Meta-analysis of reef fish data in Hawaii to examine natural and anthropogenic processes

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Statement of need

- Reef fishes have declined in Hawaii
- Major obstacle to wise management is lack of comprehensive data
- Currently numerous disparate fisheries-independent datasets
- Information critical to:
  - Develop sustainable fisheries management
  - Improve existing MPAs
  - Aid in development of MPA network

Processes to be examined in Meta-analyses of Hawaiian Fisheries-independent data

- Spatial and temporal variation in fish assemblage structure (e.g., richness, biomass, trophic, L-H traits)
- Biogeographic gradient across the archipelago
- Effect of human population density
- Effects of oceanography (e.g. wave exposure, productivity)
- Contributions of remote areas
- Fish stock health across the archipelago
- Effectiveness of existing MPAs

Datasets to be used in analyses

- NOAA CRED, PMNM, NOAA Biogeography, DAR WHAP, DAR statewide, NPS, HIMB CRAMP, TNC, KIRC

Program	Contributor	Year range	Geographic coverage	Method
NOAA CRED	Williams	2000-2012	NWHI and MHI	Belt < 2008, SPC 2008
TNC	Conklin	2008-2012	Statewide	Belt
DAR - Kona	Walsh	1999-2012	West Hawaii	Belt
DAR - Maui	Sparks		Maui	Belt
DAR - Oahu	Schumacher		Oahu	Belt
NPS	Brown, Friedlander, Beets	2008-2012	Kalaupapa, Kaloko, Honaunau, Puukohola	Belt
FHUS (NOAA Biogeography)	Friedlander, Brown,	2000-2004	12 MLCDs and adjacent areas statewide	Belt
FHUS (NOAA Biogeography)	Friedlander, Wedding	2004-08	Pupukea, Honolua, Kealakekua, Hanauma	Belt
HCFRU	Friedlander	1992-2012	Hanalei	Belt
HCFRU	Friedlander	2012	Lanai	Belt
HCFRU	Friedlander	2012	Kaneohe Bay	Belt
CRAMP	Rodgers, Brown, Friedlander	1998-2012	Statewide	Belt

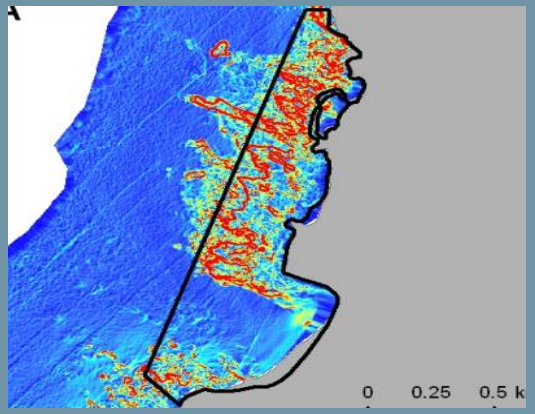
Bio-physical parameters to be used to examine correlations with fish assemblage structure

Category	Data source	Metrics
Anthropogenic influence	2010 Census	Human population density
Anthropogenic influence	Landuse/Landcover	USGS & State office of planning
Anthropogenic influence	Multiple	Watershed specific nitrogen footprints
Benthic habitat	LiDAR	Bathymetry (depth), slope, aspect
Benthic habitat	NOAA Habitat Maps	Benthic habitat zone, structure and cover
Oceanography	Wave Watch III	Wind/wave exposure
Oceanography	NOAA Pathfinder	sea surface temperature
Oceanography	SeaWiFS	Productivity

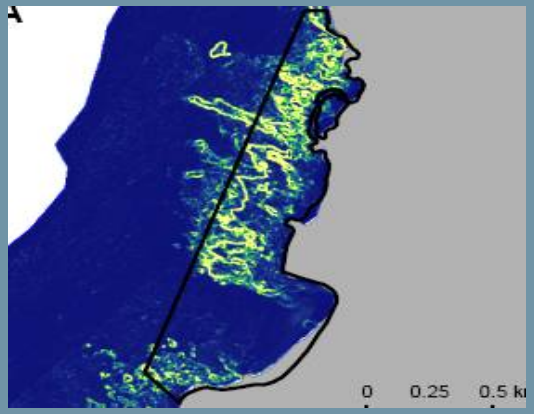
MHI Abiotic Spatial Data Sets

LIDAR DATA

Bathymetry

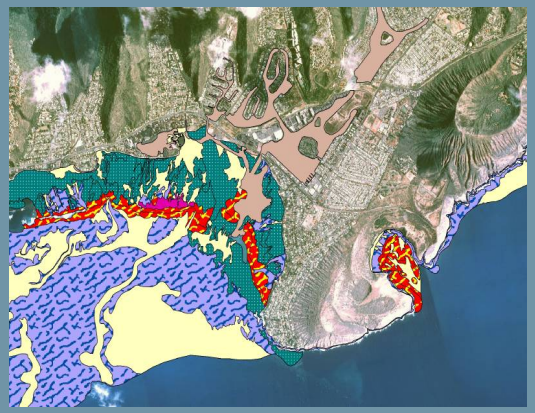


Percent Slope



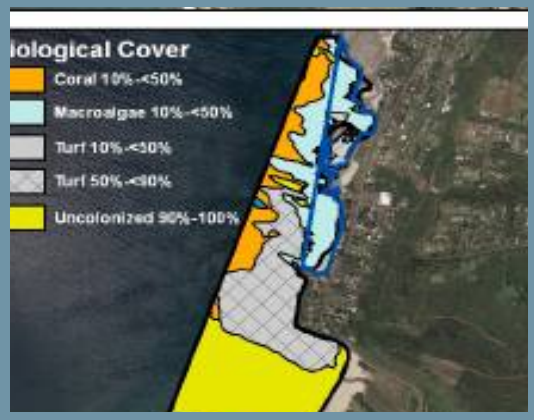
Rugosity

BENTHIC HABITAT DATA



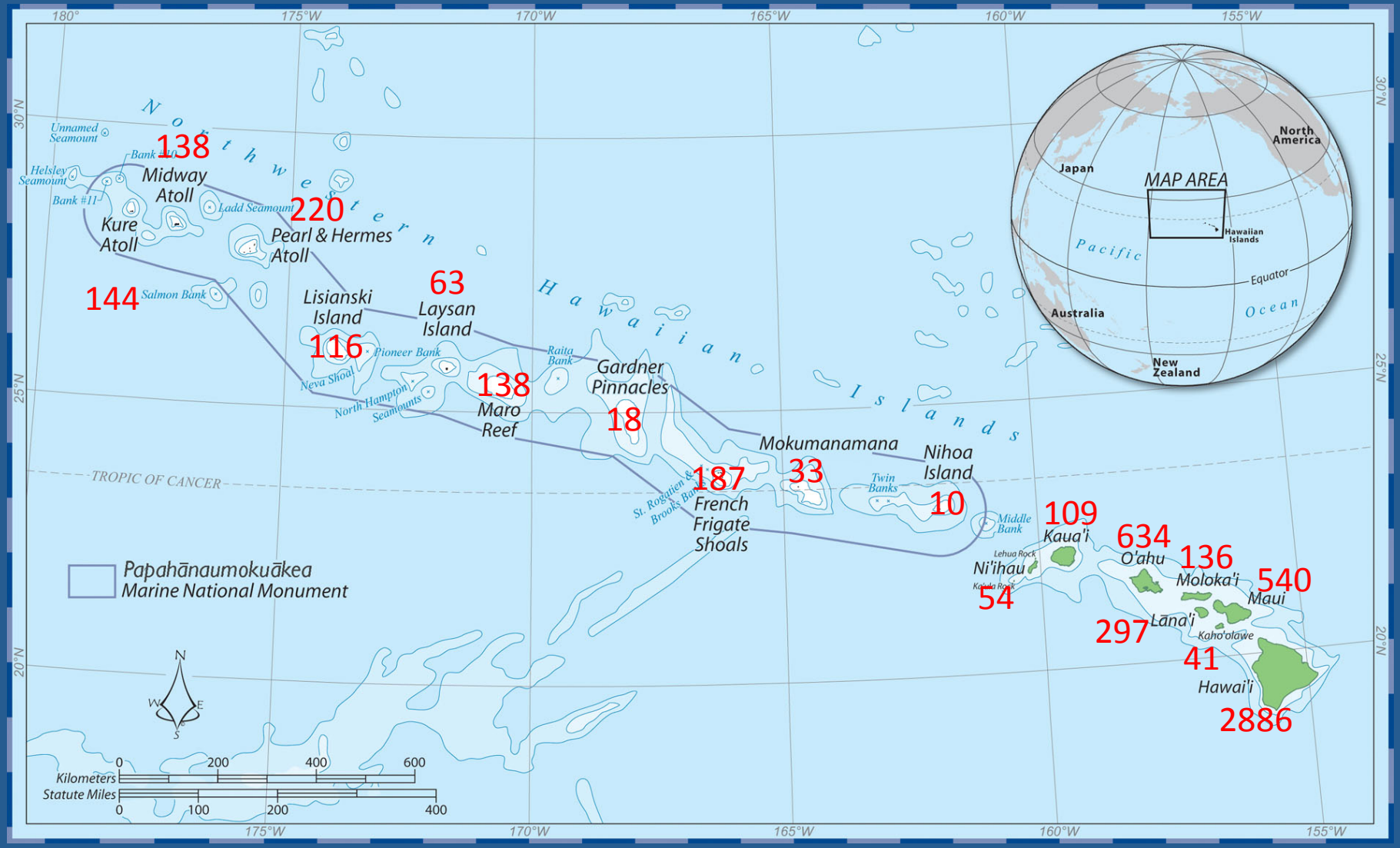
Zone

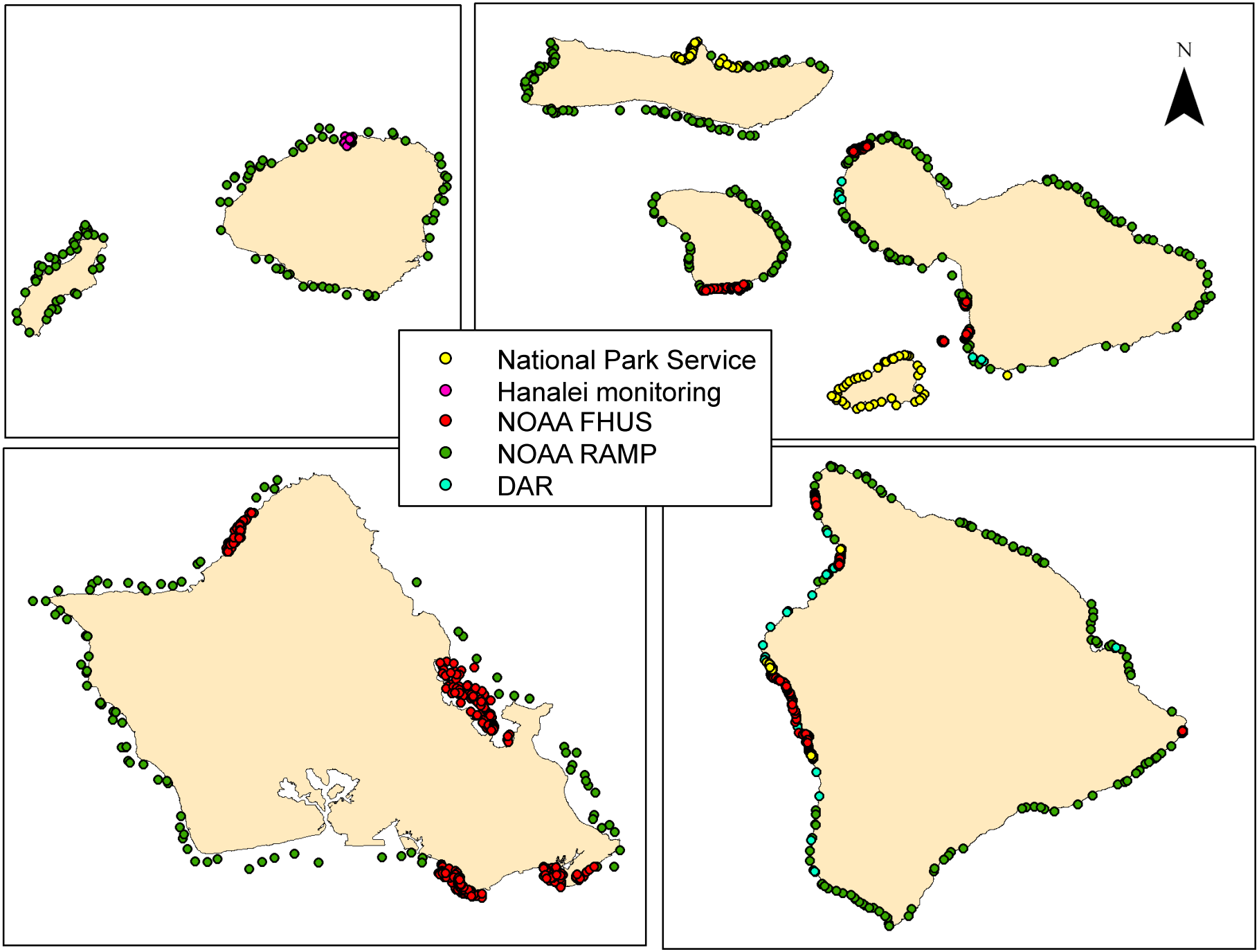
Geomorphic Structure



Biological Cover

Sample sizes by island for analyses




N
National Park Service
Hanalei monitoring
NOAA FHUS
NOAA RAMP
DAR

Meta-analysis - “An analysis of results”

Meta-analysis combines disparate studies to test of the hypothesis and explore its moderators.

Effect size: Magnitude of the treatment effect (e.g., % change per year)

Data weighted based on sample size & appropriate effect size & analytical models derived

$$A_R = [\log A_e - \log A_i]/d$$

$$A_r = \frac{\sum_{x=1}^{n}(W_X * A_{rx})}{\sum_{x=1}^{n} W_x}$$

AR - annual rate of change in density

Ae and Ai are numerical densities of a given reef fish species at the end and start, of the time series at a given reef,

d is the length of the time series in years.

Individual effect sizes weighted by spatial area covered in each fish survey (e.g., area of transect multiplied by number of replicate transects per survey),

Recent Region-wide Declines in Caribbean Reef Fish Abundance

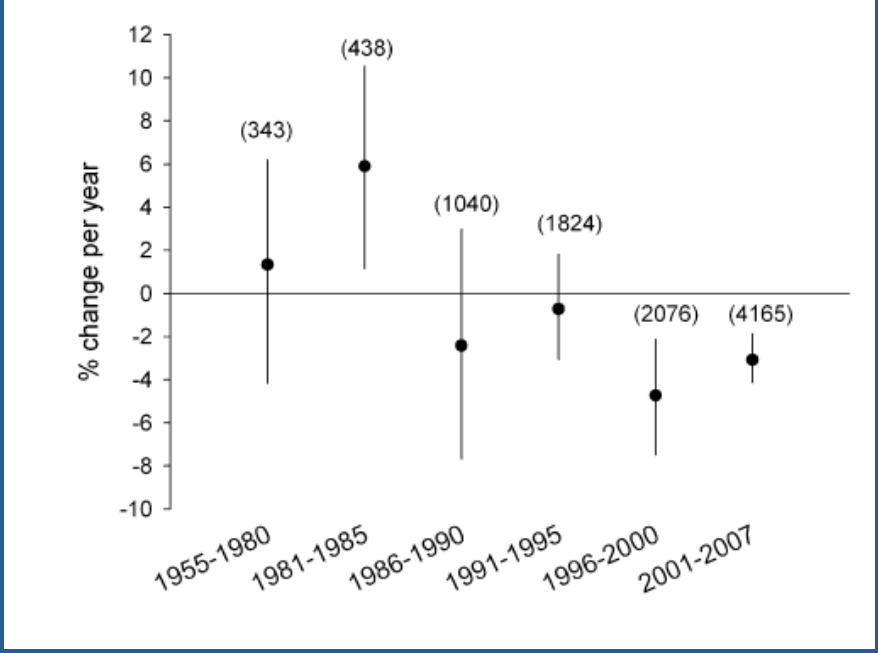


Figure 1. Annual Percent Change in Fish Density per 5-Year Period

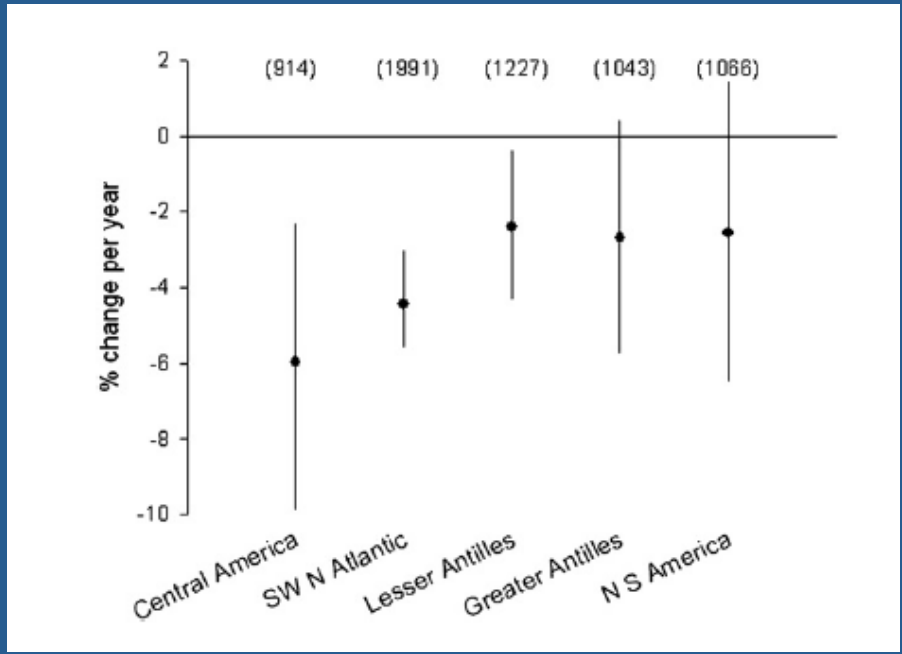
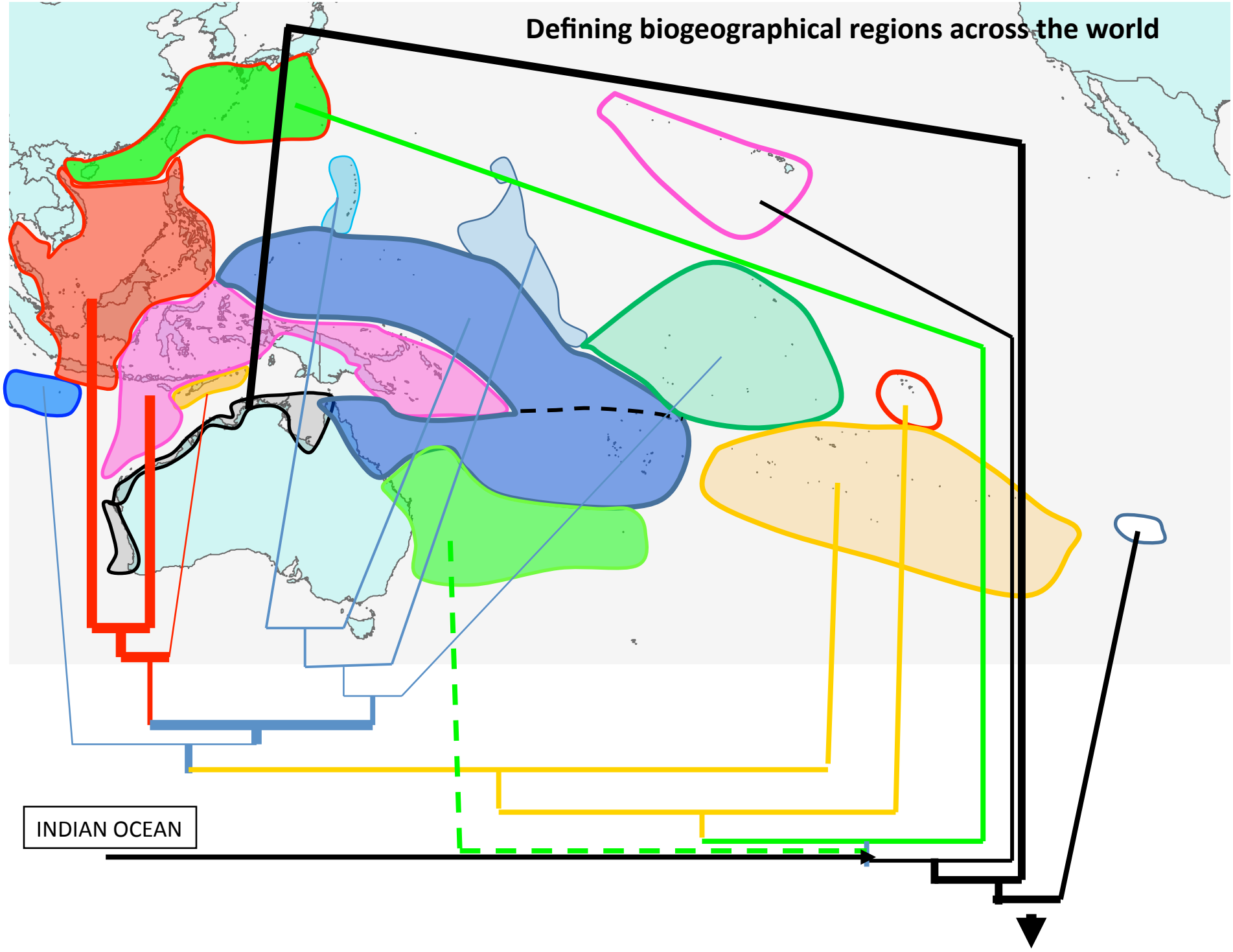


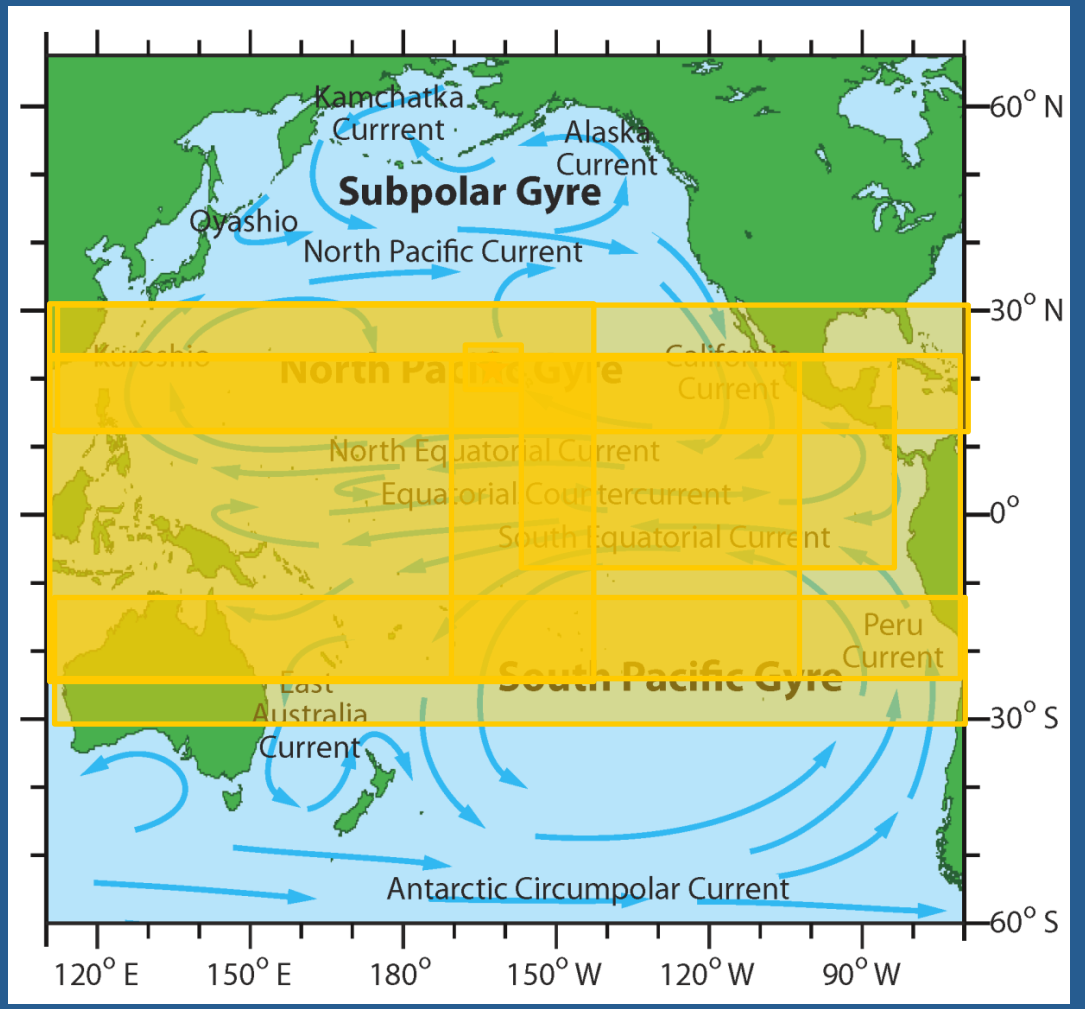
Figure 2. Annual Percent Change in Fish Density across Five Subregions of the Caribbean Basin 1996–2007

Paddock, MJ *et al.* (2009) Recent Region-wide Declines in Caribbean Reef Fish Abundance. *Current Biology* 19: 590-595


Defining biogeographical regions across the world
INDIAN OCEAN

Zoogeography of the inshore Hawaiian fish fauna

- Circumglobal
- Wide-ranging Indo-Pacific
- Eastern tropical Pacific
- Japan to Taiwan
- Antitropical
- Central Pacific
- Waifs
- Endemics



Randall, J.E. (1995) Zoogeographic analysis of the inshore Hawaiian fish fauna. In: Marine and Coastal Biodiversity in the Tropical Island Pacific Region, J.E. Maragos *et al*. (eds). East-West Center, Honolulu, HI. 193-203

Zoogeographic categories of inshore fish fauna

Hawaii is subtropical - Some species distribute based on temperature

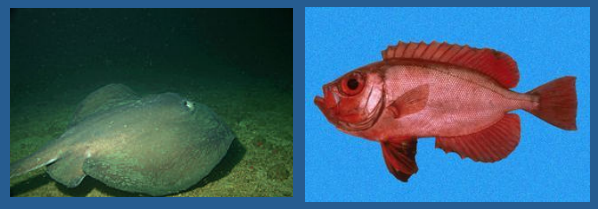
Indo-Pacific

Japan-Taiwan

Circumglobal

Central Pacific

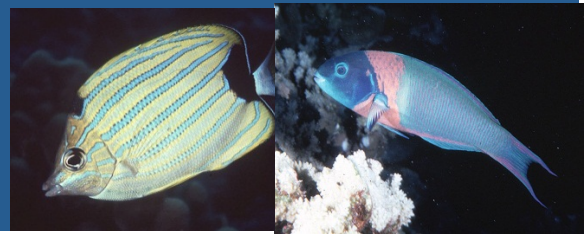
Eastern tropical Pacific



Antitropical

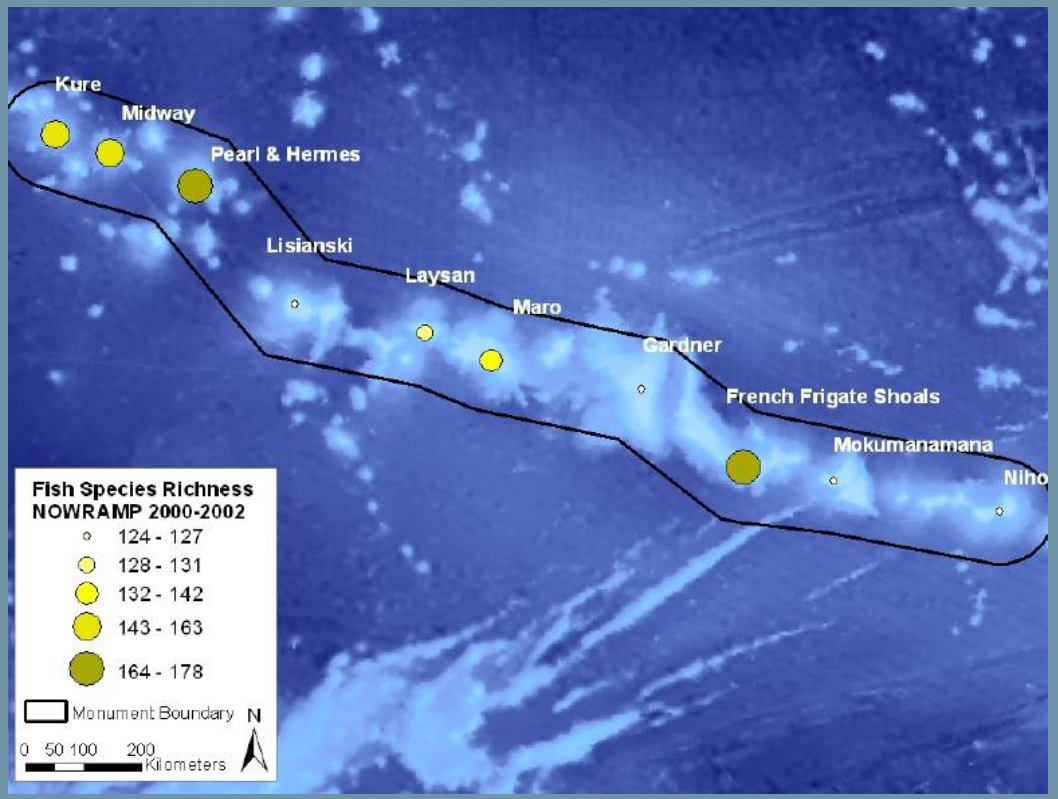
Waifs

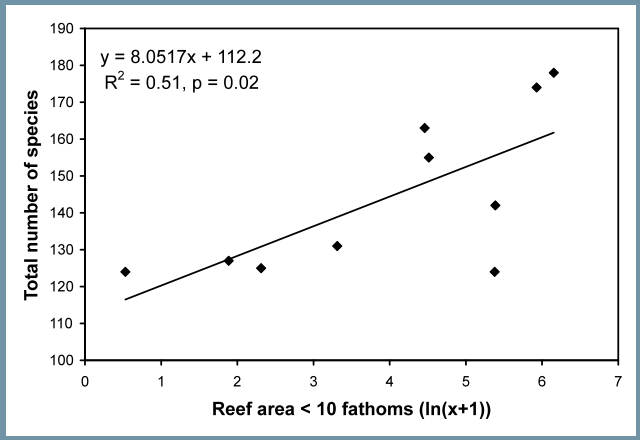
Endemic



Fish species richness

- Overall lower richness in NWHI relative to MHI
- Lowest at small basalt islands
- Positive relationship w/ reef area (island biogeography theory)



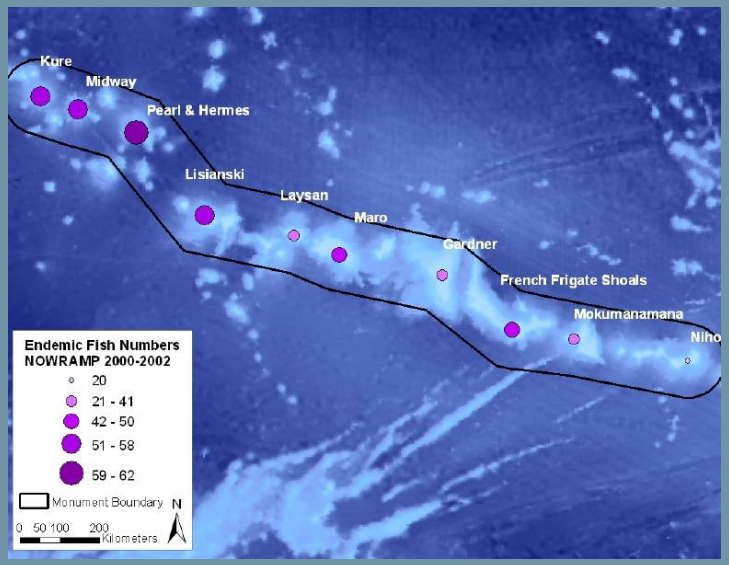


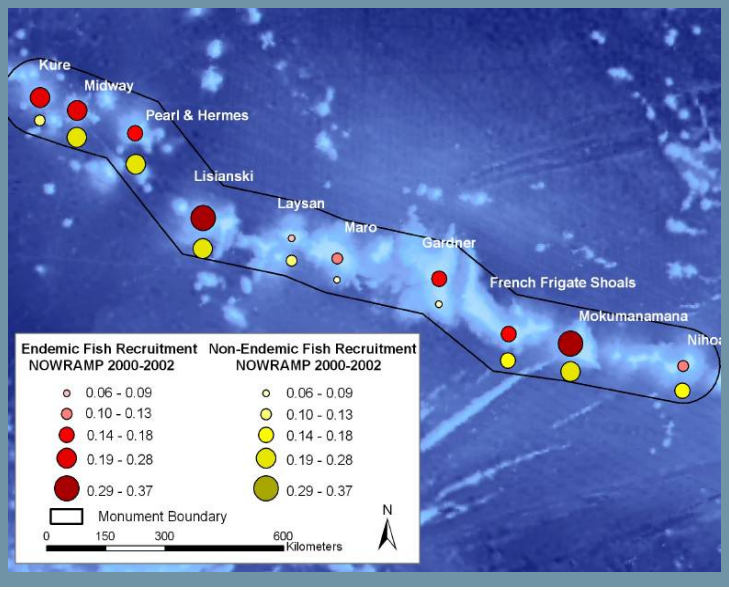
Friedlander et al. 2008

Fish endemism

- Global biodiversity hotspot (30% by sp.)
- Numerical endemism is 52%
- Higher endemism at the N end of chain
  - Related to higher recruitment

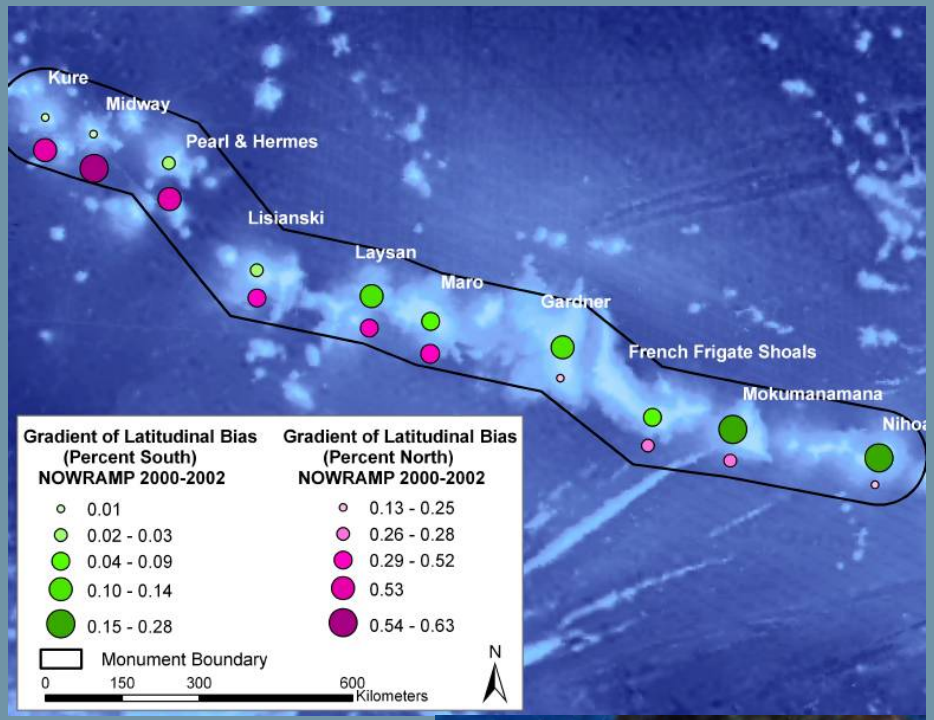
Friedlander et al. 2008





Gradient of latitudinal bias

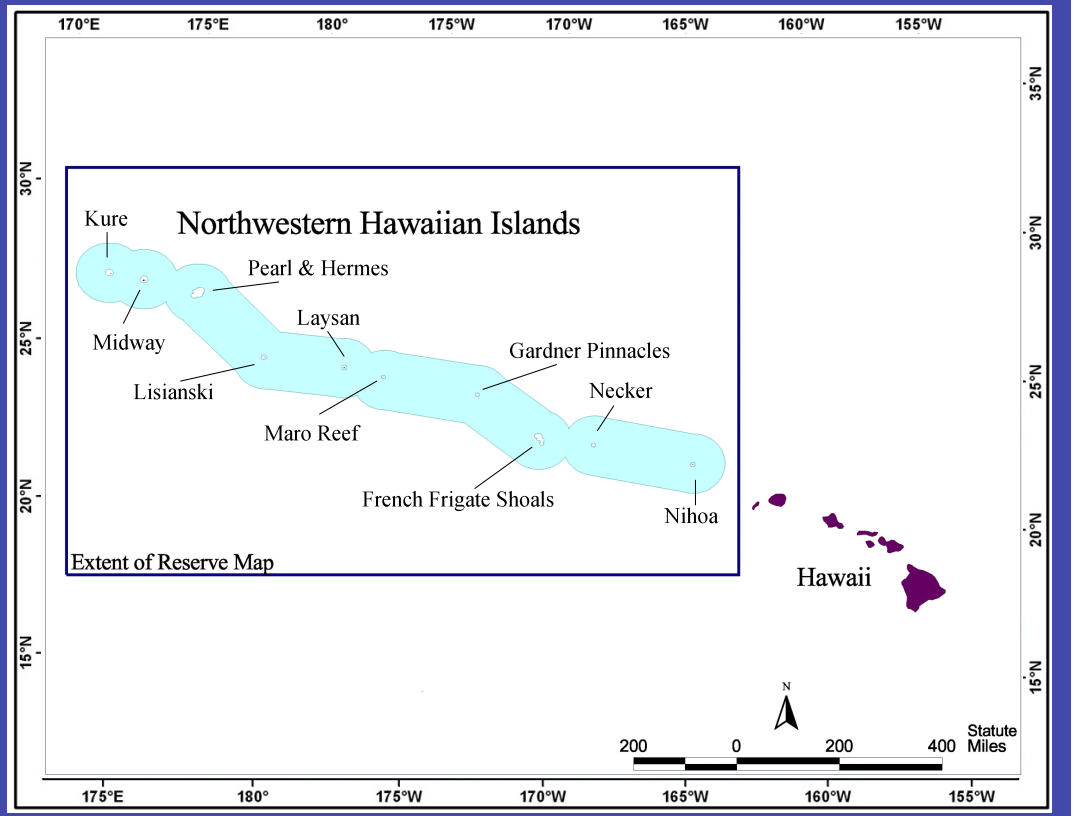
- Large lat. gradient leads to broad biogeographic distribution of species
- At N end of chain more subtropical species and S end more tropical associated species
- Biogeographic break occurs about midchain



Friedlander et al. 2008

Analyses of Fish Stocks in the Main Hawaiian Is. using the Northwestern Hawaiian Is. as a Large Reference Area

- Use visual surveys to estimate biomass densities of food & aquarium fishes
- NWHI as reference
  Status = $MHI_{total}/NWHI$
- Excluded rare species



- Examined latitudinal gradients within NWHI, filtered out those that showed tropical or temperate affinity.

Examined patterns for consistency with fishing pressures, ecology and life history

- Fishing effects— consumption & ornamental catch data

$$\text{Fishing pressure} = \frac{\text{recorded catch}}{\text{biomass density MHI}}$$

- Ecology/Life History —
  - trophic group (apex, herbivore, secondary consumer)
  - mobility (resident, 10s m^2, 100s m^2, transient)
  - maximum size

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Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Multispecies survey design for assessing reef-fish stocks, spatially explicit management performance, and ecosystem condition

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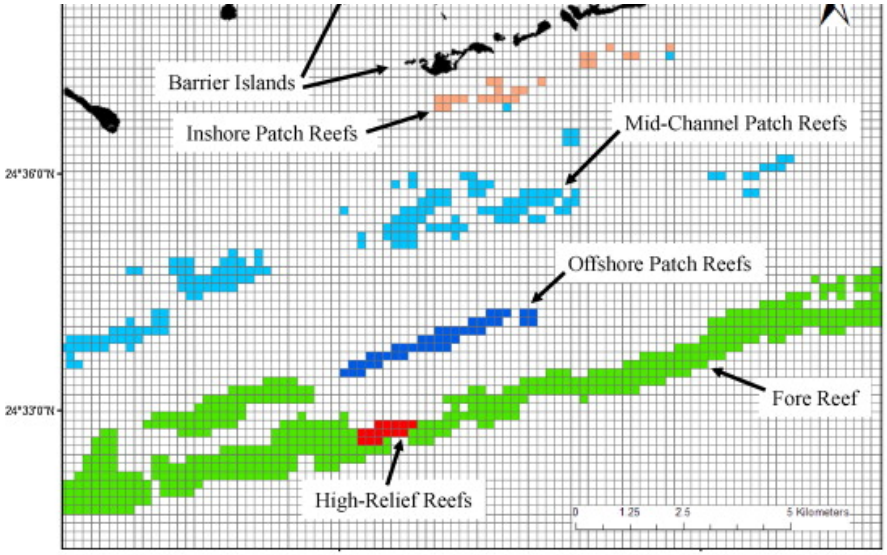
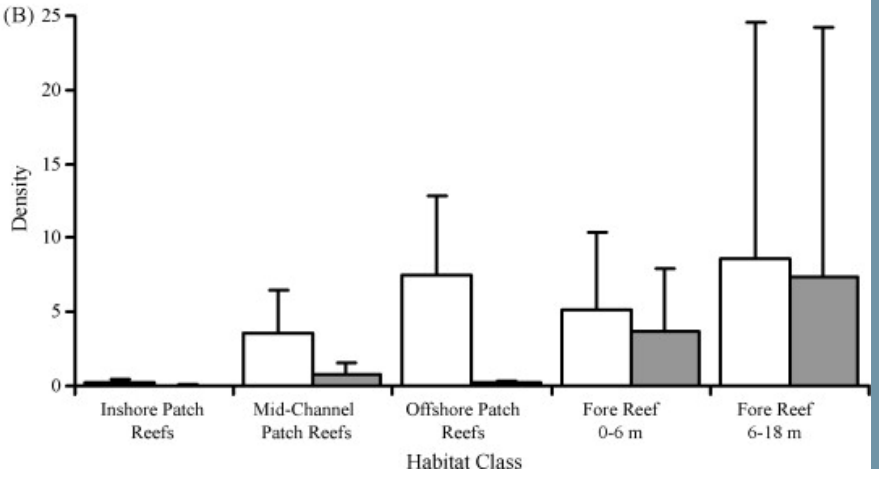
[b] NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL 33149, USA

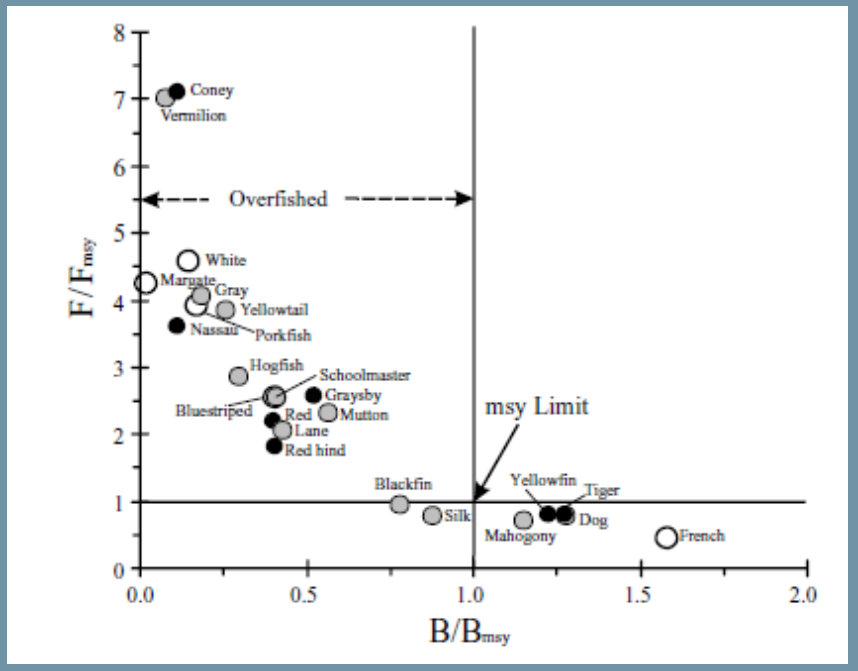




Environmental Conservation 35 (3): 221–231 © 2008 Foundation for Environmental Conservation doi:10.1017/S0376892908005043

Length-based assessment of sustainability benchmarks for coral reef fishes in Puerto Rico

JERALD S. AULT*[,1], STEVEN G. SMITH[1], JIANGANG LUO[1], MARK E. MONACO[2] AND RICHARD S. APPELDOORN[3]



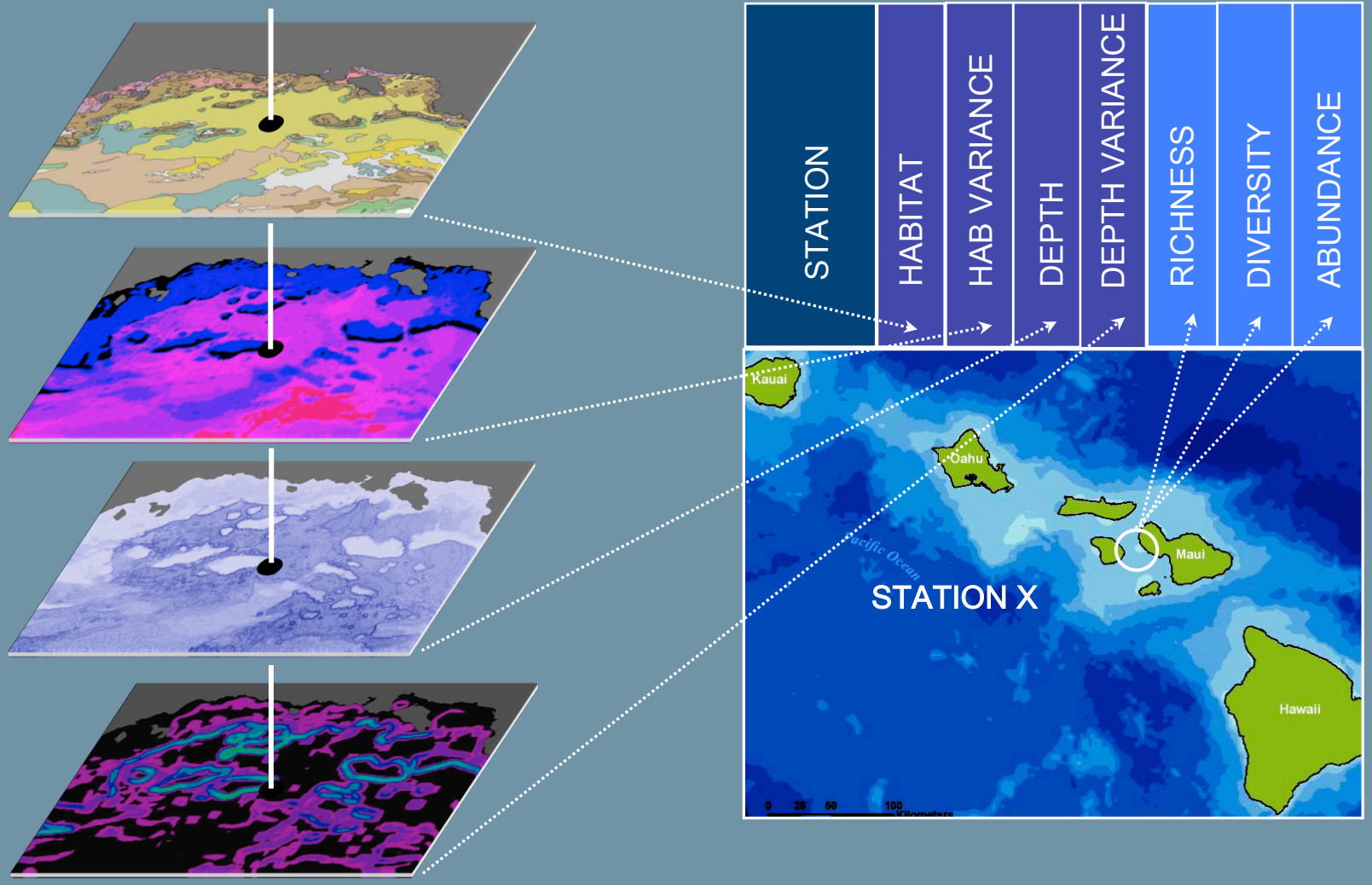
F/Fmsy ratio versus B/Bmsy ratio for the 25 species (groupers = dark circles, snappers = shaded circles and grunts = open circles) analysed for the years 2000–2002.

Habitat types among the MHI

NOAA Biogeography

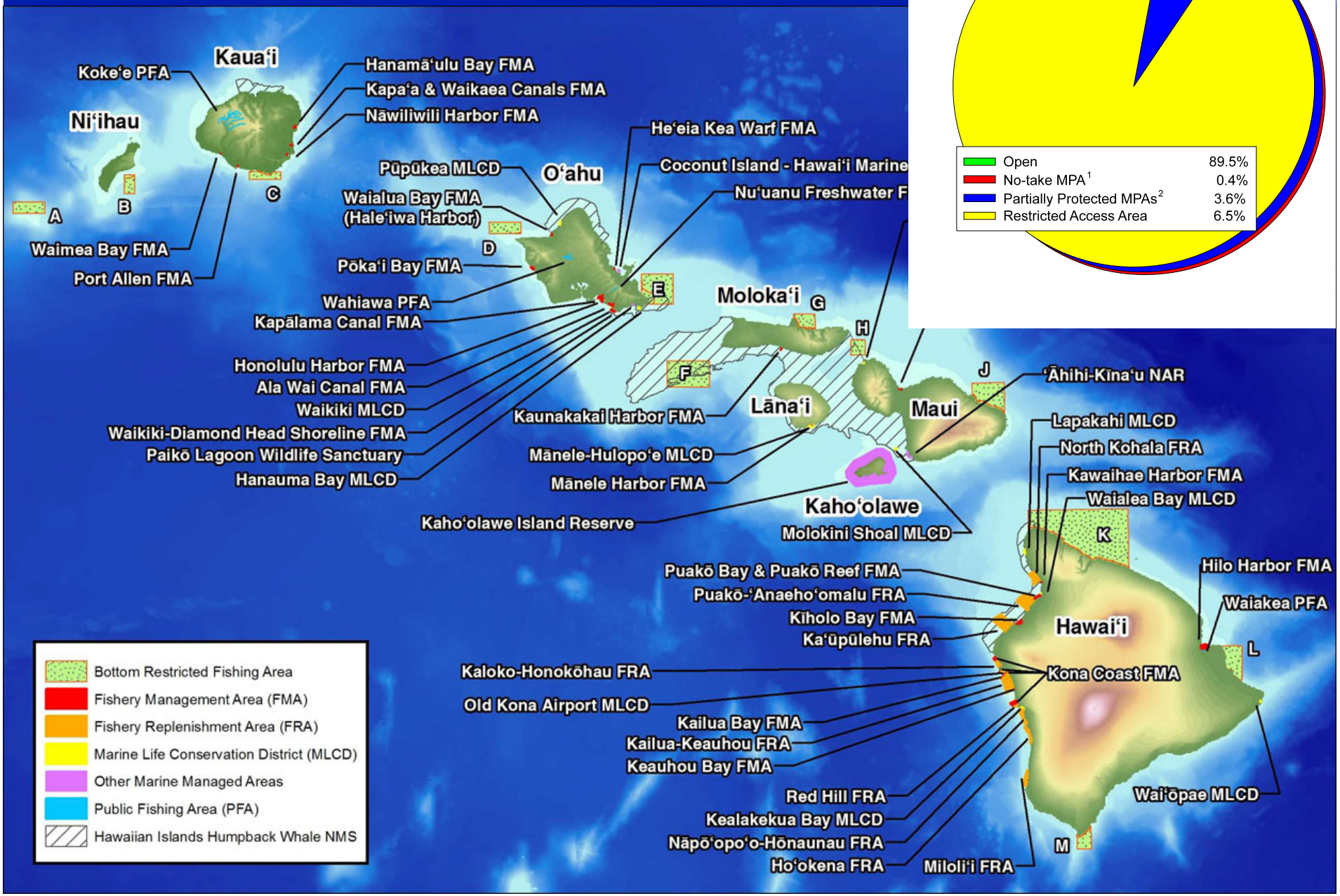
Coral reef structure type	Niihau/ Kaula	Kauai	Oahu	Molokai	Maui	Lanai	Kahoolawe	Hawaii
Pavement	0.14	127.89	187.90	70.92	32.53	9.14	5.61	1.60
Spur and Groove		1.10	20.00	6.87	4.20	4.20	1.10	4.09
Individual Patch Reef			1.78	0.01	0.13			
Aggregated Patch Reef			0.65	0.57	0.46	0.03	0.48	
Aggregated Reef		7.82	10.72	12.08	18.36	5.81	0.76	11.40
Rock/Boulder	98.56	8.12	17.91	16.00	46.17	7.14	4.20	87.16
Pavement with Sand Channels		21.30	43.44	7.83	0.60	0.00	1.10	0.47
Rubble		0.50	2.08	0.23	0.11	0.02		0.16
Scattered Coral/Rock		0.47	1.29	2.10	0.15	0.02		0.11
	98.70	167.20	285.75	116.61	102.70	26.36	13.25	104.97
Total Hard Bottom	98.70	167.20	285.75	116.60	102.70	26.36	13.25	104.97
Total Unconsolidated Sediment	14.44	57.39	113.46	57.22	99.62	14.16	6.40	25.16

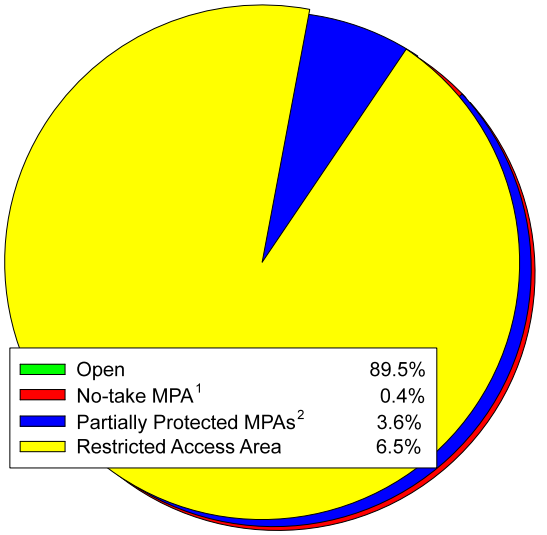
Abiotic data integrated with fish data sets to provide analytical products to aid in spatial management



Understanding species' habitat relationships to develop management tools

State: Marine Managed Areas





Next steps

- Continue data collections and discussions with partners
- QA/QC all data and put in a common format for analyses
- Construct database structure for data analyses
- Conduct biogeographic assessment combining fish and bio-physical data
- Examine fish assemblage metrics across gradients of anthropogenic influence
- Examine the efficacy of MPAs