Assessment of Fish in Maunalua Bay, O‘ahu
Findings from Three Years of Marine Surveys (2009-2012)

by

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Summary of Key Findings

In 2009, 2010, and 2012, The Nature Conservancy's (TNC) marine monitoring team conducted 123 surveys on 3-18 m (10-50 ft) deep hard-bottom reef areas in Maunalua Bay. Survey methods were comparable to statewide surveys of Marine Life Conservation Districts (MLCDs) and open areas, and with TNC monitoring efforts at other locations around Hawai'i. Maunalua Bay was stratified into three survey areas: Black Point (West), Wailupe (Central), and Portlock (East).

Key findings from this effort include:

- **The mean total fish biomass in Maunalua Bay was lowest of the 24 sites for which we have comparable data.** The mean total fish biomass in the bay was less than 10% of biomass in Oʻahu reserves (Waikiki MLCD, Hanauma Bay MLCD, Pūpūkea MLCD, Moku o Loʻe [Coconut Island] Reserve).
- **"Target fishes" (i.e., species that are generally preferred by fishers) were rare at all Maunalua survey sites.** Maunalua Bay's mean resource fish biomass of 4.3 ± 0.2 g/m^2 was 8.5% of the average for Oʻahu MLCDs. "Prime spawners" (i.e., target fishes > 70% of their maximum size) were seldom encountered during surveys, and their mean biomass of 1.3 ± 0.9 g/m^2 was 7% of the average for Oʻahu MLCDs.
- **"Non-target" fishes were also depleted in Maunalua Bay**, but to a lower degree than target fishes and prime spawners.
- **The introduced grouper *roi* (*Cepaholpholis argus*) was present but not abundant** at the survey sites. *Roi* constituted only 0.5% of the total fish biomass, among the lowest portion of total fish biomass of any reef area for which comparable data exist. Therefore, the presence of *roi* does not adequately explain the generally poor condition of the reef fish assemblage in Maunalua Bay.
- **Overall, the Maunalua reef fish assemblage is in poor condition and is among the most adversely impacted in the state**. Target species and, in particular, large individuals of those species, were especially depleted.

The TNC marine monitoring surveys are intended to determine the status and trend of fish populations in Maunalua Bay, and not to unequivocally identify the stressors responsible for the current reef conditions in the bay. While recognizing that the coral reef habitat in the bay appears degraded by land-based sources of sediment and pollution, Maunalua Bay, even in its currently condition, should be capable of supporting significantly higher fish biomass. The clearest evidence for this is the Waikiki MLCD, which has similar water quality and habitat degradation issues, but **the Waikiki MLCD has seven times higher total fish biomass, eight times higher target fish biomass, seven times higher parrotfish biomass, and eight times higher prime spawner biomass than Maunalua Bay.** Based on these findings, reductions in fishing pressure through increased fishery management would likely result in increases in target fish biomass and the average size of fish.

Setting and Goals

The Nature Conservancy's primary goal in Maunalua Bay is to support community-led initiatives to manage the Maunalua reef and its associated marine communities. A key element of this effort is to collect information on the status and trends of biological communities within the bay, and to place the condition of Maunalua Bay reef communities into a broader context by comparing them with other reef areas in Hawai'i.

With the support of the Harold K.L. Castle Foundation, TNC initiated its marine monitoring program in 2009. This monitoring involves a dedicated survey team applying standard survey methods and a consistent monitoring approach at locations around the state where communities are interested in managing near shore marine resources.

Survey Methods and Sampling Design

Target Habitat and Biological Communities

TNC's monitoring program focuses on reef areas within a specific target habitat: 3-18 m (10-50 ft) deep hard-bottom. This depth range has been selected for several reasons. Human impacts and resource-use conflicts are likely to be greatest in shallow and nearshore waters. Areas shallower than 3 m are excluded because they tend to be highly variable, hence making it difficult to draw meaningful conclusions. It can also be challenging, and in some instances unsafe, to work in shallow water due to surge. Reefs deeper than 18 m were excluded because surveying in deeper water reduces the time a team can spend underwater per day, and because most of the species targeted by our surveys are primarily found in shallower reef areas. Surveys are restricted to hard-bottom habitats, because they are primary habitat for the majority of nearshore reef fish of interest to community members and fishers. This includes the aggregate reef areas and pavement that are the dominant nearshore habitat types in Maunalua Bay.

Sampling Design

In Maunalua Bay, the coastline of interest spans from Black Point to Portlock (Figure 1). Because of the size of the area (~11 km of shoreline), and the perception that the reef at the edge of the bay may be in better condition than the reef in the central portion of the bay, we stratified our sampling into three distinct reef areas: Black Point (hereafter West), Wailupe (Central), and Portlock (East).

Surveys sites were randomly selected within the area of interest. In 2009, 58 survey sites (Table 1) were selected using Excel to generate random depths and distances from a shoreline starting point. In 2010 and 2012, 23 and 42 survey sites, respectively, were randomly generated using ARC GIS software.

The 2009 surveys were conducted between 6 and 24 April. Winter 2010 surveys were conducted between 1 and 9 December and 13 and 28 January. Surveys in 2012 were completed between 11 January and 8 February. Ideally, annual surveys would have been conducted during the same calendar month(s) to reduce intra-annual variation in fish populations. Given the timing of the 2009 surveys, trends in the data across years should be interpreted with caution.

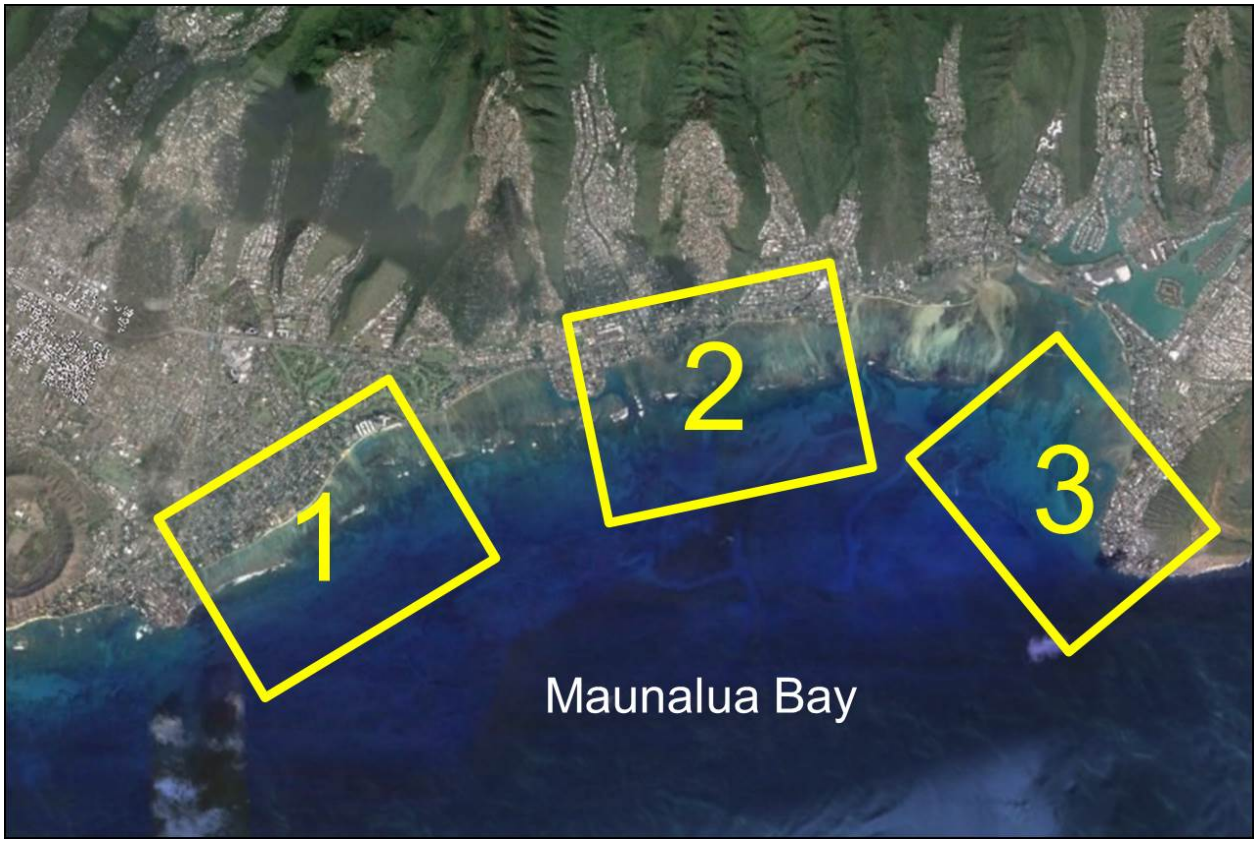

Figure 1. Three survey areas within Maunalua Bay: 1=West (Black Point), 2=Central (Wailupe), 3=East (Portlock).

Table 1. Number of survey sites within each of three survey locations in Maunalua Bay for 2009, 2010, and 2012.

Survey Date		West	Central	East	Total
2009	April	10	9	10	29
2010	January	18	23	11	52
2012	January	14	15	13	42
Total		42	47	34	

Survey Method

At each survey site, a pair of divers swimming 10 m apart on parallel 25-m transects, identified and counted all fish within or passing through a 5-m wide belt centered on the transect. All fish were sized into 5 cm "slots" (i.e. 0-5, 5-10, 10-15 cm, etc.). Divers moved slowly along the transects, taking between 10 and 15 minutes to complete each transect.

This fish survey method corresponds closely with that used by Dr. Alan Friedlander and colleagues for the "Fish Habitat Utilization Study (FHUS)" in 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 (Friedlander *et al.* 2006, Friedlander *et al.* 2007a, Friedlander *et al.* 2007b). Using similar methods allows for direct comparison of the Manualua Bay data with the sites surveyed for the FHUS study. Crucially, as the FHUS sites include both MLCDs and fished areas on O‘ahu, Maui, Lana‘i, and Hawai‘i Island, the range of sites available for comparison includes some of the most protected as well as some of the most impacted reef areas in the main Hawaiian Islands.

Data Analysis

Fish data are presented as biomass (i.e., wet weight) of fish per m^2 of reef area (i.e., g/m^2). We calculated biomass per fish from the estimated fish lengths using size-to-weight conversion parameters from FishBase (Froese and Pauly 2000) or the University of Hawai‘i Cooperative Fisheries Research Unit (HCFRU). Prior to comparison with other sites, data were pooled into four broad categories:

- **All fishes:** All species excluding manta rays, which are generally infrequently encountered, but when present tend to overwhelm the biomass of all other fishes;
- **Target fishes[1]:** Reef species that are targeted or regularly harvested by fishers throughout the Hawaiian Islands. These include parrotfish, goatfish, most predatory fishes (e.g., jacks, sharks, uku), most surgeonfish species, many red fish (largely soldierfish and bigeyes), and some large wrasses. For a complete list, see Appendix A.
- **Prime Spawners**: Target fishes larger than 70% of the maximum size reported for the species (Froese and Pauly 2000, Randell 2007). Prime spawners are generally preferentially targeted by fishers. In addition, fishes at the large end of their size range tend to be a disproportionately-important component of total stock breeding potential due to their greater fecundity and the higher survivorship by the larvae they produce (Birkeland and Dayton 2005). Therefore prime spawner biomass is likely to be a good indicator of fishing impacts, while also representing an important component of ecological function (i.e., population breeding potential).
- **Non-target fishes**: Reef species that are not significantly targeted by fishers in Hawai'i (e.g., small wrasse, hawkfish, benthic triggerfish). See Appendix A for a complete list of non-target species.

Data were also pooled by family for parrotfish and target surgeonfish. These abundant families tend to be conspicuous on the reef and provide important ecosystem services (i.e., as herbivores, they help to control algae).

Results and Discussion

Over three years of surveys, a total of 125 species in 29 families were observed in Maunalua Bay. Surgeonfish (Acanthuridae) were the most abundant family, accounting for a third of the total fish biomass. Only wrasses (Labridae), triggerfish (Balistidae), goatfish (Mullidae), and parrotfish (Scaridae) accounted to more than 5% of the total fish biomass in Maunalua Bay.

[1]Nearly all fish species are taken by some fishers at some times in Hawai'i. These groupings are intended to represent the high and low ends of the fishing pressure continuum.

Total fish biomass in the three survey areas varied between 4.7 and 15.0 g/m^2 (Table 2) with relatively little variability among years. While there appears to be a trend of lower biomass in the East survey area compared to the West and Central, we found no significant difference among the three areas.

Table 2. Mean (± SEM) total fish biomass (g/m^2) in the three survey areas within Maunalua Bay (West, Central, and East) and across the bay as a whole (Maunalua Bay).

Survey Date		West	Central	East	Maunalua Bay
2009	April	4.7 ± 1.6	6.1 ± 1.3	7.4 ± 2.0	6.7 ± 0.9
2010	January	10.9 ± 3.0	10.8 ± 3.4	5.8 ± 1.8	9.6 ± 1.7
2012	January	12.7 ± 3.7	5.2 ± 1.0	4.8 ± 1.1	7.6 ± 1.4

Maunalua Bay had the lowest total fish biomass among sites with comparable data (Figure 2). The mean total fish biomass in Maunalua Bay (8.0 ± 0.3 g/m^2) was approximately one tenth of that in the O‘ahu MLCDs (Waikiki MLCD, Hanauma Bay MLCD, Pūpūkea MLCD, and Moku o Lo‘e [Coconut Island] Reserve). Given wave exposure, habitat and water quality, the Waikiki MLCD is the most comparable MLCD to Maunalua Bay. Total fish biomass at Waikiki (68.8 ± 25.5 g/m^2) was more than seven times higher than in Maunalua Bay (Figure 2).

Target fish biomass in Maunalua Bay averaged 4.3 ± 0.2 g/m^2, which was among the lowest values among comparable sites. Target fish biomass at Maunalua was ~6% of that found in O‘ahu MLCDs (Figure 3). Prime spawners were scarce in Maunalua Bay; over three survey years, only fifty-six prime spawners were encountered, averaging 1.3 ± 0.9 g/m^2. Prime spawner biomass in Maunalua Bay was ~5% of that in O‘ahu MLCDs. The biomass of non-target fishes in Maunalua (2.7 ± 0.3 g/m^2) was also among the lowest among reef areas, but the degree of depletion relative to O‘ahu MLCDs was much less than for target fishes. Biomass of non-target fishes in Maunalua Bay was ~60% of that found in O‘ahu MLCDs.

As with target fish in general, parrotfish biomass in Maunalua Bay (0.8 ± 0.3 g/m^2) was low relative to comparable sites. The average parrotfish biomass in Maunalua Bay was ~5% of that in O‘ahu MLCDs. Target surgeonfish biomass in Maunalua Bay (1.8 ± 0.2 g/m^2) was similarly low when compared with other sites. The mean target surgeonfish biomass in Maunalua Bay was ~7% of that in O‘ahu MLCDs. However, while reefs in Maunalua Bay were on the low end of the range, these biomass values were roughly similar to those found on other O‘ahu reefs open to fishing, particularly on south and southeast O‘ahu shorelines.

Roi (Peacock grouper, *Cephalopholis argus*) were rarely observed in Maunalua Bay. Only seven individuals were encountered on transects over three years of surveys. *Roi* comprised only 0.5% of the total fish biomass in Maunalua Bay, as compared to an average of 2.5% at other sites throughout the state. Therefore, the presence of *roi* does not adequately explain the generally poor condition of the reef fish assemblage in Maunalua Bay, and there is little expectation that *roi* eradication, could it be achieved, would lead to significant recovery of Maunalua Bay's fish resources.

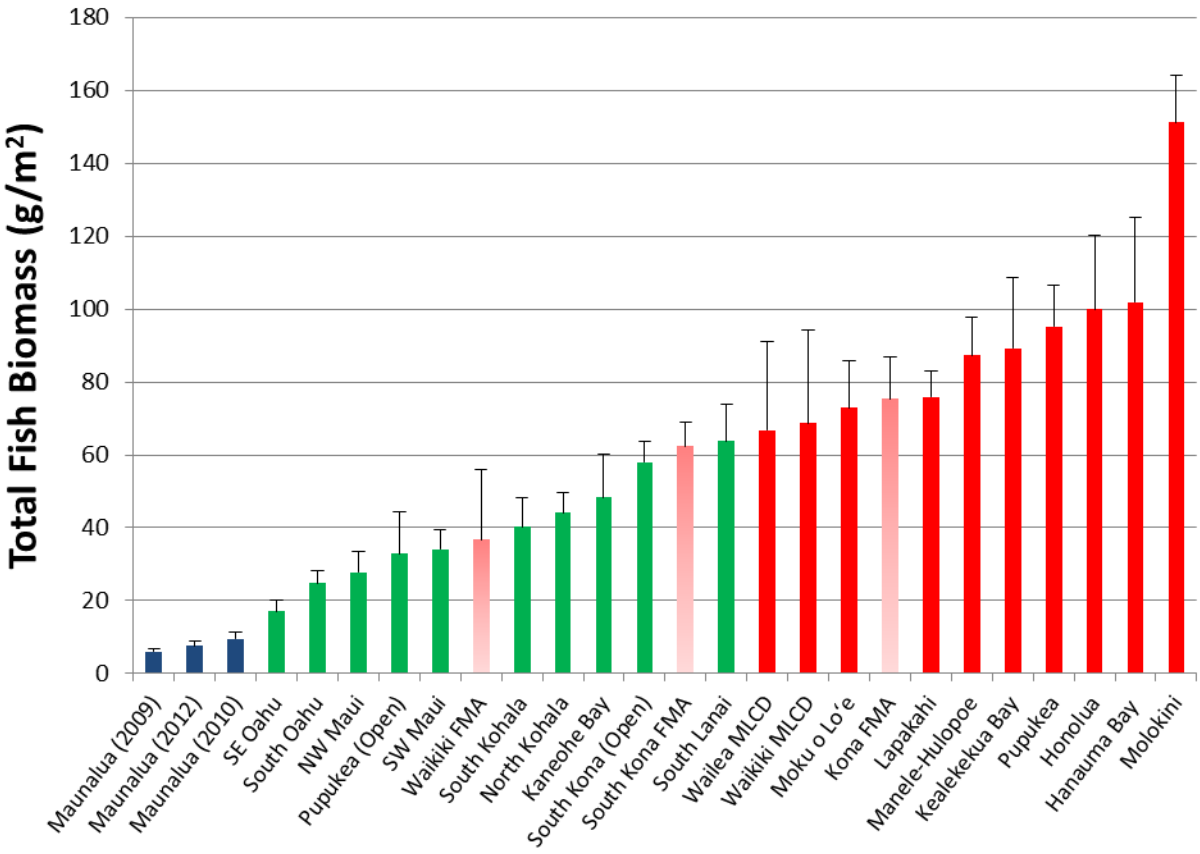

Figure 2. Total fish biomass in Maunalua Bay (blue bars) and 23 comparison sites from the Hawaiian Islands. Red bars=Marine Life Conservation Districts (MLCDs). Gradated red bars= Fisheries Management Areas (FMAs). Green bars=Open fishing areas. Maunalua is an FMA (gill net fishing restricted). Error bars represent one standard error of the mean.

Summary

Maunalua reef fish communities are in poor condition relative to all other comparison sites throughout the state. Heavily targeted and ecologically important fish groups (parrotfish, surgeonfish, target fish generally, prime spawners in particular) were particularly depleted.

These surveys are intended to determine the status and trends of fish population in Maunalua Bay and not to determine the cause of the differences with other locations. However, habitat quality appeared to be degraded at many Maunalua sites, and it's likely that numerous factors including poor water quality, run-off of terrestrial sediments, and other pollutants have contributed to this condition. It is also notable that other Hawaiian reef areas with very low fish biomass (south and southeast O‘ahu, and northwest Maui) are also adjacent to densely populated and heavily developed shorelines, which likely suffer from similar stressors as Maunalua Bay.

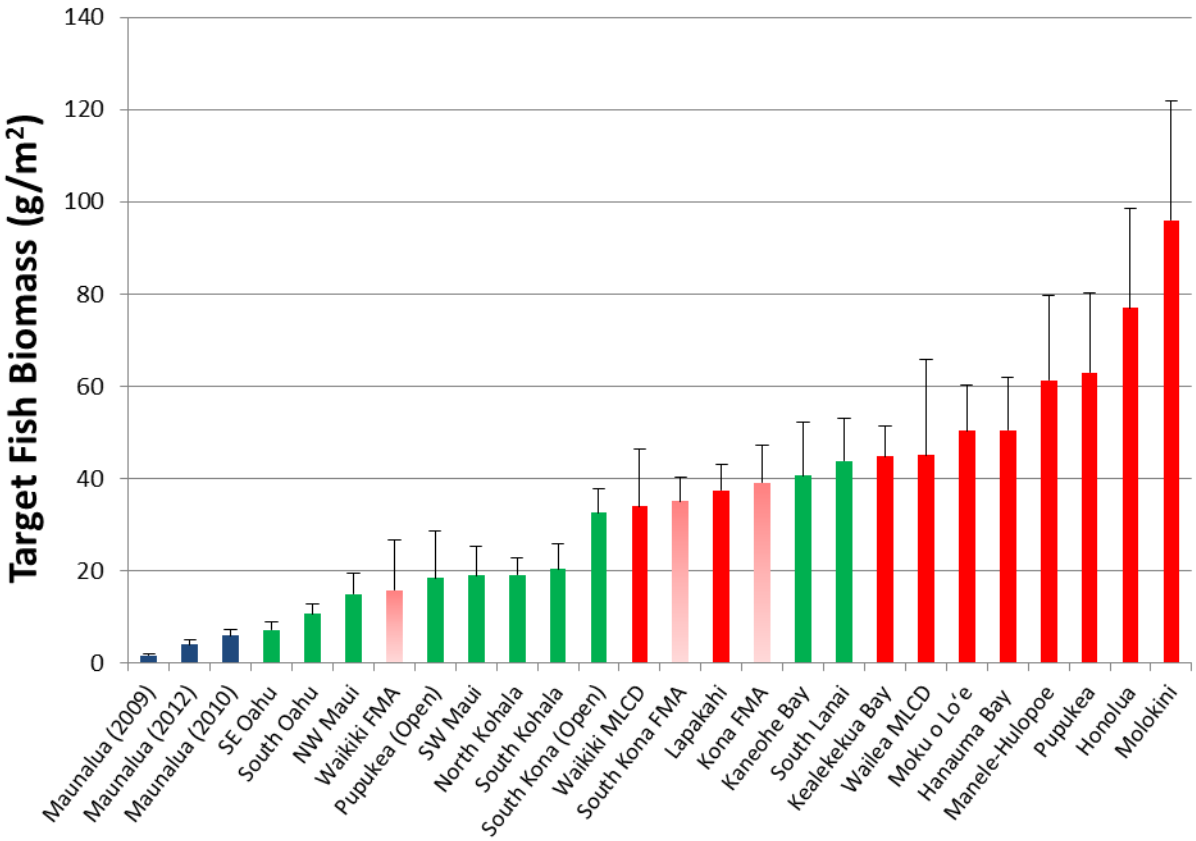

Figure 3. Target fish biomass in Maunalua Bay (blue bars) and 23 comparison sites from the Hawaiian Islands. Red bars=Marine Life Conservation Districts (MLCDs). Gradated red bars= Fisheries Management Areas (FMAs). Green bars=Open fishing areas. Maunalua is an FMA (gill net fishing restricted). Error bars represent one SEM.

While recognizing that control of sedimentation and pollution issues will be essential to the complete restoration of the bay, even in its currently degraded condition, Maunalua Bay should be capable of supporting significantly higher fish biomass. The clearest evidence for this is the Waikiki MLCD, which has similar water quality and habitat degradation issues, but has eight times higher total fish biomass, eight times as much target fish biomass, seven times the biomass of parrotfishes, and eight times the biomass of prime spawners.

References

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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 3-18 m deep hard-bottom habitats and are only rarely encountered in that habitat. Kyphosidae and zooplanktivorous triggerfish (*Melichthys* spp.) are also taken by fishers in Hawai‘i, but were excluded from analyses due to clumped distributions (i.e., large numbers of individuals in some areas but not others).

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.