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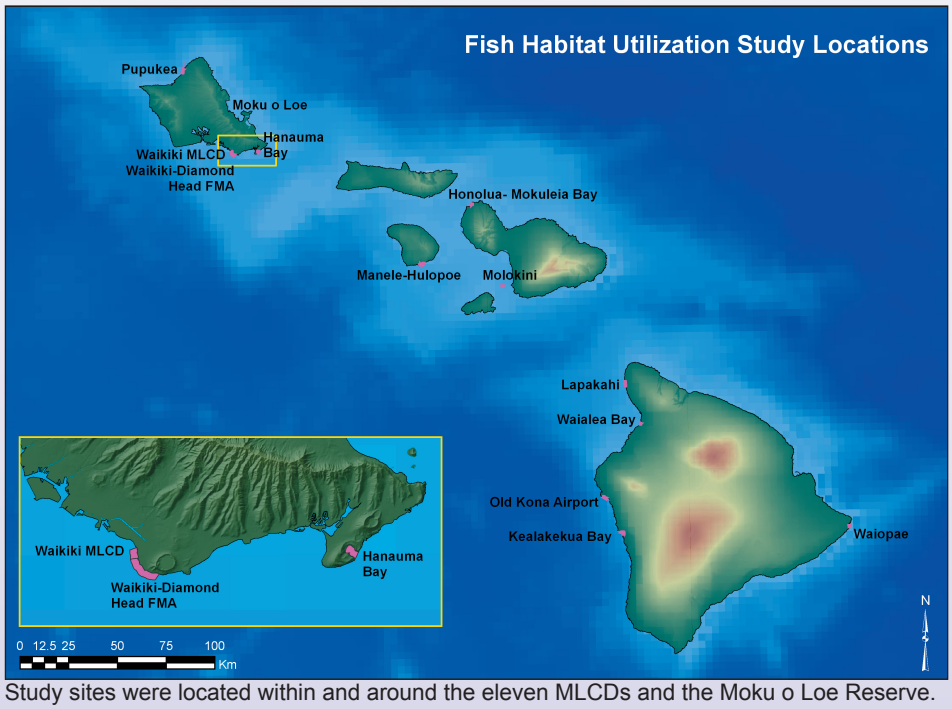
FISH HABITAT UTILIZATION PATTERNS AND THE EFFICACY OF MARINE PROTECTED AREAS IN THE MAIN HAWAIIAN ISLANDS

Over the past four decades, Hawaii has developed a network of 11 Marine Life Conservation Districts (MLCDs) to conserve and replenish marine resources around the state. Initially established to provide opportunities for public interaction with the marine environment, MLCDs vary in size, habitat quality, and management regimes. The evolution of MLCDs into a spatial management tool used to protect marine ecosystems presents an excellent opportunity to test hypotheses concerning marine protected area (MPA) design and function. Digital nearshore habitat maps developed by NOAA's Center for Coastal Monitoring and Assessment, Biogeography Team were used to structure field investigations and identify patterns of habitat use for various fish species. Habitat utilization patterns are useful in defining essential fish habitat and biologically relevant boundaries for MPAs.

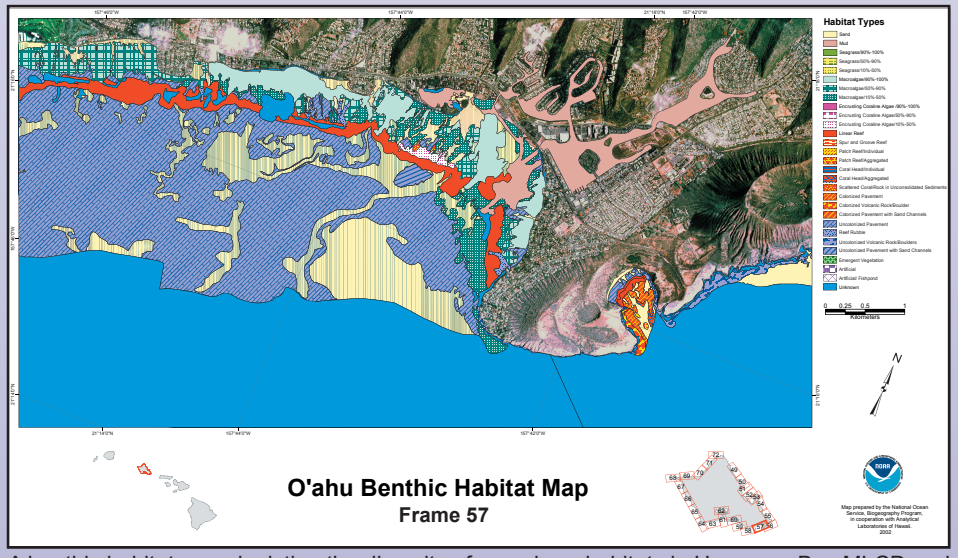


Study sites were located within and around the eleven MLCDs and the Moku o Loe Reserve.

Results of the study, which was undertaken cooperatively between Hawaii's Department of Land and Natural Resources, Division of Aquatic Resources and NOAA's Biogeography Team, show that the abundance and distribution of species and assemblages was strongly tied to habitat type. Management also played an important role, as MLCDs had higher values for most fish assemblage characteristics (e.g. biomass, size, diversity) than adjacent control areas. In addition, apex predators and other target species were more abundant and larger in MLCDs, illustrating the effectiveness of these closures in conserving fish populations. Habitat complexity, quality, size and level of protection from fishing were important determinates of MLCD effectiveness. Other major findings include:

Benthic assemblage characteristics

- The most abundant substrate type was turf algae (48% cover) followed by sand (23%), coral (16%), macroalgae (7%), coralline algae (5%), macroinvertebrates (1%), and seagrasses (<1%).
- Oahu sites had less coral and more macroalgae than Hawaii, Lanai, and Maui sites.
- Coral cover was higher in MLCDs than in open access areas or FMAs. In contrast, macroalgae cover was lowest in MLCDs and highest in the open access areas.



A benthic habitat map depicting the diversity of nearshore habitats in Hanauma Bay MLCD and adjacent areas of south Oahu near Hawaii Kai.

Factors influencing fish assemblages

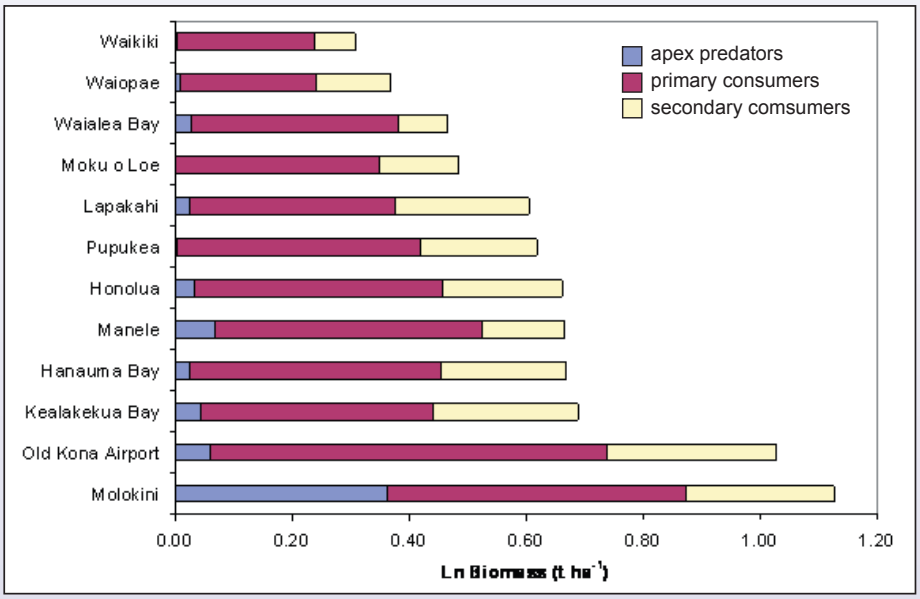
- Habitat complexity explained most of the variability in fish biomass, species richness, and diversity. Habitat complexity was higher in MLCDs than in adjacent open areas, as many MLCDs were established specifically to protect high quality habitat. When controlling for habitat complexity, MLCDs still had significantly greater fish biomass than open areas of similar habitat complexity.
- Fish biomass was 2.6 times greater in MLCDs and the Moku o Loe reserve than in open areas.
- Depth range explained most of the variability in species richness and diversity among protected areas; MLCDs with wider depth ranges had more species and higher diversity than protected areas with a more narrow range of depths.
- Size spectra analysis indicated that adult fish were larger and that larger fish were more abundant in protected areas.

Trophic composition observations

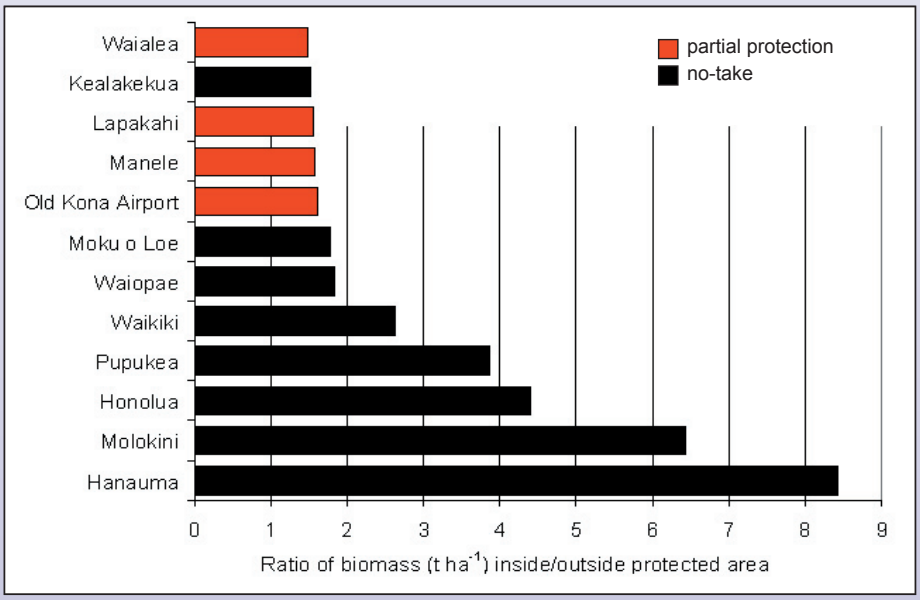
- Primary consumers (herbivores) were the most abundant (numerical and biomass) trophic group among major habitat types.
- Although overall biomass was low in sand habitats, apex predators accounted for 60% of the biomass there, highlighting the importance of sand habitats and the need to incorporate them into reserve design.
- The mean ratio of apex predator biomass was more than 17 times higher in MPAs than in adjacent areas open to fishing.
- Herbivore biomass in protected and open areas showed a negative relationship with macroalgal cover.

Comparisons among Hawaiian MPAs

- Molokini Shoals MLCD had the highest fish biomass observed in all MLCDs, followed by Old Kona Airport, Kealakekua Bay, and Hanauma Bay. Molokini also had the highest biomass of apex predators (primarily sharks and jacks).
- Fish biomass in Hanauma Bay MLCD was more than 8 times higher than in the adjacent open area. This is likely due to poor habitat quality (sedimentation and invasive seaweeds) and high fishing pressure outside the MLCD.
- Waialea, Kealakekua, Lapakahi, Manele, and Old Kona Airport all had relatively small differences in the ratio of fish biomass inside the MLCD and in adjacent open areas. Lower fishing pressure and high habitat quality outside the MLCDs may explain these relatively small differences.
- Species richness, biomass, and diversity were low at Waikiki, Moku o Loe, Waiopae, and Waialea. The small size and shallow depth range of these MPAs limit their effectiveness for biodiversity conservation and fisheries replenishment.



Mean biomass (t/ha^{-1}) by trophic guild on hardbottom habitat only among all MLCDs and the Moku o Loe refuge.



Ratio of biomass (t/ha^{-1}) in hardbottom habitats inside MLCDs and the Moku o Loe refuge vs. outside areas open to fishing.

Future protected area design in the main Hawaiian Islands needs to incorporate a mosaic of habitats to support viable reef fish populations. Complex habitats harbor higher biomass and greater species richness. Shallow nearshore habitats are necessary for recruit settlement and juvenile survival, while deeper habitats are important foraging, sheltering, and spawning sites for large adults. In addition to these hardbottom habitats, sandy areas are important corridors for the movement of species between hardbottom habitats. Adjacent non-reef habitats provide coral reefs with a net gain in energy through feeding guilds that shelter on the reef by day and forage in surrounding habitats at night.

MLCDs in Hawaii were established to support the State of Hawaii's conservation and education objectives, not to enhance fish stocks. As a consequence, most MLCDs are currently too small and encompass too few habitat types to provide substantial benefits to coastal reef fisheries. MLCDs currently encompass less than 1% of the total reef area of the main Hawaiian Islands. Reserves of sufficient size can be self-sustaining over time through retention of larvae. Alternately, a well-designed network of reserves, established at distances that enable transfer of propagules between reserves, can also protect existing populations and enhance non-protected populations through larval dispersal.

For more information, please contact:
Alan Friedlander at (808) 259-3165 or Alan.Friedlander@noaa.gov
Mark Monaco at (301) 713-3028 x174 or Mark.Monaco@noaa.gov
Athline Clark at (808) 587-0099 or Athline.M.Clark@Hawaii.gov
Additional information may also be found at: http://biogeo.nos.noaa.gov.