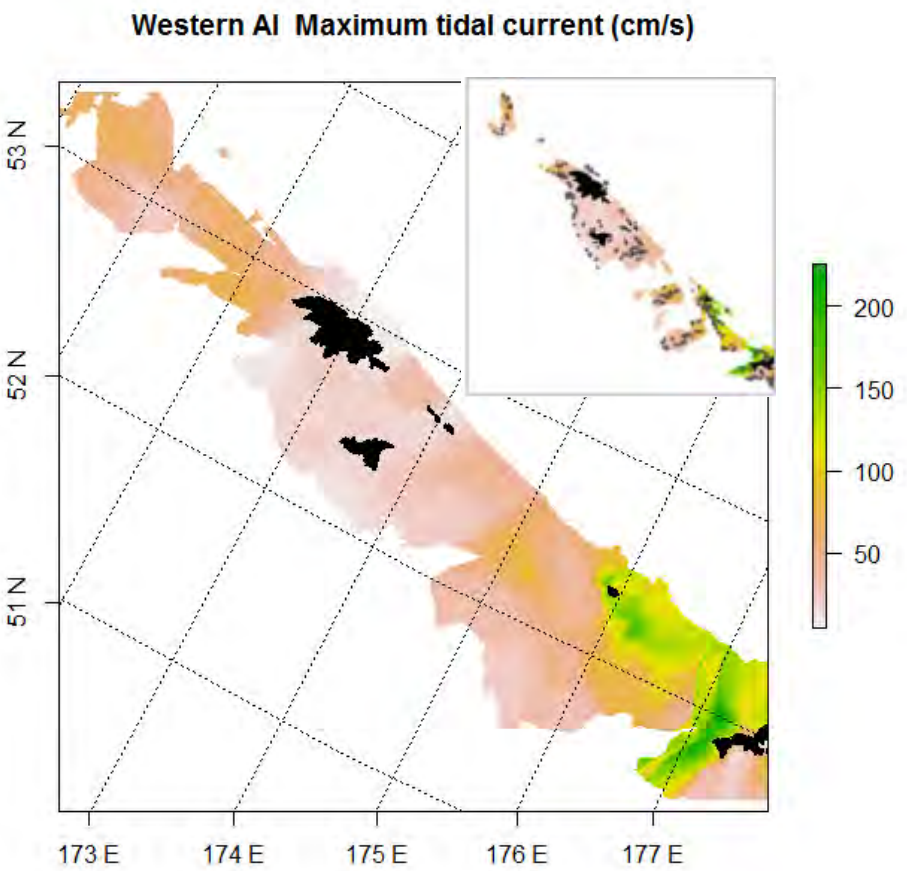
Mapping (raster, rgdal, gstat, sp, mapping, etc.)

Analyses (mgcv, PresenceAbsence, pROC, tweedie)

Independent Data:

Current speed - AI Hermann (ROMS) and Egbert & Erofeeva (2002)



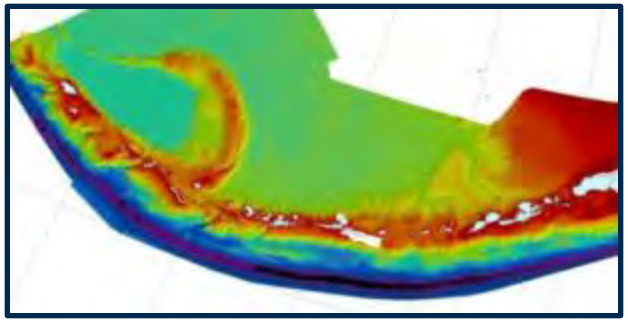


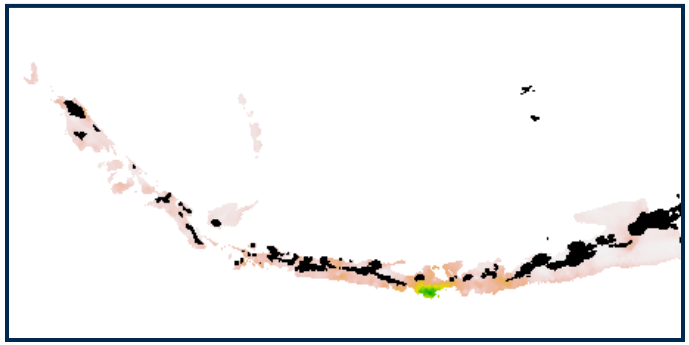
Source: ROMS model
Interpolation method: IDW
n = 1,917

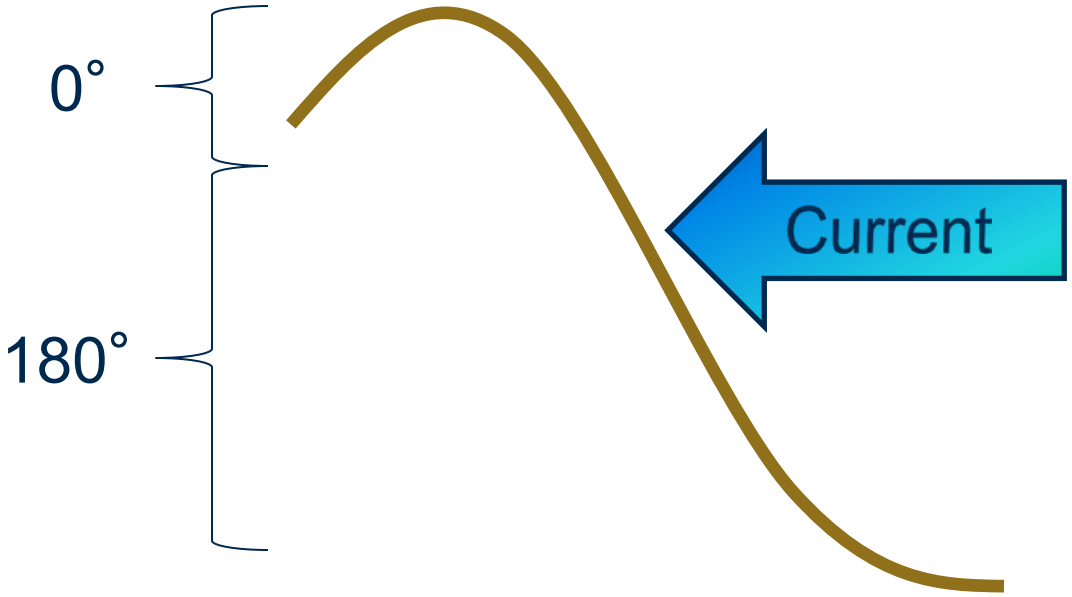
Source: OSU Tidal Inversion model
Interpolation method: Kriging
n = 3,051

Independent Data:

Aspect (combines bathymetry and mean current direction)

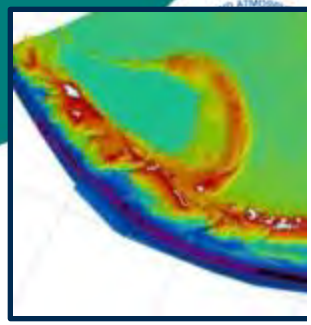


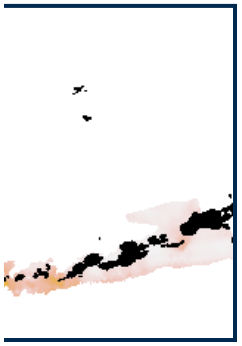




Independent Data:

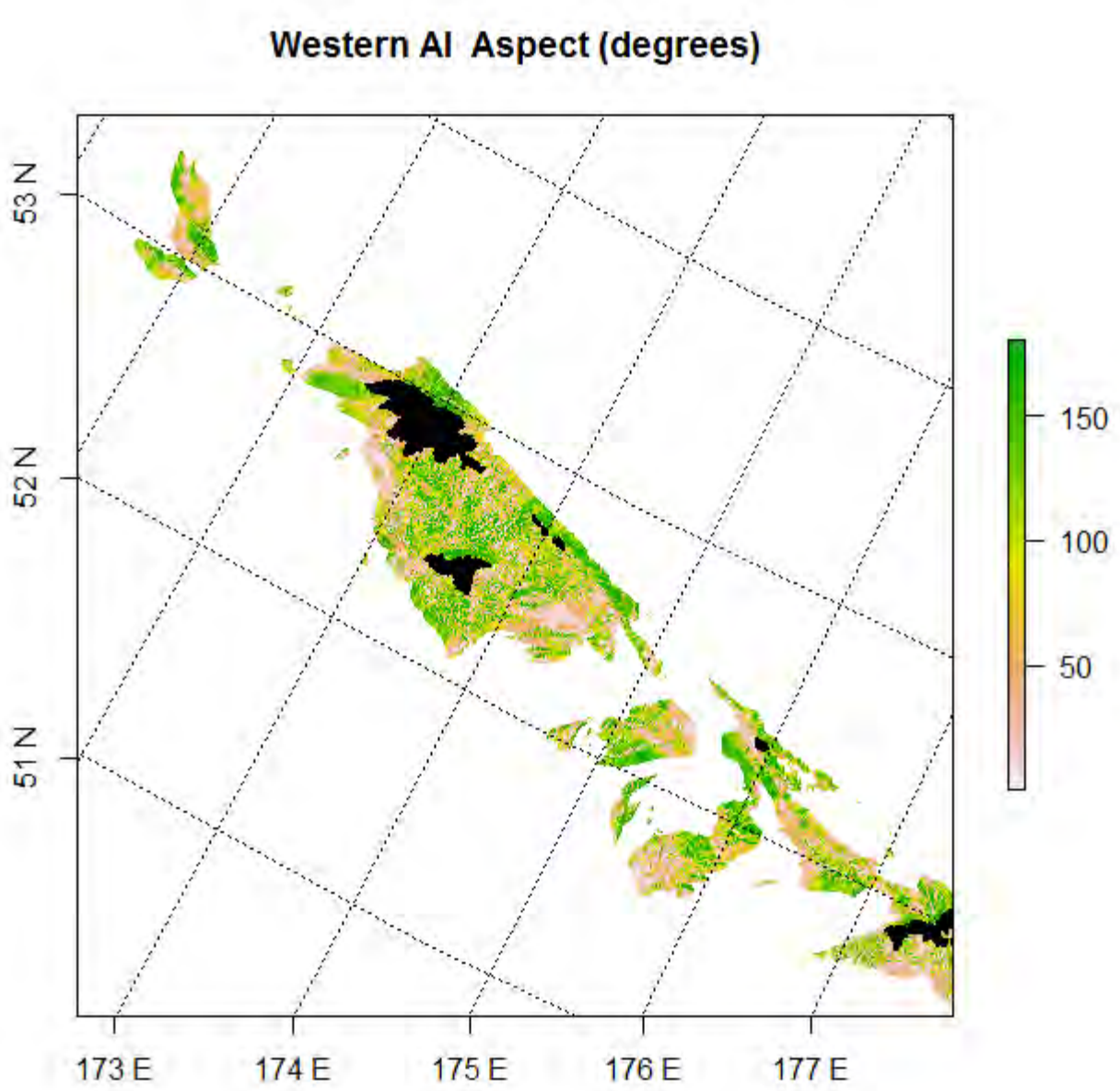
Aspect (comb





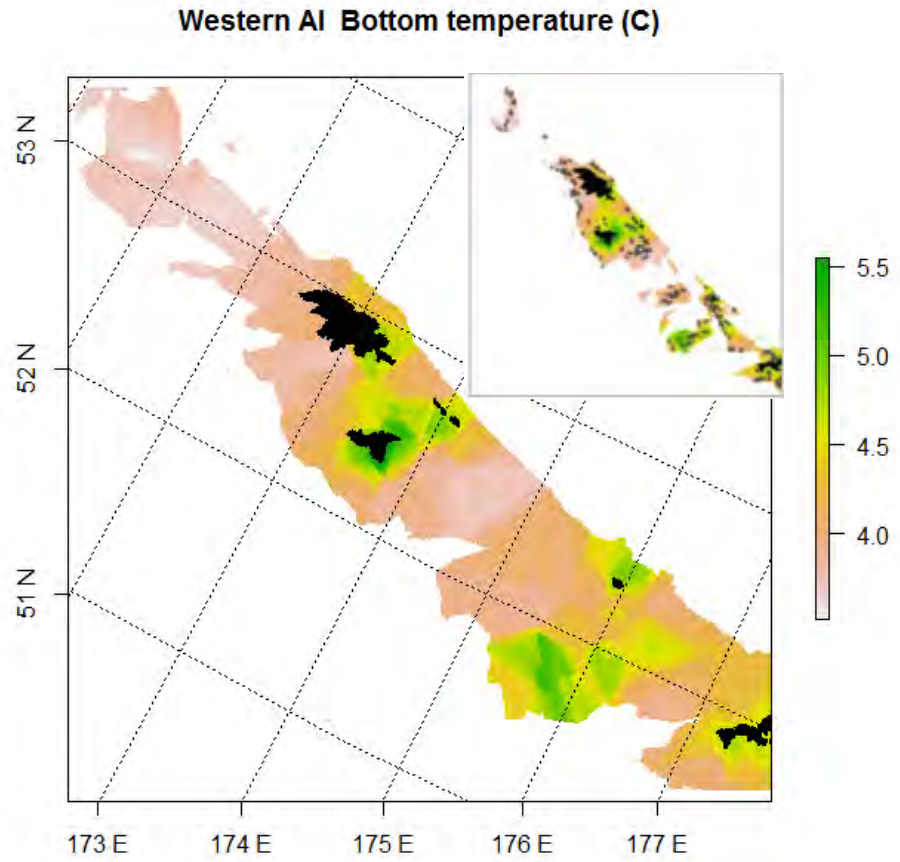
0°

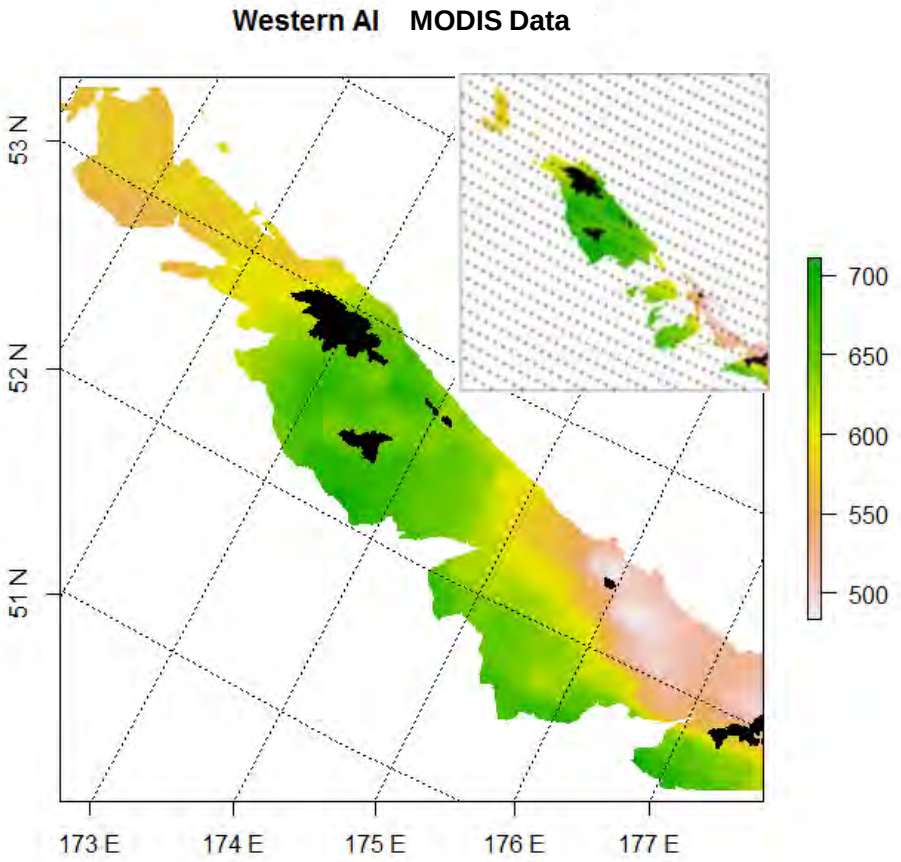
180°



Independent Data:

Bottom Temperature (trawl surveys) & Ocean color (MODIS)

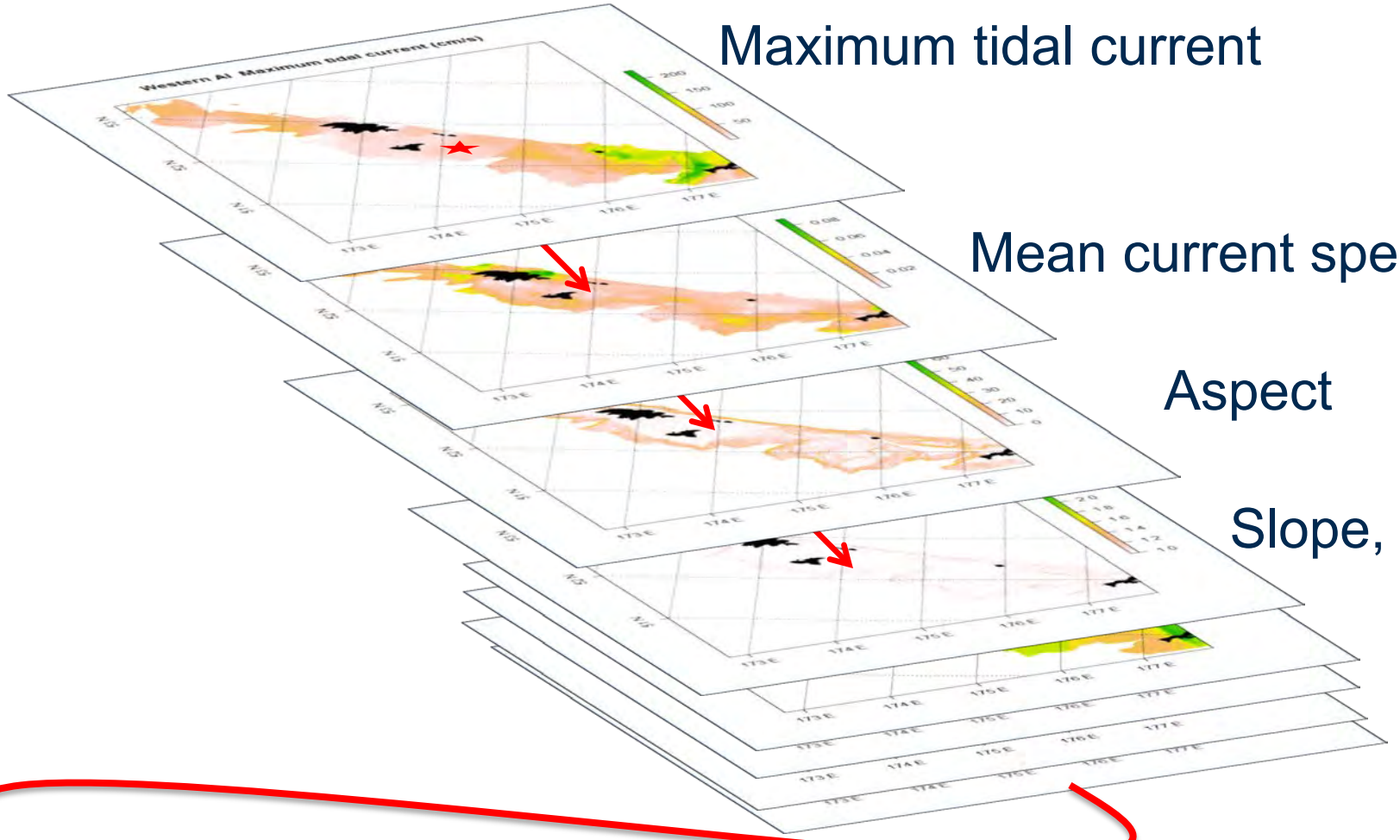




Source: Bottom trawl survey 1991-2012
Interpolation method: Kriging
n = 2,814

Source: Ocean Productivity Website (OSU)
Interpolation method: IDW
n = 19,929

Method Part I. Data extraction



Data

Eastings	Northings	Hauljoin	Cruise	Coral	All_spong	Upright_s	bathyt	rugt	slopet	tmaxt	colorkt	speedt	btempt	sedt	aspectt
-1724844	622375.9	1211155	200401	0.234757	-999	0	406	1.00051	1.77448	31.58791	541.9287	0.009334	3.792883	-3.04834	40.40086
-1737596	589496.8	1211159	200401	0.146251	-999	33.97403	90	1.000093	0.418171	118.024	561.1726	0.012461	4.562544	-3.1559	40.97159
-1738269	587606.1	1304609	200601	0.605925	-999	2.759369	93	1.000188	0.498922	118.3989	561.8009	0.012488	4.561443	-3.1596	42.47778
-1738261	587595.9	-6835	201001	0.048756	-999	0.513659	93	1.000188	0.521538	118.4221	561.8882	0.01249	4.56139	-3.15983	38.1242
-1723829	622375.4	31734	199101	0	-999	0.010858	391	1.000965	2.001224	30.39524	542.9734	0.009265	3.787413	-3.04834	38.01564
-1724063	620752.1	1145973	200201	0.028932	-999	0.51676	395	1.000624	1.864233	30.42523	543.6204	0.009114	3.787336	-3.04834	36.16538

Method Part II. Generalized Additive Modeling

$$y = s(location) + s(depth) + s(temperature) + s(slope) + s(rugosity) + s(maximum\ tidal\ current) + s(mean\ current\ speed) + s(ocean\ color) + s(aspect) + open\ or\ closed + \varepsilon$$

Details:

MGCV package in R

Presence-absence = Binomial distribution

Log(CPUE) = Gaussian or Tweedie

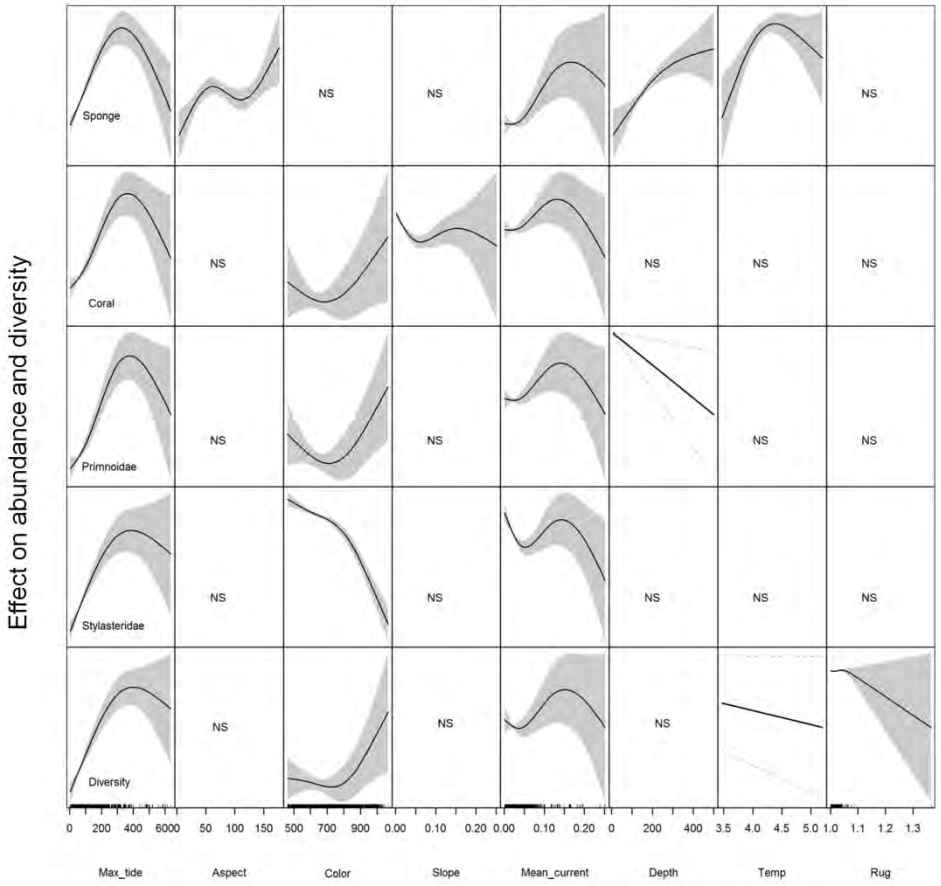
Diversity = Poisson

k = 30 for bivariate term, 4 for univariate terms

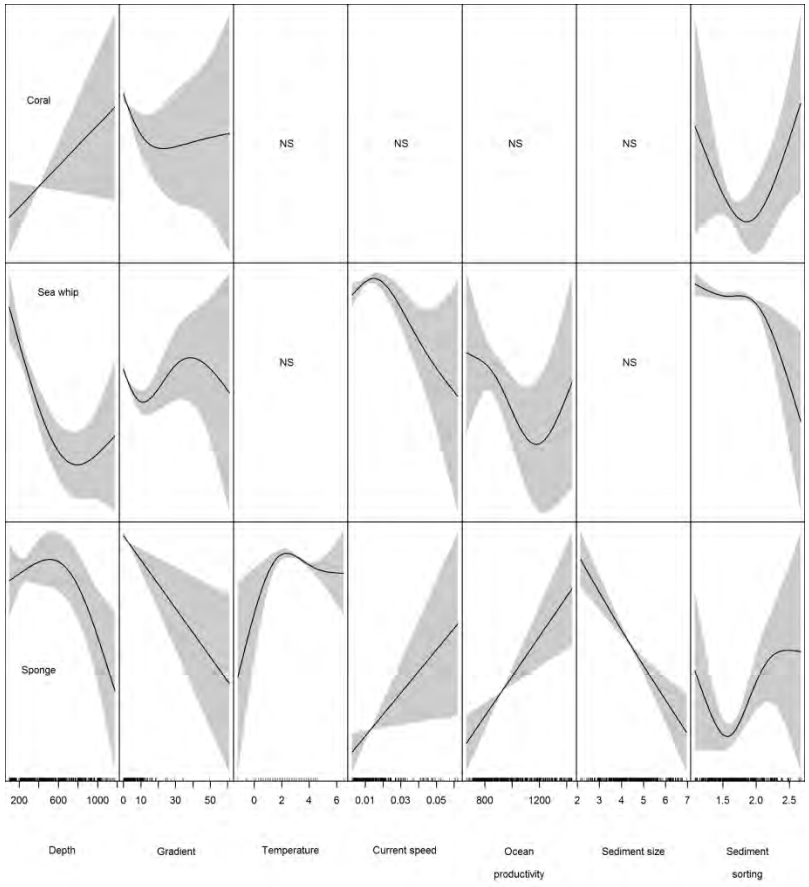
Backwards elimination of insignificant variables based on GCV

Results – Variable Relationships

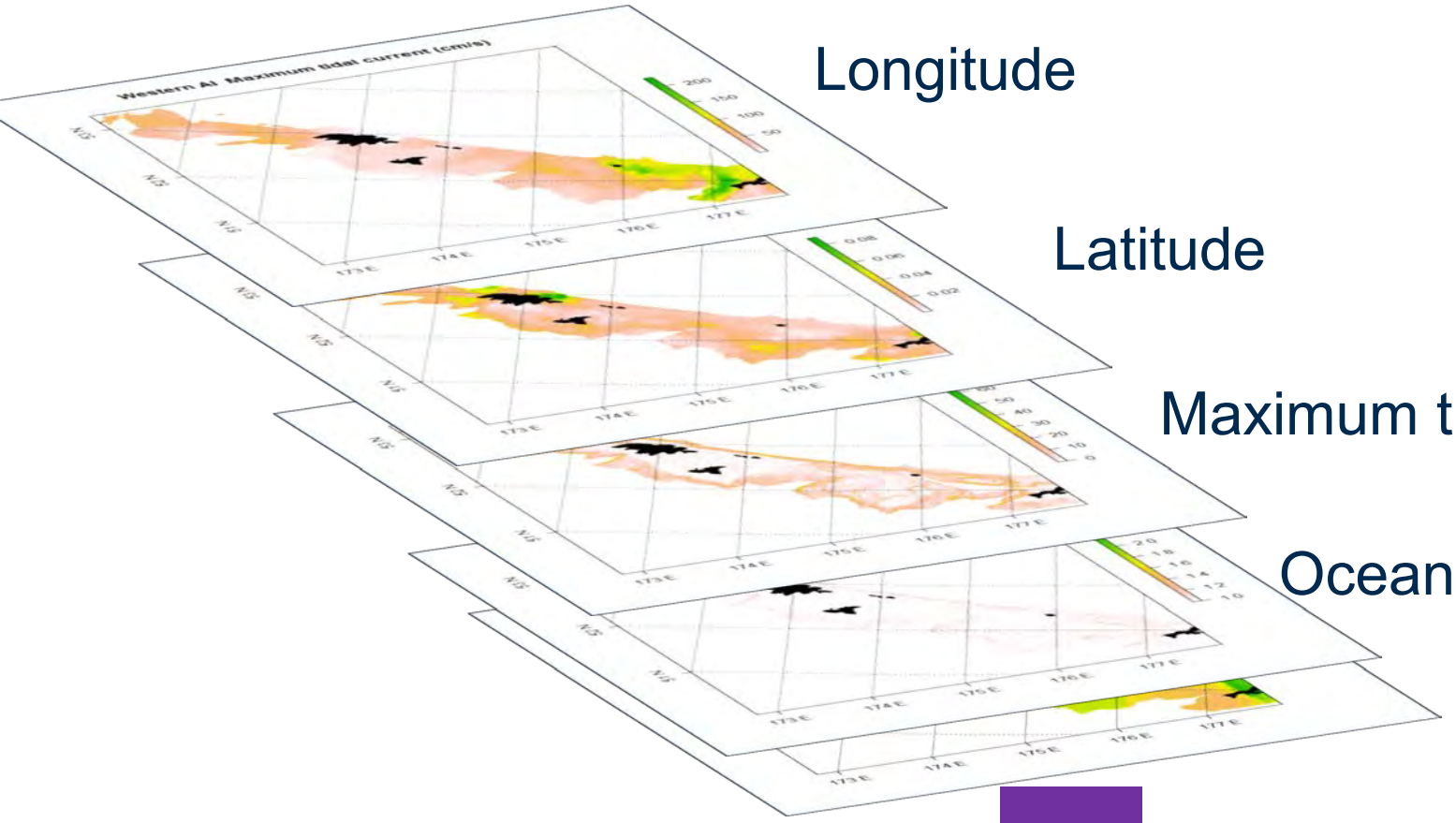
Aleutian Islands



Eastern Bering Sea

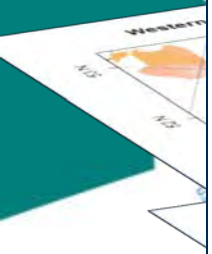


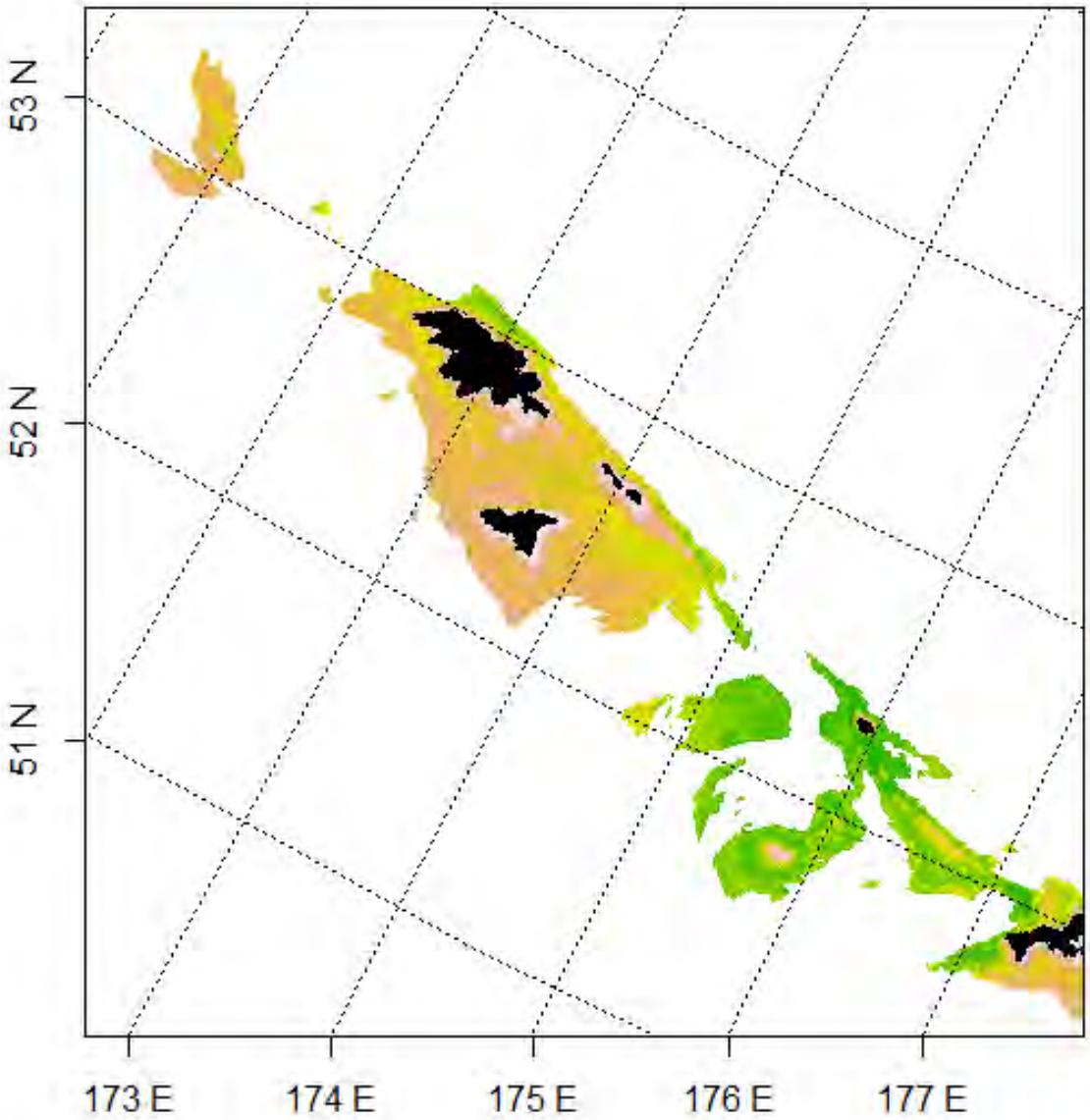
Results III. Predictions



Best fitting GAM model

y = s(longitude, latitude)+s(maximum tidal current)+s(ocean color)+s(slope)





current

or

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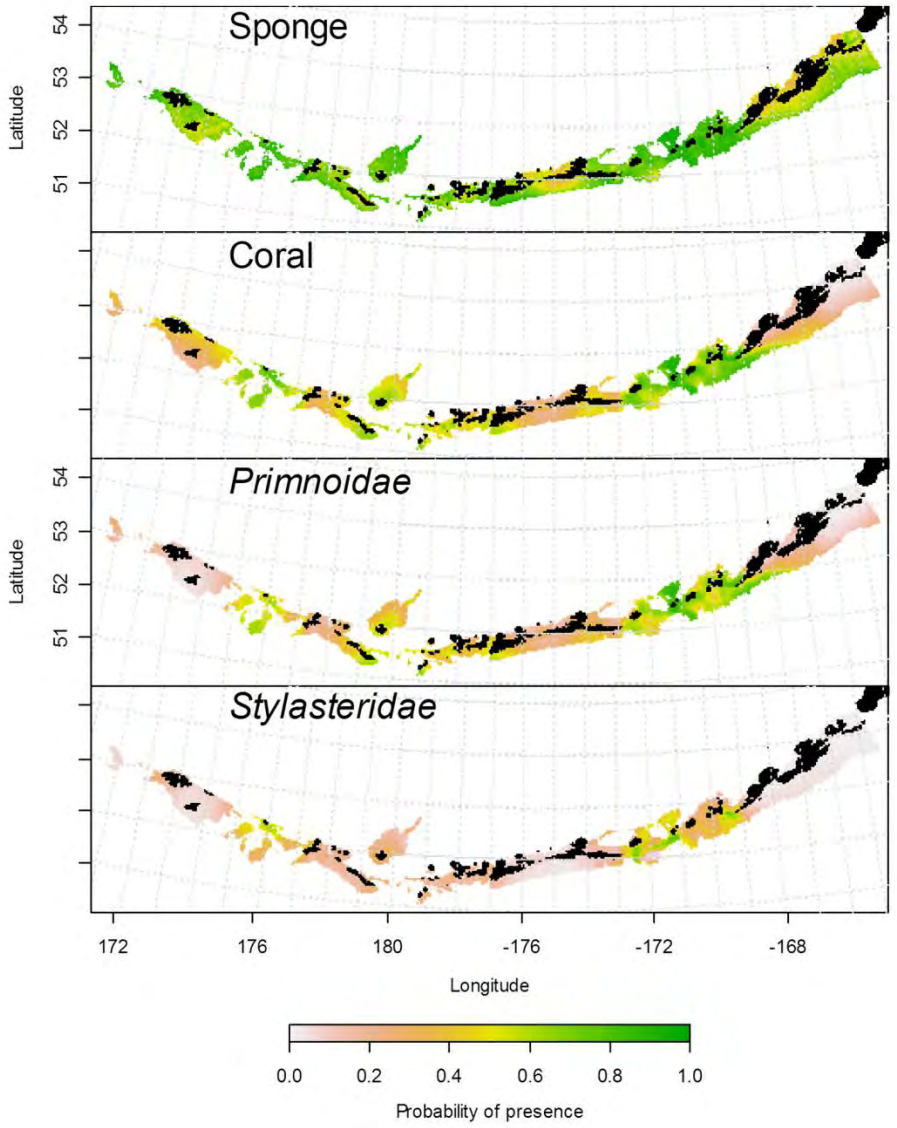
Best fi

y = :

pe)

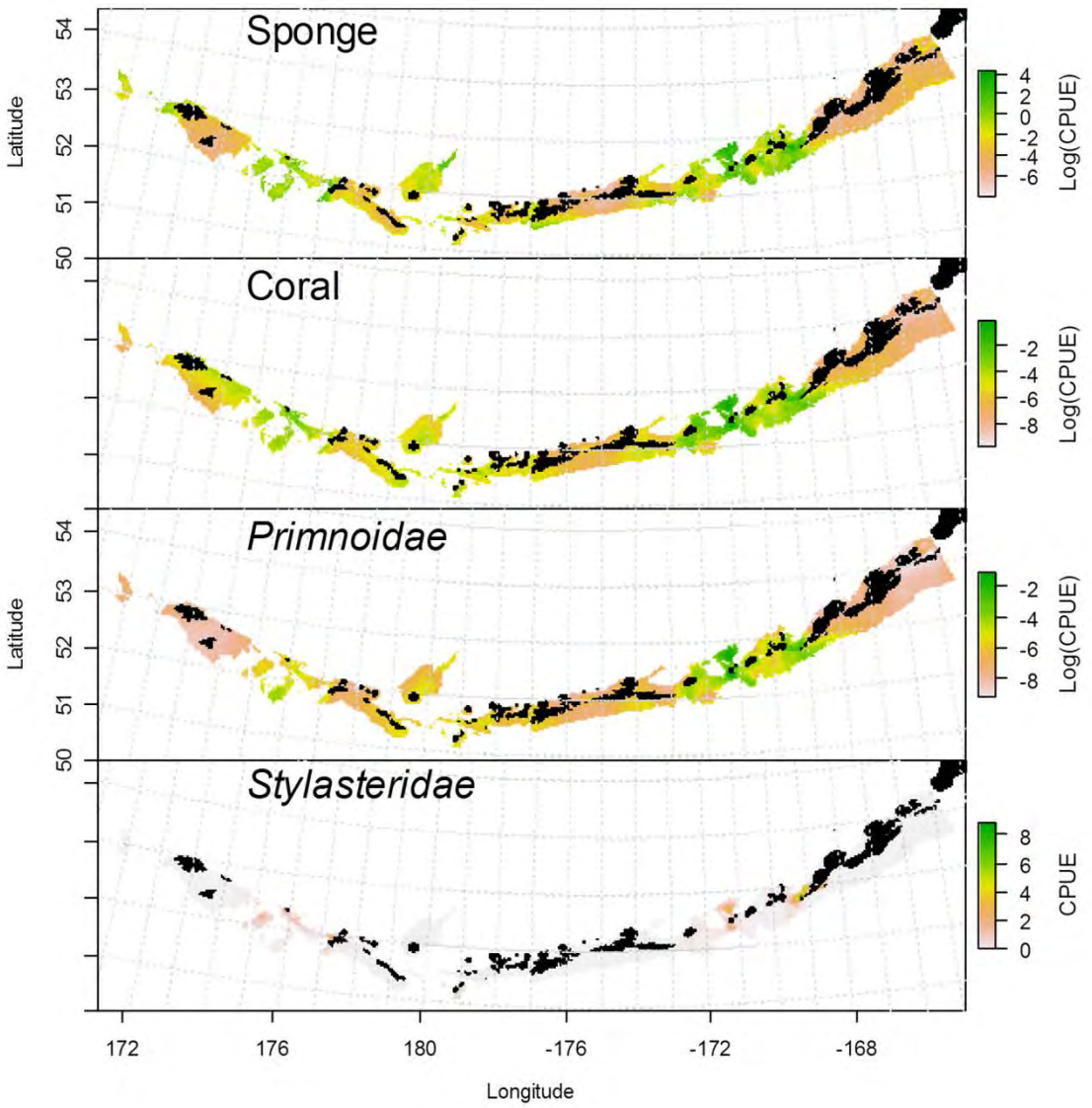
Predicted Probability of Presence

Trawl data

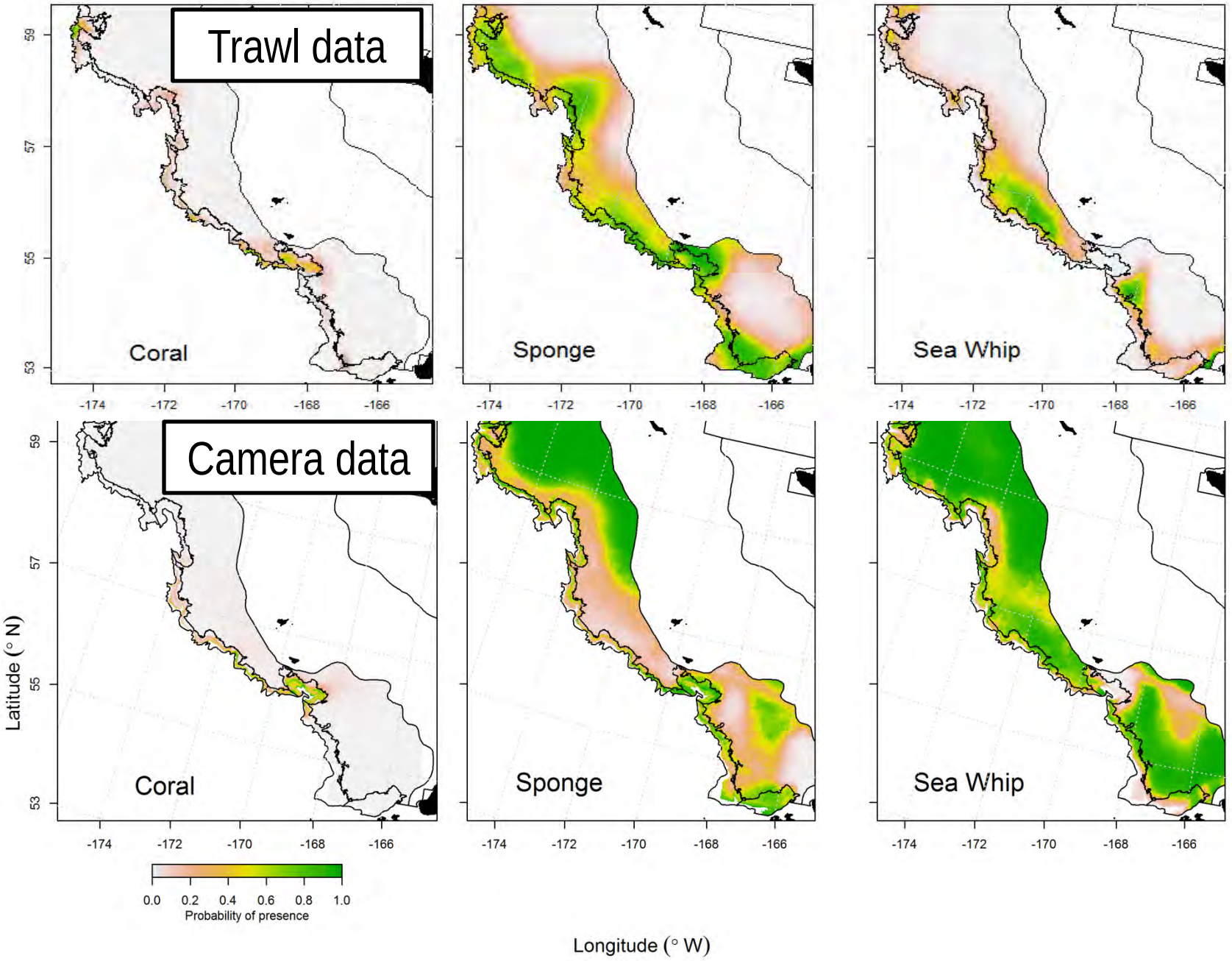


Predicted Catch-per-Unit-of-Effort (CPUE)

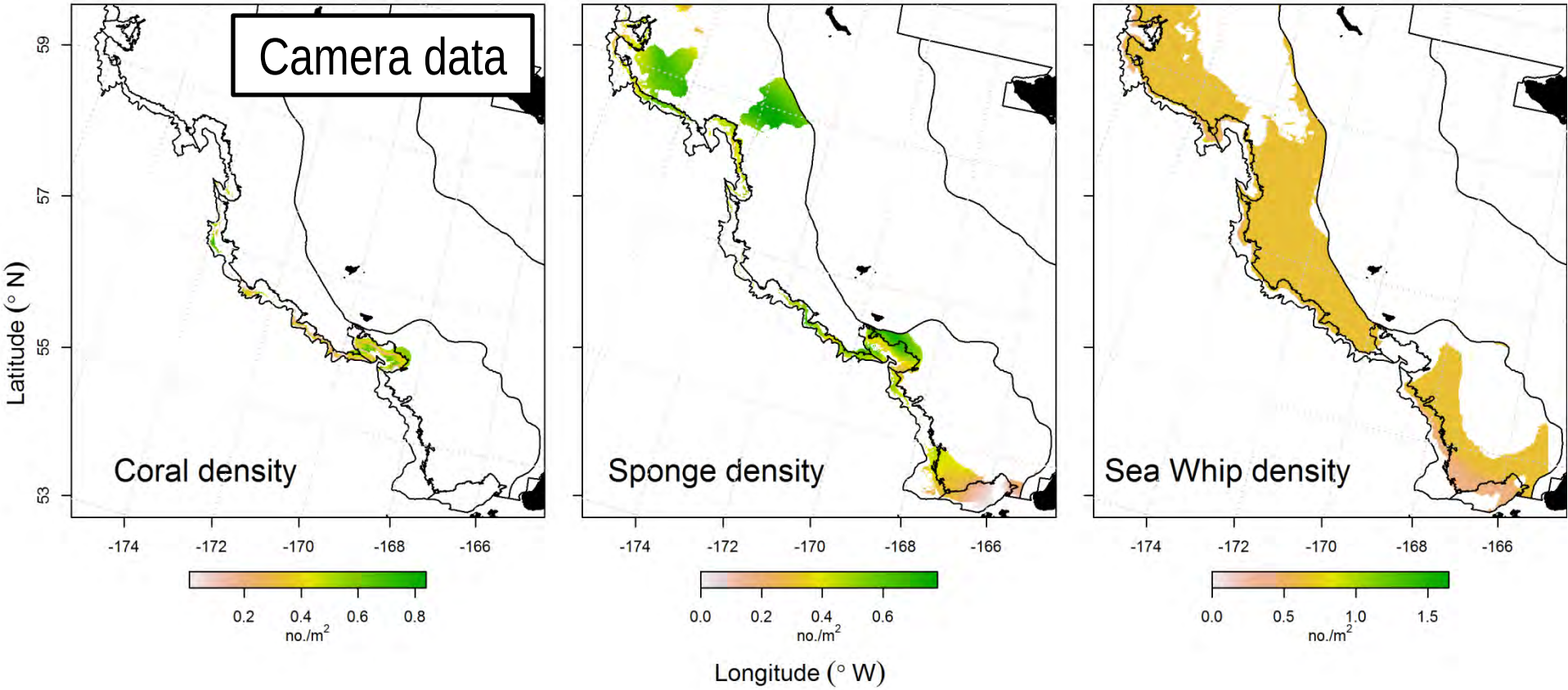
Trawl data



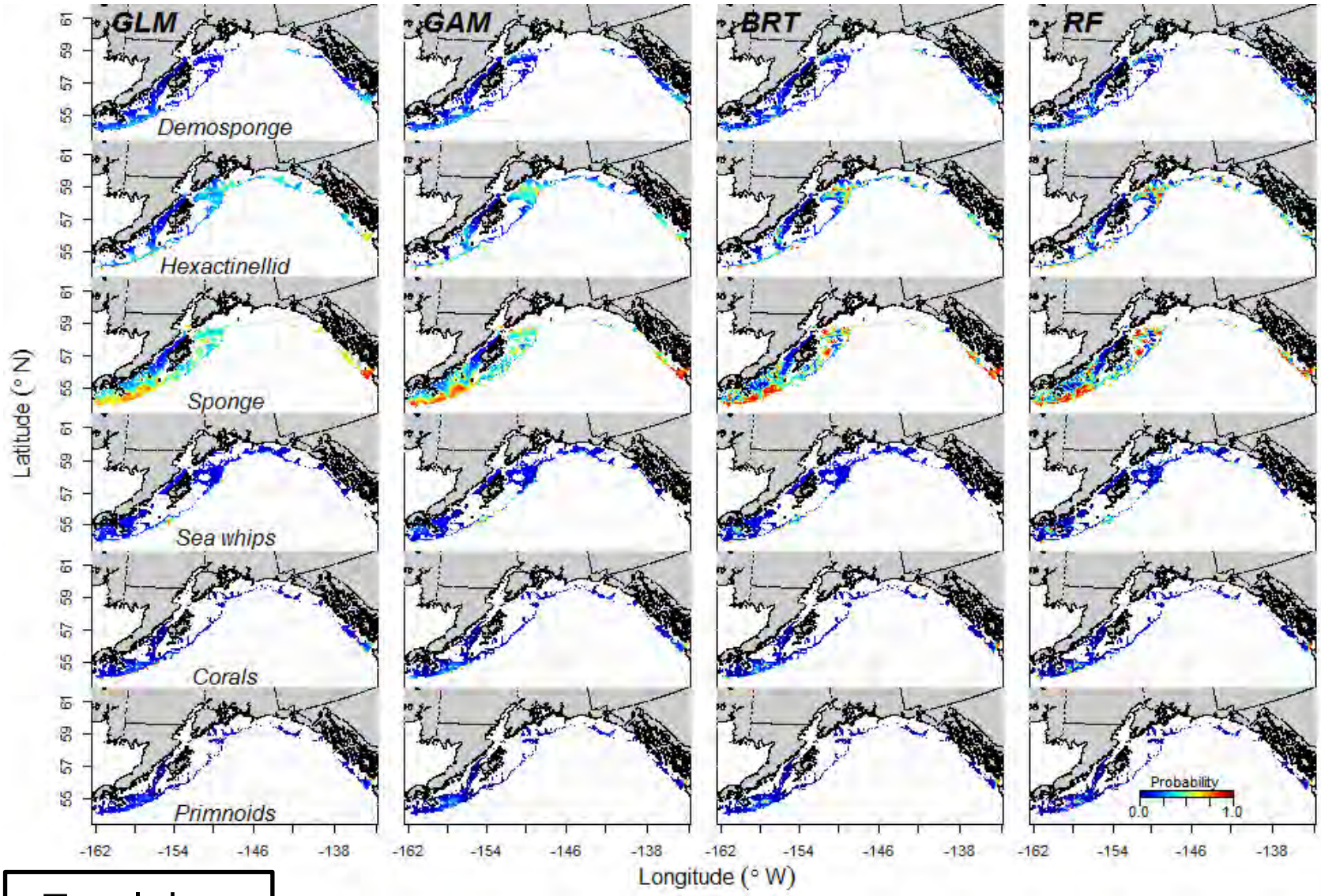
Predicted Presence or Absence



Predicted Density

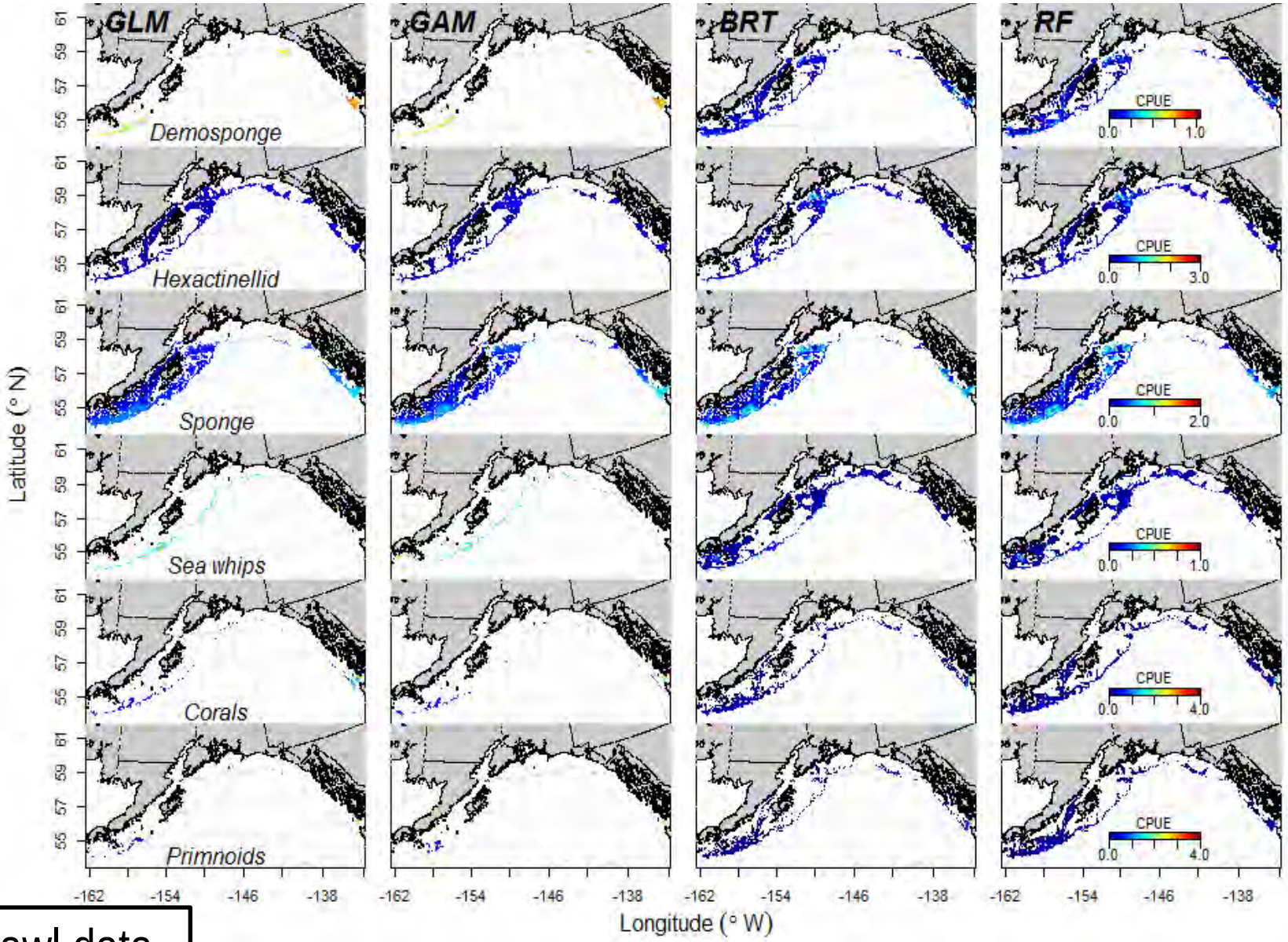


Predicted Probability of Presence



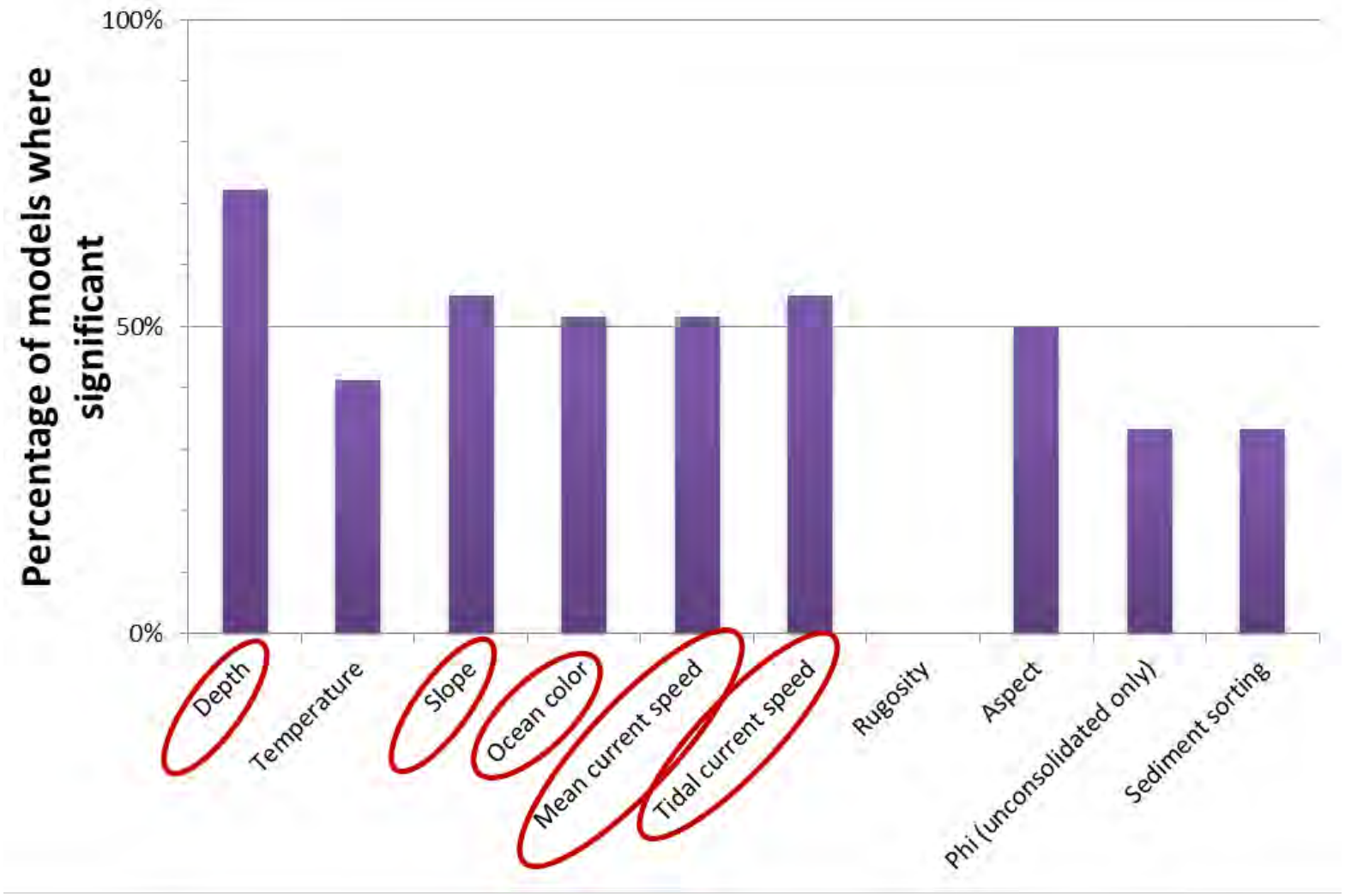
Trawl data

Predicted Catch-per-Unit-of-Effort (CPUE)

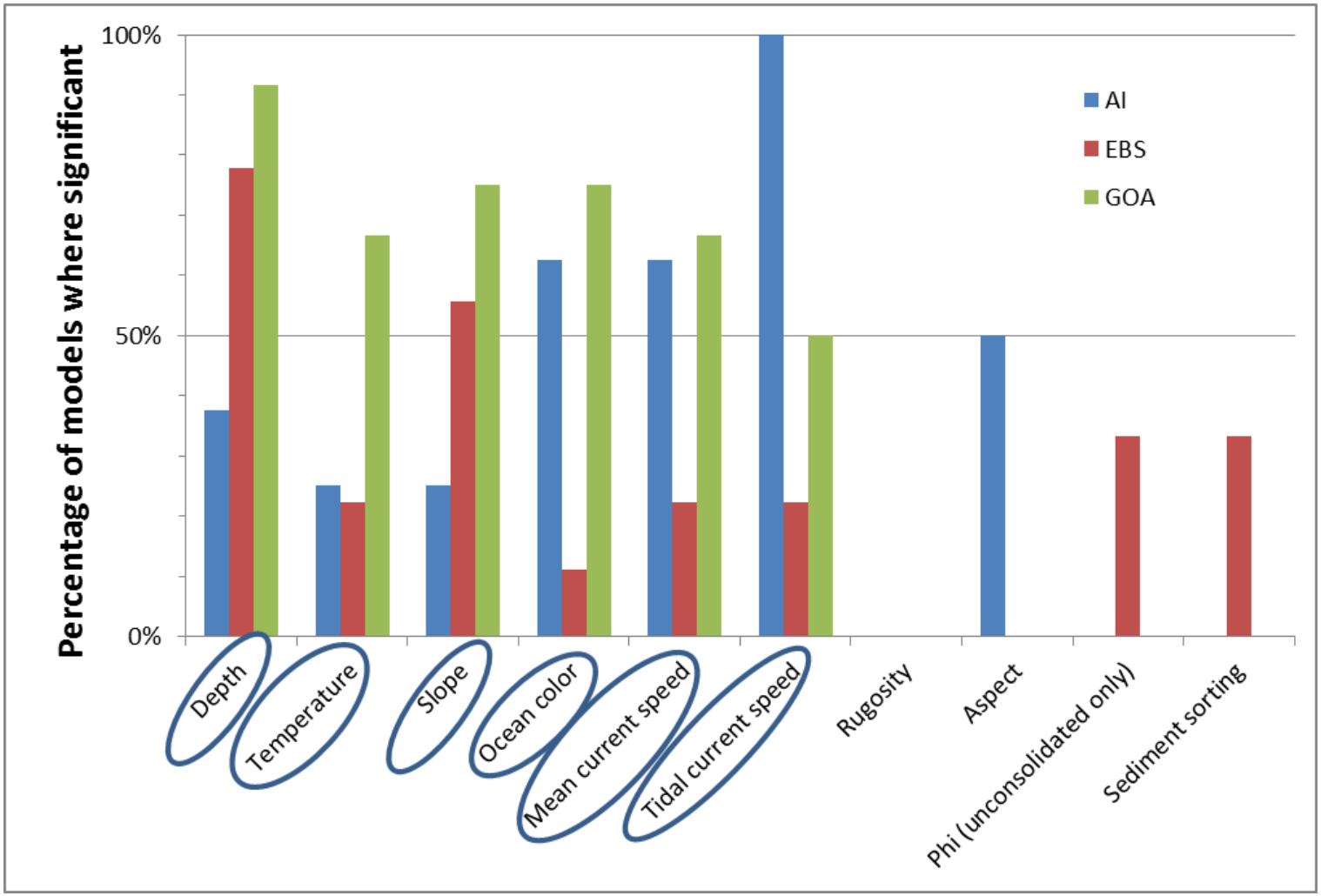


Trawl data

Which variables are important across ecosystems?



How about within ecosystems?



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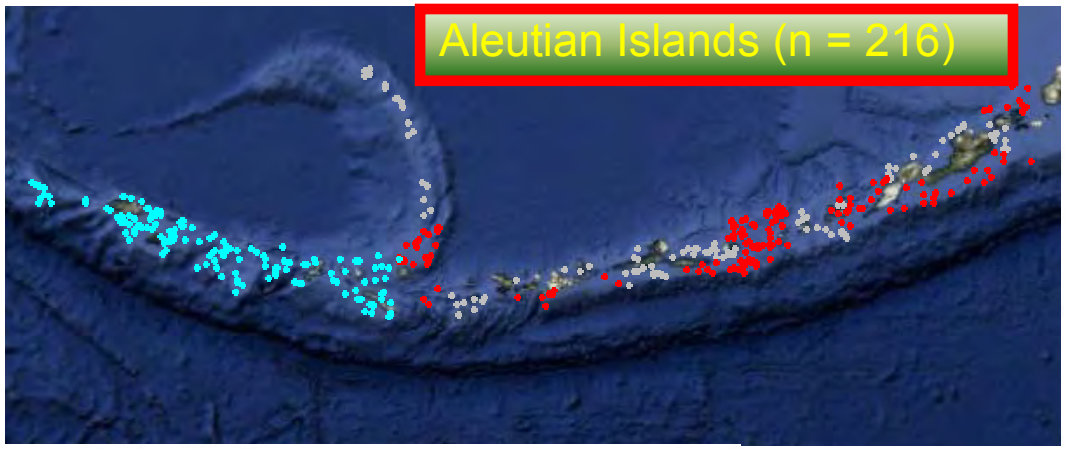
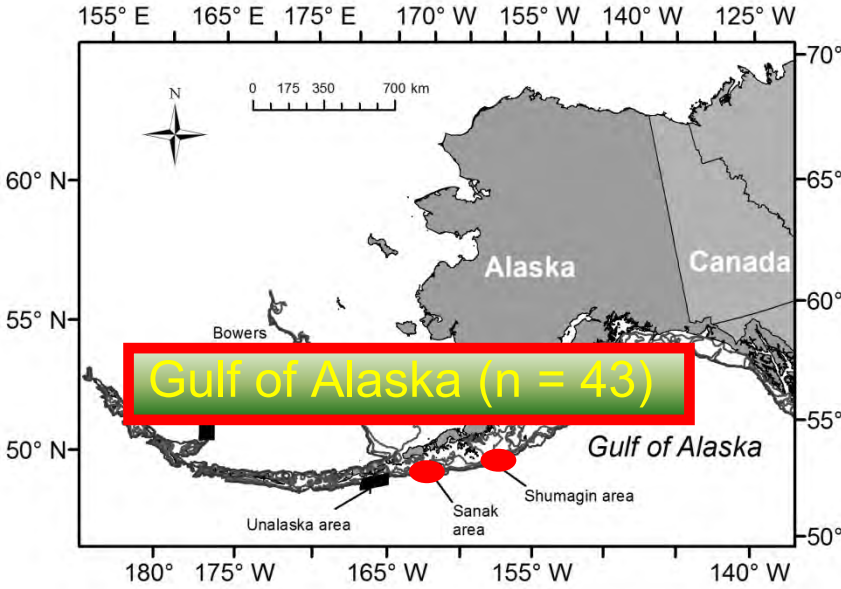
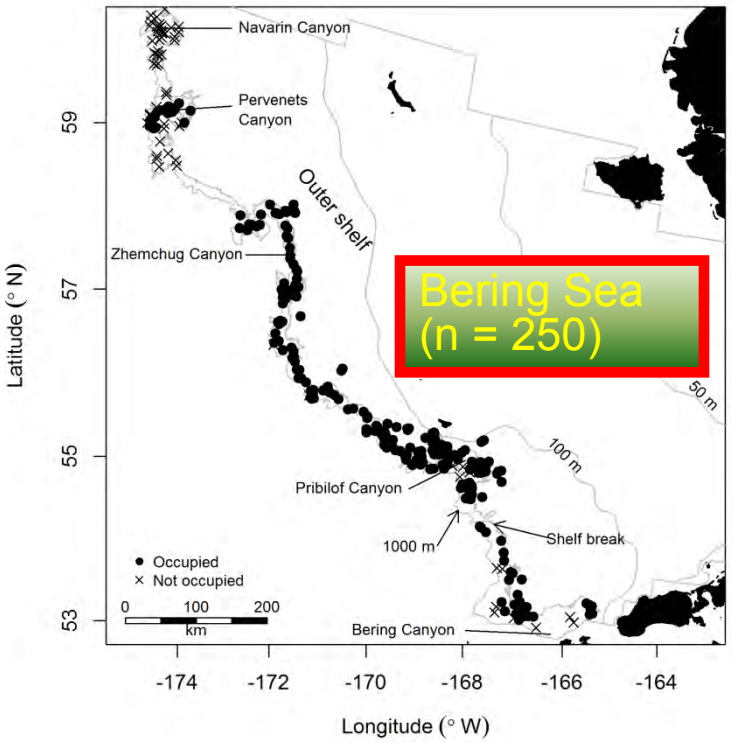
Small Scale Modeling

Underwater Camera Surveys (2010-2014)







Stereo camera systems

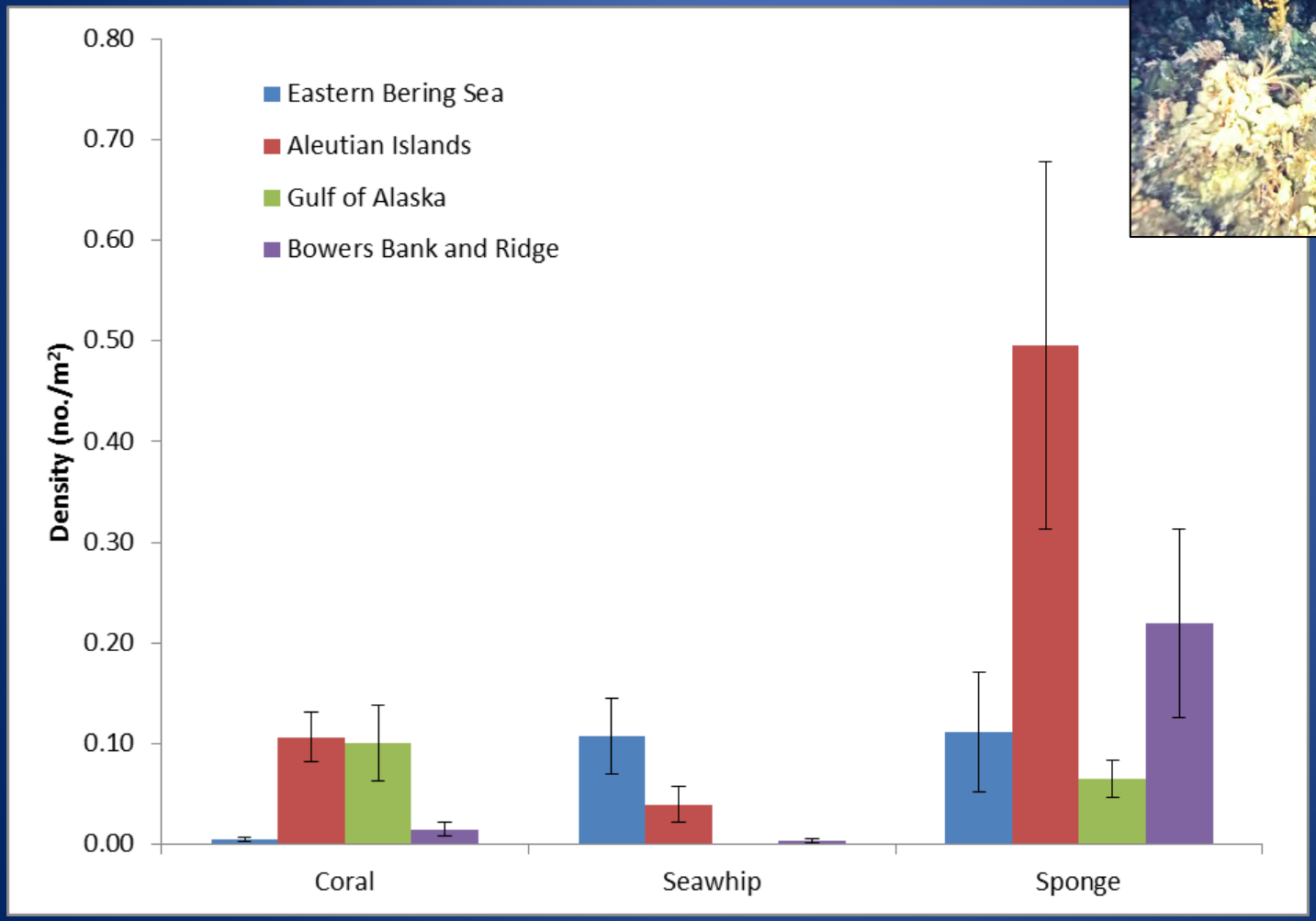
Groundtruthing study sites 2010-2014

Standard 15 minute transects (~1000 m^2)

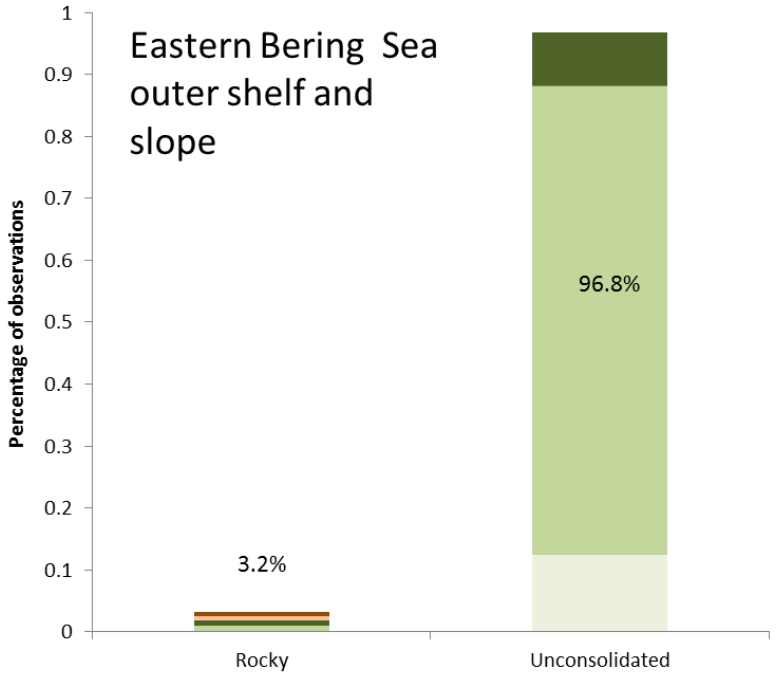
Random sampling design (except GOA)

n ~ 510 sites

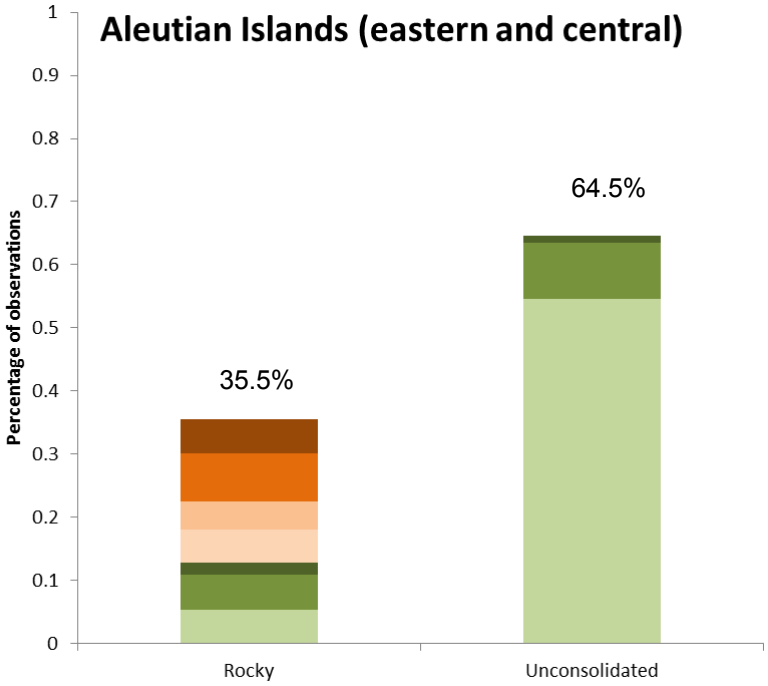
Densities of All Structure-forming Invertebrates

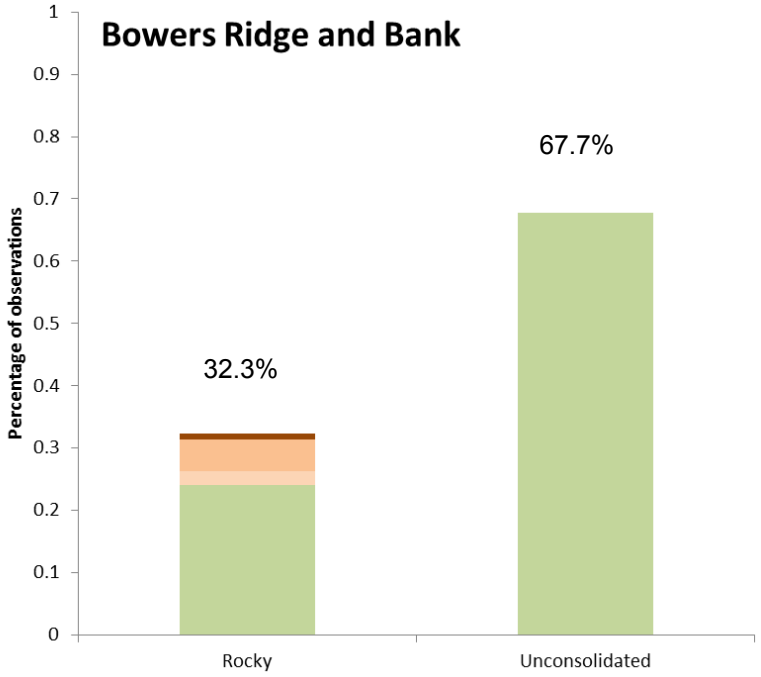


Why?

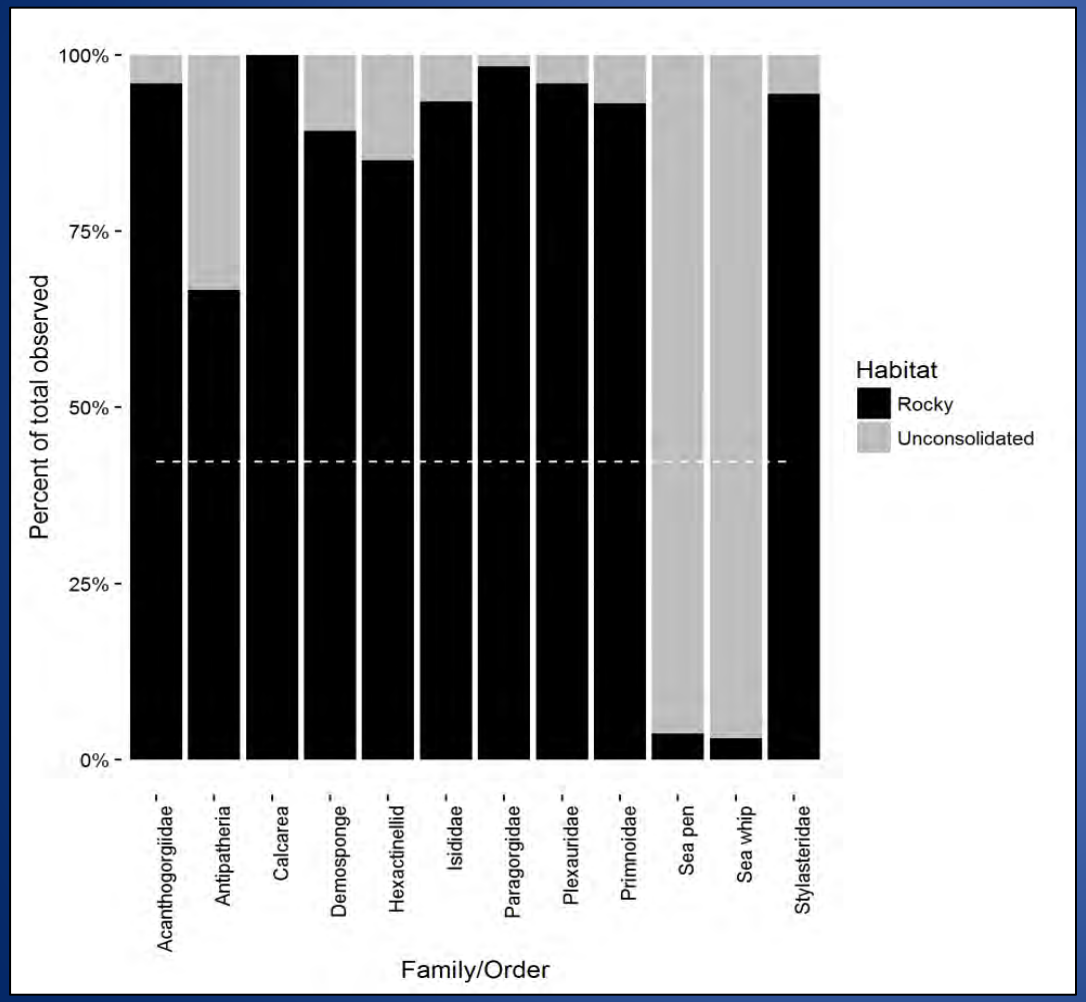


Region	Transects with rocky habitat	Transects with coral
Gulf of Alaska	35%	30%
Aleutian Islands	63%	60%
Bowers Bank	42%	47%
Eastern Bering Sea	19%	13%





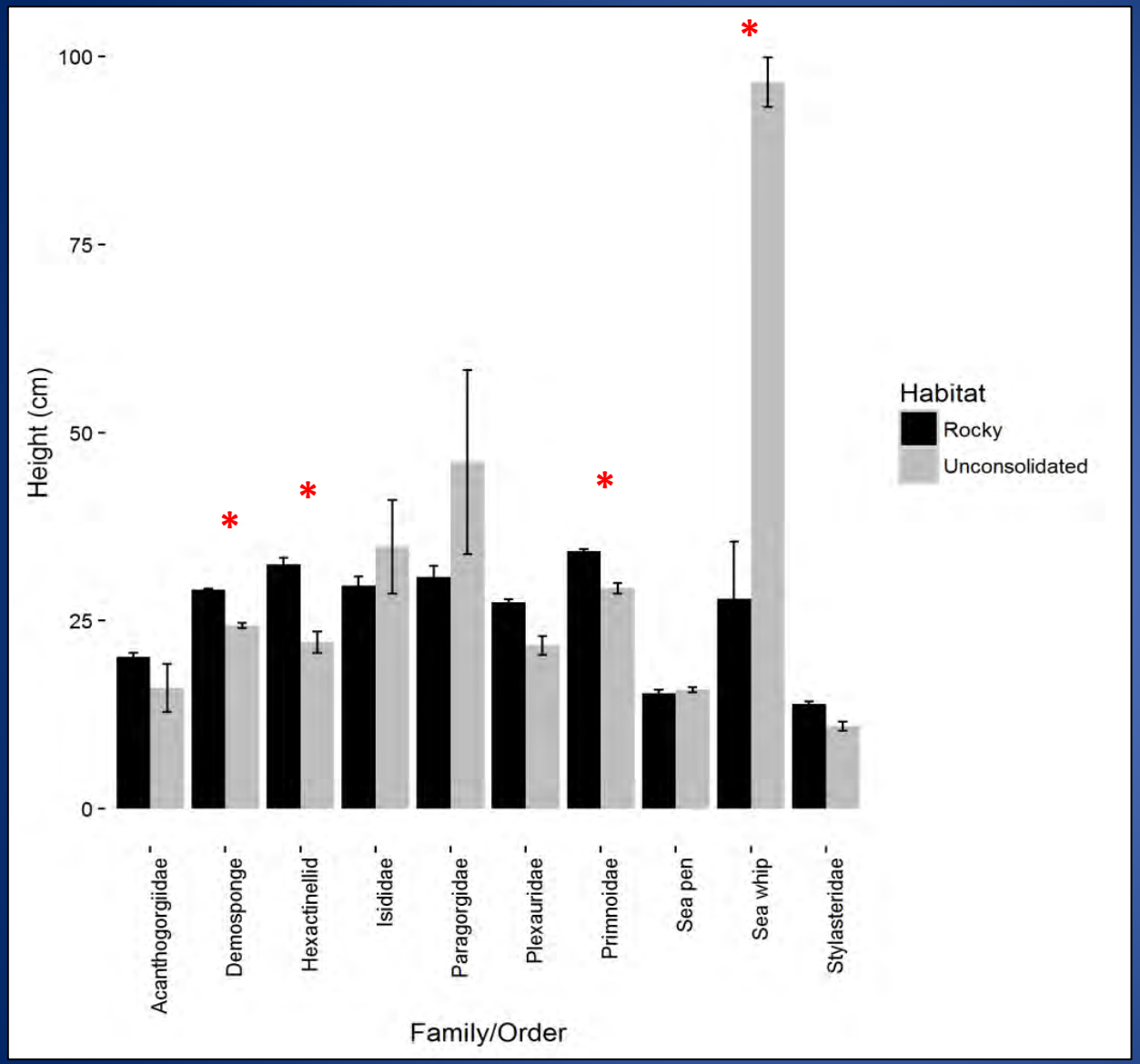
Coral, Sponge, and Pennatulacean Substrate Associations



- All corals and sponges (except pennatulaceans) were more frequently observed on rocky substrates

***Almost 42% of habitat surveyed was identified as rocky substrate.

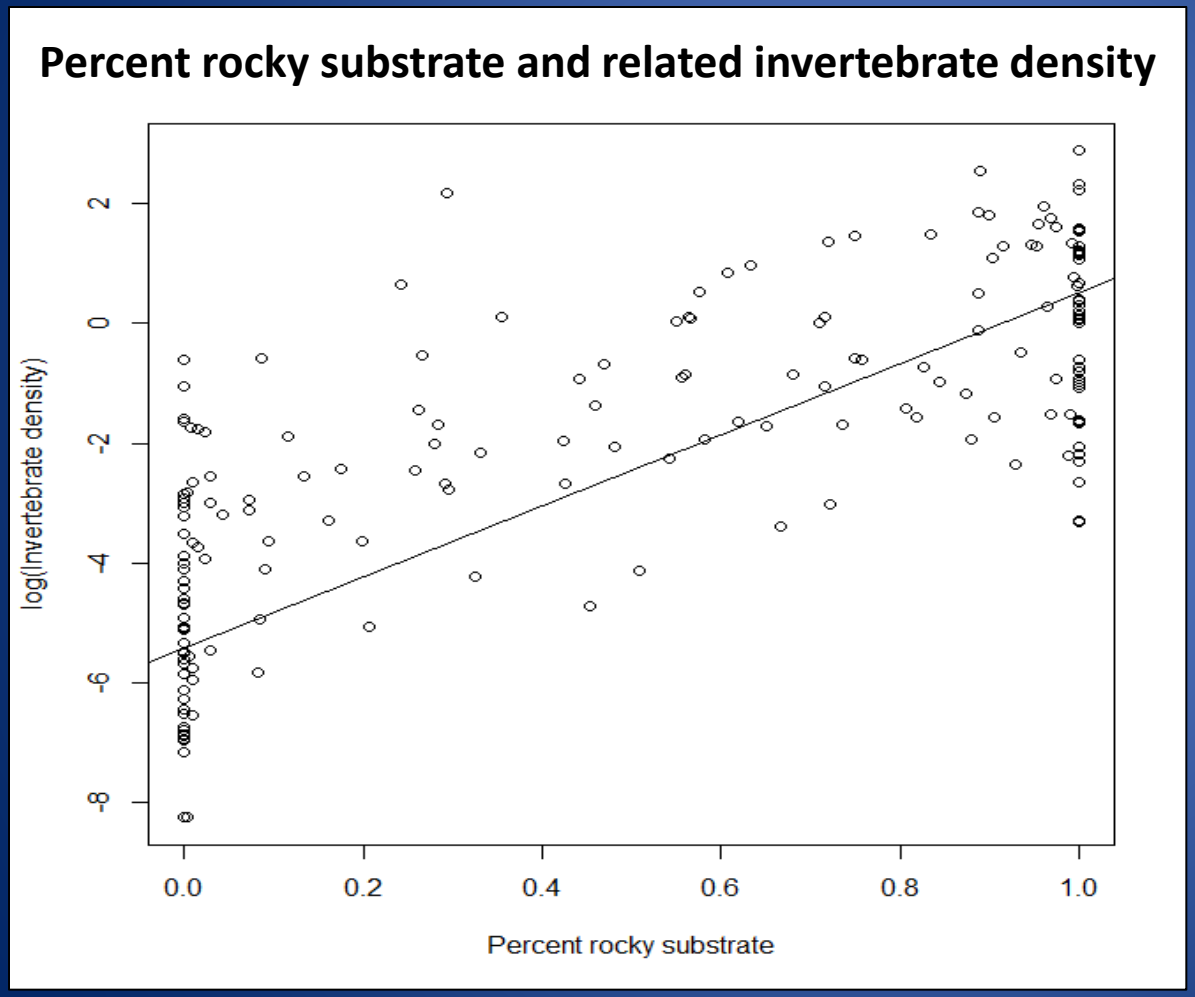
- Density, Distribution, & Vertical Structure



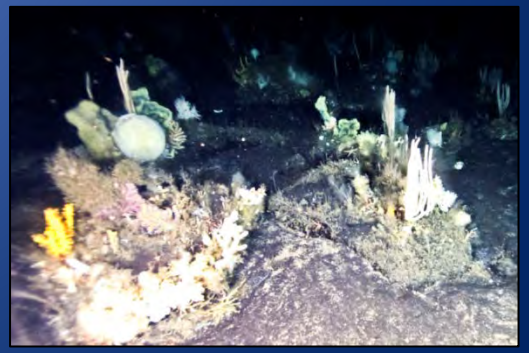
- Demosponges, hexactinellids, and primnoids all significantly taller ($p<0.01$) on rocky habitats
- Sea whips significantly taller ($p<0.01$) on unconsolidated substrate

Aleutian Islands –

If there are rocks, there will be some coral or sponge

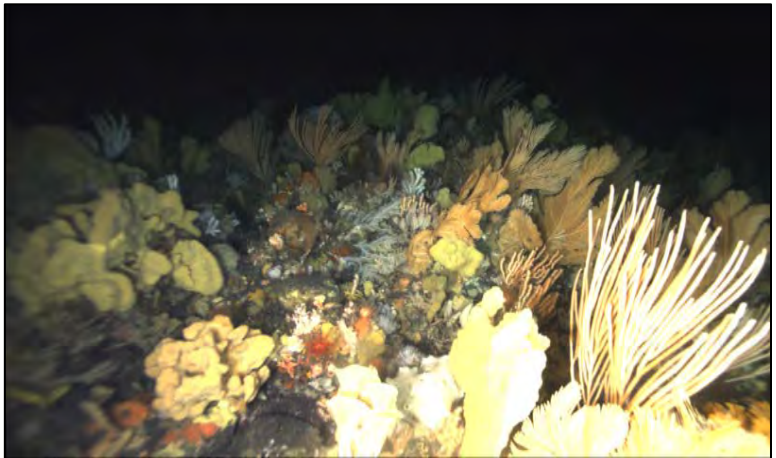


- Strong association of coral ($p<0.0001$, $R^2=0.54$)and sponge (0.0001, $R^2=0.58$) to rocky substrate

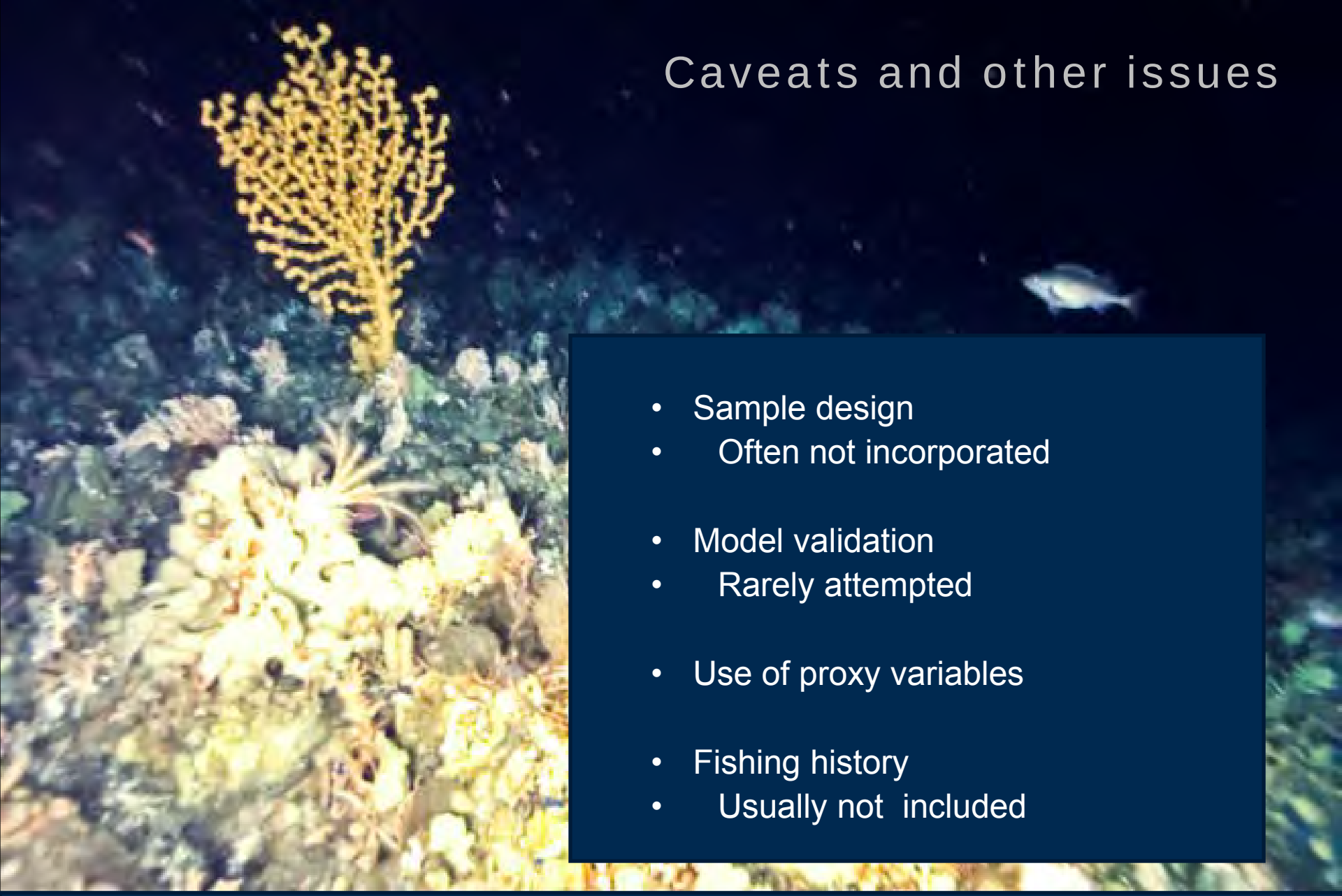


Models with substrate

- Coral ~ Substrate + Tidal Current + Depth
  - Explains 60% of variance in density 50% of presence
- Sponge ~ Substrate + Tidal Current + Depth
  - Explains 66% of variance in density, 55% of presence



Caveats and other issues



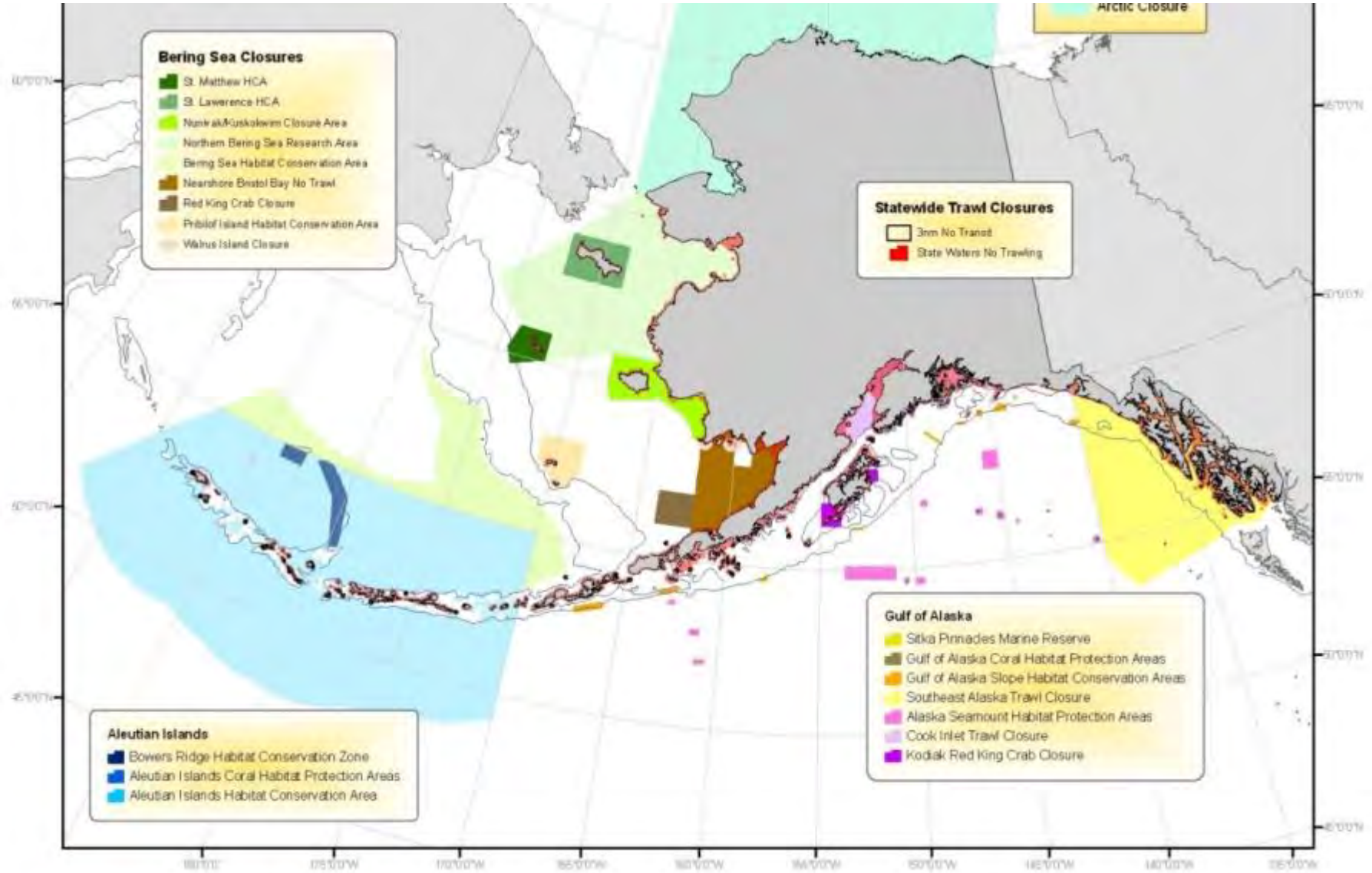
- Sample design
- Often not incorporated

- Model validation
- Rarely attempted

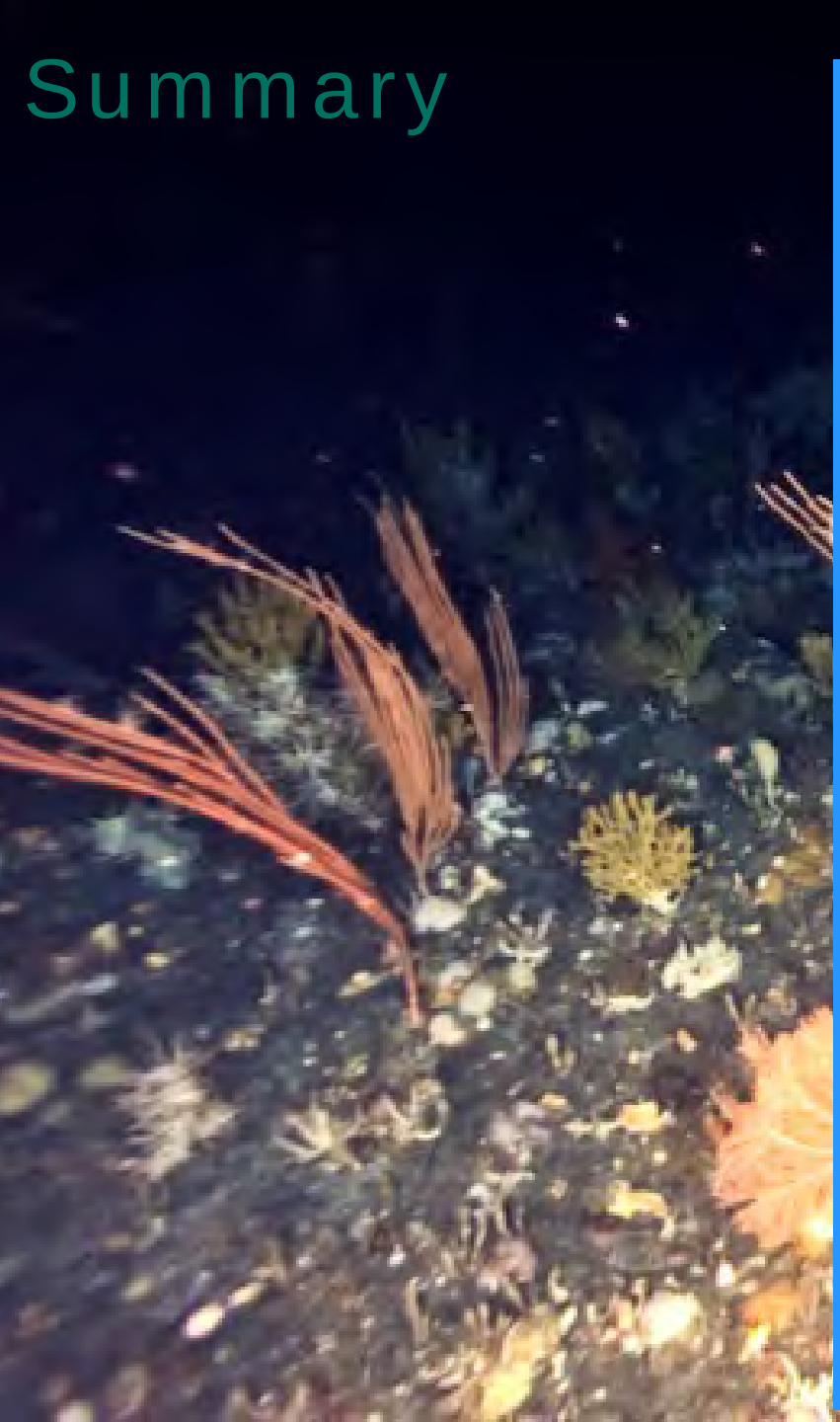
- Use of proxy variables

- Fishing history
- Usually not included

Open or closed to mobile fishing gear



Summary



Large scale processes (basin-wide)

- —Aragonite/Calcite saturation depth
- —Temperature
- —Productivity
- —Currents
- —Slope

Medium scale processes (~10-100 km

- —Depth/Slope
- —Temperature
- —Particulate organic carbon
- —Current speeds

Small scale processes (~1 m – 10 km

- —Substrate
- —Current speeds

Future Directions

Large-scale mapping

Ensemble models

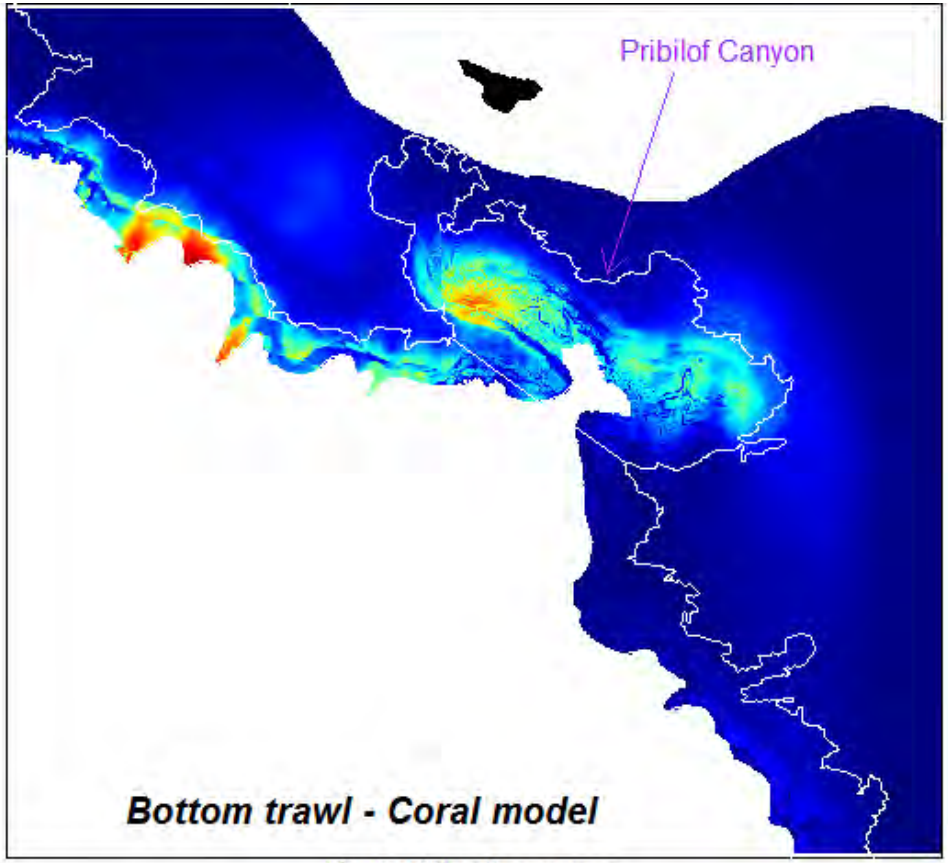
Reducing the number of proxy variables

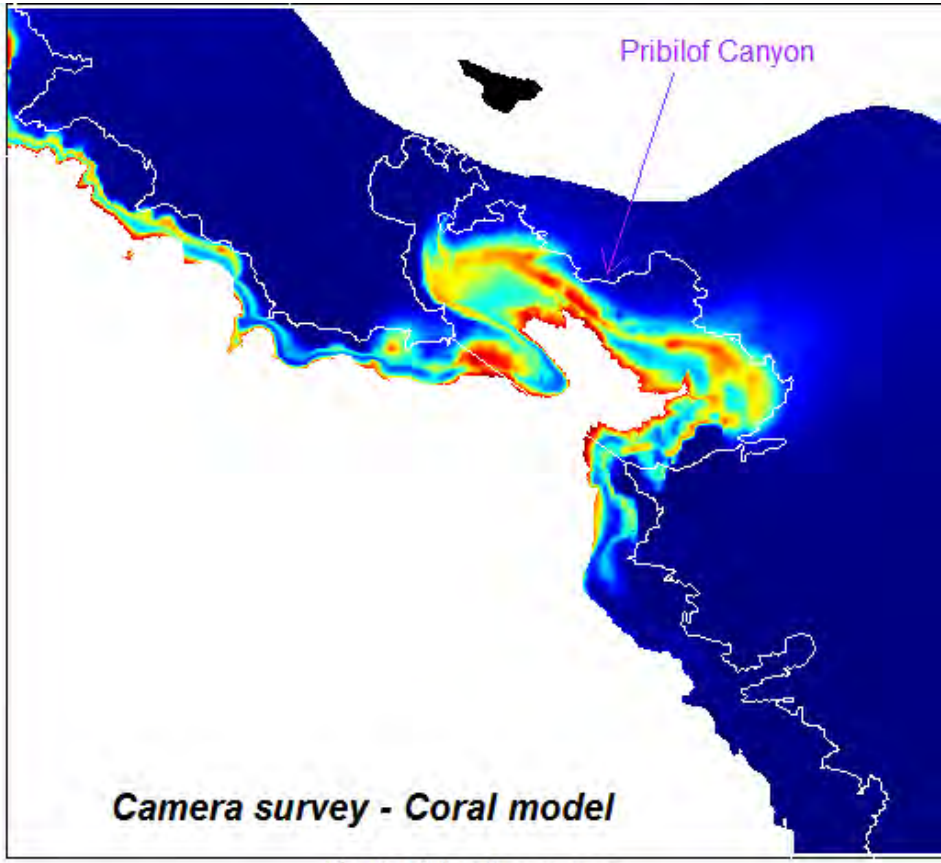
Predicting effects of climate change on distribution

Impacts from human activities (fishing, deep-sea mining, oil and gas development

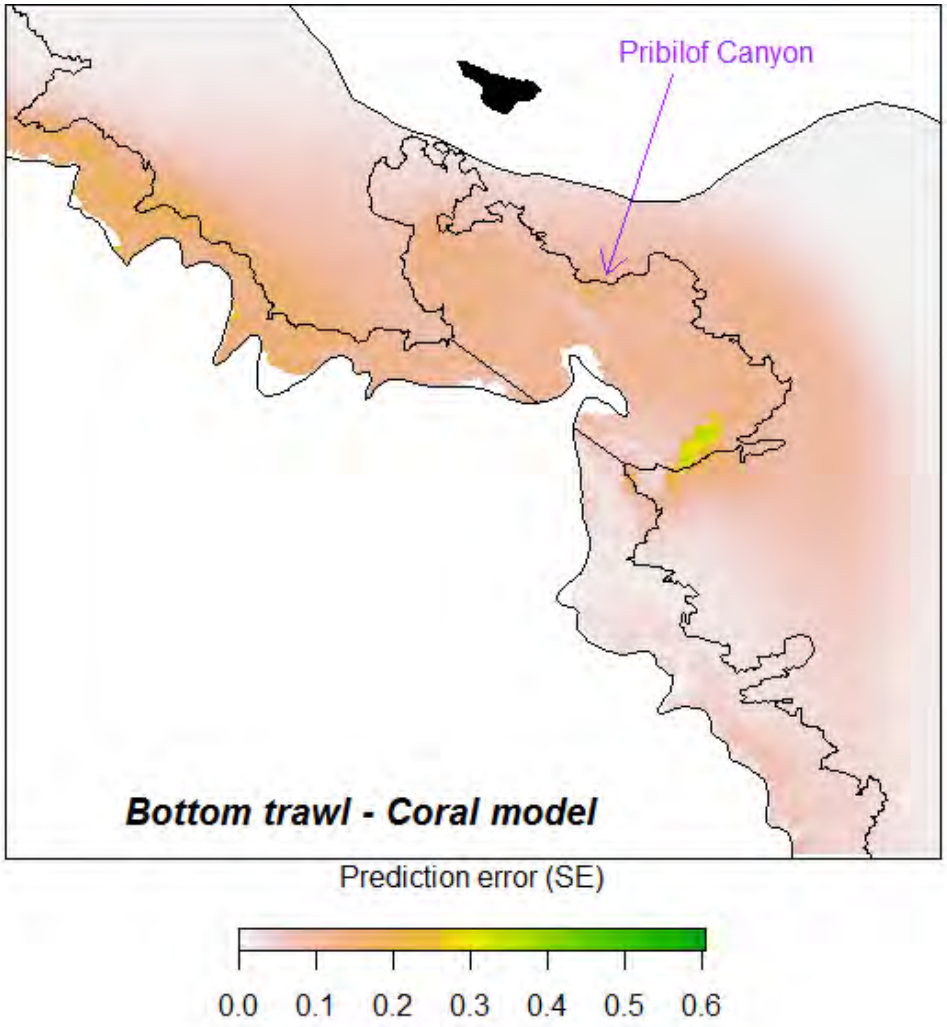
Moving coral and sponges into stock assessment framework

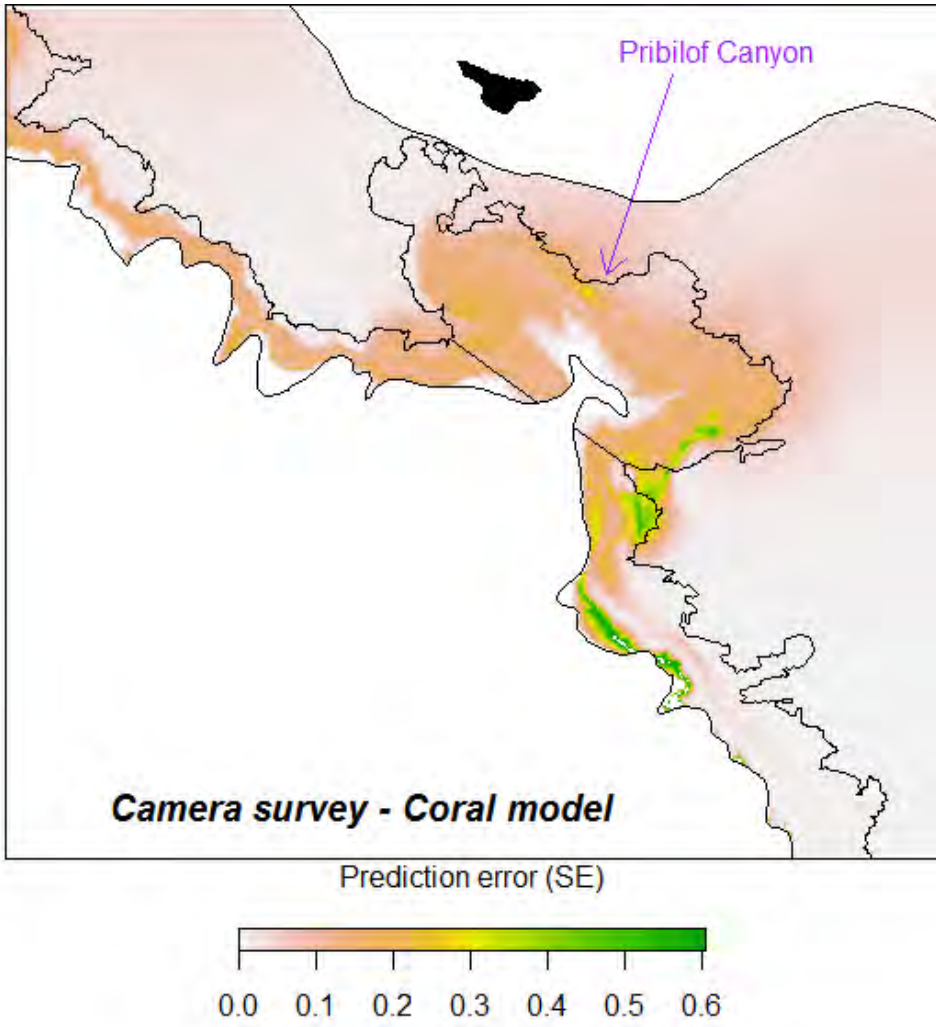
Prediction Averaging





Model Error


Pribilof Canyon
Bottom trawl - Coral model
Prediction error (SE)
0.0 0.1 0.2 0.3 0.4 0.5 0.6


Pribilof Canyon
Camera survey - Coral model
Prediction error (SE)
0.0 0.1 0.2 0.3 0.4 0.5 0.6

Unified coral model