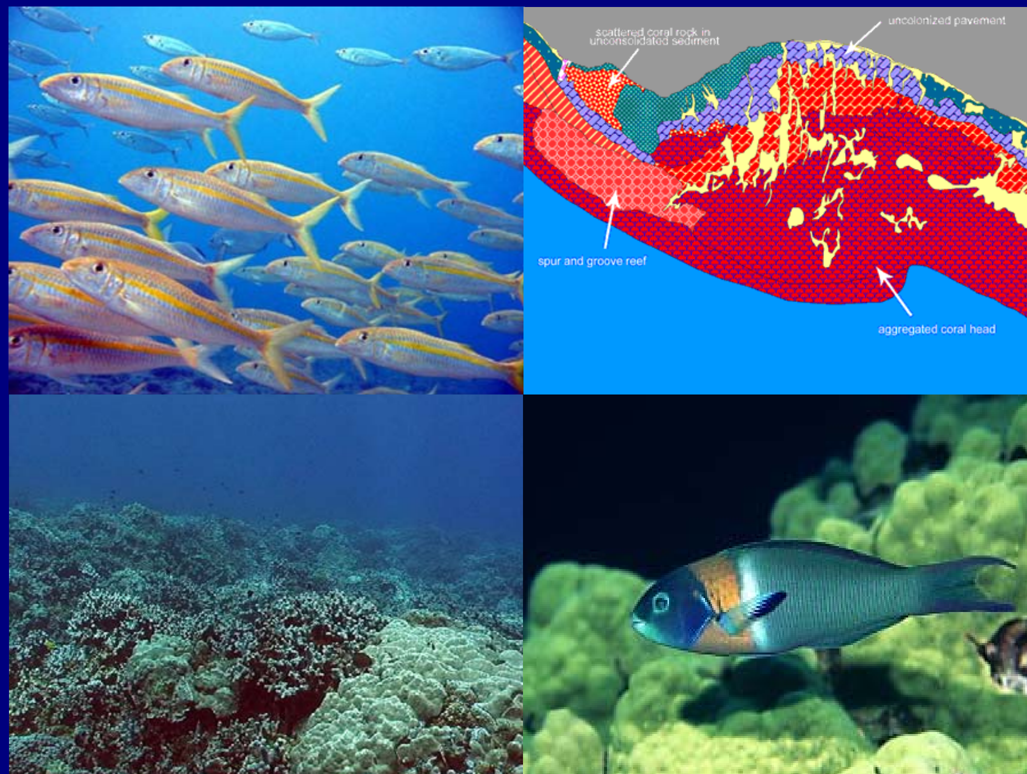
Coupling Ecology and GIS Technology to Evaluate the Efficacy of Marine Protected Areas in Hawaii



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Organization of Presentation

• **Objective: Conduct integrative coral reef ecosystem mapping and monitoring to evaluate MPA effectiveness, define essential fish habitat, and identify biologically relevant MPA boundaries.**

I) Background - Integrated Benthic Habitat Mapping and Monitoring

II) Define Reef Fish Habitat Utilization Patterns

III) Evaluate MPA Effectiveness

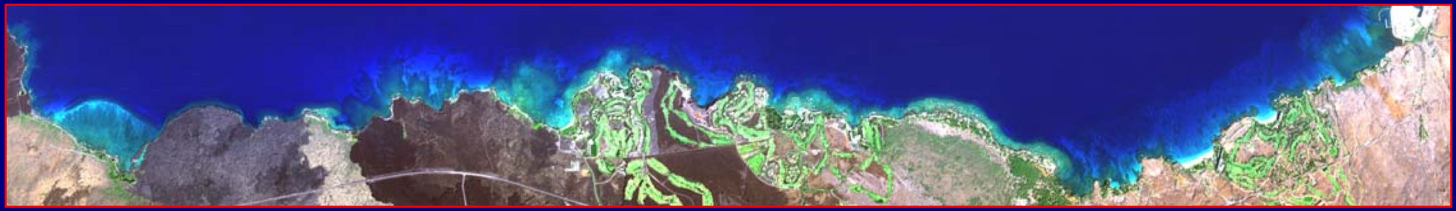
IV) Design principles for reserves in Hawaii

Imagery for Developing Benthic Habitat Maps

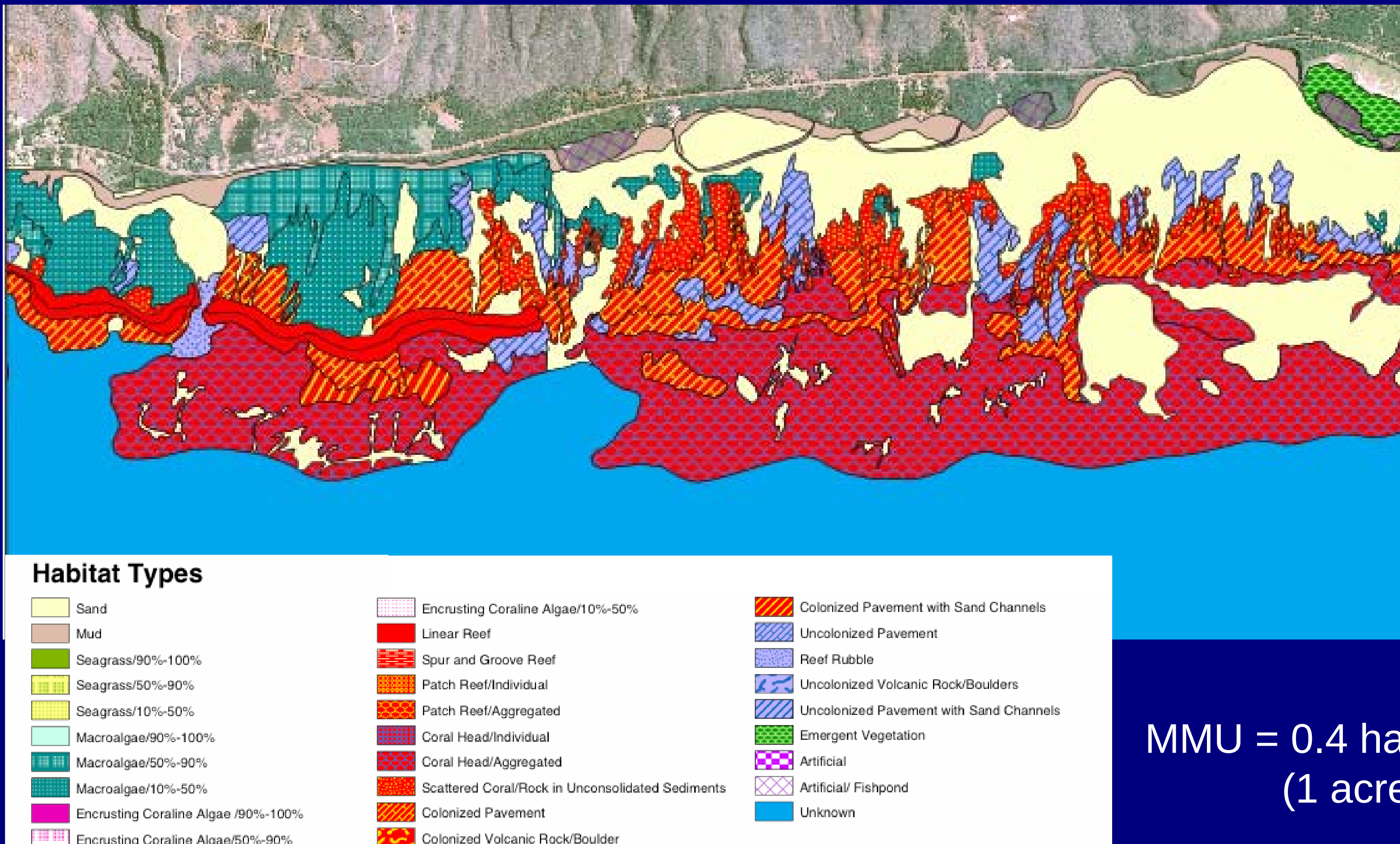
IKONOS – true-color; 4 m pixel

AERIAL PHOTOGRAPHY – true-color; 1.2 m pixel

HYPERSPECTRAL – 72 bands between 350 and 1000 nm; 3 m pixel

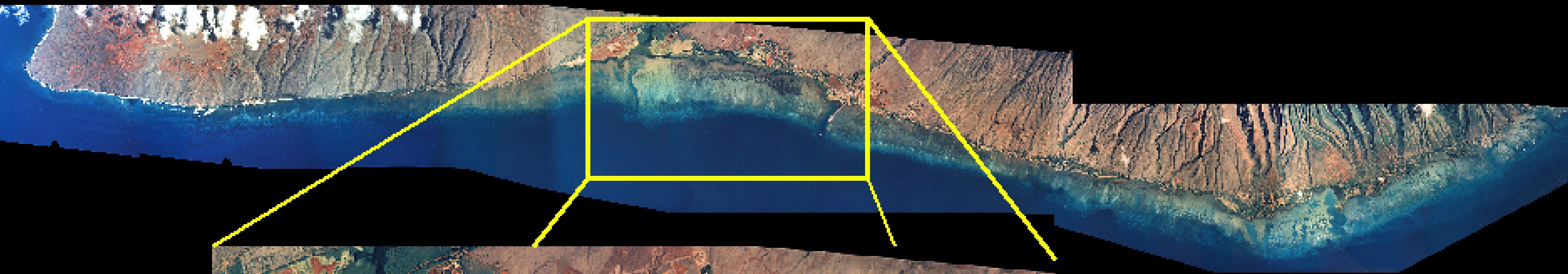


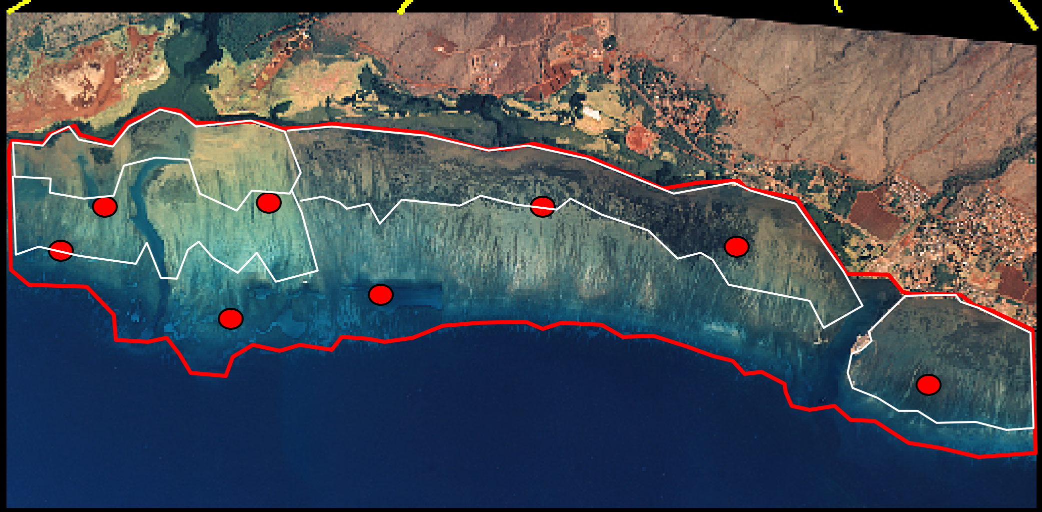
South Molokai, Hawaii Coral Reef Ecosystem Habitats



MMU = 0.4 ha
(1 acre)

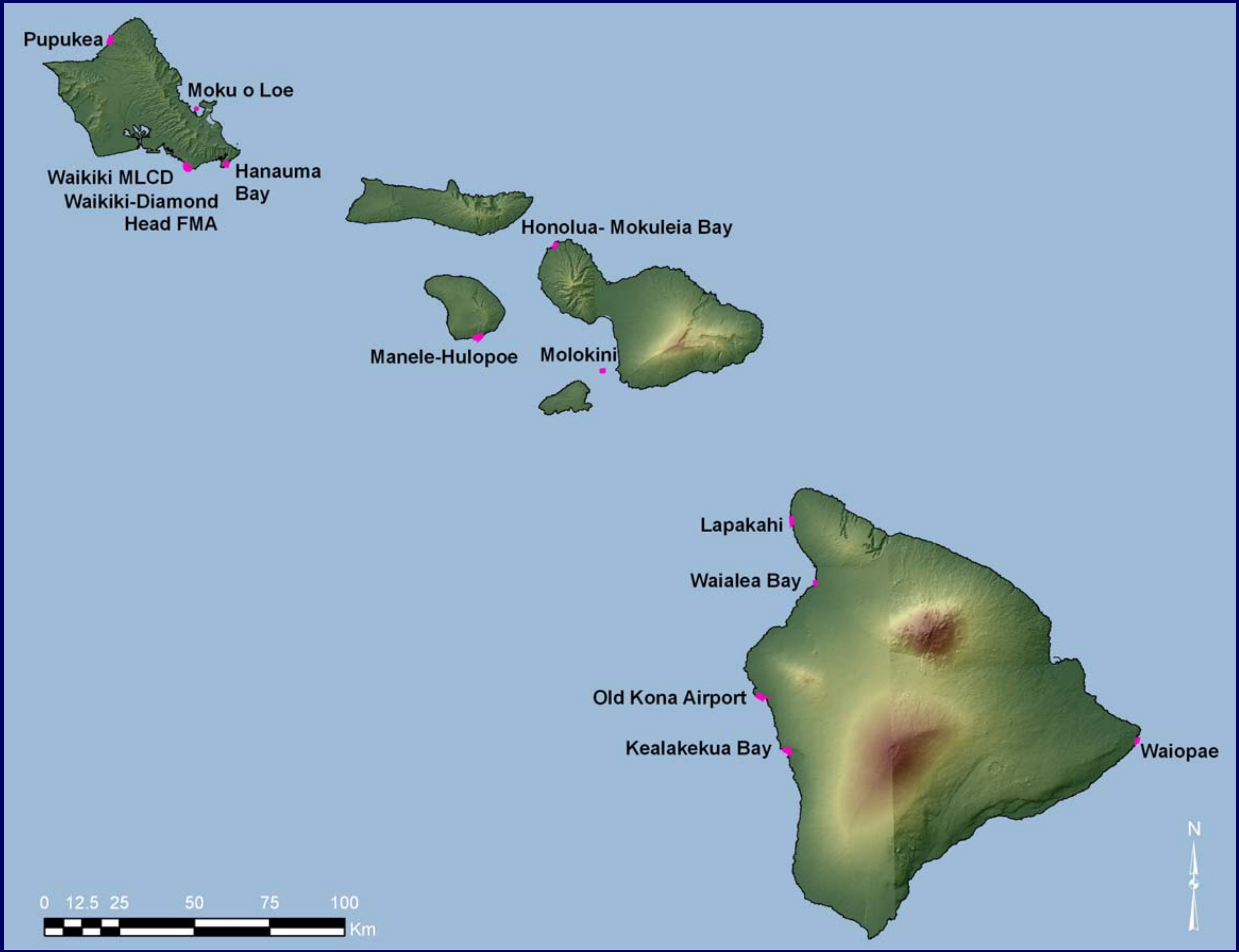
South Molokai Study Area





1. Draw Boundary
2. Delineate Habitats
3. Generate Random Points
4. Map Accuracy Analysis
5. Assessment Transects- Fish/benthic Community
6. Identify Essential Fish Habitat
7. Evaluation of Marine Protected Areas

Locations of Hawaii Marine Life Conservation Districts and the University Marine Laboratory Refuge (Moku o Loe)



Marine Life Conservation Districts in Hawaii

Island	Protected area	Acres	Year estab.	Use	Protection from fishing
Oahu	Hanauma Bay	101	1967	High	High
	Pupukea	179	1983*	Mod	Mod
	Waikiki	76	1988	High	High
	Moku o Loe	73	1967	Low	High
Hawaii	Kealakekua Bay	315	1969	High	Mod
	Lapakahi	146	1979	Low	Low
	Waialea Bay	35	1985	Low	Low
	Old Kona Airport	217	1992	Mod	Mod
	Wai Opae	84	2000	Mod	High
Lanai	Manele-Hulopoe	309	1976	Mod	Mod
Maui	Molokini Shoal	211	1977	High	High
	Honolua-Mokuleia Bay	45	1978	Mod	High

Friedlander and Brown 2003

* Modified 2003

Using Maps to Support Field Activities

Random stratified design

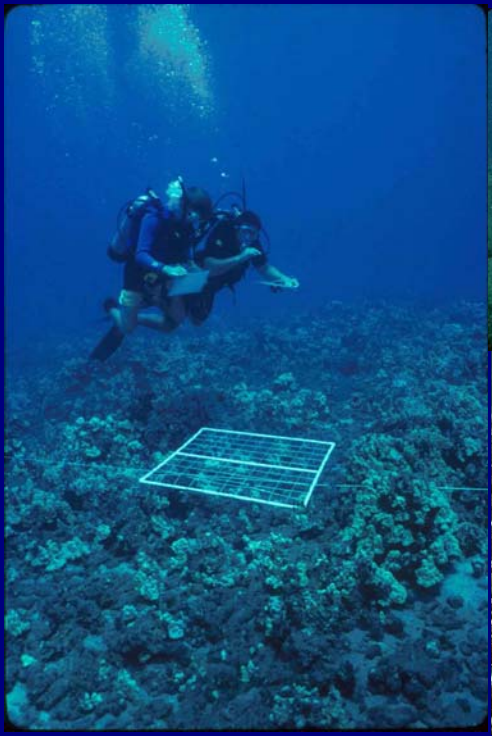
- inside vs. outside MPAs
- coral, other hard bottom, macroalgae, sand

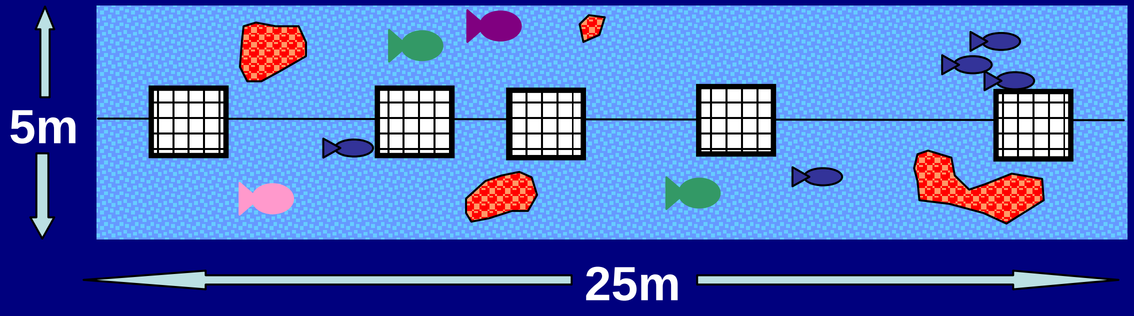
Fish Censuses

- 25m x 5m transects

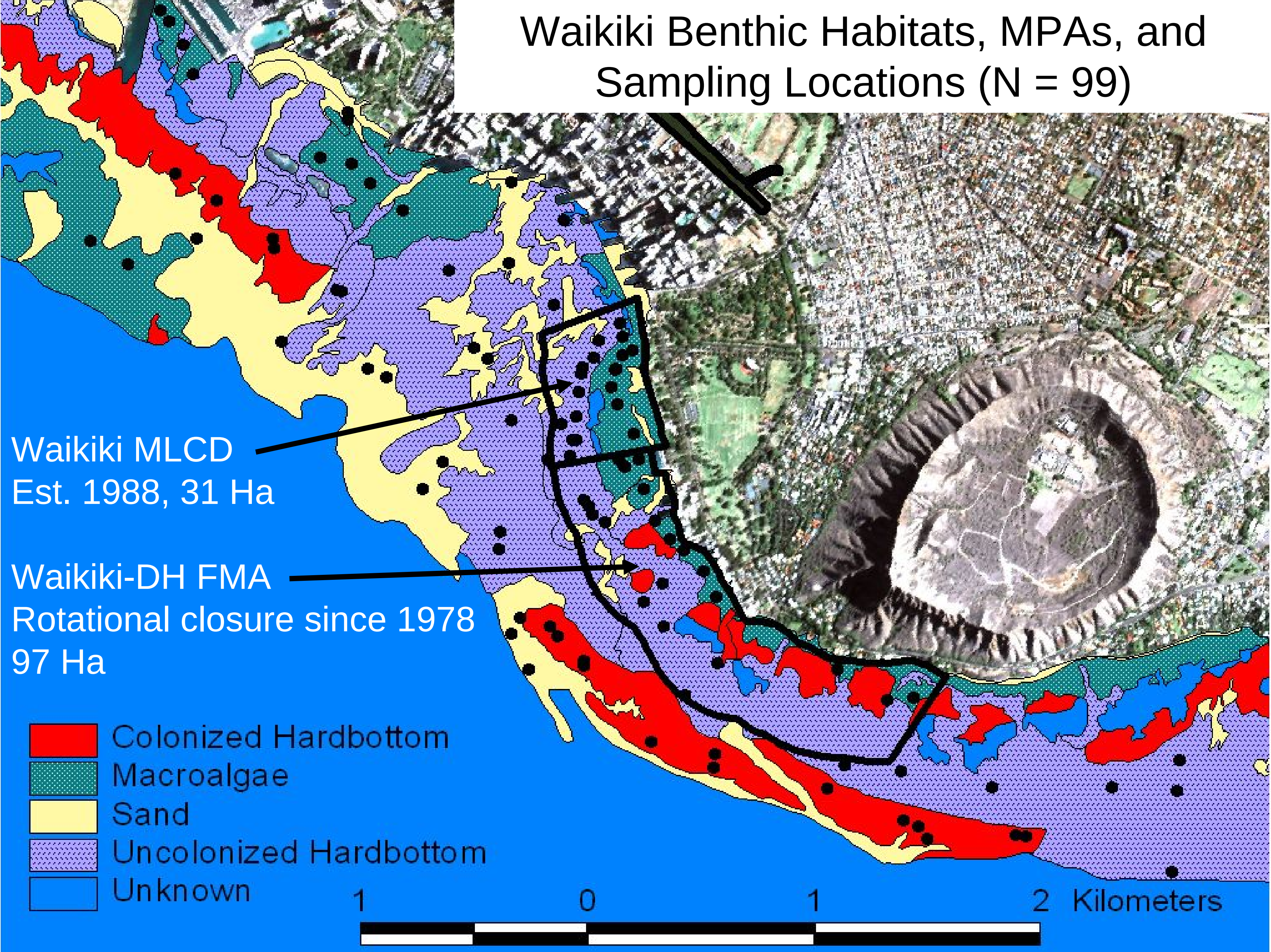
Corresponding habitat metrics

- biotic cover
- abiotic cover
- habitat complexity

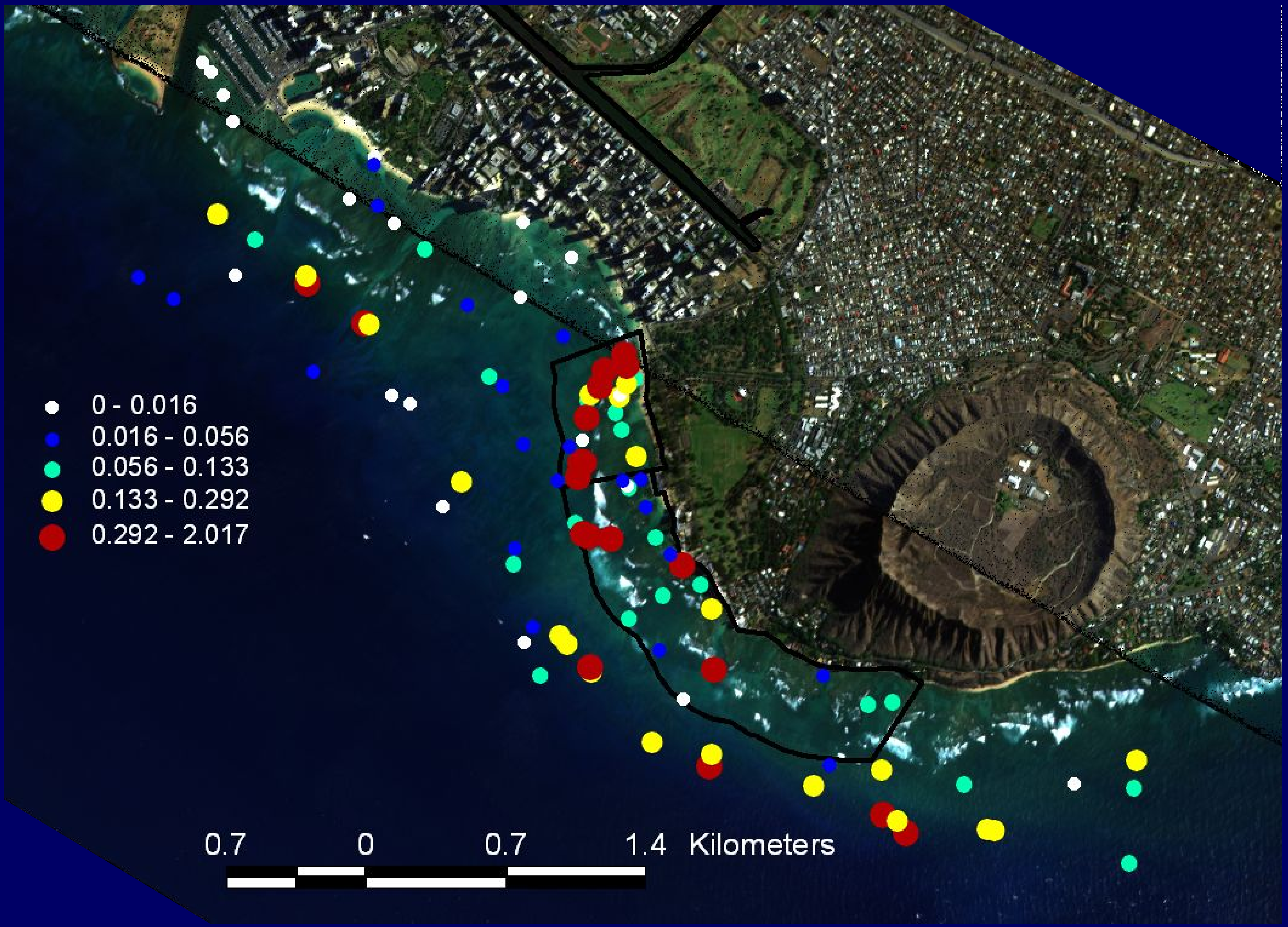




Waikiki Benthic Habitats, MPAs, and Sampling Locations (N = 99)

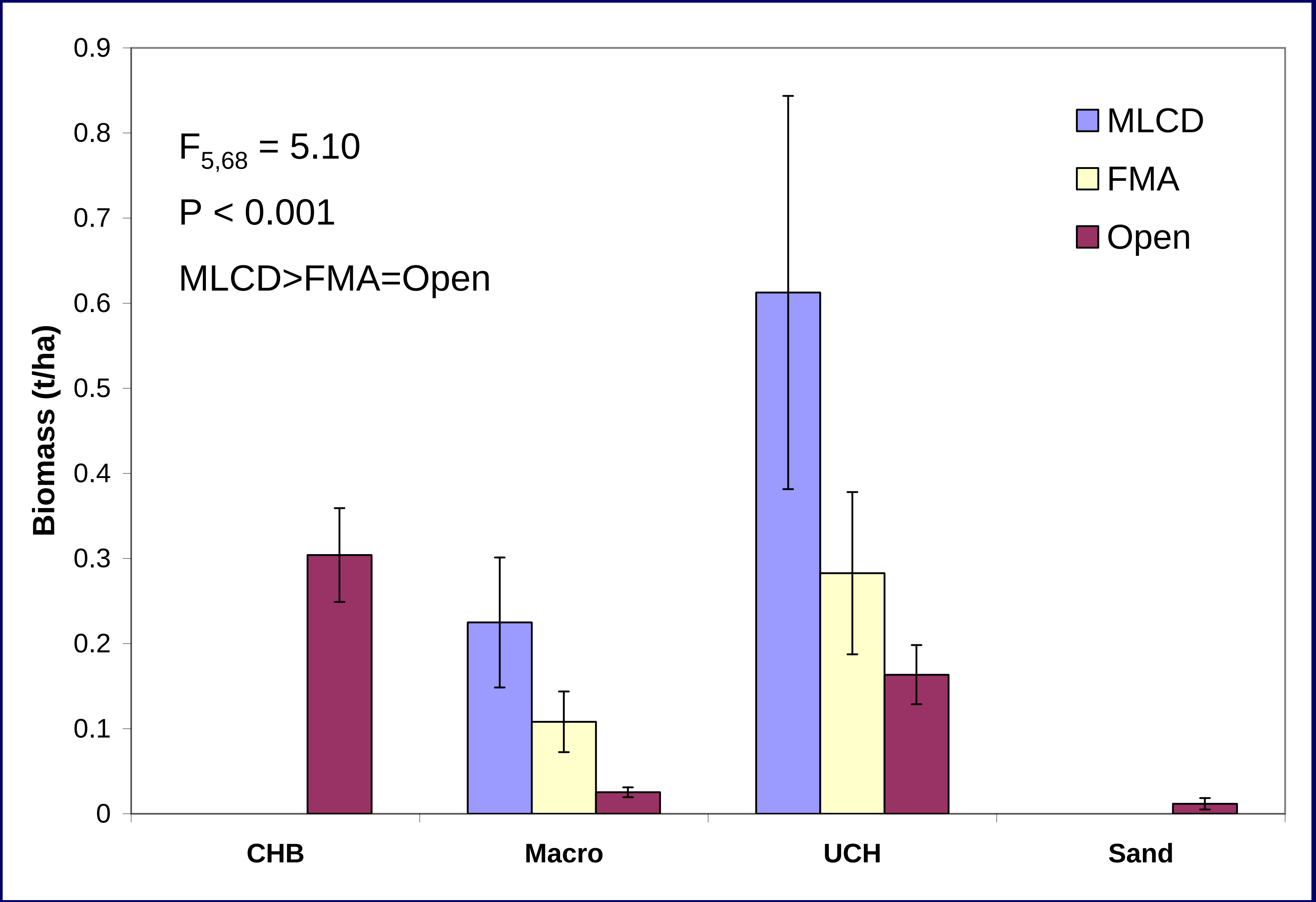


Fish biomass (t ha^{-1}) by individual transects (N=99) for Waikiki including Waikiki MLCD and Waikiki-Diamondhead FMA.

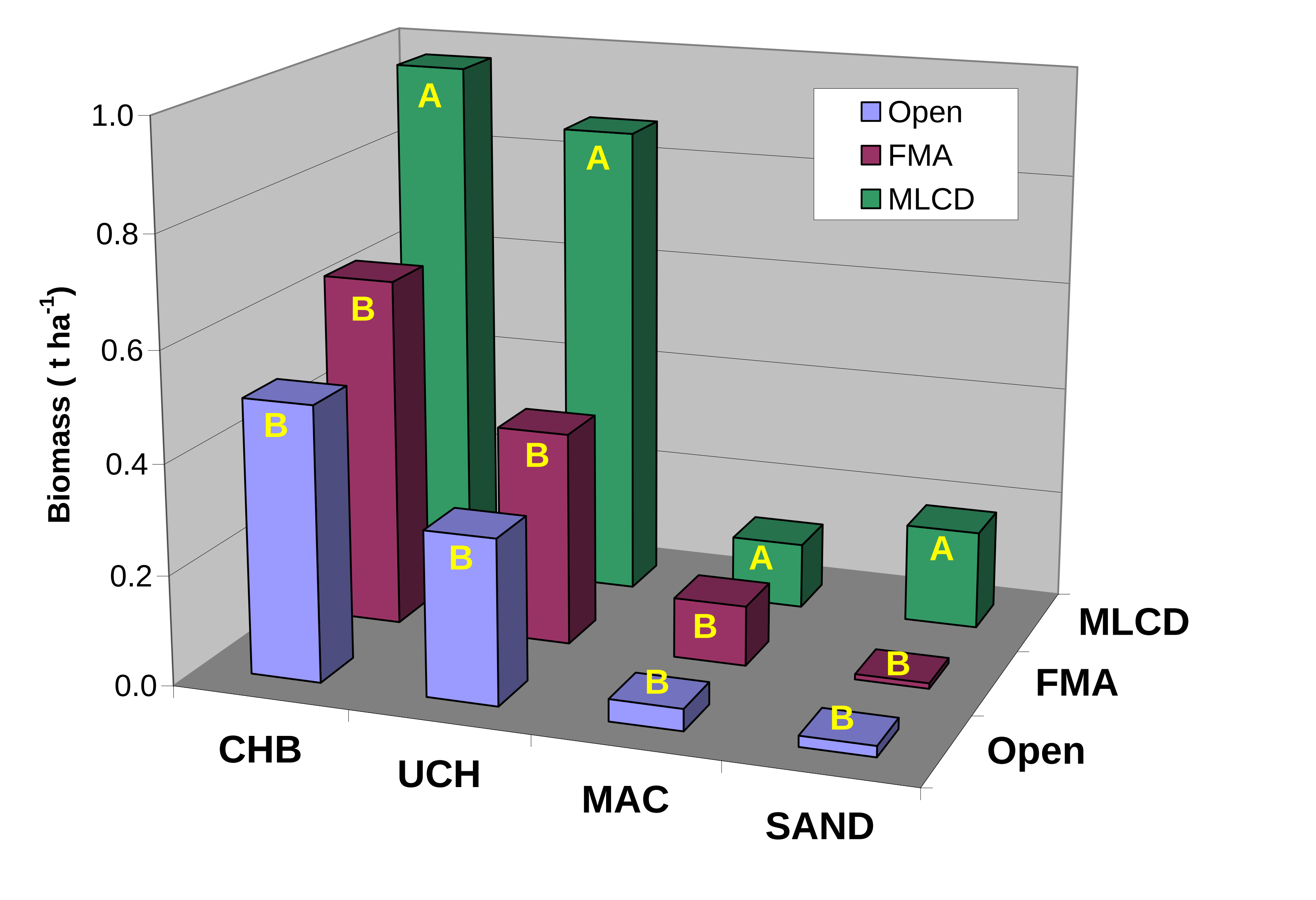


Mean biomass (t ha^{-1}) by habitat type and management regime for Waikiki

Error bars are standard error of the mean



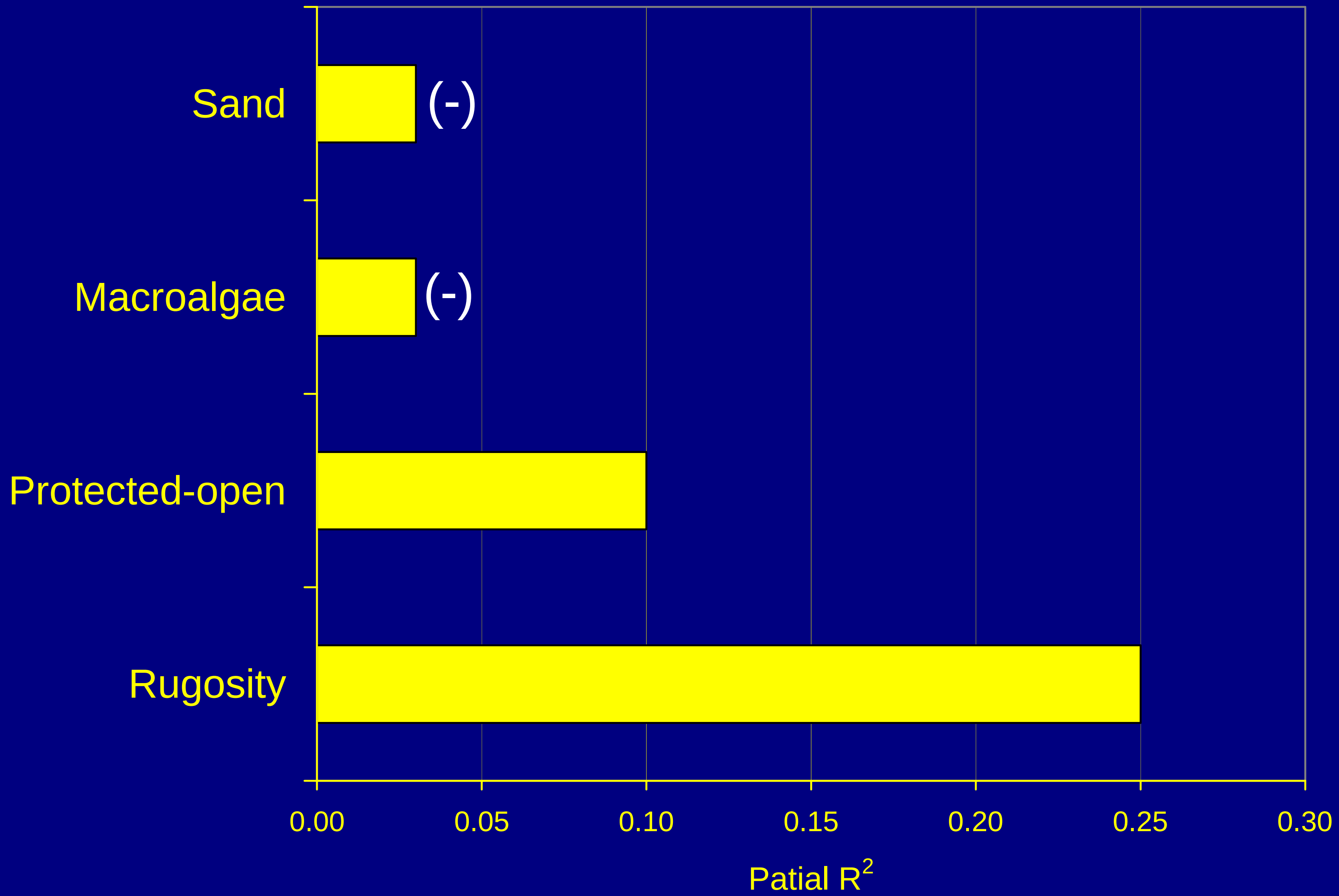
Fish Biomass ($t\ ha^{-1}$) by Habitat among Management Regimes



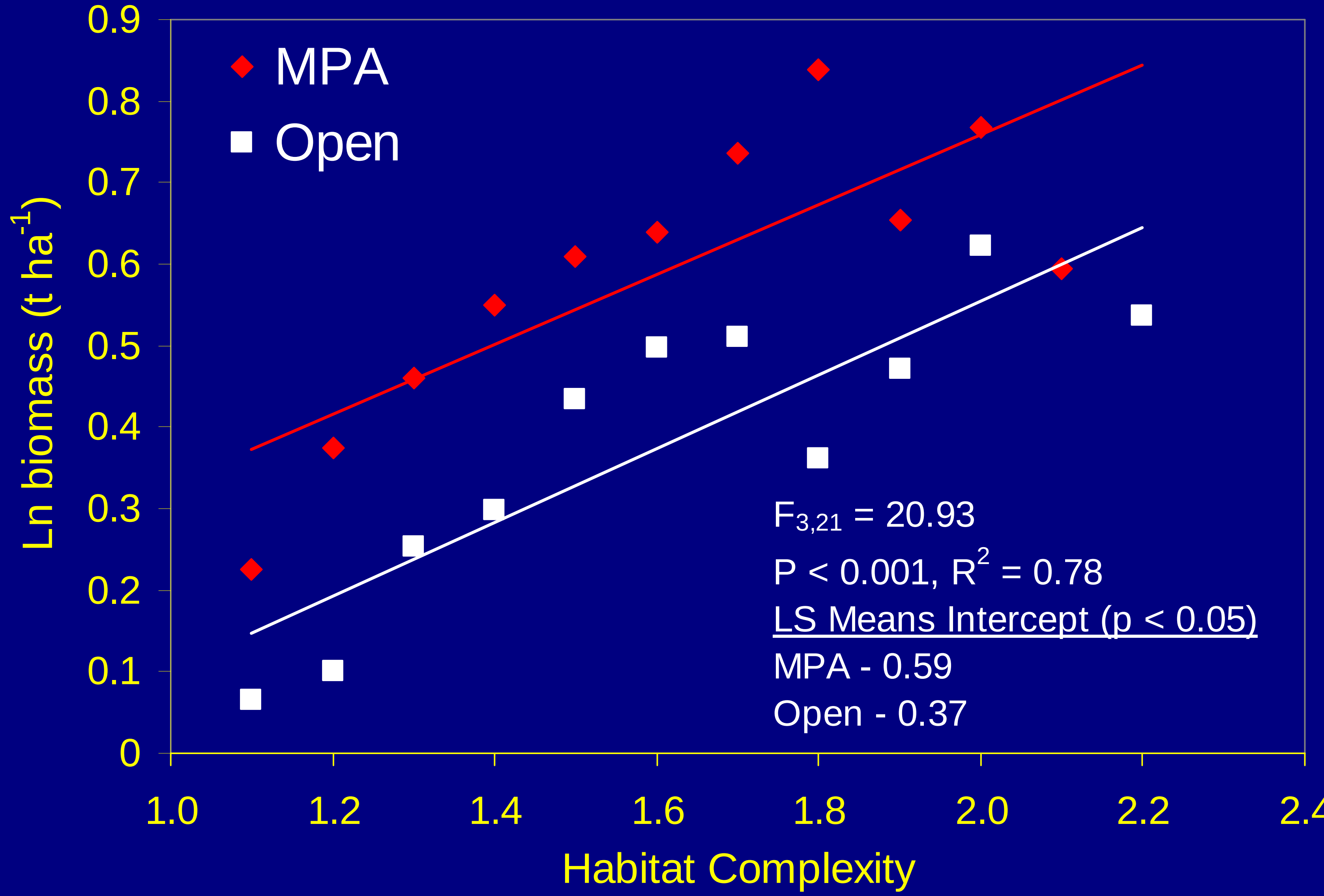
Factors Influencing Fish Biomass (t ha^{-1}) among all Locations

Stepwise multiple regression analysis (hardbottom only)

Probability to enter model 0.25, probability to leave 0.10, $R^2 = 0.41$

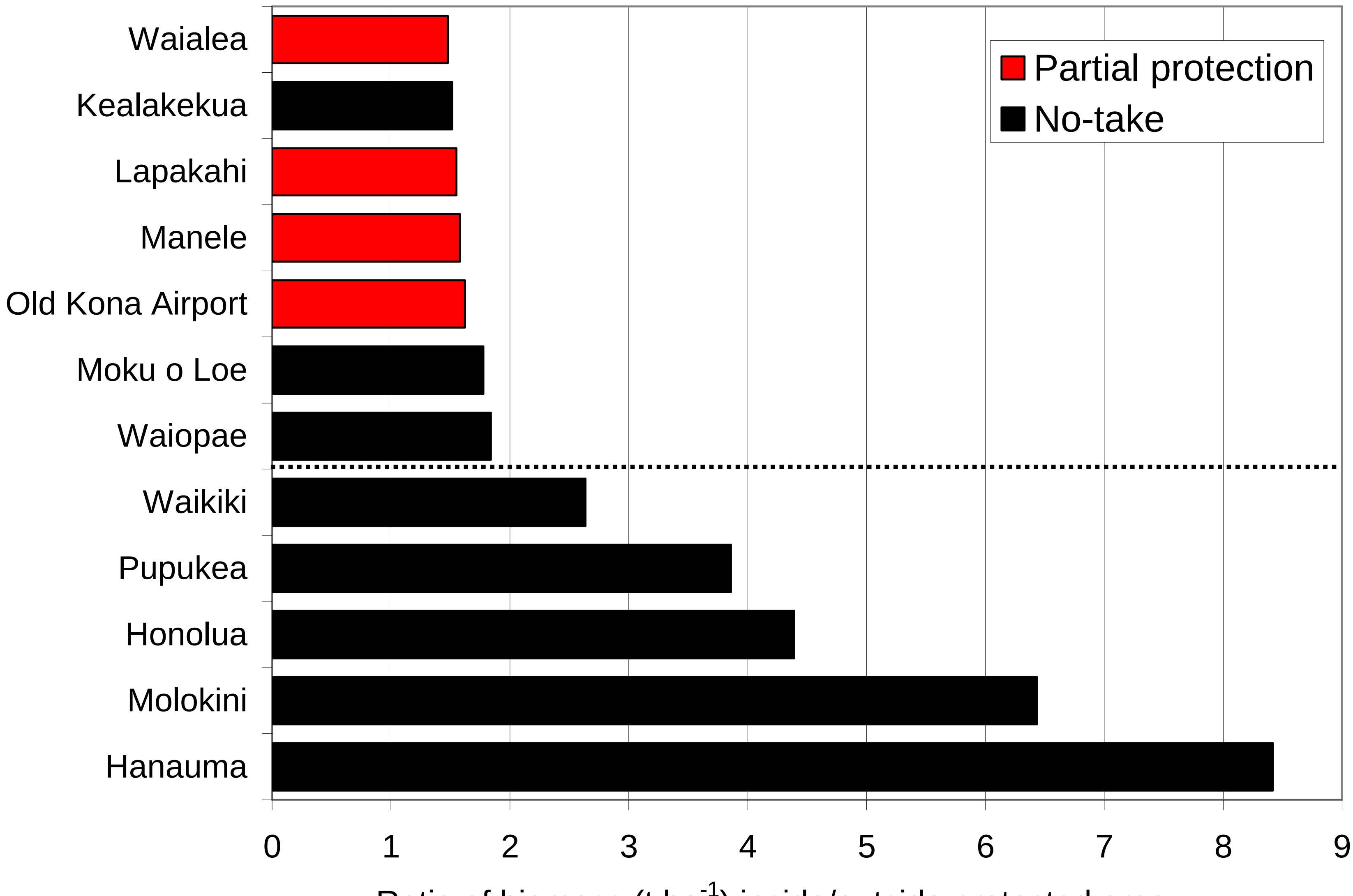


Comparison of Fish Biomass between MPAs and Open Areas Across Range of Habitat Complexities

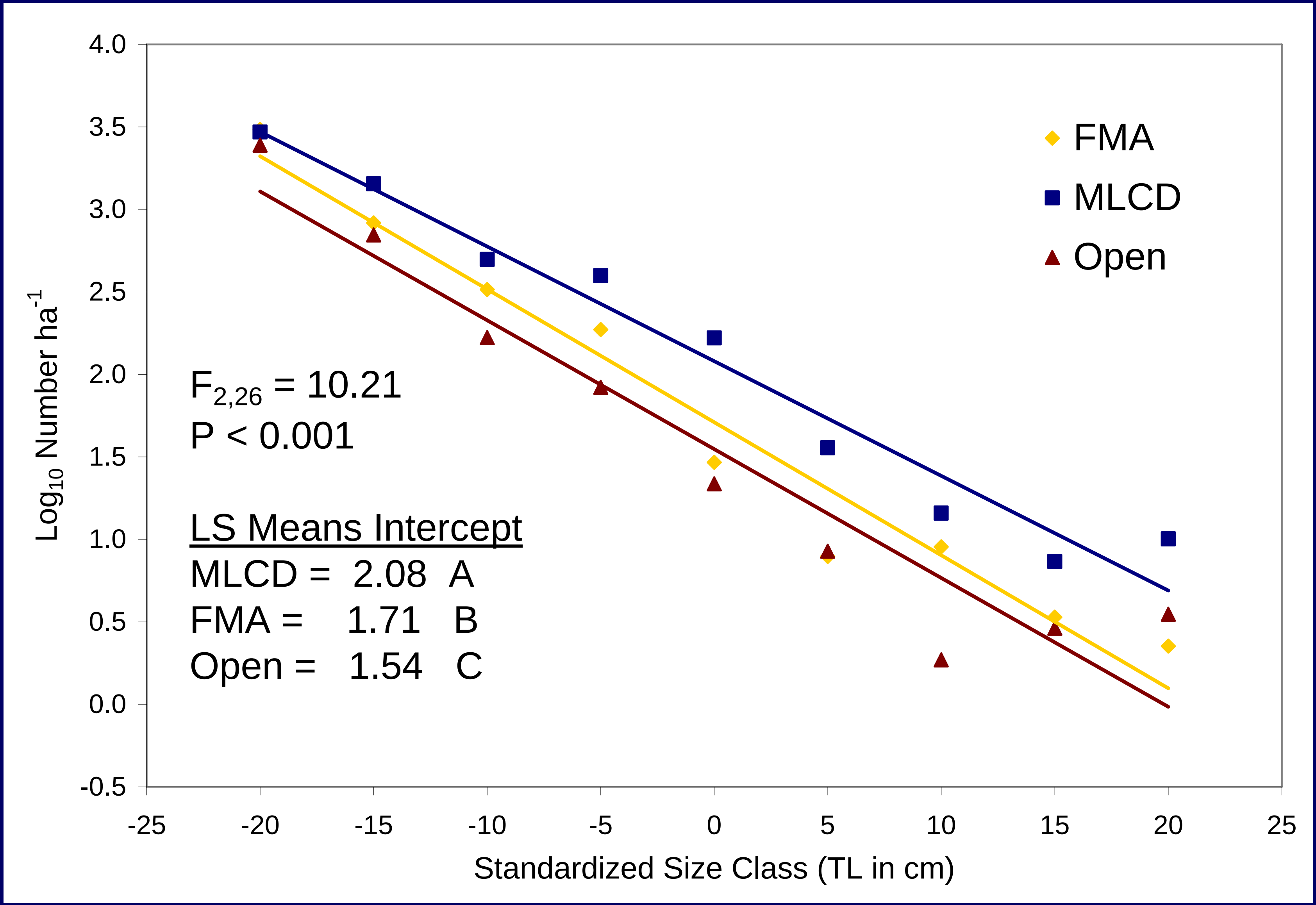


Ratio of biomass (t ha^{-1}) inside MPAs vs. outside areas open to fishing

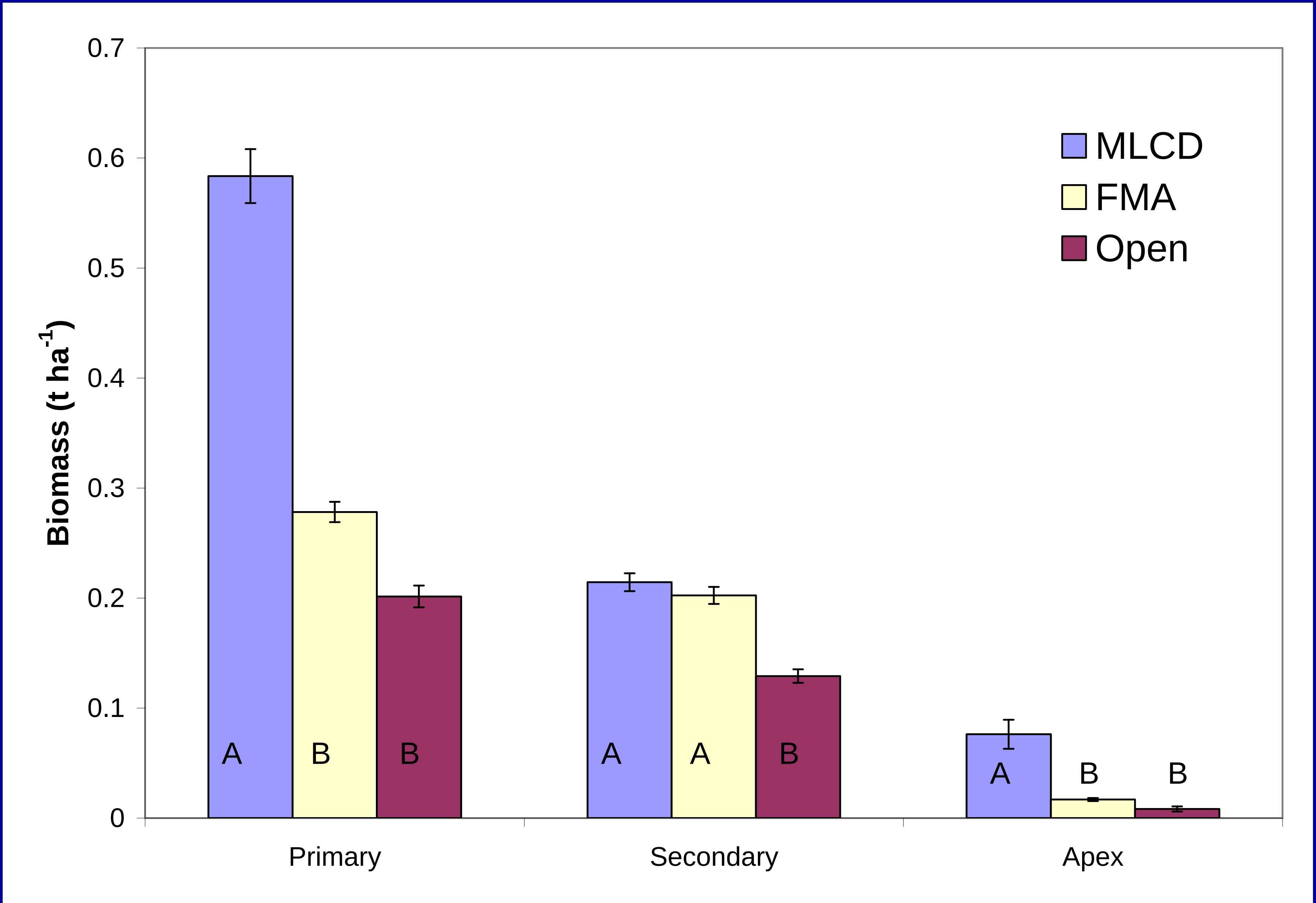
Hardbottom habitats only.

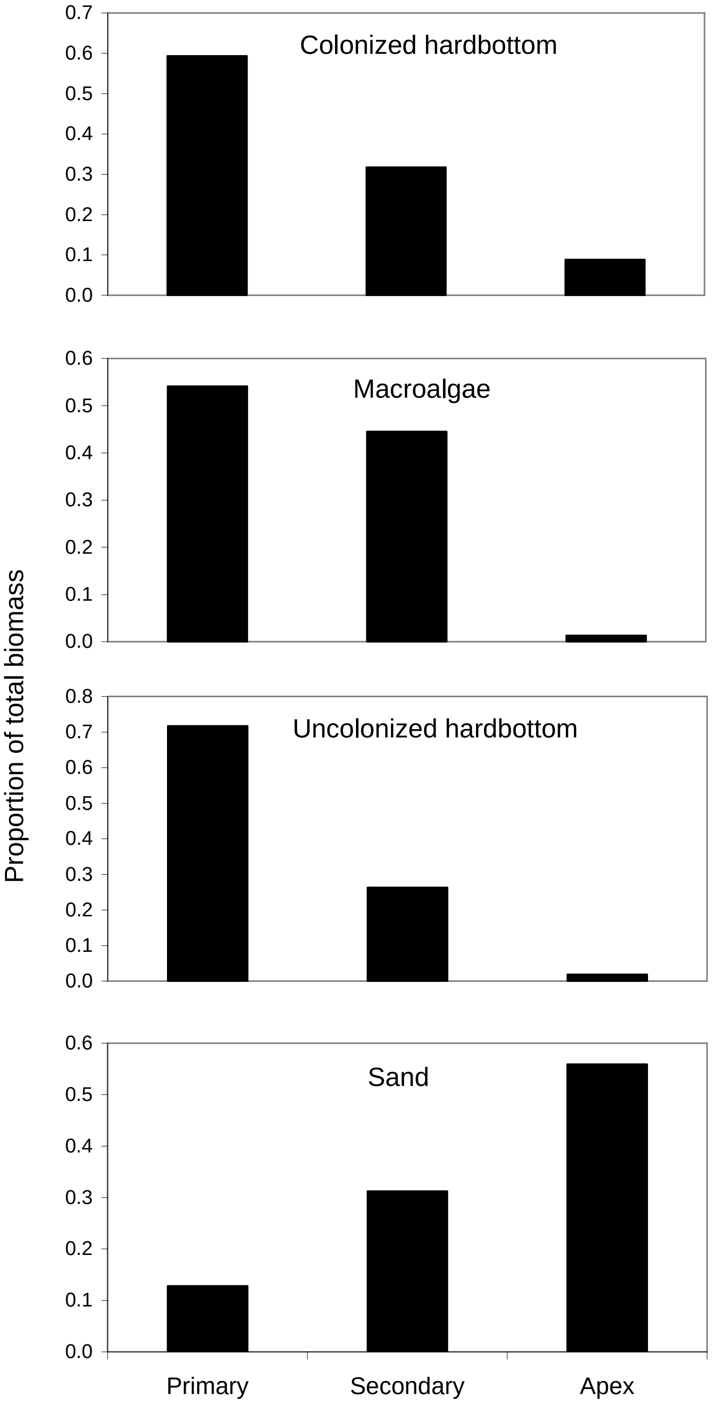


Size spectra of Log_{10} number ha^{-1} by standardized size class (TL in cm) for all fishes on hardbottom habitats



Mean biomass per transect (t ha^{-1}) by trophic guild and management regime on hardbottom habitats





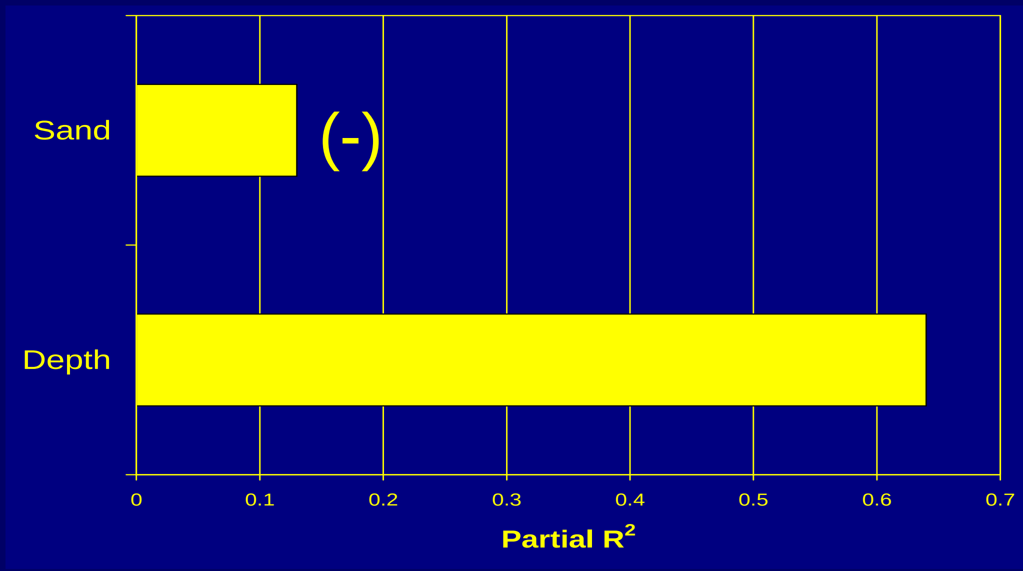
Trophic composition among major habitat types pooled across all locations

- Highest biomass of apex on colonized hardbottom
- Highest proportion on sand
- Sand important corridor
- Lowest on macroalgae and uncolonized hardbottom

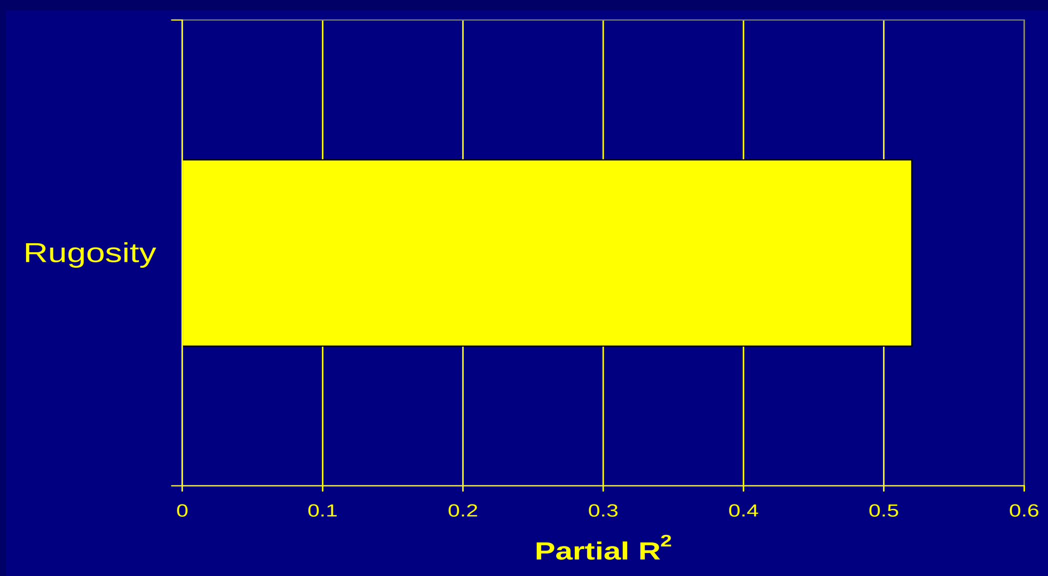
Habitat Variables Affecting Fish Assemblage Characteristics in MLCDs

Results of General Linear Models
hardbottom only

Fish Species Richness



Fish Biomass



Major Conclusions

- Habitat complexity explained much of the variability in fish species richness, biomass, and diversity

- Overall fish biomass was 2.6 times greater in reserves

- Apex predators showed the greatest difference between open and protected areas

- Depth explained most variability in richness and diversity among reserves

- Overall size of the adult fish assemblage larger in the protected areas & larger size classes had greater number of individuals compared with the other management regimes

- Despite their proven success, no-take reserves account for less than 1% of nearshore areas in the main Hawaiian Islands

Design Criteria for Effective MPAs in Hawaii

- Range of habitat complexities
- Full protection from fishing
- Shoreline to deep habitats
- Mosaic of habitats
- Sand corridors
- Low macroalgae cover
- Representative wave exposures

Spatial Management is the Best Solution for Fisheries and Biodiversity in Hawaii

- Conventional fisheries management not well suited for Hawaii or other tropical insular areas
  - Catch/effort restrictions not effective in non-commercial fisheries
  - Closed seasons not effective with non-selective gear
  - Gear restrictions difficult to enforce
  - Size limits (little enforcement, lack of compliance, non-selective gear)
    - Large fish contribute more and higher quality offspring
- High endemism = biodiversity hotspot
- Ecosystem management = spatial management