



Performance Testing of Ecosystem Indicators across Multiple Spatial Scales for the California Current

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2010 NOAA Integrated Ecosystem Assessment for the California Current

Levin and Schwing, In press.
Levin et al. 2008 NOAA Tech Memo
Levin et al. 2009 PLOS Biol

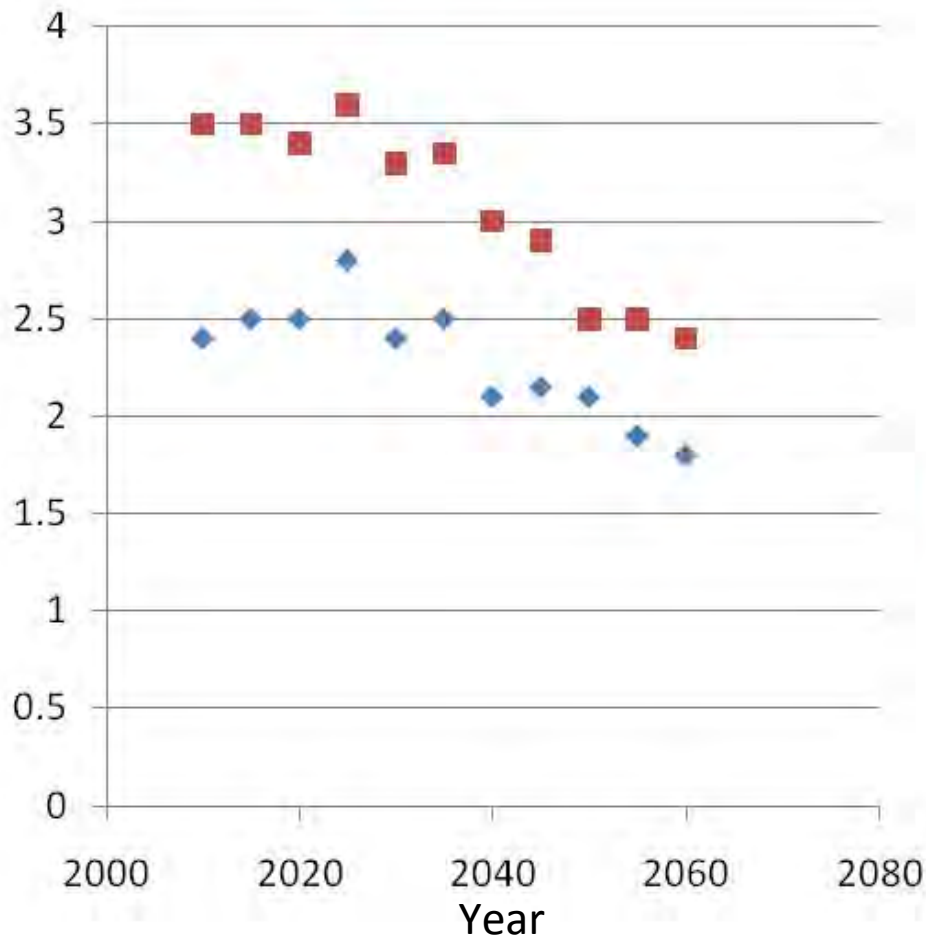
Groundfish



Ecosystem Health



Indicator/ Attribute Testing

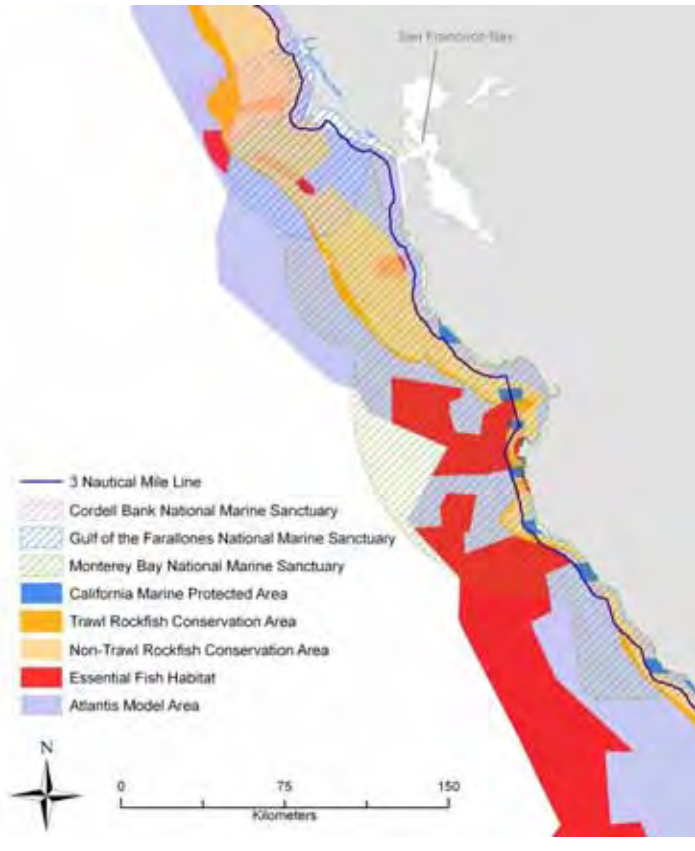


Correlation = 0.94

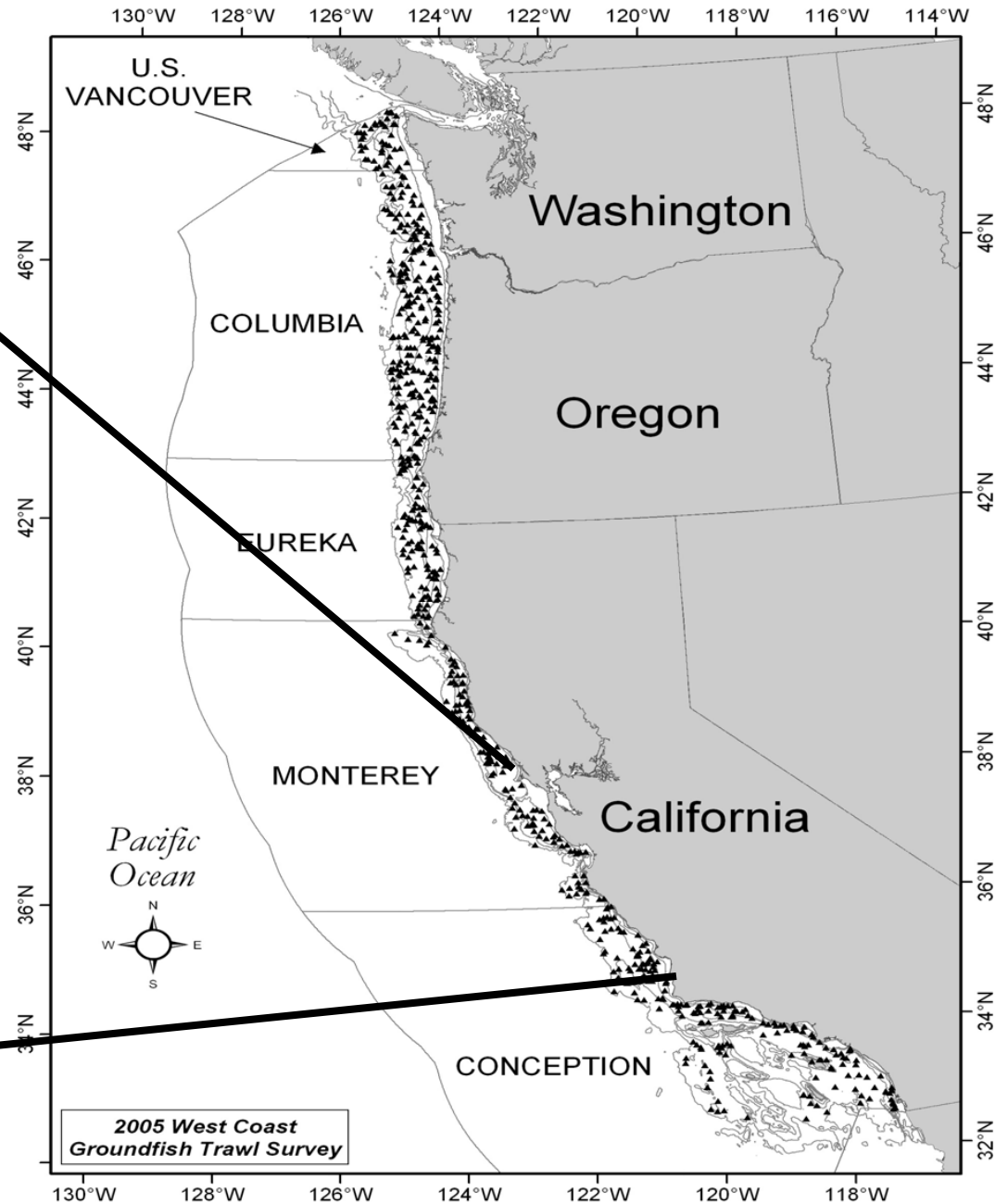
- ◆ Mean trophic level of system biomass
- Mean trophic level of the catch

We want to test the strength of the attribute-indicator correlation across a range of **scenarios**, driven by spatially explicit fishing, marine protected areas, and nutrients

Local scales



Coast-wide scale



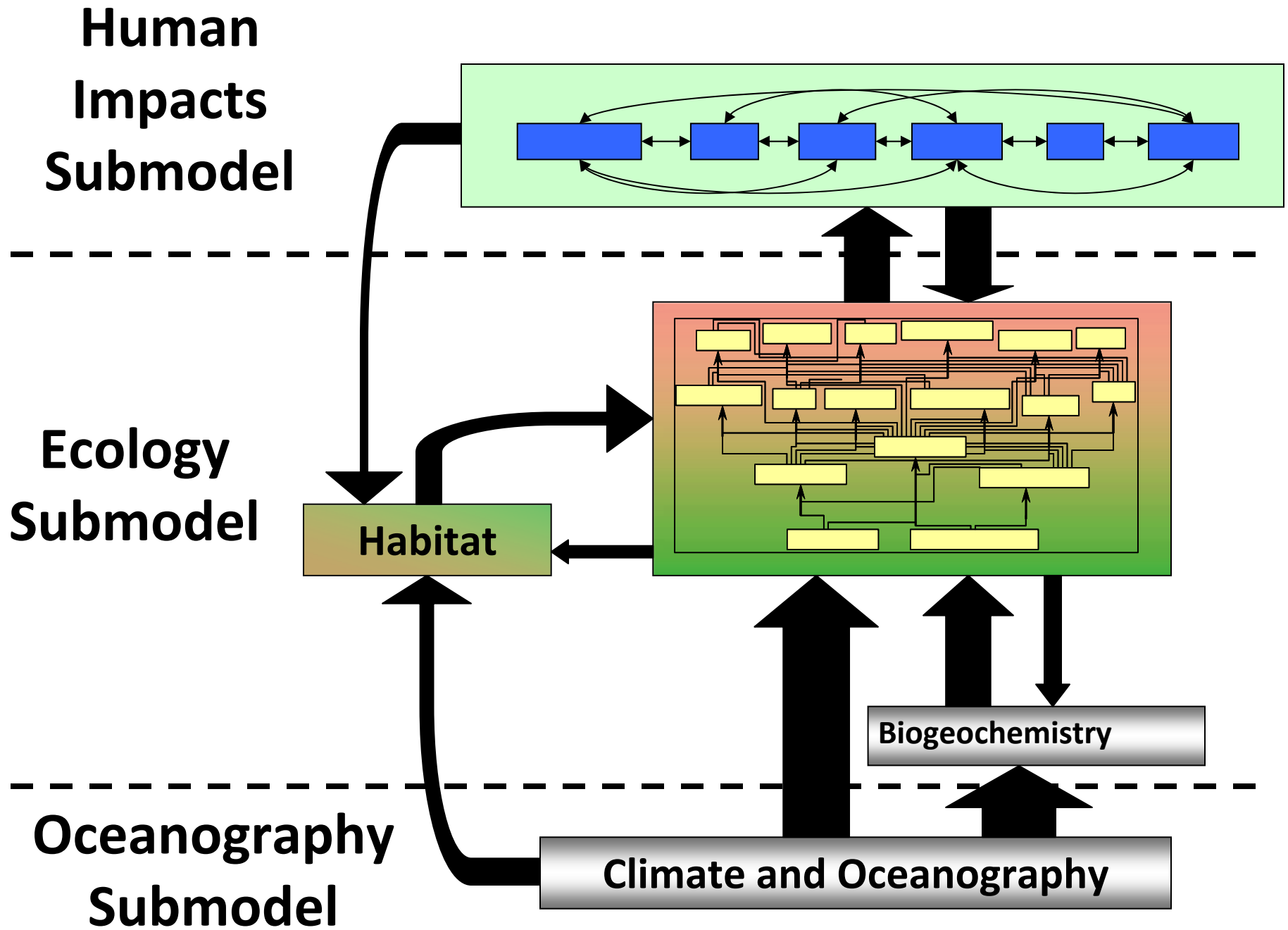
Examples of spatial scaling

		Indicators	Indicators
		Coast-wide	Local
Attributes	Coast-wide	<p>Coast-wide survey to determine coast-wide population status</p>	<p>Upscaling: local monitoring to infer coast-wide population status</p>
	Local	<p>Downscaling: inferring local attribute status from a coast-wide survey and population estimate</p>	<p>Local monitoring within a protected area to determine population status within the protected area</p>

Spatial Scaling of Indicators

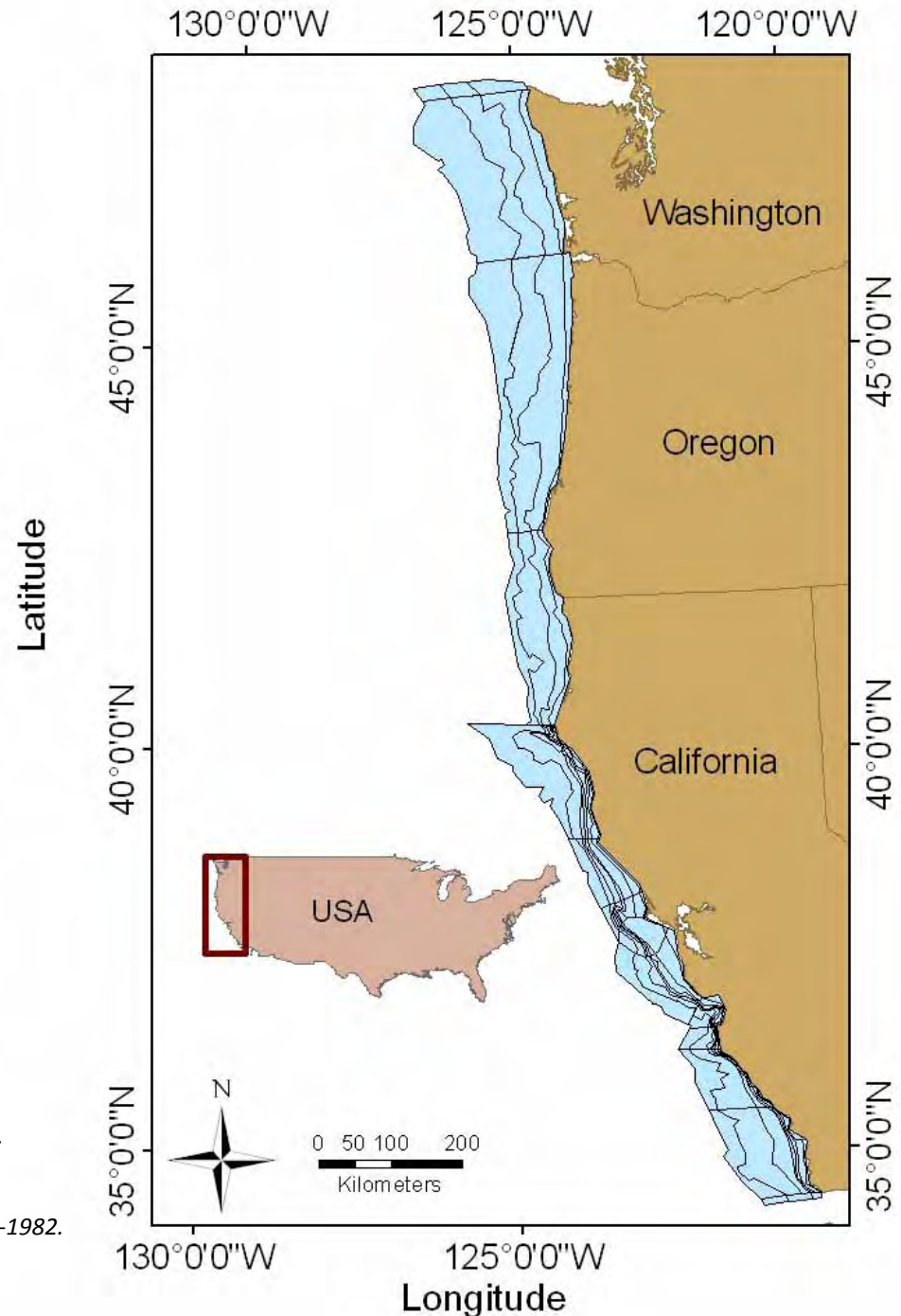
For scenarios that are spatially heterogeneous (Protected Areas, Nutrients, and Fishing Hotspots):

- Do you need different attribute-indicator pairs at local scales than coast wide scales?
- What do local indicators tell you about coast-wide attributes?
- What do coast-wide indicators tell you about local attributes?



Atlantis Model of the California Current

- 94,000 km²
- 3 primary producer groups
- 2 bacteria groups
- 3 infaunal invertebrate groups
- 9 epifaunal invertebrate groups
- 5 pelagic invertebrate groups
- 21 fish groups
- 3 seabird groups
- 6 marine mammal groups
- 2 detritus pools



Brand, E. J. et al. 2007. NOAA Tech. Memo. NMFS-NWFSC-84.

Kaplan, I.C., and P.S. Levin. 2009. In: *The Future of Fisheries Science in North America*.
Beamish, Richard J.; Rothschild, Brian J. (Eds.).

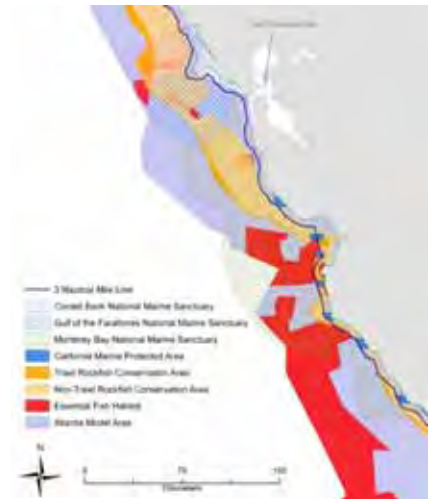
Horne, P., et al. NOAA Tech. Memo., 2010, NMFS-NWFSC-104.

Kaplan, I.C., et al.. 2010. *Canadian Journal of Fisheries and Aquatic Sciences* 67: 1968-1982.

Scenarios: Projecting 2010-2060

Marine protected areas

- 50% closure of all coastal boxes
- 100% closure of Central California Sanctuaries
- 100% closure off Oregon, Monterey Bay, and Cordell/Farallones Sanctuaries



Fishing hotspots

- 1.5x, 2x off Oregon, Monterey, and Moss Landing



Nutrient addition

- low, medium, high, 5x high, 10x high

Local attributes or indicators = within marine protected areas, fishing hotspots, or coastal boxes



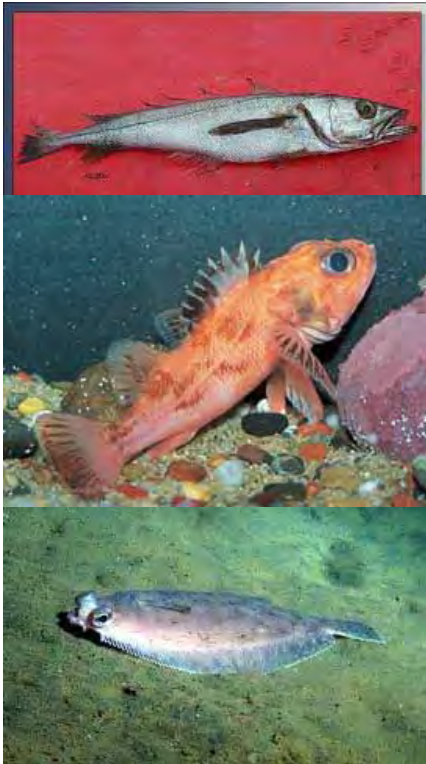
Attributes

Groundfish

- Fishery target species' biomass
- Rockfish biomass
- Total catch
- Proportion of groundfish mature
- Number of depleted unassessed species (less than B40%)
- Number of severely depleted unassessed species (less than B25%)

Ecosystem Health

- Net primary productivity
- Mean trophic level of biomass
- Biodiversity (Shannon index)
- Net primary productivity/ biomass
- Total Biomass



Indicators

Species abundance and catch

Num. depleted assessed groundfish
Num. severely depleted assessed groundfish
Bottomfish
Roundfish
All Rockfish
Lingcod
Shallow large, midwater, and shortbelly rockfish
Halibut and small flatfish
Shallow large rockfish
Shallow small rockfish
Shallow and midwater rockfish
Lingcod and rockfish

Population condition

Shallow large rockfish % mature
Midwater rockfish % mature
Shortbelly rockfish % mature
Lingcod % mature
Num. juvenile groundfish
Num. juveniles, assessed species
Mean weight at maturity, groundfish
Mean weight at maturity, assessed species

Species abundance and catch

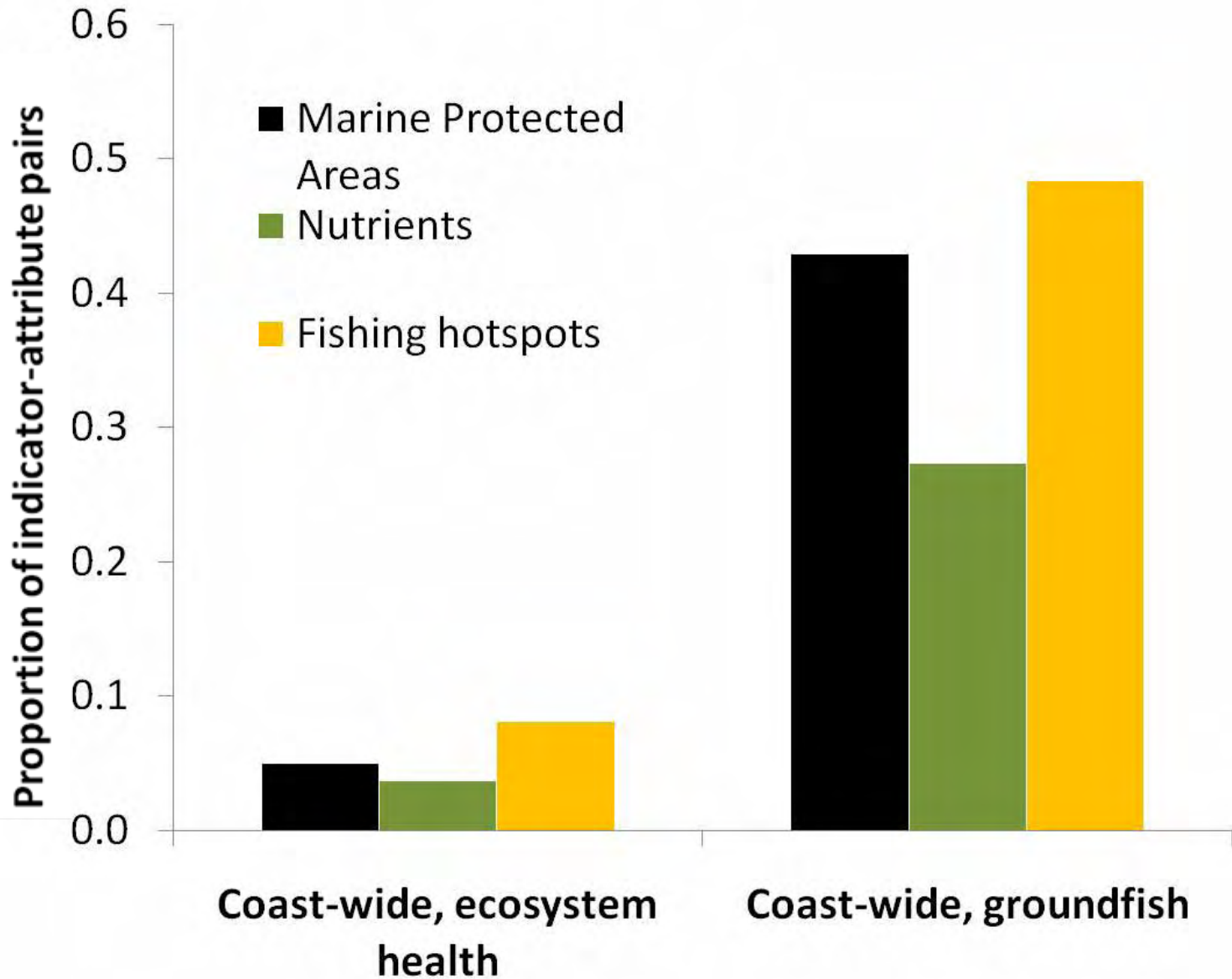
Mean trophic level of the catch
Unfished species biomass
Forage fish
Zooplankton
Krill
Phytoplankton
Flatfish
Salmon
Sablefish biomass
Benthic invertebrates
Reef top invertebrates
Habitat-forming species
Kelp
Seastar, abalone, urchins
Dungeness crab and seastars
Dungeness and other crabs
Gelatinous zooplankton
Marine mammals and birds
Seabirds
Diving and migratory birds
Baleen whales
Pinnipeds
Sea otters
Marine mammals
Cetaceans

Feeding guilds and abundance ratios

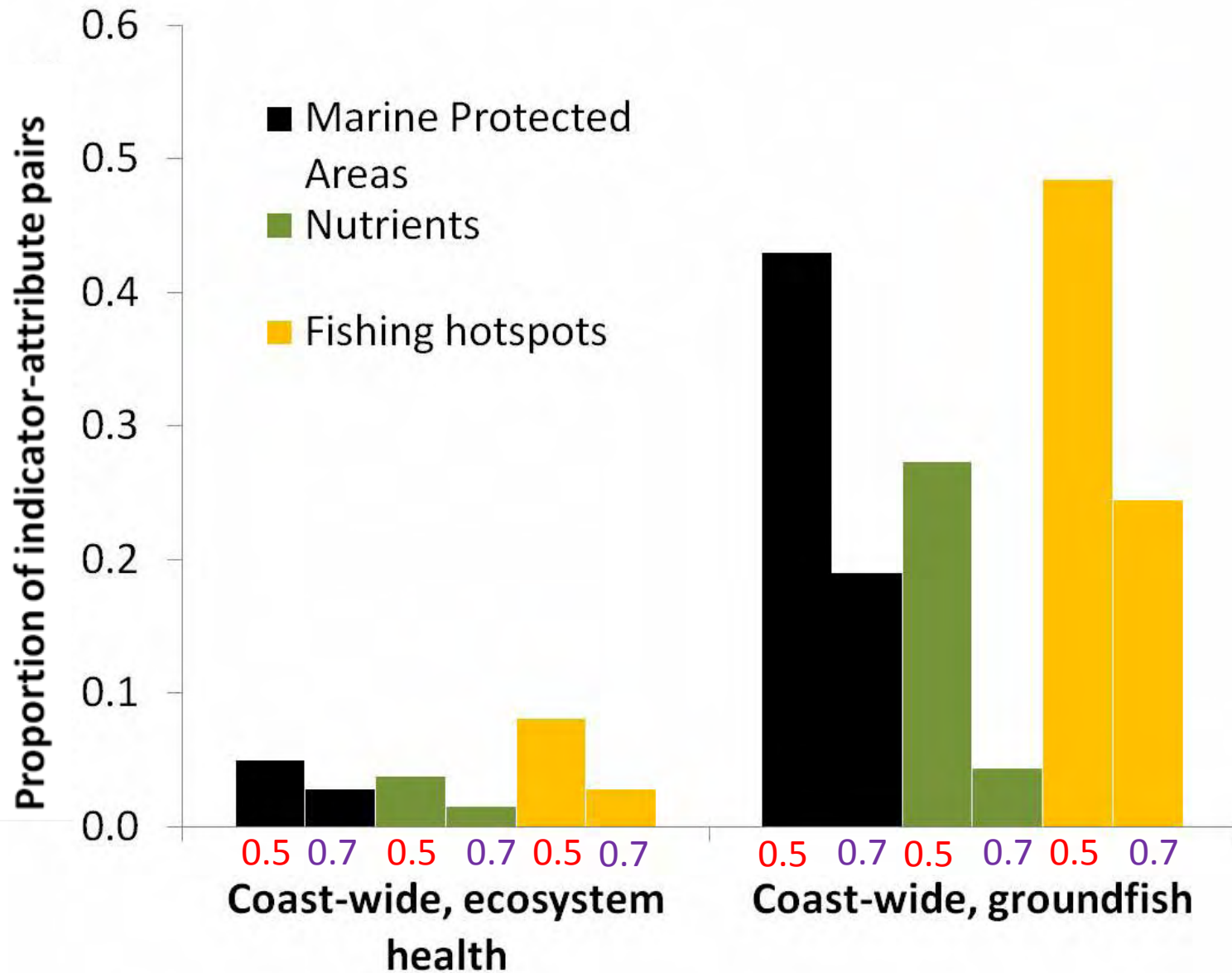
Rockfish/Flatfish
Detritivores
Herbivores
Piscivorous fish
Zooplanktivorous fish
Planktivores
Invertivores
Benthic fish/pelagic fish
Piscivorous fish/planktivorous fish
Piscivorous fish/scavengers
Forage fish/jellyfish
Finfish biomass/crustacean biomass
Invertivores/herbivores

Results

Correlations with $|r|>0.5$: More attribute-indicator pairs for groundfish than ecosystem health



Correlations with $|r|>0.7$ are rare versus $|r|>0.5$



Ecosystem Health

- Degradation of ecosystem health resulted in increased primary production, low diversity, and low abundance of many target species that are invertivores.

Indicators: Net primary productivity, phytoplankton, forage : jellyfish ratio, finfish: crustaceans, invertivores

Attributes of ecosystem health tend to be impacted at a local scale, and relevant indicators tend to involve groups and species that operate at a similar local scale.



Groundfish

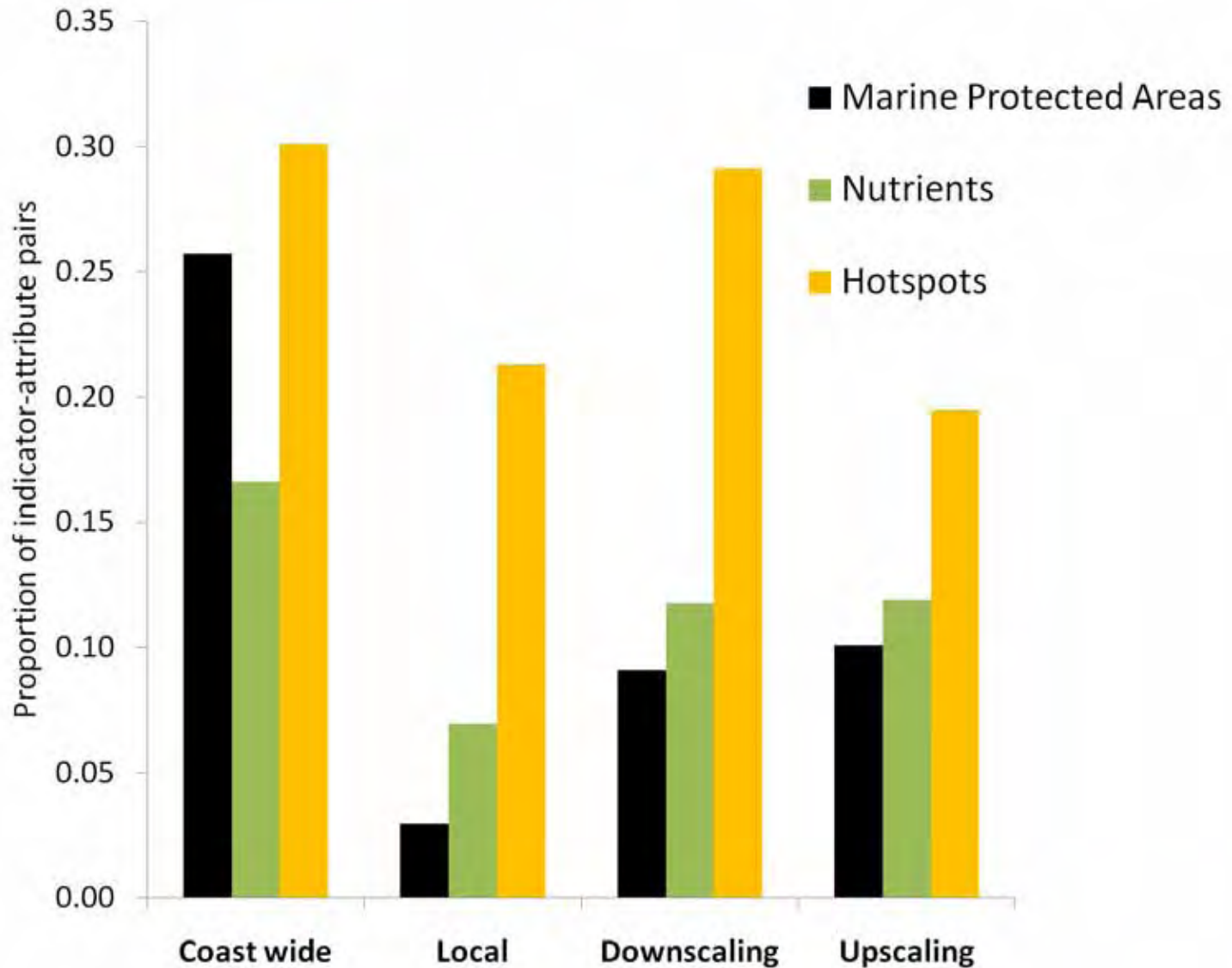
- Groundfish attributes were related to:

Direct metrics of groundfish, but also mammals, birds, benthic invertebrates, pinnipeds, and sea otters, seastars, abalone, sea urchins, and some crabs.

Many of these groups have strong, coast-wide trends, which are spatially synchronous due to stock-level migration and coast-wide distribution of recruits.

Spatial scaling

Attribute-indicator relationships that are strong at the coast-wide scale may break down at the local scale and across scales



Downscaling and upscaling yield intermediate #'s of correlations. 'Fishing Hotspots' differs from this.

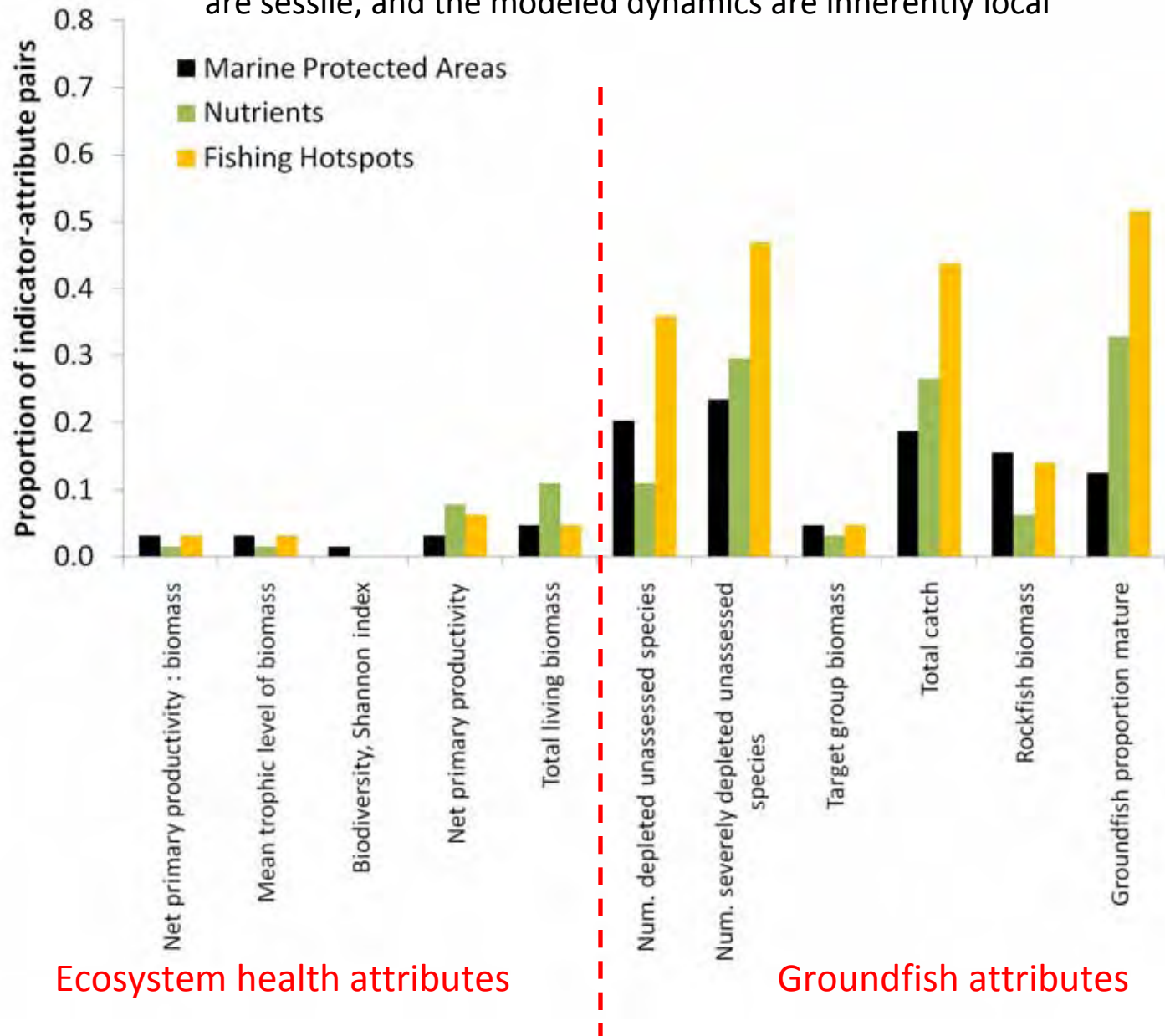
Most indicators selected at local or mixed scales are a subset of indicators selected at the coast-wide scale, with the main exceptions in the Fishing Hotspots and Nutrient scenarios...

At the local scale for the nutrient scenario , additional indicators were added such as metrics of crabs, other invertebrates, scavengers, and rockfish



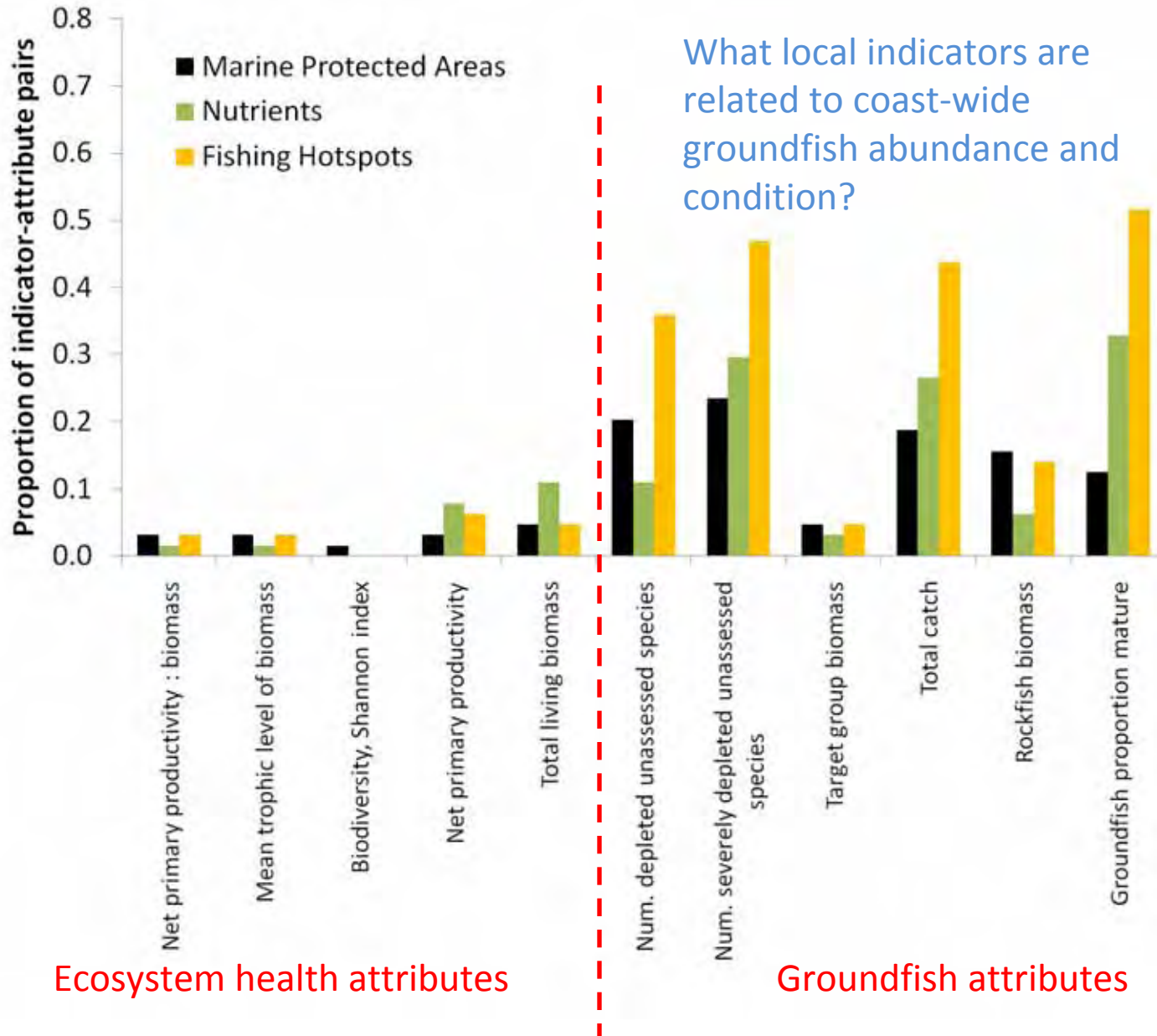
Downscaling and Upscaling

Upscaling leads to a moderate number of strong relationships between attributes and indicators, particularly for groundfish attributes. For ecosystem health attributes, many of the components and species are sessile, and the modeled dynamics are inherently local



Ecosystem health attributes

Groundfish attributes



Upscaling: Local indicators related to coast-wide groundfish

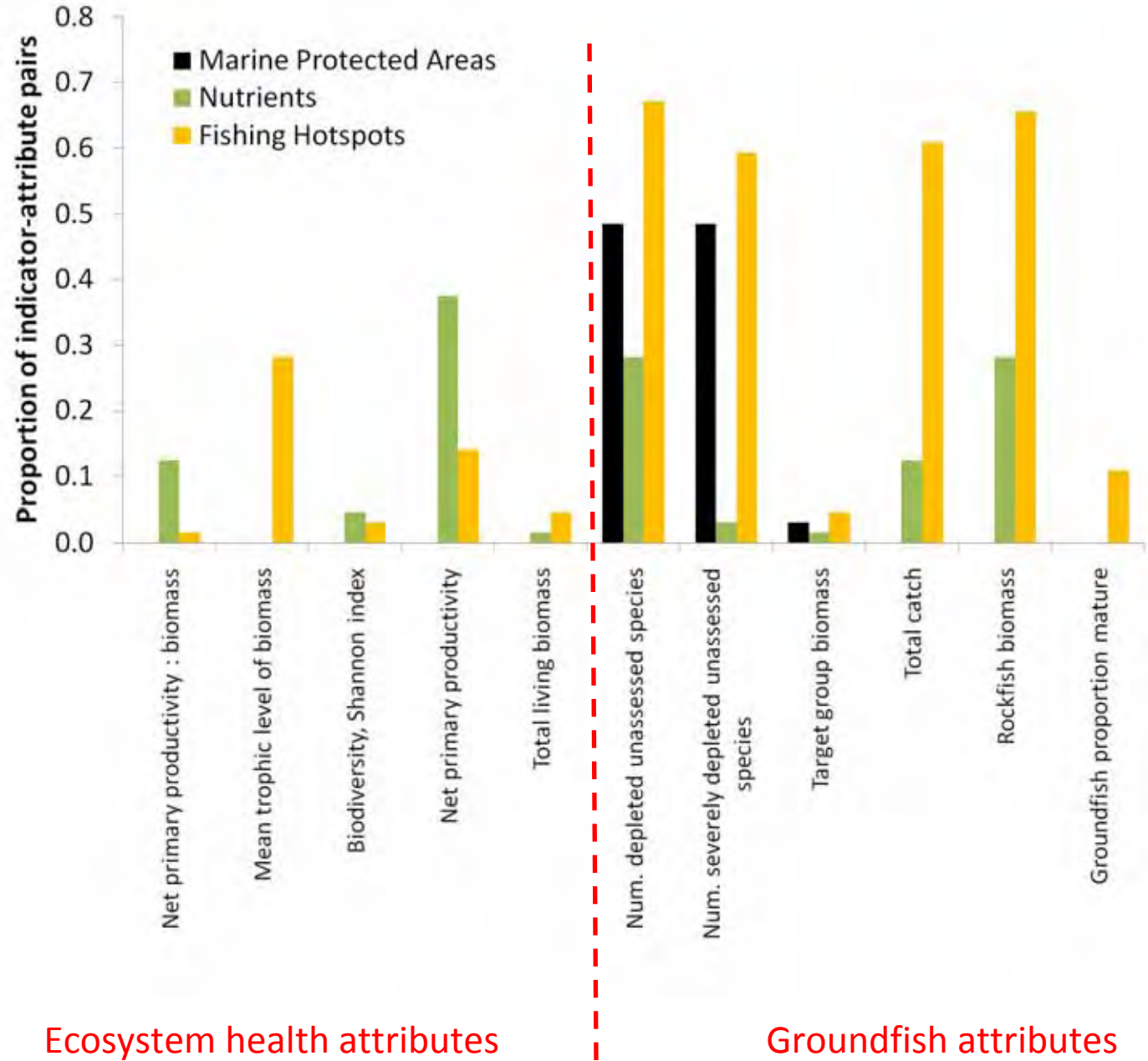


- Indicators consistent across scenarios types included:

Krill, zooplankton, benthic invertebrates, habitat-forming species, herbivores, and sea otters

These species tend to be highly abundant, are key prey of groundfish, or have strong trends in abundance.

Downscaling leads to very few strong, consistent relationships between attributes and indicators



Ecosystem health attributes

Groundfish attributes

Summary

- More attribute-indicator pairs for groundfish than for ecosystem health
- Strong correlations ($|r| > 0.7$) were rare
- Attribute-indicator pairs selected for coast-wide use may break down at local scales
- Downscaling unsuccessful
- Upscaling for ecosystem health attributes unsuccessful
- Upscaling successful for groundfish attributes, particularly with indicators related to species groups (not limited to groundfish) that had strong, synchronous coast-wide trends.
- Consider spatial scale of the underlying processes when selecting indicators

Acknowledgements

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