Nature Conservancy of Hawaii
Maunalua Marine Survey Report

I.D. Williams, M. Mejia, Z.R. Caldwell, K.S. Pollock, E.J. Conklin

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Summary of Main Findings

- The TNC Circuit Rider team conducted a total of 28 fish surveys of 10-50ft deep hard-bottom reef areas at the Maunalua reef in April 2009. Survey methods were comparable to recent statewide surveys of MLCDs and open areas by scientists from NOAA and UH, and with TNC monitoring at other circuit rider sites including Puako. Hence Maunalua fish communities can be meaningfully compared with 26 other locations statewide.
- Maunalua survey effort was distributed among 3 locations in the bay: Black Point (west), Wailupe (central), and Portlock (East).
- Total fish biomass values of 9.4 to 14.7 g m^{-2} at the three Maunalua reef areas surveyed were the three lowest values of the 29 sites from which we have comparable data. Mean Maunalua biomass in the bay (average of the three survey areas) was only 14.5% of biomass in Oahu reserves (Waikiki MLCD, Hanauma Bay MLCD, Pupukea MLCD, Moku o Loe [Coconut Island] Reserve).
- "Target fishes" (i.e. species which are generally preferred by fishers) were particularly scarce at the Maunalua areas surveyed: mean biomass of those of 3.1 gm^{-2} was a little over $1/20^{th}$ of the average for Oahu MLCDs. "Prime spawners," (i.e. target fishes > 70% of their maximum size, which constitute the main portion of the breeding stock for most species) were almost never encountered during surveys: mean biomass of those at Maunalua of 0.03 gm^{-2} was 0.2% of the average for Oahu MLCDs (i.e. *one five hundredth* of the Oahu MLCD average).
- "Non-target" fishes were also depleted at Maunalua Bay relative to Oahu MLCDs, but to a far lower degree than was the case for target and prime spawner fishes described above. Non-target biomass at Maunalua of 6.7 gm^{-2} was 59% of the average of Oahu MLCDs.
- The introduced grouper *roi* (*Cepaholpholis argus*) were present but not abundant at the surveyed Maunalua reef areas. Roi constituted only 0.6% of total fish biomass – which was among the lowest portion of total fish biomass of any of the reef areas from which we have data.
- Overall, Maunalua reef fish communities are in very poor condition indeed – and almost certainly among the very worst in the Hawaiian Islands. Target groups and, particularly, large individuals of those groups, are especially depleted.
- The Circuit Rider program was designed to generate reliable information on status and trends, but it does not provide direct information as to why or how reef condition at Maunalua has reached its current state. Clearly (based on visual observation), the reef habitat is highly degraded, and almost certainly a range of factors including poor water quality and terrestrial run-off of sediments and pollutants have contributed to that. However, multiple strands of evidence indicate those are not the only factors to have contributed to the current state of fish stocks, including that depletion of non-target fishes is much less than of non-target species. It is also notable that biomass of target fishes at Waikiki MLCD is around 10 times higher than in Maunalua Bay in spite of the fact that the Waikiki reef area likely experiences many of the same water quality, run-off, and poor habitat quality issues as Maunalua Bay.

Setting and Goals

The Nature Conservancy of Hawaii's primary goal at Maunalua is to support community-led initiatives to strengthen protection of the Maunalua reef and associated marine communities. One element of that is to generate information on the status, and ultimately trends, of biological communities of the Maunalua reef. A core goal is to put the condition of Maunalua reef communities into a broader context by comparing results from the Maunalua surveys with data from other comparably-surveyed reef areas in Hawaii.

With the support of the Harold K.L. Castle Foundation, TNC initiated the "circuit rider" reef monitoring program in 2009. Circuit rider monitoring involves a dedicated survey team that works with local staff to apply standard survey methods and a consistent monitoring approach at locations around the state where communities are interested in managing near shore marine resources. Presently, the circuit rider team spends around 2 weeks per year on field work per location, and our expectation is that a similar level of commitment will be possible into the future.

The portion of coastline of interest spans from Black Point to Portlock (Figure 1). Because of the size of the area (shoreline of approximately 7 miles), and the perception that reef areas around the edge of the bay may be in better condition than reefs in more central portions of the bay, we decided to sample in three distinct reef areas representing two "edge" areas and a central area: Black Point, Wailupe, and Portlock.

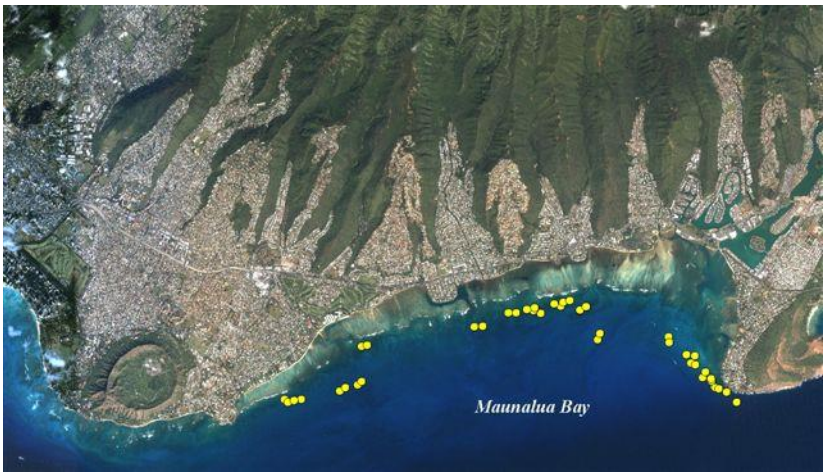

Figure 1. The yellow dots indicate the survey locations from the April 2009 monitoring effort in Maunalua Bay. The three clusters of points occur in the three distinct reef areas selected for surveys.

Target Habitat and Biological Communities

TNC Circuit rider monitoring at Maunalua (and elsewhere) focuses on reef areas within a specific target habitat: 10-50 ft deep hard-bottom. The 10-50 ft bounds were decided for logistical and practical reasons. Areas shallower than 10 ft are excluded because they tend to be highly variable (hence, it is difficult to draw ecologically or statistically meaningful conclusions based on large-scale surveys of very shallow reef areas) and because it can be difficult or impossible to work in very shallow water when there is much surge. Deeper areas (below 50 ft) are excluded, because surveying in deeper water drastically reduces the time the team can spend underwater per day, and because human impacts and resource-use conflicts are likely to be greatest in relatively shallow and nearshore waters. Surveys are

restricted to hard-bottom habitats, which includes the aggregate reef areas and pavement that are the dominant nearshore habitat types at Maunalua.

Future reports will include information on benthic communities and invertebrates (e.g. sea-urchins), but the current focus is on coral reef fish communities. Because of the constraints of underwater visual surveys, fish surveys are largely of diurnal and non-cryptic species.

Survey Methods and Sampling Design

Surveys locations are randomly located within the area of interest (10-50 ft hard-bottom). For the current round of surveys, locations were selected using Excel to generate random depths and distances from a shoreline starting point. For future surveys, randomization will be done using an ArcGIS extension to select points within the Maunalua survey polygons.

Surveys are conducted by pairs of divers, surveying 10m-apart parallel 25*5m transects at each of the randomly-selected locations (Figure 2). Each diver records the species and size within 5 cm "slots" (i.e. 0-5, 5-10, 10-15 cm, etc.) of all fishes within or passing through the transect ahead of the diver. Divers move very slowly along transects, aiming to spend between 10 and 15 minutes to complete each transect.

The chosen fish survey method closely corresponds with that used by Dr. Alan Friedlander and colleagues for the "Fish Habitat Utilization Study (FHUS)" for which they surveyed reef assemblages in all Hawaii MLCDs and in comparable open (i.e. fished) areas. Details of the method and results of those surveys are given in a number of recent publications [1-3]. Using comparable methods allows TNC and partners to compare the results from circuit rider surveys with data from the 25 sites surveyed for the FHUS study. Crucially, as the FHUS sites include both MLCDs and fished areas on Oahu, Maui, Lanai, and Hawaii, the range of sites available for comparison with Maunalua and other circuit rider sites includes both some of the most protected as well as some of the most impacted reef areas in the main Hawaiian Islands.

The Maunalua circuit rider surveys covered by this report were conducted between 6 and 24 April 2009.

Data Handling

Fish data are generally given as biomass (i.e. wet weight) of fish per m^2 of reef area. Biomass per fish was calculated from estimated lengths using size to weight conversion parameters from FishBase [4] or the Hawaii Co-operative Fisheries Research Unit at the University of Hawaii. For purposes of comparison among sites, fish survey data were pooled into a number of broad categories, including:

- **All fishes** combined (excluding manta rays, as encounters with those are infrequent, but when they do occur biomass of even a single manta ray will overwhelm biomass of all other fishes recorded);
- **Target fishes**, i.e. reef species which are targeted or regularly harvested by fishers throughout much of the Hawaiian Islands. Those species include parrotfish, goatfish, most predatory fishes (e.g. jacks, sharks, uku), most surgeonfish species, many red fish (largely soldierfish and

bigeyes), and some large wrasse. A number of other species are also considered target species, and a full listing is given in Appendix A.

- **Prime Spawners**, i.e. target fishes larger than 70% of the maximum size reported for the species [4, 5]. Large target fishes are generally heavily targeted by fishers. In addition, fishes at the high end of their size range tend to be a disproportionately important component of total stock breeding potential due to greater fecundity of large individuals, and higher survivorship of larvae produced by large fishes [6]. Therefore prime spawner biomass is likely to be a good indicator of fishing impacts, and also represents an important component of ecological function (i.e. population breeding potential).
- **Non-target fishes**, i.e. species which are not targeted by fishers to any significant degree at most sites in Hawaii (e.g. small wrasse, hawkfish, benthic triggerfish). Appendix A also lists all non-target species used for this analysis.

In addition, data are polled by family for parrotfish and target surgeonfish. Those are abundant and conspicuous fishes which provide important ecosystem services (i.e. as herbivores).

NB. It should be noted that nearly all fish species are taken by some fishers at some times in Hawaii. Hence, it is not the case that all fish species are either targeted or non-targeted. Those groupings are intended to represent the high and low ends of the fishing pressure continuum, and in fact the majority of fish biomass at most sites is made up of species which fall somewhere in the middle of that continuum and which are not included in either group for this analysis.

Results and Discussion

Total fish biomass at Maunalua sites (mean ± standard error) was: 9.4 ± 3.2 g m^{-2} at Black Point; 12.7 ± 2.8 g m^{-2} at Wailupe; and 14.7 g m^{-2} at Portlock. As shown in figure 3, those values were the three lowest biomass values of any of the 29 Hawaiian sites from which we have comparable data (Figure 3).

The best comparisons with Maunalua are probably with the 4 Oahu reserves (Waikiki MLCD, Hanauma Bay MLCD, Pupukea MLCD, and Coconut Island Reserve). Fish biomass at Maunalua was approximately one seventh (14.5%) of the average of Oahu MLCDs (84.7 g m^{-2}). Of the Oahu MLCDs, Waikiki MLCD is likely to be the most comparable area to Maunalua, in terms of exposure, habitat and water quality. Fish biomass at Waikiki (68.8 ± 25.5 g m^{-2}) was more than 5 times higher than the average of Maunalua sites (Figure 3).

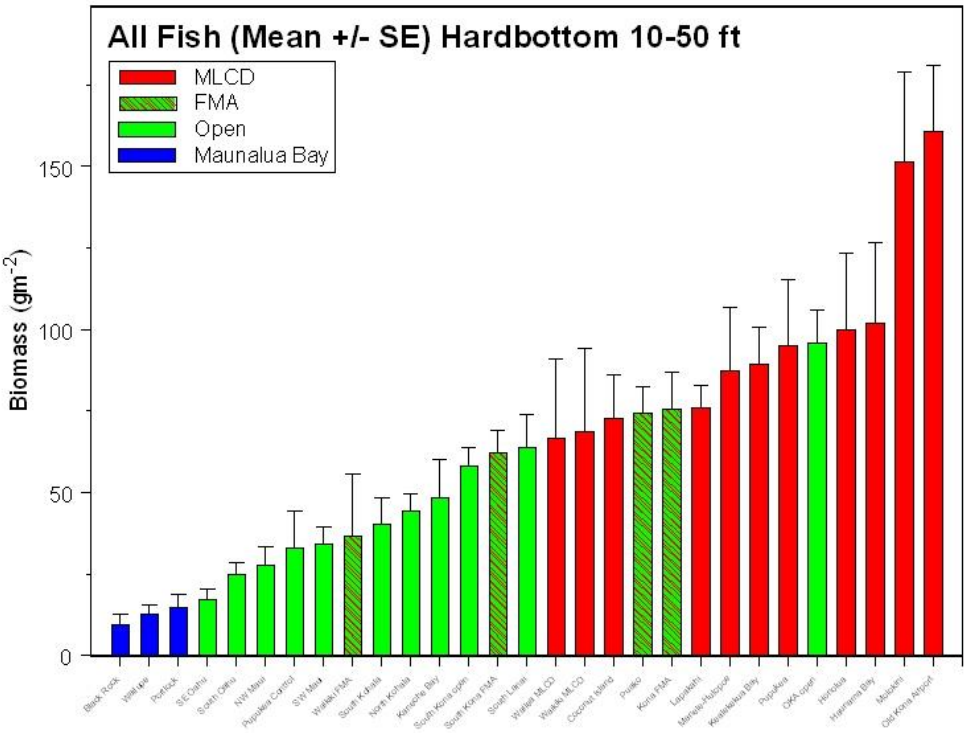

Figure 3. Biomass of all fishes at Maunalua (blue column) and 25 comparison sites from the Hawaiian Islands surveyed using comparable methods by Friedlander and colleagues for their "Fish Habitat Utilization Study" (FHUS). FHUS sites were either Marine Life Conservation Districts (MLCDs – fishing heavily regulated); Fisheries Management Areas (FMAs – some fishing restrictions, usually by gear type); or Open areas (comparison sites which were similar in structure and exposure to MLCDs, but were open to fishing). Maunalua is an FMA (gill net fishing restricted). Error bars represent one standard error.

Mean target fish biomass at Maunalua reef areas of between 2.3 and 3.9 g m^{-2} were again the three lowest values of the Hawaii reef areas from which we have comparable data, and Maunalua mean biomass of this group was only 6.4% of the average of Oahu MLCDs (Figure 4). Prime spawners were particularly scarce at Maunalua reef areas -- only one fish meeting that criteria (i.e. target fish >70% of max size) was encountered during the 28 surveys in Maunalua Bay. With only one encounter in the dataset, it is important not to over-interpret the result, but nevertheless it is worth noting that mean Prime spawner biomass at Maunalua was approximately *one five-hundredth* of the average of Oahu MLCDs, all of which were surveyed with comparable effort in the target habitat.

Biomass of non-target fishes in Maunalua (Black Point 2.3 ± 1.1 g m^{-2}; Portlock 3.6 ± 1.4 g m^{-2}; Wailupe 3.6 ± 1.4 g m^{-2}) were among the lower values of the comparable reef areas in Hawaii (Figure 4), but the degree of depletion relative to Oahu MLCDs was much less than for target fishes: Maunalua biomass being 59% of the average of Oahu MLCDs.

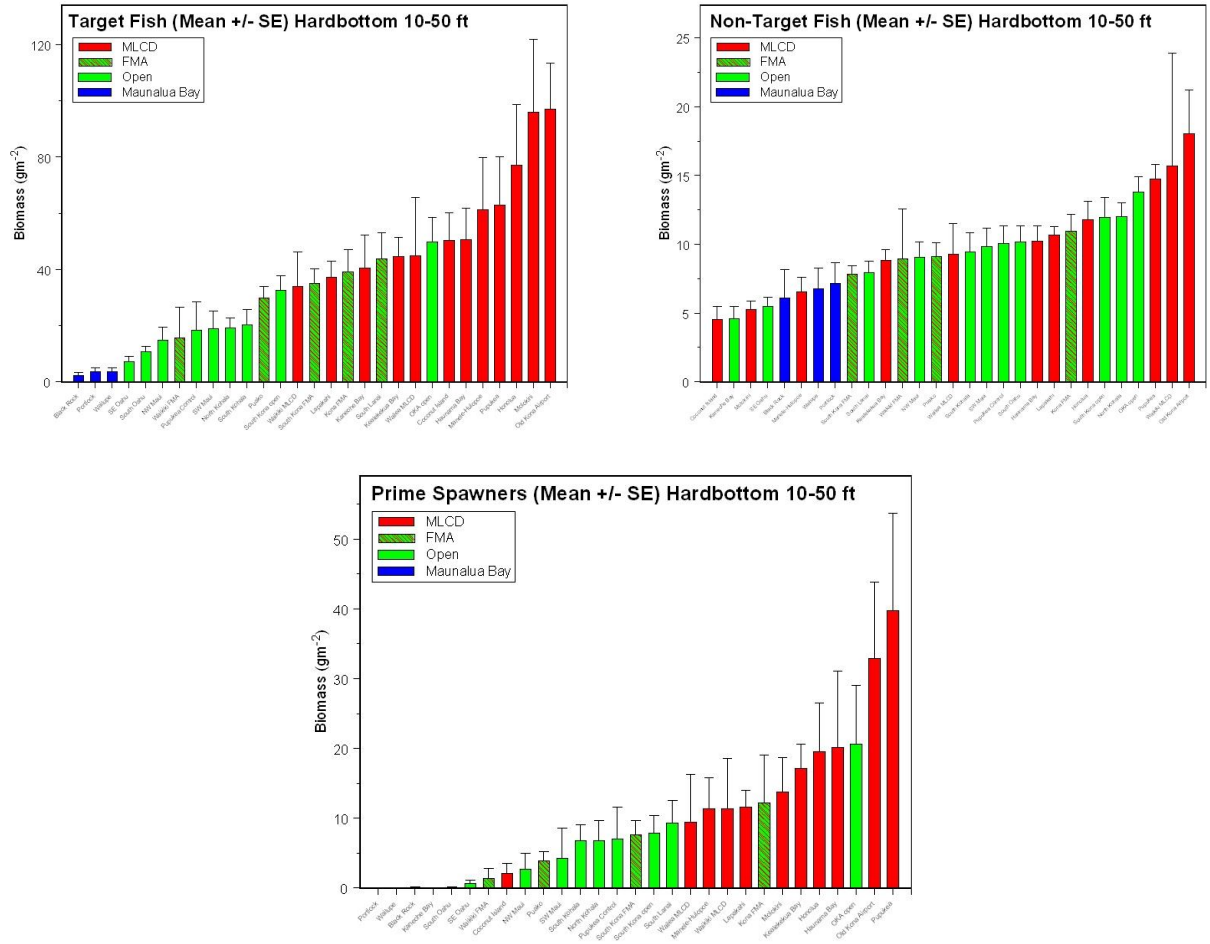

Figure 4. Target, non-target, and prime spawner fish biomass at Maunalua (blue column) and 25 comparison sites. Target and non-target fishes are specified in Appendix A. Because they are large fishes, prime spawners are likely to be key breeding individuals.

As with target fish generally, parrotfish biomass at Maunalua areas (Black Point 0.2 ± 0.2 g m^{-2}; Portlock 0.4 ± 0.2 g m^{-2}; Wailupe 1.3 ± 0.5 g m^{-2}) was very low relative to nearly all comparative sites (figure 5). The average of the 3 Maunalua areas (0.6 g m^{-2}) was 4% of the Oahu MLCD average. Target surgeonfish biomass at Maunalua (Black Point 1.4 ± 0.7 g m^{-2}; Wailupe 1.4 ± 0.8 g m^{-2}; Portlock 2.3 ± 1.0 g m^{-2}) was similarly at the extreme low end of the comparable sites (Figure 5). The Maunalua average of target surgeonfish was 6.4% of the Oahu MLCD average of 26.4 gm^{-2}. However, while the Maunalua Bay reef areas are certainly at the low end, biomass of these groups was roughly similar to that recorded at other open (unprotected) reefs on Oahu, particularly on south and south east Oahu (Figure 5).

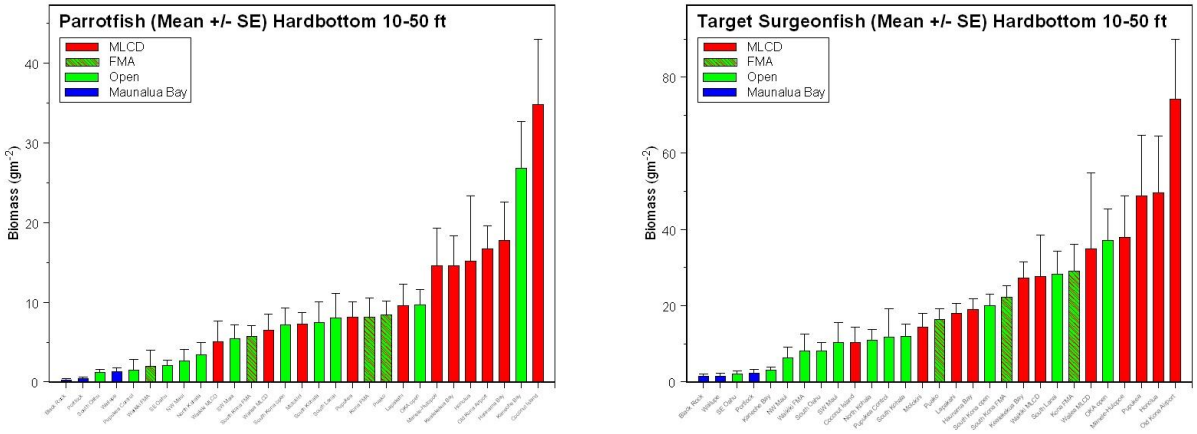

Figure 5. Parrotfish and Target Surgeonfish (surgeonfish in Target fish listed in Appendix A) at Maunalua and 25 comparison sites.

Roi (Peacock grouper, *Cephalopholis argus*) were observed at Maunalua sites by the circuit rider team, but only one individual was encountered on a transect during the course of the 28 surveys, indicating that they are not abundant relative to other reef areas surveyed using the same methods (Figure 6). *Roi* made up 0.6% of the total fish biomass recorded during Maunalua surveys, as compared to an average of 2.5% at other sites throughout the state. Hence, not only were *roi* rare in absolute terms, they were actually rare as a proportion of the total fish community at Maunalua. Therefore, the presence of *roi* in Maunalua Bay is by no means a likely explanation for the generally poor condition of reef fish resources there, and there is little basis for believing that *roi* eradication, could it be achieved, would lead to significant recovery of reef fish assemblages in Maunalua Bay. Given the great interest in the possible impacts of predation by *roi* on other reef fishes, it may be worth noting that the location where *roi* made up the greatest proportion of total reef fish biomass, Puako (where *roi* made up > 10% of reef fish biomass) has among the highest reef fish biomass of any non MLCD reef area from which we have data.

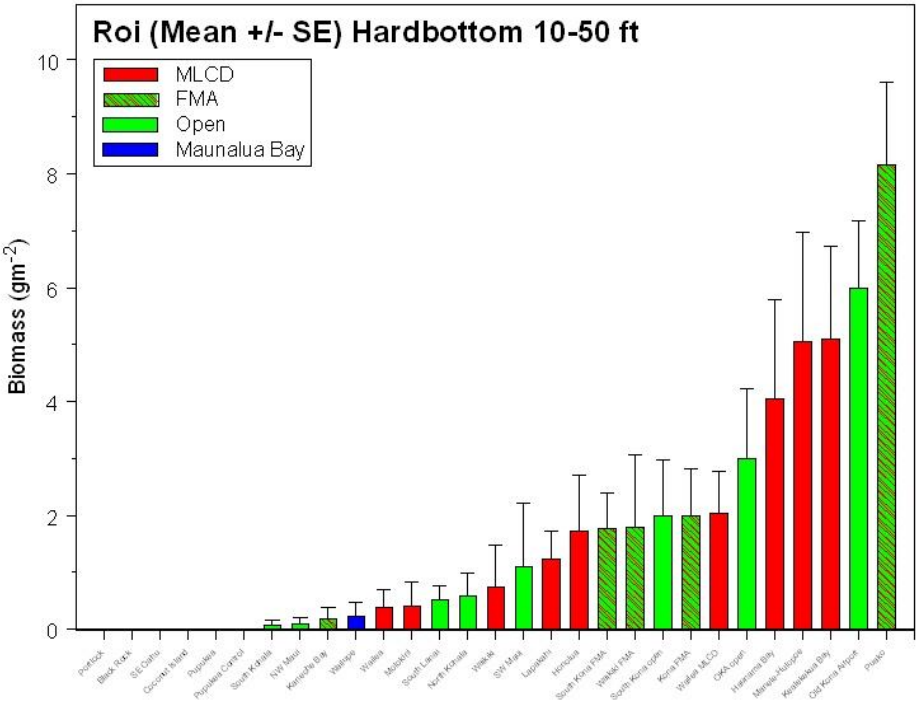

Figure 6. *Roi* biomass at Maunalua (blue column) and comparison sites.

In 28 surveys, each involving a pair of divers, no jacks or other apex predators were recorded.

Fish species richness in Maunalua Bay as a whole, i.e. the average number of fish species recorded across the 28 sites surveyed in the bay, of 10.9 ± 1.1 per transect was lower than at all 26 of the comparison sites, but was very similar to other values for unprotected reef areas around Oahu (11.0 at SE Oahu sites near Portlock, 11.9 in Kaneohe Bay, and 12.8 at South Oahu sites close to Waikiki).

Summary Remarks

Maunalua reef fish communities are in very poor condition relative to comparison sites throughout the state. Heavily targeted and ecologically important fish groups (parrotfish, surgeonfish, target fish generally, prime spawners in particular) were particularly depleted: biomass of those groups being between 0.2% and 6.4% of the average of the Oahu reserves from which we have data.

The nature of the circuit rider program, which focuses on status and trends, does not allow us to unequivocally determine the cause of differences among locations. However, habitat quality appeared to be degraded at nearly all the Maunalua sites visited by the circuit rider team, and it seems very likely that a variety of factors including poor water quality as well as run-off of terrestrial sediments and other pollutants have contributed to that condition. It is also notable that other Hawaiian reef areas with very low fish biomass (south and southeast Oahu, and northwest Maui) are also adjacent to densely populated and heavily developed shorelines, which likely suffer from many of the same pressures as Maunalua Bay.

However, while recognizing that the longer term control of a range of sedimentation and pollution issues will be essential to anything approaching full restoration of the health of the bay, it is worth noting that, even in their currently degraded state, south Oahu reefs are capable of supporting much higher fish biomass than was found at Maunalua. The clearest evidence for that is the case of Waikiki MLCD which likely suffers from many of the same water quality issues as other south Oahu reefs and also has mostly very poor habitat quality. Nevertheless, compared to Maunalua Bay reef areas, Waikiki MLCD has five times higher total fish biomass, 10 times as much target fish biomass, eight times the biomass of parrotfishes, and 30 times the biomass of prime spawners.

References

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2. Friedlander, A.M., E. Brown, and M.E. Monaco, *Defining reef fish habitat utilization patterns in Hawaii: comparisons between marine protected areas and areas open to fishing.* Marine Ecology-Progress Series, 2007. **351**: p. 221-233.
3. Friedlander, A.M., E.K. Brown, and M.E. Monaco, *Coupling ecology and GIS to evaluate efficacy of marine protected areas in Hawaii.* Ecological Applications, 2007. **17**(3): p. 715-730.
4. Froese, R. and D. Pauly, *FishBase 2000: Concepts, design and data sources*. 2000, Los Banos, Laguna, Philippines: ICLARM. 344.
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6. Birkeland, C. and P.K. Dayton, *The importance in fishery management of leaving the big ones.* Trends in Ecology & Evolution, 2005. **20**(7): p. 356-358.
7. Williams, I.D., et al., *Assessing the importance of fishing impacts on Hawaiian coral reef fish assemblages along regional-scale human population gradients.* Environmental Conservation, 2008. **35**(3): p. 261-272.

Appendix A. Target and Non-target fish groupings

Nearly all species of reef fish are taken to some degree, but certain groups are much more heavily targeted than others. As an indication of the relative importance of fishing (or, in reserves, protection from fishing) and other factors affecting local reef fish populations, we separately pool and analyze "target" and "non-target" groups of fishes. Groupings are as used for a recent large-scale analysis of Hawaii reef fish populations[7].

Table A1. Target Fish taxa used in analyses.

Family, Taxon	Family, Taxon
Surgeonfish - Acanthuridae	**Snappers - Lutjanidae**
Acanthurus achilles	*Aphareus furca*
Acanthurus blochii	*Aprion virescens*
Acanthurus dussumieri	
Acanthurus leucopareius	**Goatfishes – Mullidae**
Acanthurus nigroris	ALL
Acanthurus olivaceus	
Acanthurus triostegus	**Big-Eyes – Priacanthidae**
Acanthurus xanthopterus	ALL
Ctenochaetus spp.	
Naso spp.	**Jacks – Carangidae**
	ALL
Wrasse - Labridae	
Bodianus albotaeniatus	**Soldier/Squirrelfish - Holocentridae**
Coris flavovittata	*Myripristis* spp.
Coris gaimard	*Sargocentron spiniferum*
Iniistius spp.	*Sargocentron tiere*
Oxycheilinus unifasciatus	
Thalassoma ballieui	**Barracuda – Sphyraenidae**
Thalassoma purpureum	ALL
Parrotfish – Scaridae	**Others**
ALL	*Chanos chanos*
	Cirrhitus pinnulatus
Snappers - Lutjanidae	*Monotaxis grandoculis*
Aphareus furca	all Belonidae
Aprion virescens	all Scombridae

Note: other families including Albulidae, Elopidae, Mugilidae, would normally be considered as targeted taxa, but were not recorded during FHUS surveys of 10-50ft deep hard-bottom habitats and are only rarely encountered in that habitat. Kyphosidae and zooplanktivorous triggerfish (*Melichthys* spp.) are also taken by fishers in Hawaii, but were excluded from analyses due to extremely clumped distributions.

Table A2. Non-target Fish taxa used in analyses.

Family, Taxon
Surgeonfish - Acanthuridae
Acanthurus nigrofuscus
Acanthurus nigricans
Wrasse - Labridae
All species except those listed in Table A1
Hawkfish - Cirrhitidae
All species except *C. pinnulatus* (listed in Table A1)
Triggerfish - Balistidae
Sufflamen spp.
Rhinecanthus spp.
Rhinecanthus spp.
Corallivorous Butterflyfish - Chaetodontidae
Chaetodon auriga
C. ephippium
C. fremblii
C. lineolatus
Forcipiger spp.
Benthic Damselfish - Pomacentridae
Plectroglyphidodon spp.
Stegastes spp.