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REPORT ON THE FINDINGS AND RECOMMENDATIONS OF EFFECTIVENESS OF THE WEST HAWAI'I REGIONAL FISHERY MANAGEMENT AREA

Prepared by

Department of Land and Natural Resources
State of Hawai'i

In response to

Section 188F-5, Hawai`i Revised Statutes

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REPORT ON THE FINDINGS AND RECOMMENDATIONS OF EFFECTIVENESS OF THE WEST HAWAI'I REGIONAL FISHERY MANAGEMENT AREA

The West Hawaiʻi Regional Fisheries Management Area (WHRFMA) was created by Act 306, Session Laws of Hawaii (SLH) 1998, largely in response to longstanding and widespread conflict surrounding commercial aquarium collecting. The Act, now Chapter 188F, Hawaii Revised Statutes (HRS), required of the Department of Land and Natural Resources (DLNR), 1) A review of the effectiveness of the WHRFMA every five years, in cooperation with the University of Hawaii (UH), and 2) A report of its findings and recommendations prepared by DLNR to the Legislature following the review.

The overall goals of the Act are to effectively manage fishery activities, enhance nearshore resources and reduce conflict. Four management objectives were mandated: 1) Prohibit aquarium collecting in a minimum of 30% of West Hawaiʻi coastal waters, 2) Establish a day-use mooring buoy system, 3) Establish no-take reef fish reserves, and 4) Designate areas which prohibit gill nets.

SUMMARY OF FINDINGS

In order to accomplish the mandates of Act 306, SLH 1998, with required substantive community input, a community advisory group, the West Hawaiʻi Fisheries Council (WHFC) was convened by DLNR's Division of Aquatic Resources (DAR) in 1998. The first accomplishment of the WHFC was the designation of a network of nine Fish Replenishment Areas (FRAs), comprising 35.2% of the coastline. Aquarium collecting is prohibited within the FRAs. The FRAs became effective 31 December 1999.

Ten years after closure of the FRAs, the top 20 aquarium species showed a small overall increase in abundance relative to the period before the FRAs were operational. Most of the increase was attributed to the top two species Yellow Tang and Goldring Surgeonfish (kole) which comprise 91% of the West Hawaiʻi aquarium catch. These species increased in the FRAs by 57% and 13% respectively. Seven of the top 10 most collected species (representing <6% of all collected fish) decreased in overall density. Three of these decreases were significant (Achilles Tang, Multiband Butterflyfish and Black Surgeonfish).

The FRAs were ‘effective’ (increases in FRAs relative to long term MPAs) for eight of the top 10 collected species with three being statistically significant. With only a single exception, the FRAs were highly effective in increasing the abundance of Yellow Tang within their areas spread along the West Hawaiʻi coastline. While habitat characteristics, FRA size, and density of adult fishes are important factors influencing the effectiveness of FRAs, successful recruitment of young fish is a fundamental requirement. Poor recruitment appears to be a key factor in the population declines within the FRAs of some aquarium species.

The effect of the FRAs on the aquarium fishery itself has been positive overall. The number of commercial aquarium collectors in West Hawaiʻi increased 19% over the past 10 years, catch increased 25%, and its value 71%. In terms of conflict reduction between stakeholder groups, survey data indicated that for both aquarium fishers and SCUBA dive operators, more individuals felt the FRAs were effective than not.

As a management adjunct to the FRAs, the WHFC has recommended a 'white list' of 25 species which can be harvested by aquarium collectors. All other species would be off limits. 12+ other species of special concern, with particular ecological and cultural importance, were also proposed for protected (i.e. no-take) status. To prevent the continued unbridled growth of the aquarium fishery, the WHFC has proposed the implementation of a limited entry program for West Hawaiʻi, which would be the first of its kind in state waters.

The day-use mooring buoy system is well established with limited expansion anticipated in the near future. As part of a 10-Year Strategic Management Plan for the day-use mooring system, the Malama Kai Foundation is working with DLNR to write and refine objectives for the system and develop bio-physical criteria for site selection.

Somewhat delayed progress on the establishment of no-take reef fish reserves is being realized. Educational and outreach efforts have been reinvigorated recently and survey results indicate increasing acceptance of the utility and benefit of such marine protected areas. Several local communities are actively engaged in developing management recommendations which include some form of a highly protected nearshore area.

Eight no lay gill netting areas were established in West Hawaiʻi in 2005, comprising 25% of the coastline (including already protected areas). Preliminary nearshore monitoring results do not find major differences in food fish abundance in/out of the no netting areas. The lack of a marked effect of protection may be due to several factors including the relatively low number of lay gill nets that are presently being used (i.e. registered) in West Hawaiʻi.

Although not formally established by statute, the West Hawaiʻi community's formation of the WHFC has been, and continues to be, invaluable and instrumental in achieving the objectives of Act 306, SLH 2008. Recent WHRFMA initiatives which are in the process of administrative rule making include a ban on SCUBA spearfishing, species of special concern listing and resolution of aquarium related conflict at Pebble Beach, South Kona. Based on over a decade of experience, the WHFC has been a model system for the resolution of issues surrounding reef fisheries resources. Based on this review, a number of specific recommendations are proposed.

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BACKGROUND

The WHRFMA was conceived and established primarily in response to the activities of aquarium collectors along the West Hawai'i coastline. Overall, the marine aquarium fishery in the State of Hawai'i is one of the most economically valuable commercial inshore fisheries with Fiscal Year (FY) 2009 reported landings of 557,673 specimens and a total value of $1.08 million. The reported values may be underestimated by a factor of approximately 2 to 5X (Cesar et al. 2002, Walsh et al. 2003). Walsh et al. 2003 provides an historical overview of the commercial aquarium fishery in Hawai'i.

The aquarium collecting industry in Hawai'i and especially in West Hawai'i has long been a subject of controversy. In contrast to other areas in the State, in West Hawai'i the aquarium fishery has undergone substantial and sustained expansion over the past 30 years (Figure 1). Presently 75% of fish caught in the State and 67% of the total aquarium catch value comes from the Big Island and almost exclusively from West Hawai'i (Table 1). As the number of collectors in West Hawai'i began to rise and the numbers of animals collected increased markedly, conflict escalated along the coast, most particularly between dive tour operators and collectors. A short-lived informal "Gentleperson's Agreement" was reached in 1987 whereby aquarium collectors agreed to refrain from collecting in certain areas. In return, charter operators agreed not to initiate legislation opposing collecting and to cease harassment. In 1991 four of the areas from

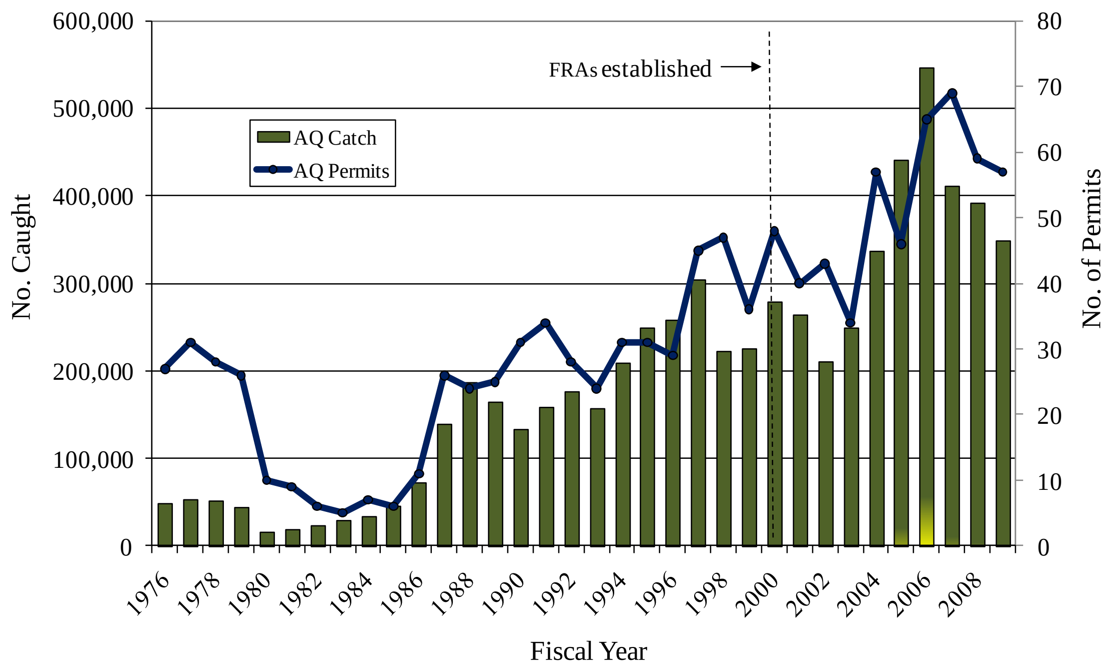

Figure 1. Number of aquarium animals collected and number of commercial aquarium permits in West Hawai'i for Fiscal years 1976-2009.

the Gentleperson's Agreement were established as the Kona Coast Fisheries Management Area (FMA) within which aquarium collecting is prohibited (§13-58, Hawaii Administrative Rules (HAR)).

In spite of these management efforts, controversy and conflict over aquarium collecting continued unabated. Various meetings were held and legislative resolutions and bills were drafted to address the issue. A 1996 House Concurrent Resolution (HCR 184) requested DLNR, in conjunction with a citizens' task force, to develop a comprehensive management plan to regulate the collection of aquarium fish. A West Hawai'i Reef Fish Working Group (WHRFWG) involving over 70 members of the West Hawai'i community including aquarium collectors and charter operators and other stakeholders held nine meetings over a 15 month period. The WHRFWG opened a dialog between user groups and community members and provided a forum for the education of its members on social and biological issues involved in resource management

Table 1. Changes in West Hawai'i aquarium fishery since implementation of the FRAs. Dollar value is adjusted for inflation.

	FY 2000	FY 2009	Δ
No. Permits	48	57	19% ↑
Total Catch	279,606	349,250	25% ↑
Total Value	$745,129	$1,271,329	71% ↑
% of State Fish Catch	70%	75%	5% ↑
% of State Fish Value	67%	69%	2% ↑
% of State Total Catch	55%	63%	8% ↑
% of State Total Value	59%	67%	8% ↑

The WHRFWG identified "hot spots" along the coast where conflict over ocean resources was especially intense and also proposed a wide range of management recommendations, some of which were included in the 1997 DLNR legislative package. Working directly with the people of Ho'okena and Miloli'i, DAR developed comprehensive FMA rule proposals for each of these communities. To finally begin investigating the biological impact of collecting, DAR also commenced a joint research project with the University of Hawai'i-Hilo. Due in part to opposition by O'ahu aquarium collectors, only one legislative recommendation of the WHRFWG passed; establishing licenses for aquarium exporters. Similarly, recommendations involving the DAR FMA rule proposals languished.

Act 306, SLH 1998

In response to the perceived lack of success in adequately dealing with aquarium collecting, a number of citizens, including several members of the WHRFWG formed a grassroots organization, the Lost Fish Coalition (LFC), to push for a total ban on aquarium collecting in West Hawai'i. They collected almost 4,000 signatures on a petition to ban such collecting. In January 1997, Representative (Rep.) Paul Whalen (R-Kona, Ka'u) introduced legislation (House Bill (HB) 3349) which proposed an outright ban on all collecting between Kawaihae and Miloli'i. Shortly thereafter, Rep. David Tarnas (D-N. Kona, S. Kohala) introduced HB 3457. This bill proposed establishing a West Hawai'i Regional Fishery Management Area (WHRFMA) along the entire 147 mile West Hawai'i coast (Upolu Pt. to Ka Lae) to provide for effective management of marine resources. Among several provisions of this bill was a requirement to set aside 50% of the WHRFMA as Fish Replenishment Areas (FRAs) where aquarium collecting was prohibited. In February 1998, HB 3348 was put on hold. During committee hearings on HB 3457, the 50% provision for FRAs was reduced to "a minimum of 30%." Aquarium collectors and other user groups endorsed the bill and it was passed by the Legislature as Act 306, SLH 1998; effective 13 July 1998.

Given the longstanding and contentious nature of the aquarium issue in West Hawai'i, the importance of government action in finally addressing the issue cannot be underestimated. It was only when organized and concerted community effort was applied directly via the legislative process that the means for resolution was made possible. It seems highly likely that without the direct legislative mandates of Act 306, SLH 1998, which provided DLNR with the administrative authority to manage the fishery and region, little progress would have been made in successfully managing this controversial fishery. However, as this report later notes, additional legislative action is needed to provide authority to adopt a limited entry management tool.

Act 306, SLH 1998, established a West Hawai'i Regional Fishery Management Area along the entire west coast of the Island of Hawai'i (§188F-4, HRS). Overall, the purposes of Act 306 are to:

(1) Effectively manage fishery activities to ensure sustainability;
(2) Enhance nearshore resources;
(3) Minimize conflicts of use in this coastal area.

There were also four specific management objectives to be accomplished by DLNR:

(1) Designate a minimum of 30% of coastal waters as Fish Replenishment Areas (FRAs) where aquarium collecting is prohibited.
(2) Establish a day-use mooring buoy system and designate some high-use areas where no anchoring is allowed.
(3) Establish a portion of the FRAs as fish reserves where no fishing of reef-dwelling fish is allowed.
(4) Designate areas where the use of gill nets is prohibited.

A review of the WHRFMA management plan was to be conducted every five years in cooperation with the UH.

Additionally, Act 306, SLH 1998, also directed DLNR/DAR to identify the specific areas and restrictions "after close consultation and facilitated dialogue with working groups of community members and resource users" mandating "substantive involvement of the community in resource management decisions" was a unique and key aspect of the legislation rather than a purely "top-down" (i.e. government-driven) approach which specified all the details of required management actions, Act 306, SLH 1998, instead directed the community to actively participate in the development of such actions. This approach was at once both innovative and far-reaching.

The West Hawai'i Fisheries Council (WHFC)

In order to accomplish the mandates of Act 306, SLH 1998, with substantive community input, The West Hawaiʻi Fisheries Council (WHFC) was convened June 16, 1998 under the aegis of DLNR and the University of Hawai'i Sea Grant. Consisting of 24 voting members and 6 ex-officio agency representatives from DLNR, Sea Grant, and the Governor's Office, the WHFC's members represented diverse geographic areas and various stakeholder, community and user groups in West Hawai'i. Four aquarium representatives (three collectors and one aquarium shop owner) were members of the WHFC, 40% of the WHFC were kanaka maoli and most of the members were previously on the WHRFWG.

The WHFC provided the vehicle for stakeholders to participate directly in the development of management recommendations. Such participation has important benefits for increasing legitimacy of decisions in the eyes of stakeholders, as well as increasing compliance with decisions and rules subsequently established (Kessler 2004).

The first mandate of Act 306 was the establishment the FRAs. FRAs were mandated to address concerns over user conflict and localized resource depletion caused by aquarium fish collectors in West Hawai'i. Working under a punishing deadline, the WHFC, by determination, consensus and vote, developed an FRA plan consisting of nine separate areas along the coast (Figure 2) encompassing a total of 35.2% of the West Hawai`i coastline (including already protected areas). Perhaps somewhat surprisingly the areas specifically recommended as FRAs by the aquarium collecting representatives on the Council showed remarkable congruence with those selected by the WHFC as a whole.

The WHFC's FRA plan was subsequently incorporated by DLNR into administrative rules. The 28 April 1999 public hearing on the FRA Rule (§13-60.3, HAR) was the largest ever conducted by DAR with at least 860 attendees. The Plan received overwhelming support (93.5% of 876 testimonies) from a wide range of community sectors. The FRA administrative rule was signed into approval by Governor Benjamin Cayetano on 17 December 1999 becoming effective 31 December 1999.

The FRAs prohibit all collecting of aquarium animals within their boundaries as well as non-fishing related fish feeding. The seaward boundaries of the FRAs extend to a depth of 100 fathoms and distinctive signs mark the boundaries on shore.

The WHFC and the FRA development process have been the focus of a number of in-depth reports and scientific case studies (Walsh 1999, Capitini et al. 2004, Tissot 2005, Maurin and Peck 2008, Tissot et al. 2009, Gregory 2009) making it one of the most intensively studied community driven management efforts in the State of Hawai'i.

In addition to the development of the FRA network the WHFC, in conjunction with DAR and UH Sea Grant, has been successful in achieving a number of other accomplishments (after Maurin and Peck, 2008):

- **Sea Urchin Limited Harvest**: The WHFC developed a management plan permitting the sustainable harvest of *wana* (long-spine/black sea urchin) at Makae'o, the Old Kona Airport Marine Life Conservation District (MLCD). This recommendation was adopted by DLNR as an administrative rule.
- **The West Hawai'i Youth Fisheries Council**: An outreach component of the WHFC, the Youth Fisheries Council worked with the Hawai'i County Council to ban smoking at Kahalu'u Beach Park.
- **Gill Net Rules**: The WHFC developed a set of gill net rule recommendations focused on limiting impacts of large-scale commercial netting while providing for subsistence netting (see Gill Net Section). This recommendation was adopted as an administrative rule).
- **Day-Use Mooring Buoys**: In collaboration with the Malama Kai Foundation, the WHFC is a working partner in the site selection process and educates communities on the value of day use moorings to preserve our coral reefs (See Mooring Buoy Section).
- **SCUBA Spear Fishing Recommendations**: The WHFC set forth a set of recommendations to ban SCUBA spear fishing in West Hawai'i. This recommendation was adopted by DAR and is currently in the administrative rule making process.
- **Pebble Beach User Conflict**: The WHFC drafted recommendations addressing a conflict between aquarium collectors and this South Kona community. It recommended creating a new FRA in the Pebble Beach area and opening up to collecting a similarly sized section of another FRA (by a non-residential area). This recommendation was adopted by DAR and is currently in the administrative rule making process.
- **Species of Special Concern:** Based on scientific input from DAR, the WHFC developed a list of 25 species which can be harvested by aquarium collectors. Several other species of special concern are to be protected from all harvesting. This recommendation was adopted by DAR and is currently in the administrative rule making process.
- **Limited Entry Aquarium Program:** The WHFC recommended to DAR that Limited Entry Rules be adopted for further management of the Aquarium Industry. Capping the number of permitted aquarium collectors on the reef will curtail unregulated expansion of the aquarium fishery and ensure that participation in fishery requires a high level of skill, experience and regulatory compliance. The rules will enhance the economic value of the reefs and their marine life and will serve as an economic incentive to fishers to promote good stewardship of the reefs. This recommendation, which would be the first of its kind in state waters, has been passed on to DAR.
- **Informal Council Involvement:** The WHFC has helped mediate between a community group and a live aboard dive operator, to ensure minimal disruption to the endangered Hawksbill sea turtle nesting and hatching.

The creation and functioning of the WHFC is entirely attributable to the volunteer commitment of time, energy and resources of its members. The 62 members of the community who have been members at one time or another of the WHFC have contributed nearly 5,000 hours of their own time at no cost to the State. While not directly authorized by state law, this community-based advisory body represents a valuable tool to state government in terms of its approach to and recommendations on marine resource management. These efforts have been assisted by the support of community organizations such as the Hawaiʻi Community Foundation, The Nature Conservancy, Community Conservation Network and the Harold Castle Foundation, all of whom recognize the significance and value of the WHFC and its role in assisting in effective management of our marine resources.

West Hawai`i Aquarium Project (WHAP)

Although Act 306, SLH 1998, mandated review and evaluation (thus monitoring) of the FRAs in conjunction with the UH, no funding was provided to accomplish this. In order to investigate the effectiveness of the FRAs to replenish depleted fish stocks, a consortium of researchers established the West Hawai'i Aquarium Project (WHAP) in early 1999. Funding was secured for the early years of the project through the Hawai'i Coral Reef Initiative Research Program (HCRI-RP), a federal initiative under the aegis of the National Oceanic and Atmospheric Administration (NOAA). Subsequent funding has been provided by Coral Reef Monitoring Grants under NOAA's Coral Reef Conservation Program. The initial project researchers were Dr. Brian Tissot, Washington State University, Dr. William Walsh, DAR/DLNR and Dr. Leon Hallacher, University of Hawai'i-Hilo. They have been joined in recent years by Dr. Ivor Williams, National Marine Fisheries Service, Dr. Mark Hixon, Oregon State University and Dr. Helen Fox, World Wildlife Fund.

WHAP established 23 study sites (Figure 2) along the West Hawai'i coastline in early 1999 at 9 FRA sites, 8 open sites (aquarium fish collection areas) and 6 previously established Marine Protected Areas (MPAs) to collect baseline data both prior to and after the closure of the FRAs. The MPAs are MLCDs and Fishery Management Areas (FMAs), which have been closed to aquarium collecting for at least 9 years and were presumed to have close to "natural" levels of aquarium fish abundances. They serve as a reference or 'control' to compare with the FRAs and open areas.

The overall goals of WHAP were two-fold: 1) To evaluate the effectiveness of the FRA network by comparing targeted aquarium fishes in FRAs and open areas relative to adjacent control sites and, 2) To evaluate the impact of the FRA network on the aquarium fishery.

Detailed explanations of the study sites and survey methodology are contained in Tissot et al. 2004 and Division of Aquatic Resources 2004. To briefly summarize: Densities of all fish and selected invertebrate species are visually estimated along four 25X4m strip transects at each of 23 permanent sites in the three types of management areas. All survey divers either have extensive experience in conducting underwater fish surveys in Hawai'i or received training through the UH's Quantitative Underwater Ecological Survey Techniques (QUEST) training course prior to collecting data (Hallacher and Tissot, 1999). In addition to the transect surveys, a 10 minute 'free-swim' survey is also

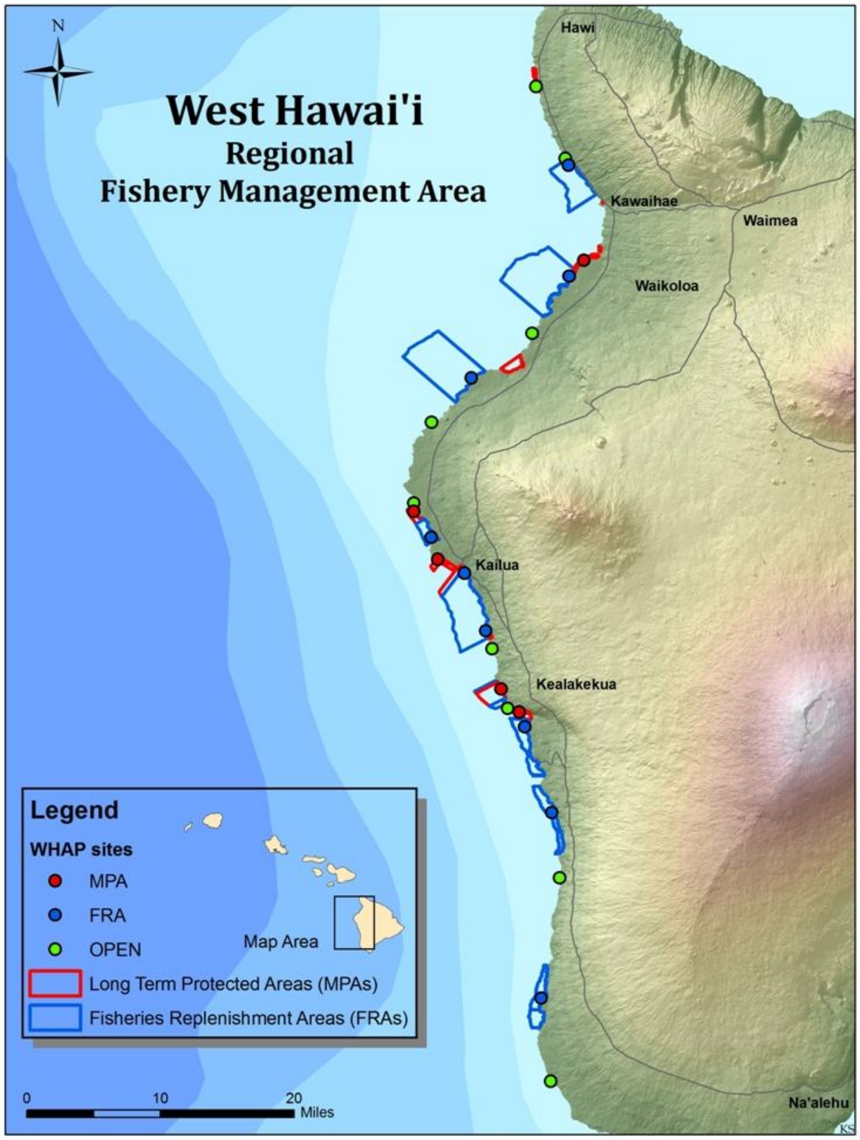

Figure 2. Locations of Fish Replenishment Areas (FRAs) in West Hawai'i and DAR monitoring sites (6 MPAs, 9 FRAs and 8 open sites).

conducted by two divers in the areas surrounding the actual transects. The purpose of this survey is to better census uncommon or rare species and species of particular ecological interest such as taape, roi, terminal phase parrotfish, cleaner wrasses and crown-of-thorns starfish. All sites are surveyed at least four times a year. As of December 2009, a total of 55 survey rounds of all study sites have been completed (>5,000 transects). Six rounds were conducted prior to FRA closure in 1999.

The general rationale for WHAP's goals was based on the premise that changes in FRAs and open areas can best be estimated by comparing them to other areas which have been protected for relatively long periods of time. These areas (MPAs) serve as control areas against which the FRAs are measured both before and after the closure of the FRAs. This rationale is derived from a well-known statistical procedure known as the BACI (Before-After-Control-Impact) procedure (Tissot et al, 2004) which is an appropriate and statistically powerful method for examining FRA effectiveness.

The BACI procedure attempts to take into account changes that may be affecting the ecosystem but are unrelated to the workings of the FRAs. For example, there could be several years of widespread and plentiful recruitment of aquarium fish to the reefs of West Hawai′i. The numbers of fish would thus increase in the FRAs (as well as other areas) over time, but the increase in a particular FRA may not have anything to do with it being protected from aquarium collecting. Instead, the increase in fish could just be the result of favorable ocean currents or more food available during the fish's offshore larval stage which results in more young fish recruiting to the reefs. The BACI procedure separates out these factors by comparing the FRAs (or open areas) to control areas which serve as reference points to gauge change.

For this study FRA effectiveness (R) is measured statistically as the change in the difference between each FRA and the mean of all MPA sites during each survey (control vs. impact) from before (1991-2000) vs. after (2007-2009) FRA establishment. Details on this procedure are covered in (Tissot et al, 2004, Division of Aquatic Resources 2004).

R measures the changes within the FRA as a percent of the baseline abundance relative to control sites. In the case of this study, R is a measure of the effectiveness or 'protective value' of the FRAs. That is, what effect is increased protection having on targeted fish?

Scientific studies on reef fishes are notoriously difficult due to the very high variability of fish abundance in both time and space. Even with a rigorous statistical design (such as BACI) and 11 years of study, it is difficult to statistically detect changes in abundances except for the most common species that exhibit relatively large changes.

FINDINGS AND EVALUATION

Fish Replenishment Areas (FRAs)

The overall changes in fish abundance and effectiveness of the FRAs are shown in Table 2. Young-of-Year (YOY) fishes (i.e. newly settled/recruited) are not included in analyses since their initial abundance is not directly related to aquarium collecting. The top 20 aquarium fishes in general have shown only a minor, nonsignificant increase and most of the increase is attributable to the two most heavily collected species, the Yellow Tang and Goldring Surgeonfish (Table 3). These two species account for 91% of total fish catch over the last five years (Appendix A) and thus are key indicators of the protective value of the FRAs and the sustainability of the aquarium fishery.

Table 2. Overall FRA effectiveness for fishes. 'Before' = Mean of 1999-2000; 'After'= Mean of 2007-2009. YOY not included.

GROUP	MEAN DENSITY (NO/100M²)		OVERALL% CHANGE IN DENSITY	ρ	R	ρ
	Before	**After**				
Top 20 aquarium species	64.75	66.38	+3%	0.80	+6%	0.57
Aquarium fishes w/o Yellow Tang	52.01	46.43	-11%	0.27	**-17%**	0.02
Non-aquarium fishes	70.10	113.95	**+63%**	<0.01	**+95%**	0.03

Bold = statistically significant at $\rho \leq 0.05$

Changes for the ten most collected aquarium fishes across all FRAs are shown in Table 3. Yellow Tang density increased markedly (and significantly) in the FRAs while seven of 10 decreased (Achilles Tang, Multiband Butterflyfish and Brown Surgeonfish decreased significantly). These seven species represent <6% of the total West Hawai′i aquarium catch (Appendix A).

The FRAs were 'effective' (increases in FRAs relative to long term MPAs) for eight of the top 10 collected species with three being statistically significant. As with density there were significant decreases in effectiveness for the Multiband Butterflyfish and Brown Surgeonfish. Both of these species are not very heavily collected averaging <2000 individuals per year over the last 5 years (Appendix A) and are fairly abundant on the reef. It's thus not clear why their numbers are declining in the FRAs. These two species exhibited overall declines in all three types of areas with the greatest decrease in the protected areas (FRAs and MPAs). For the Brown Surgeonfish this may be the result of a competitive interaction with Yellow Tang and/or Goldring Surgeonfish. As their numbers have increased the Brown Surgeonfish's has decreased. Both Yellow Tang and Brown Surgeonfish are herbivore browsers with quite similar diets (Jones 1968). In a possibly similar relationship Barlow (1974) found the numbers of Brown Surgeonfish and manini (*Acanthurus triostegus*) to be negatively correlated and this was attributed to the aggressive dominance of the Brown Surgeonfish.

Table 3. Overall FRA effectiveness for the top ten most aquarium collected fishes. 'Before' = Mean of 1999-2000; 'After' = Mean of 2007-2009. YOY not included.

COMMON NAME	SCIENTIFIC NAME	MEAN DENSITY (NO/100M²)		OVERALL% CHANGE IN DENSITY	ρ	R	ρ
		Before	**After**				
Yellow Tang	*Zebrasoma flavescens*	12.73	19.95	**+57%**	0.01	**+77%**	<0.01
Goldring Surgeonfish	*Ctenochaetus strigosus*	28.38	32.01	+13%	0.23	+83%	0.39

Achilles Tang	*Acanthurus achilles*	0.26	0.05	**-81%**	0.01	+2%	0.09
Clown Tang	*Naso lituratus*	0.81	0.59	-27%	0.10	+2%	0.37
Black Surgeonfish	*Ctenochaetus hawaiiensis*	0.18	0.16	-12%	0.77	+3%	0.41
Longnose and Forcepsfish	*Forcipiger spp.*	0.64	0.84	+32%	0.13	**+4%**	0.03
Multiband Butterflyfish	*Chaetodon multicinctus*	5.20	3.49	**-33%**	0.02	**-5%**	<0.01
Brown Surgeonfish	*Acanthurus nigrofuscus*	8.58	4.06	**-53%**	0.03	**-26%**	0.01
Orangeband Surgeonfish	*Acanthurus olivaceus*	0.13	0.10	-20%	0.63	+3%	0.45
Ornate Wrasse	*Halichoeres ornatissimus*	0.94	0.65	-31%	0.08	+2%	0.14

Bold = statistically significant at $\rho \leq 0.05$

With only a single exception all of the FRAs have proven to be effective (positive R value) in enhancing Yellow Tang stocks (Figure 3). Seven of the eight increases were statistically significant. The single FRA which was ineffective was Waiakailio Bay in North Kohala (Appendix B). This FRA had very low Yellow Tang recruitment throughout the study period and additionally the area may have been impacted by a sedimentation event in October 2006 on nearby reefs.

An examination of multiple factors associated with effective FRAs (Tissot et al., 2003) found that habitat quality, FRA size (especially reef width) and density of adult fishes are associated with significant recovery of fish stocks. Of particular importance are areas of high finger coral (*Porites compressa*) cover which is critical habitat for juvenile Yellow Tang and other fishes (Walsh, 1987). Live coral cover at Waiakailio declined 17% between 1999 and 2007 (DAR unpublished data).

The overall average changes in Yellow Tang abundance in the three management areas are shown in Figure 4. Yellow Tang exhibited a delayed increase in abundance in all areas following a strong recruitment year in 2002. Relatively low recruitment in 5 of the 7 following years resulted in subsequent downward trends in all areas. Even with low recruitment in 6 of the past 11 years the number of adult Yellow Tang has increased by 57% in the FRAs since they were established (Table 3).

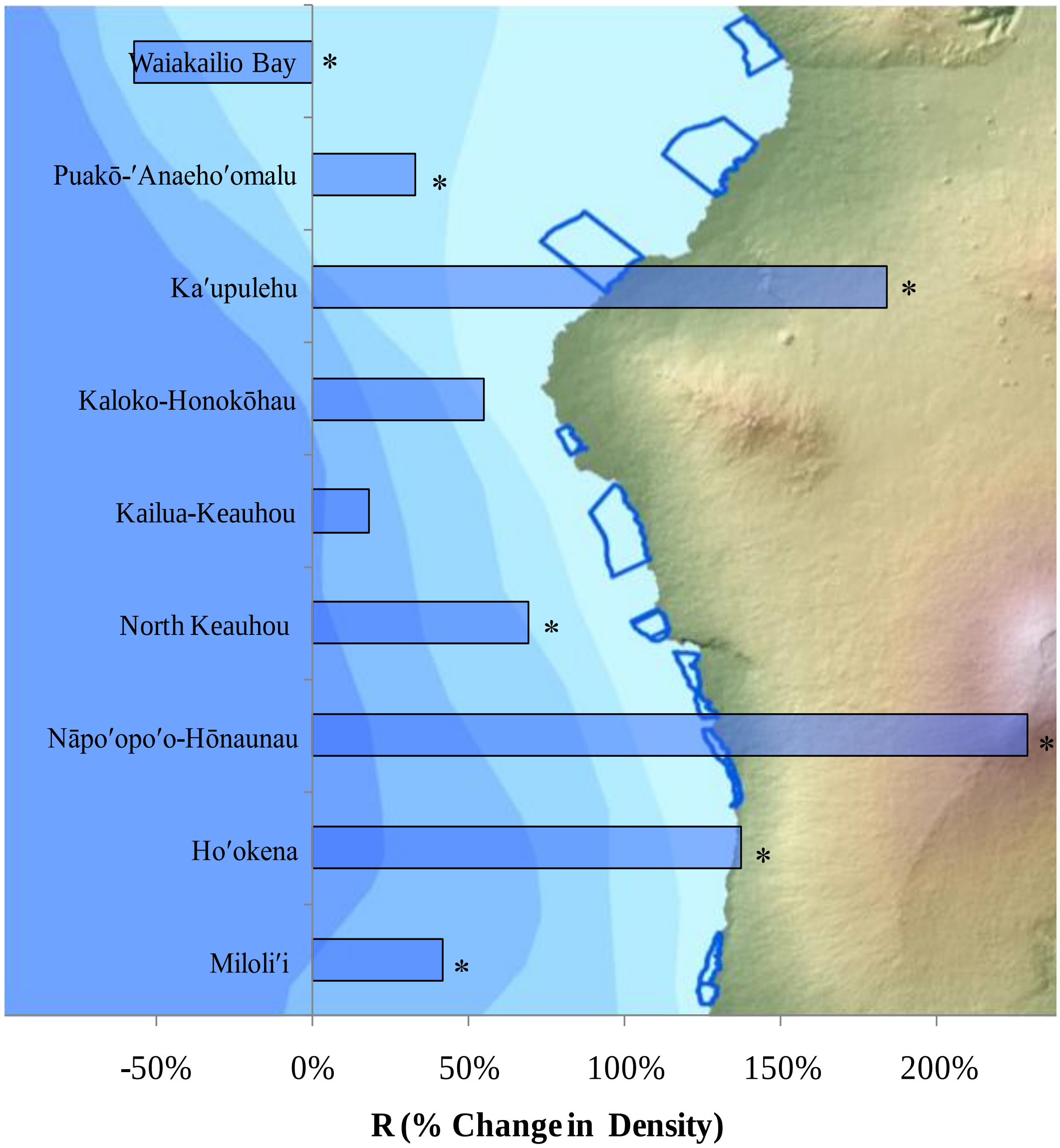

Figure 3. Effectiveness of individual FRAs to replenish Yellow Tangs, 1999-2009.
***= Statistically significant at $\rho \leq 0.05$**

Recent work (Claisse 2009) has shown that when Yellow Tang reach sexual maturity they leave the deeper coral rich reef areas where they settled (and where WHAP transects are located) for shallower reef habitat. For females this occurs at approximately 4-5 years of age and for males at age 5-7. Thus in the absence of substantial input of Young-of-the-Year fish, (i.e. low recruitment) Yellow Tang populations will invariably decline over time due to the emigration of mature fish in addition to natural mortality. This apparently is what has occurred over the last six years in the protected areas. The

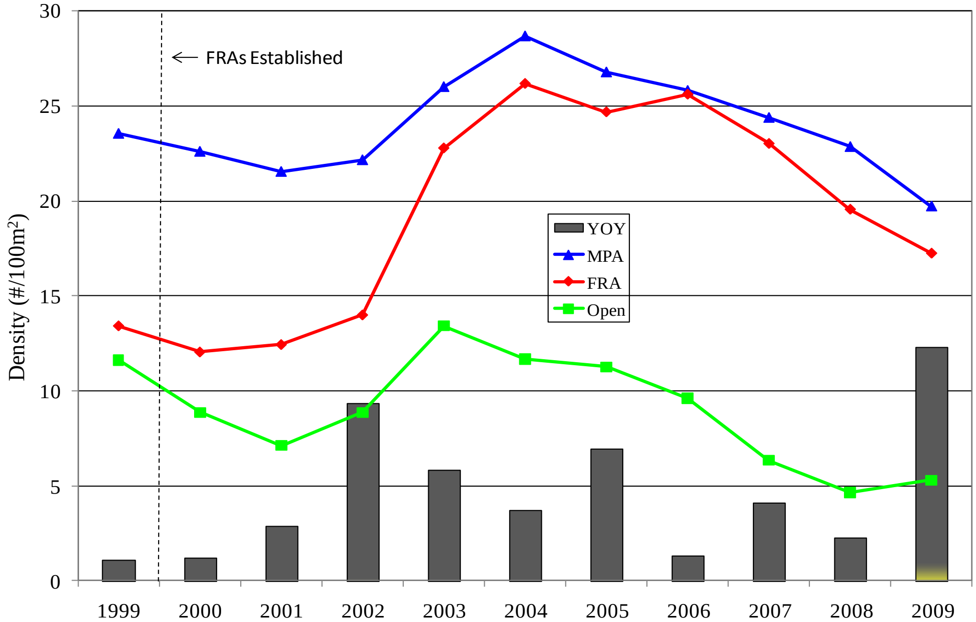

Figure 4. Overall changes in Yellow Tang abundance in FRAs, MPAs and Open areas, 1999-2009. Yellow bars indicate mean density (June-Nov) Yellow Tang Young-of-Year (YOY). YOY are not included in trend line data.

decrease of Yellow Tangs in open areas to below baseline levels is attributable to the above factors as well as an increase in the number of aquarium collectors and collected animals relative to the period when the FRAs were established (Figure 1). The continuing decline of Yellow Tang in areas open to collecting has prompted several additional proposed management actions including restricting which species can be collected (See Species of Special Concern section) and the establishment of a limited entry program for the fishery. Recruitment in 2009 is the highest in the past 11 years which is likely to ameliorate current downward trends at least over the short term.

The fishing/reserve (i.e. FRA/MPA) impacts described above are striking, but of greater significance to the role such reserves have in enhancing and sustaining West Hawai'i populations and the fishery which depends on those, are effects of the reserve network on Yellow Tang breeding stocks. To supplement long-term monitoring of juvenile habitats, DAR initiated a series of surveys in 2006 of the shallow reef habitats utilized by adult Yellow Tang (Williams et al. 2009).

Adult densities were highest within protected areas and in ’boundary’ areas (open areas adjacent to protected areas). Densities were lowest in open areas far from protected areas (Figure 5). The high densities in boundary areas are evidence of ‘spillover’ (outward movement from reserves into surrounding open areas) and indicate that protected areas supplement adult stocks not only within their own boundaries, but also in open areas up to a kilometer or more away. Thus, the 35% of the coastline in reserves sustains yellow tang breeding stocks in about 50% of the coastline.

Although reserves are already important source areas for adult Yellow Tang (2006 densities were 48% higher in FRAs, and 41% higher in boundary areas than in open areas far from boundaries), the reduced supply of new adults from open areas following recent increases in effort and catch mean they are likely to become even more important in coming years.

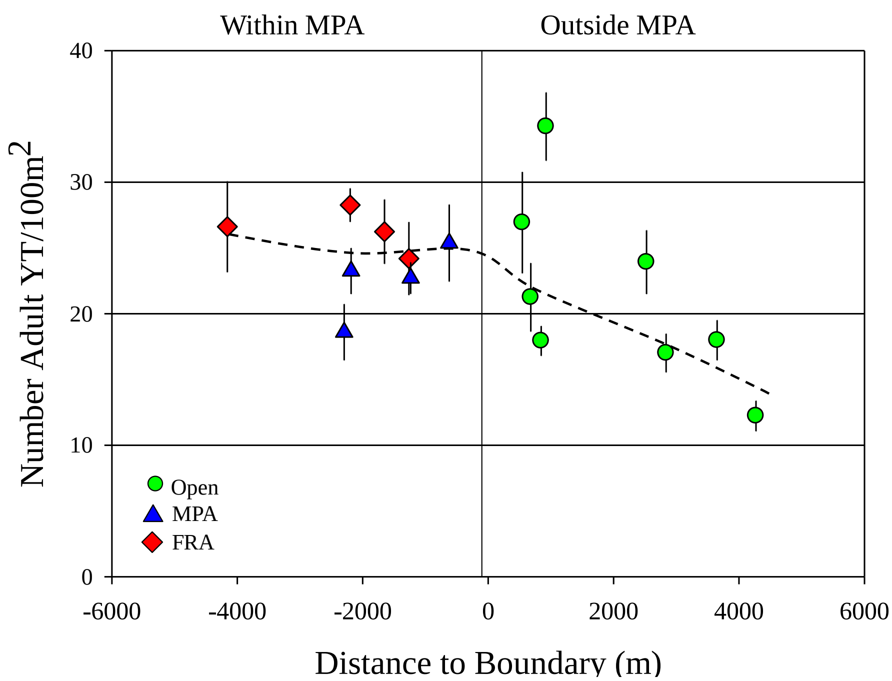

Figure 5. Abundance of adult Yellow Tang in and out of MPAs. Trend line was generated using a LOESS smoothing function.

Goldring Surgeonfish (Figure 6) exhibited trends quite similar to Yellow Tang but since they are more abundant and much less collected than the Tangs, open areas have been relatively stable. Overall, Goldring Surgeonfish have increased by 13% since FRA establishment (Table 3). As with Yellow Tang, recruitment levels have been relatively high thus enabling densities to increase in the protected areas. It is unknown at present if Goldring Surgeonfish makes a habitat change as they reach sexual maturity. Recruitment patterns are markedly similar between the two species, likely due to similarities in spawning seasonality, location and daily timing (Walsh 1984, 1987).

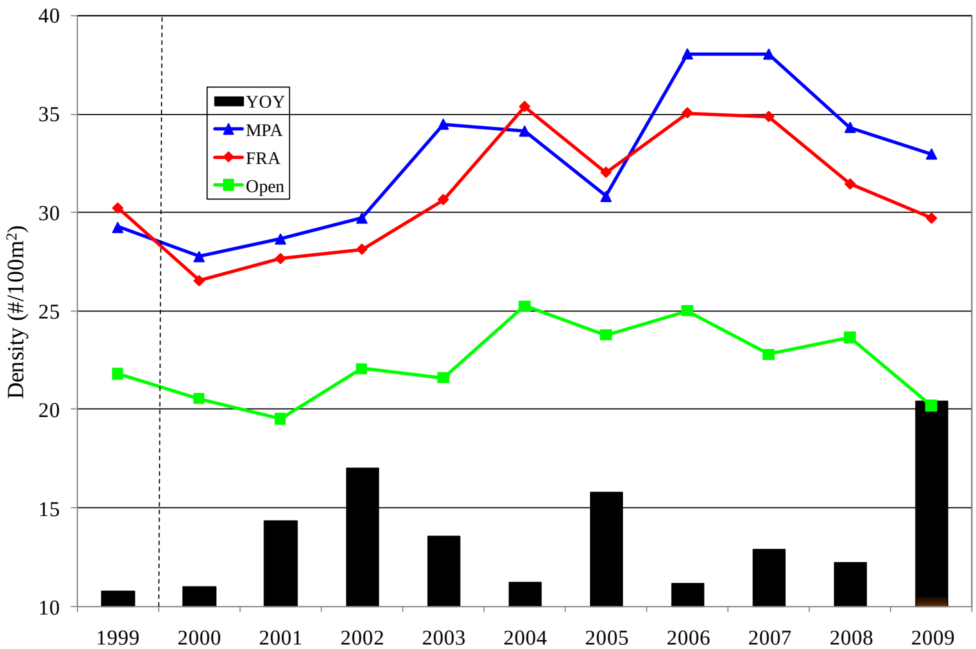

Figure 6. Overall changes in Goldring Surgeonfish abundance in FRAs, MPAs and Open areas, 1999-2009. Bars indicate mean density (June-Nov) of Goldring Surgeonfish Young-of-Year (YOY). YOY are not included in trend line data.

Achilles Tang (Figure 7) has generally shown a highly variable pattern in all management areas in the early years of the study with an overall decline in the last four years. Average densities of this species is very low ($\overline{x}$ = 0.26/100m^2) on all transects. The deeper reef areas where the WHAP transects are located is not the prime habitat for adults of this species. They prefer the high energy shallower surge zones more typical of the shoreline drop-offs areas in West Hawai'i. Presumably algal food resources are more abundant in these areas. These shallower reef areas are being surveyed by a different type of monitoring program (Shallow Water Resource Surveys) presently being conducted by DAR. Initial results from this program and other ancillary longer terms studies suggest there should be concern for the sustained abundance of this species. Achilles Tangs are a very popular food fish as well as an aquarium fish and thus are being harvested both as juveniles and adults. Low levels of recruitment over the past 11 years ($\overline{x}$ (Jun-Nov) = 0.09/100m^2) appear insufficient to compensate for the existing levels of harvest. DAR is currently in the process of developing a comprehensive package of size and bag limits for a number of popularly targeted species. There is a recommended bag limit of 10 Achilles Tangs/person/day which would apply to all harvesters including commercial fishers and aquarium collectors.

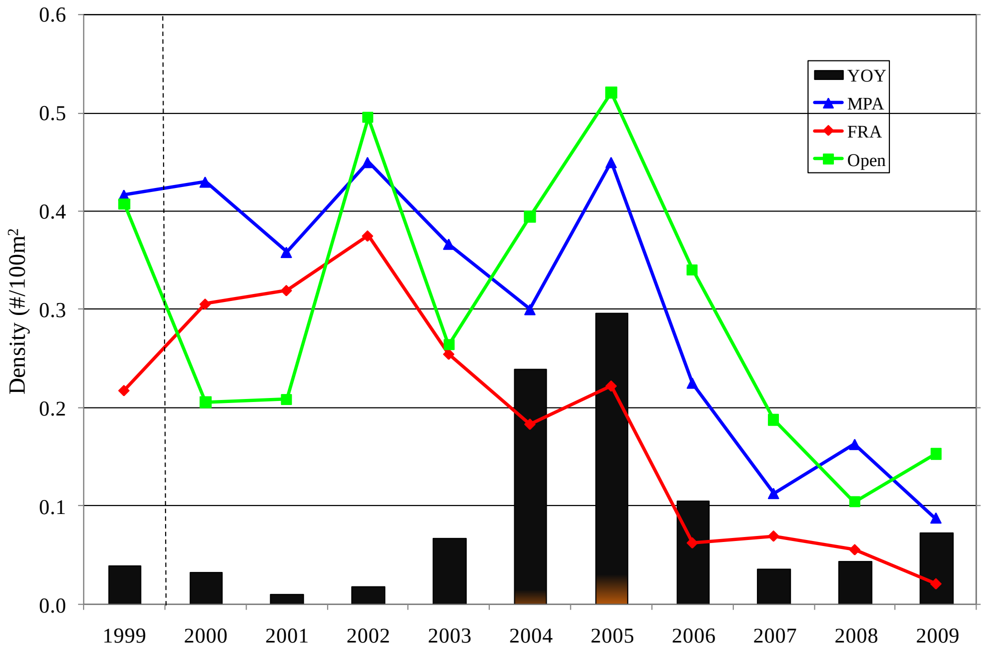

Figure 7. Overall changes in Achilles Tang abundance in FRAs, MPAs and Open areas, 1999-2009. Bars indicate mean density (June-Nov) of Achilles Tang Young-of-Year (YOY). YOY are not included in trend line data.

The abundance/recruitment trends of the Clown Tang and Black Surgeonfish, the fourth and fifth most collected species (Table 3, Appendix A), are quite similar to Achilles Tang (Figures 8 & 9). Here again the primary adult habitat is not the deeper, coral rich areas, where the WHAP transects are located. Additionally the Clown Tang is also widely taken as a food fish as well as being an important aquarium fish. The abundance of both these species on the transects closely tracks recruitment with an upturn during 2004/2005 when there was somewhat higher recruitment followed by declining trends in subsequent years that had low recruitment. Overall, recruitment has been minimal over the last decade for both Clown Tang ($\bar{x}$ = 0.05/100m^2) and Black Surgeonfish ($\bar{x}$ = 0.05/100m^2).

As observed in previous work (Walsh 1987) and emphasized again in this study, for some species, recruitment can be highly variable between years and repeated low levels of recruitment is a regular occurrence. Without substantial input of the YOY, overall abundances on the deeper reef transects decrease over time due to ontogenetic movement out of settlement habitat and natural mortality. This decrease can occur even in areas which are not subject to aquarium collecting pressure (i.e. FRAs and MPAs).

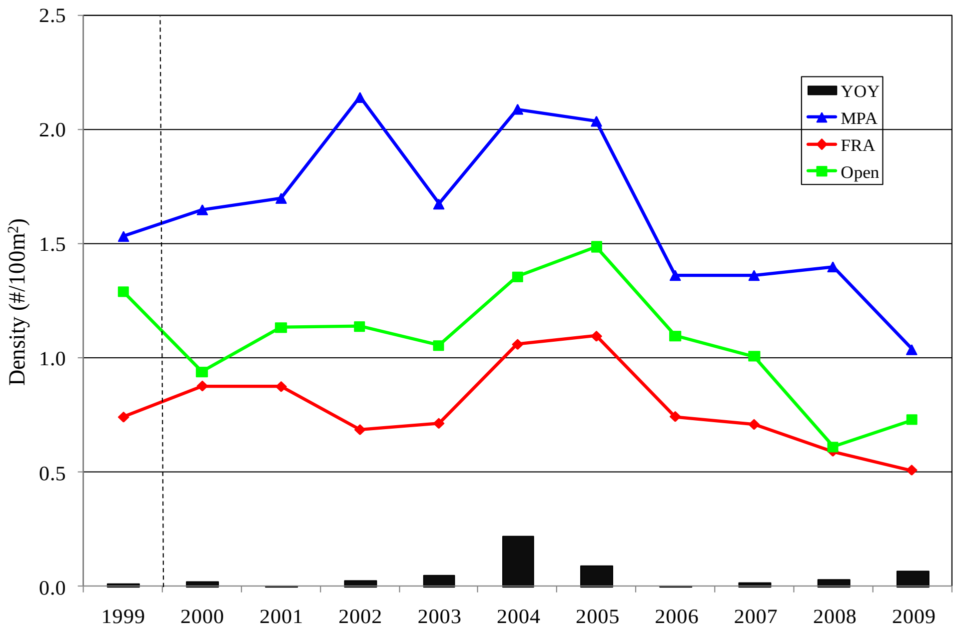

Figure 8. Overall changes in Clown Tang abundance in FRAs, MPAs and Open areas, 1999-2009. Bars indicate mean density (June-Nov) of Clown Tang Young-of-Year (YOY). YOY are not included in trend line data.

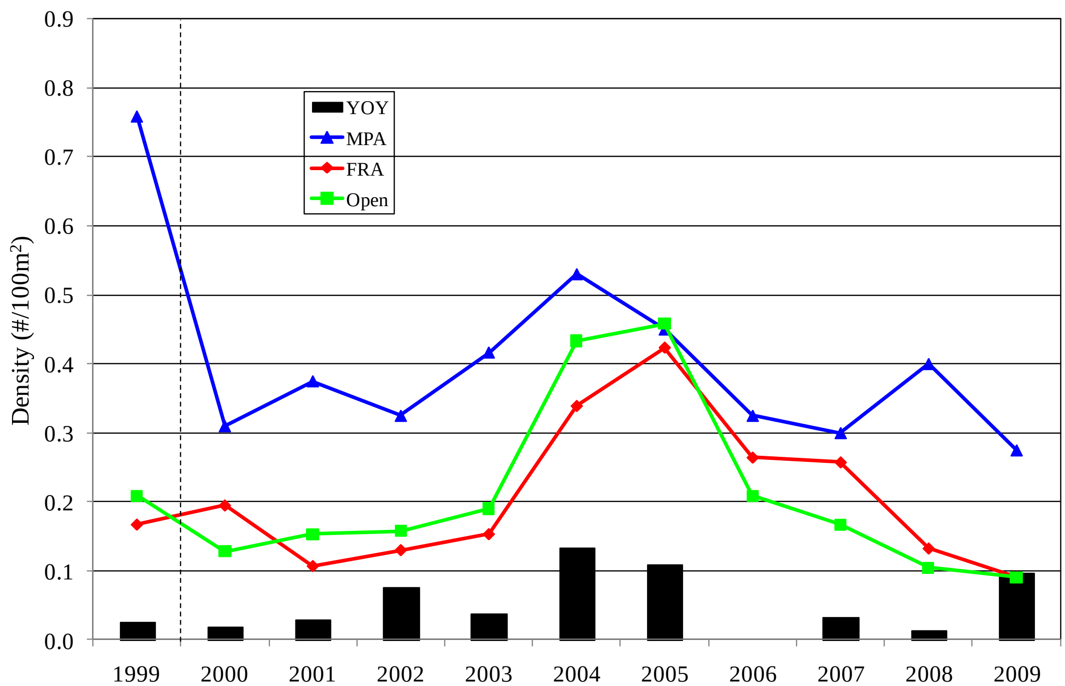

Figure 9. Overall changes in Black Surgeonfish abundance in FRAs, MPAs and Open areas, 1999-2009. Bars indicate mean density (June-Nov) of Black Surgeonfish Young-of-Year (YOY).

Although only a few species comprise the bulk of the West Hawai'i aquarium fishery, over 200 different species of fishes and invertebrates have been collected from the reefs over the last five years (Appendix A). Some of these species are uncommon or even rare and presumably have a low resilience to harvesting pressure. Even in protected areas a considerable amount of time may be required for populations of these species to increase. A good example seems to be the Flame Angel, *Centropyge loricula*. This very attractive but uncommon species is highly desired in the aquarium trade. Demand far exceeds the supply Hawai'i can provide so substantial numbers of this species are imported to Hawai'i (for subsequent reshipping) from other locales (e.g. Christmas Island). Flame Angels were rarely sighted on transect or free swim surveys during the first seven years of the study (Figure 10). Beginning in 2006 however they have become noticeably more abundant presumably due to one or more years of good recruitment. The recruits are apparently cryptic so not readily surveyed.

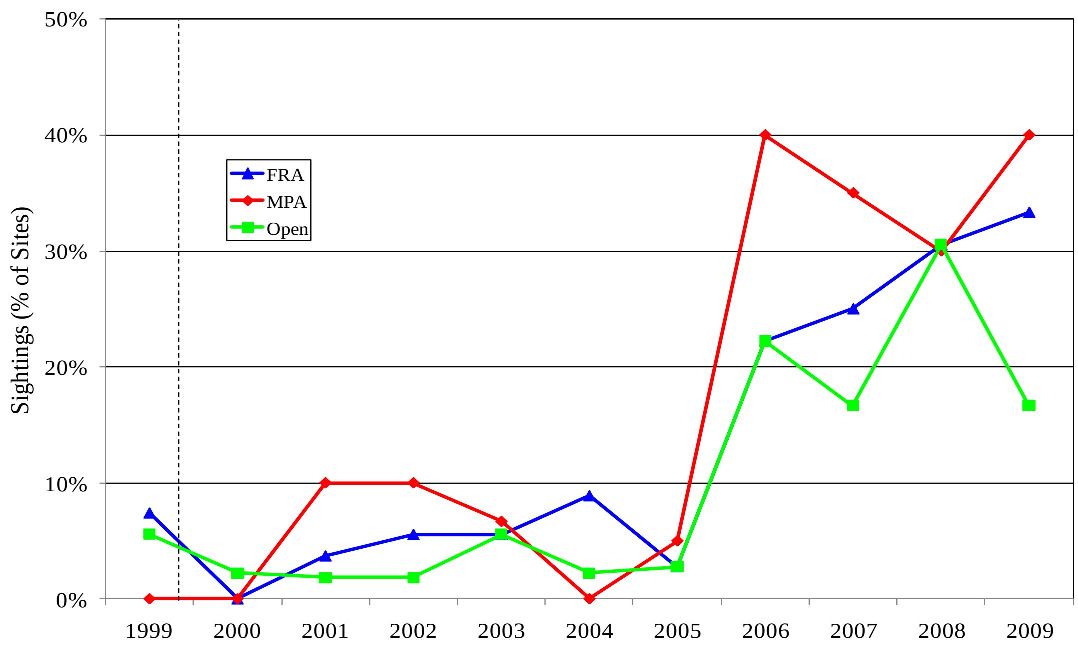

Figure 10. Sightings of Flame Angels in FRAs, MPAs and Open areas, 1999-2009.

FRAs and Conflict Reduction

One of the primary objectives associated with Act 306 was to reduce conflict between opposing reef users by spatially separating the groups via the FRAs where conflict was reportedly high. In 2007 and 2008, Washington State University researchers surveyed recreational scuba diving operators (referred to as divers) and aquarium fishers (referred to as fishers) to examine their perceptions regarding the effectiveness of Act 306 for alleviating conflict between reef user groups and enhancing reef fish populations. They surveyed 23 fishers, comprising ~62% of the active fisher population in West Hawai'i, and 11 divers, who ranged in expertise from boat captains, master divers, to shop managers using a post test survey design.

Fishers were slightly more inclined to feel the FRAs were effective (34.8%) for alleviating conflict than ineffective (30.4%); however, a similar number of fishers reported having neutral perceptions (34.8%). Likewise, more divers felt the FRAs were effective (36.4%) than ineffective (18.2%), but the majority held neutral perceptions (45.5%). Divers reported having greater conflict with extractive user groups (i.e., aquarium fishers, recreational fishers, and skin divers/spearfishers) than non-extractive user groups (i.e., dive/snorkel operators, kayakers, surfers, scuba divers, and snorkelers) (Figure 11). Informal interviews with fishers revealed that "conflict" was interpreted as conflict within and between their own and other user groups. Some fishers suggested the FRAs aggregated them into smaller geographic regions, thus increasing the competition and conflict within their own group.

In addition to alleviating conflict, Act 306 mandated using the FRAs as an aquarium fisheries management tool to enhance reef fish populations. Nearly all divers (83.3%) felt the FRAs were effective for enhancing reef fish populations; however, 47.8% of fishers felt the FRAs were ineffective while 21.2% felt they were effective, with the remaining 31% indicating neutral perceptions. The contrasting difference between the fishers and divers may be largely influenced by how they interact with the FRAs. Most dive boats operate inside the FRA boundaries where Yellow Tang abundance (including YOY) has increased +95%, whereas the fishers operate outside the FRAs where abundance of Yellow Tang has declined by 11% since 1999/2000. What is more, although Williams et al. (2009) documented spillover of adult Yellow Tang from the FRAs, it has been suggested that significant spillover of juvenile Yellow Tang (the target size class by fishers) into open areas is highly unlikely (M. E. Manuel, pers. comm.). Thus it seems reasonable that more fishers held negative perceptions regarding the FRAs since they felt they were not directly benefiting from them. It should be noted that as a whole the catch of aquarium fishery has increased 25% and the value of the catch by 71% since the inception of the FRA network (Table 1).

Although a substantial proportion of fishers question the efficacy of the FRAs for enhancing the aquarium fishery, evidence suggests socioeconomic indicators associated with veteran fishers have improved since the inception of the FRAs. We surveyed 14 fishers who were active in the West Hawai'i's aquarium fishery for 10+ years to determine if their satisfaction with bank savings, employment, health, family, economic status, and overall well-being changed since the implementation of the FRAs. Nearly all socioeconomic attributes were either unchanged, better, or much better subsequent to establishing the FRAs, with the exception of two fishers who said their health and bank savings worsened. Unchanged responses are viewed favorably because fishers frequently perceive the least benefits from protected area management (Jacobson and Marynowski 1997).

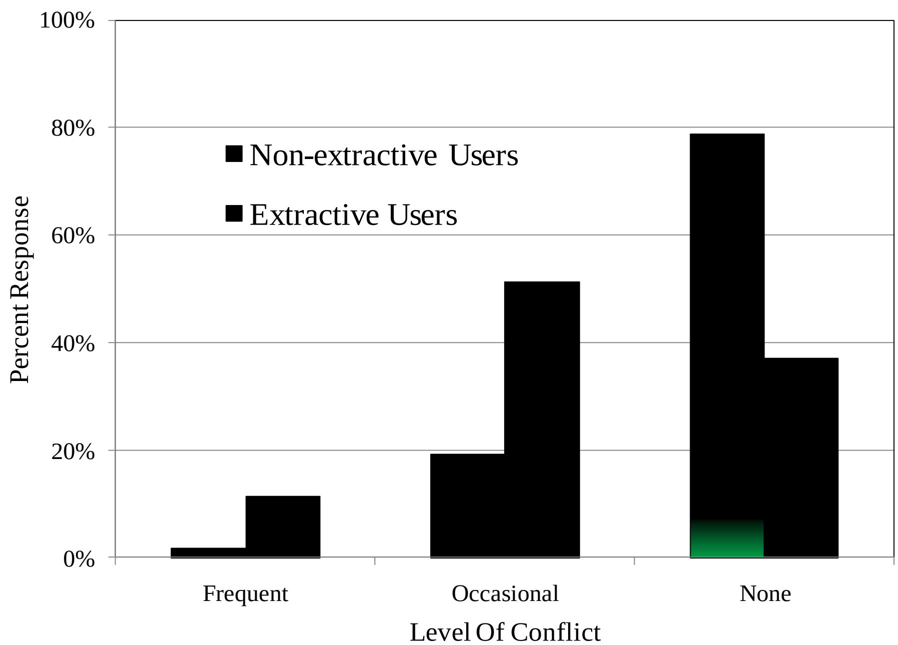

Figure 11: Level of conflict divers reported having with non-extractive vs. extractive reef user groups.

Species of Special Concern

Coral reef animals have multiple values and they serve fundamental biodiversity and ecosystem functions. They're important not only to aquarium collectors and other fishers but also to the commercial ocean recreation industry, their visitors and Hawai'i ocean users in general. Management of this resource needs to balance these values and uses. A number of reef fish species are particularly vulnerable to depletion because they may be naturally uncommon or rare but command high prices in the aquarium trade and are thus highly sought after by collectors. Examples include the Dragon Moray, Zebra Moray, Tinker's Butterflyfish, Banded Angelfish and Hawaiian Turkeyfish. All of these species (and others) are worth more (sometimes considerably more) than $20 each when collected (Appendix A).

For uncommon or rare species or those that occur in deeper reef habitats, it is difficult and/or unfeasibly expensive to gather solid information on their status and trends. Nevertheless for some of these species such as the Hawaiian Turkeyfish there is considerable anecdotal evidence that they have declined in recent decades. It's also clear from a number of long term studies presently being conducted in West Hawai'i (Puakō, Ke'ei and Hōnaunau) that a number of fairly conspicuous species have likewise declined in abundance over time – most obviously several species of butterflyfish and, in particular, the Bandit Angelfish.

In a recent study of the Florida marine aquarium fishery (Rhyne et al. 2009), researchers noted the once small ornamental fish fishery has grown dramatically in recent years to become a large scale invertebrate-dominated industry. Similar to the West Hawaiʻi fishery, a relatively small number of species (15) represent the bulk of the fishery (92% in 2007). What was noteworthy was the change in species composition attributable to a shift from the collection of purely ornamental species to ones providing biological services in home aquaria. Invertebrate grazers (e.g. snails, urchins, crabs) are now the most heavily collected animals because they can control algal growth. Noting the important role such organisms play in the wild the authors concluded the intensive collecting of such species was ecologically unsound and the fishery was "crawling to collapse."

FRAs are a key component of the sustainable management of the West Hawaiʻi aquarium fishery. They encompass many of the areas most utilized by residents and dive/snorkel business, and help maintain the biodiversity of our reefs people expect and visitors are willing to pay for. The FRAs do not of course provide protection for species in the open areas. While they do provide a population reservoir, intensive fishing pressure on species with low natural abundances across most of West Hawaiʻi's reefs is problematic. Concerns over continued expansion of the fishery (up 25% in the last decade) and harvesting effects in the open areas (65% of the coast), necessitate additional management measures.

To address such issues, DAR in conjunction with the WHFC developed a 'white list' of species which could be taken by aquarium fishers (Table 4). The approach taken by the Council was based on the fact that the West Hawai'i aquarium fishery is very heavily focused on a relatively small number of species. Six species (Yellow Tang, Goldring Surgeonfish, Achilles Tang, Clown Tang, Black Surgeonfish and Tinker's Butterfly) make up 96% of the total catch value averaged over the last 5 years. The 25 species on the white list make up 99% of the total catch value so the great majority of species taken (over 180 species - Appendix A) have very little individual or collective value; nonetheless they are important components of the reef ecosystem. It should be noted no invertebrates are included on the white list.

Table 4. List of species which may be collected for Aquarium purposes within the West Hawaiʻi Regional Fisheries Management Area.

Common Name	Scientific Name	Hawaiian (local) Name
Yellow Tang	*Zebrasoma flavescens*	*lau'īpala*
Goldring Surgeonfish	*Ctenochaetus strigosus*	*kole*
Achilles Tang	*Acanthurus achilles*	*pāku'iku'i*
Clown Tang	*Naso lituratus*	*umaumalei*
Black Surgeonfish	*Ctenochaetus hawaiiensis*	black *kole*
Forcepsfish	*Forcipiger flavissimus*	*lauwiliwilinukunuku'oi'oi*
Multiband Butterflyfish	*Chaetodon multicinctus*	*kikākapu*
Brown Surgeonfish	*Acanthurus nigrofuscus*	*māi'i'i'*
Orangeband Surgeonfish	*Acanthurus olivaceus*	*na'ena'e*
Ornate Wrasse	*Halichoeres ornatissimus*	*ōhua*

Fourspot Butterflyfish	*Chaetodon quadrimaculatus*	*lauhau*
Moorish Idol	*Zanclus cornutus*	*kihikihi*
Potter's Angelfish	*Centropyge potteri*	
Goldrim Surgeonfish	*Acanthurus nigricans*	
Saddle Wrasse	*Thalassoma duperrey*	*hinālea lauwili*
Yellowtail Coris	*Coris gaimard*	*hinālea 'akilolo*
Bird Wrasse	*Gomphosus varius*	*hinālea 'i'iwi*
Eyestripe Surgeonfish	*Acanthurus dussumieri*	*palani*
Tinker's Butterflyfish	*Chaetodon tinkeri*	
Unicorn spp.	Other *Naso spp.*	*kala*
Thompson's Surgeonfish	*Acanthurus thompsoni*	
Flame Wrasse	*Cirrhilabrus jordani*	
Peacock Grouper	*Cephalopholis argus*	*roi*
Bluestripe Snapper	*Lutjanus kasmira*	*taape*
Blacktail Snapper	*Lutjanus fulvus*	*toau*

In addition to the aquarium list of (permitted) species the WHFC also recommended that a number of ecologically and culturally important species be prohibited from being taken by anyone (Table 5). Note that Manta Rays have recently been afforded complete protection within the State by Act 92, SLH 2009.

Table 5. List of species for which all take is prohibited

Common Name	Scientific Name	Hawaiian (local) Name
Manta Rays	*Manta & Mobula spp.*	*hahalua*
Spotted Eagleray	*Aetobatis narinari*	*hīhīmanu*
Broad Stingray	*Dasyatis latus*	
Pelagic Stingray	*Dasyatis violacea*	
Hawaiian Stingray	*Dasyatis brevis*	
Tiger Shark	*Galeocerdo cuvier*	*Manō/niuhi*
Whale Shark	*Rhincodon typus*	*lele wa'a*
Whitetip Reef Shark	*Triaenodon obesus*	*manō lālākea*
Blacktip Reef Shark	*Carcharhinus melanopterus*	*manō pā'ele*
Gray Reef Shark	*Carcharhinus amblyrhynchos*	*manō*
Triton's Trumpet*	*Charonia tritonis*	*'olē*
Horned Helmet*	*Cassis cornuta*	*pū puhi*
*Cultural harvesting by permit		

The last focus of the species of special concern related to protecting the breeding stock of Yellow Tang. The WHFC recommendation, motivated largely by several aquarium fishers, is that for all fishers there is a bag limit of 5 fish/person/day of Yellow Tang ≥5" (Total Length). All of the species of special concern recommendations are presently undergoing rulemaking.

Day-Use Mooring Buoys

Act 306, SLH 1998, mandated the establishment of a day-use mooring buoy system in high-use coral reef areas to prevent anchor damage. Day-use mooring buoys have proven to be an effective tool around the world in reducing damage to coral reefs by providing boaters with a convenient means of securing their boats without dropping anchor. Such a day use mooring buoy system has been in place in West Hawaiʻi for almost 15 years.

The first day-use mooring buoys in West Hawaiʻi were approved by the Hawaiʻi Board of Land and Natural Resources in early 1990. Permission to rig the buoys for use was given by DLNR's Division of Boating and Ocean Recreation (DOBOR) in June 1990 and an Environmental Assessment was completed by DOBOR in March 1994. In June 1995, the United States (U.S.) Army Corps of Engineers (COE) issued a general permit to DOBOR for the statewide installation and maintenance of 277 day-use moorings. The most recent U.S. Army COE permit for the program was issued in 2005 for the installation of 15 moorings statewide which were previously permitted but not installed, five of which are in West Hawaiʻi.

At present, 80 moorings have been either permitted, installed or in use in West Hawaiʻi (Appendix C). Seven additional moorings are currently in the permit application process with DOBOR and the U.S. Army COE. DOBOR, in consultation with DAR, the WHFC and other community members and supported by the Malama Kai Foundation, is responsible for the process of selecting additional sites for mooring buoys, as well as maintaining the statewide system of buoys.

The mooring buoys are located in popular dive and snorkel spots along the West Hawaiʻi coastline (Figure 12). A no-anchoring zone exists within a 100 yd. radius of any day-use mooring. Costs for the buoy hardware and equipment have been paid primarily by private contributions, with some state funds, while buoy installation and maintenance have been supported by in-kind contributions from ocean recreation businesses (charter boat time, divers, air, fuel, food), and assisted by technical support services provided by the UH Sea Grant Extension Service, the Hawaiʻi Institute of Geophysics and the Malama Kai Foundation.

The mooring buoy system would probably not exist without the help of the Malama Kai Foundation and its many dedicated volunteer individuals and businesses. The Malama Kai Foundation raises funds through contributions and the Adopt-A-Buoy Program. Numerous sport divers as well as dive charter businesses from around the state collaborate with Malama Kai Foundation to install, monitor and maintain the buoys. As part of the DLNR Day-Use Mooring 10-Year Strategic Management Plan Malama Kai Foundation is working with DLNR Staff to write and refine objectives for the statewide day-use mooring system and develop bio-physical criteria for site selection.

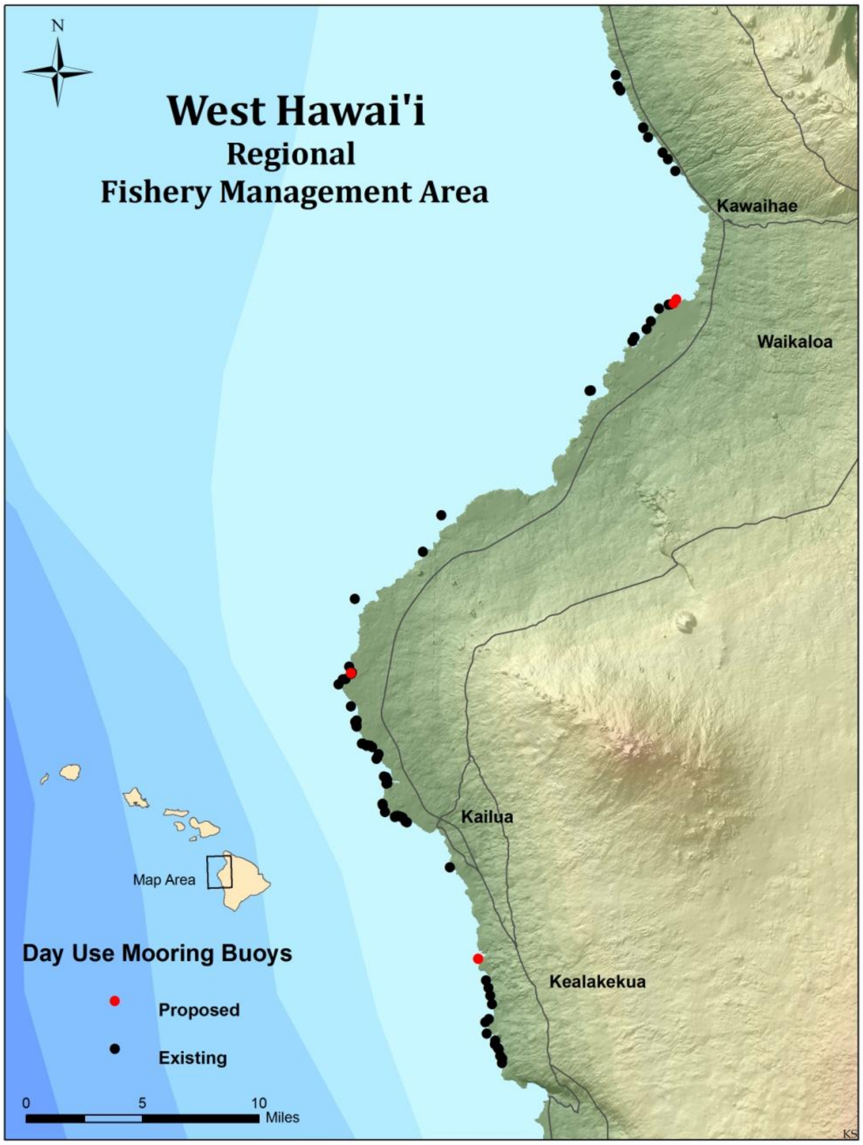

Figure 12. Locations of Day-use mooring buoys in West Hawai′i.

Gill Nets

As mandated by Act 306, SLH 1998, a laynet (i.e. gill net) management plan was developed over four years by the WHFC and DAR. The recommended plan became administrative rule in 2005. The rule provides for continued small-scale subsistence-level netting while effectively controlling large-scale commercial netting. Eight areas have been designated where the use of gill nets is prohibited. Along with existing no gill-netting areas, approximately 25% of the coastline now prohibits the use of such nets (Figure 13).

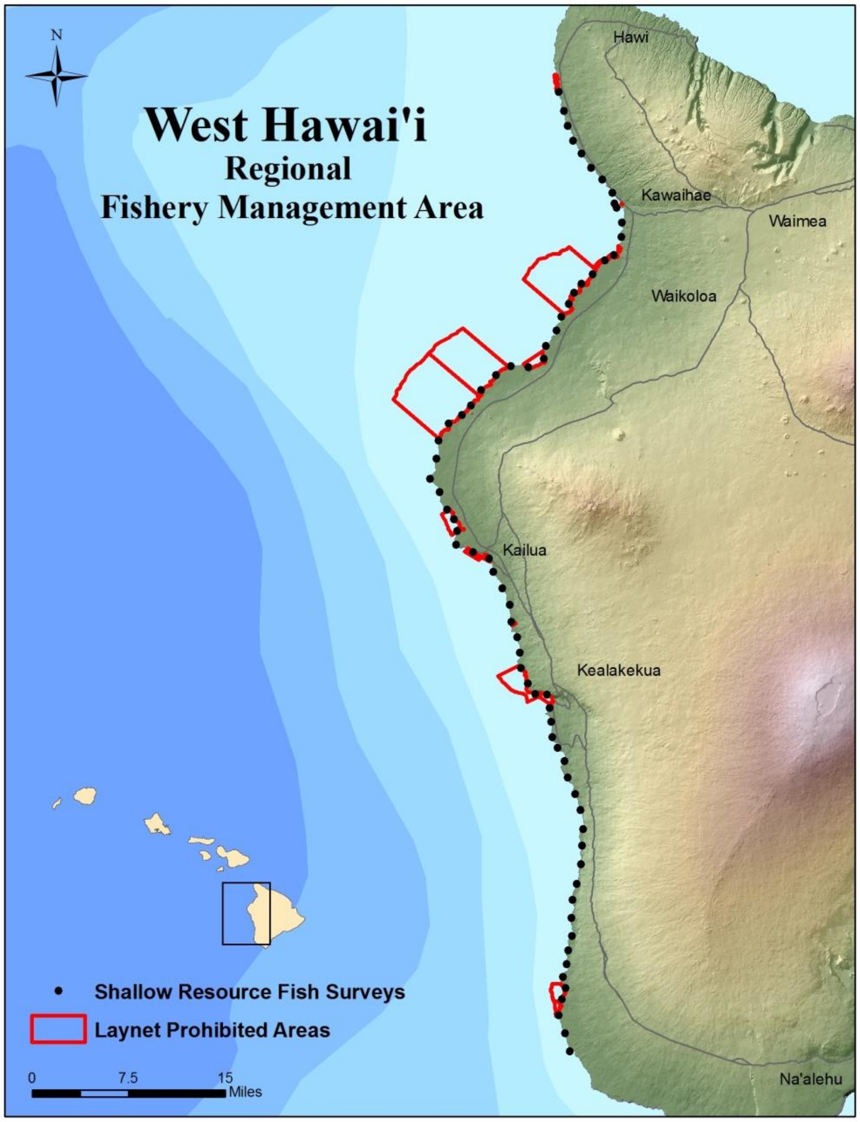

Figure 13. Locations of laynet prohibited areas in West Hawai'i and shallow water resource fish survey sites.

Additional provisions of the rule were designed to encourage responsible net use and enhance enforcement. These include such requirements as net registration and numbered identification (floats and tags), maximum soak time of four hours and maximum net length of 125'. One area (Kaloko-Honokōhau FRA) was designated a Hawaiian cultural netting area where only locally constructed handmade nets of natural fibers may be used. The West Hawaiʻi laynet rules served as a model for the rest of the state and have generally been adopted elsewhere except for Maui which completely banned their use. It is noteworthy that only in West Hawaiʻi are nets measured, inspected, registered and tagged personally by DAR staff. Such interaction with the net fishers provides a good opportunity to educate people about the rules and use of lay gill nets. Additionally it ensures the nets physically conform to the requirements of the rule and are correctly marked by identification tags and buoys.

Transects conducted in shallow water habitats most likely to be impacted by lay gill netters (Figure 13) indicate there is presently little difference in the biomass of targeted food fishes between areas open to netting and those prohibiting netting either beginning in 2005 or MPAs which have had longer (>10 years) prohibitions on laynetting (Figure 14).

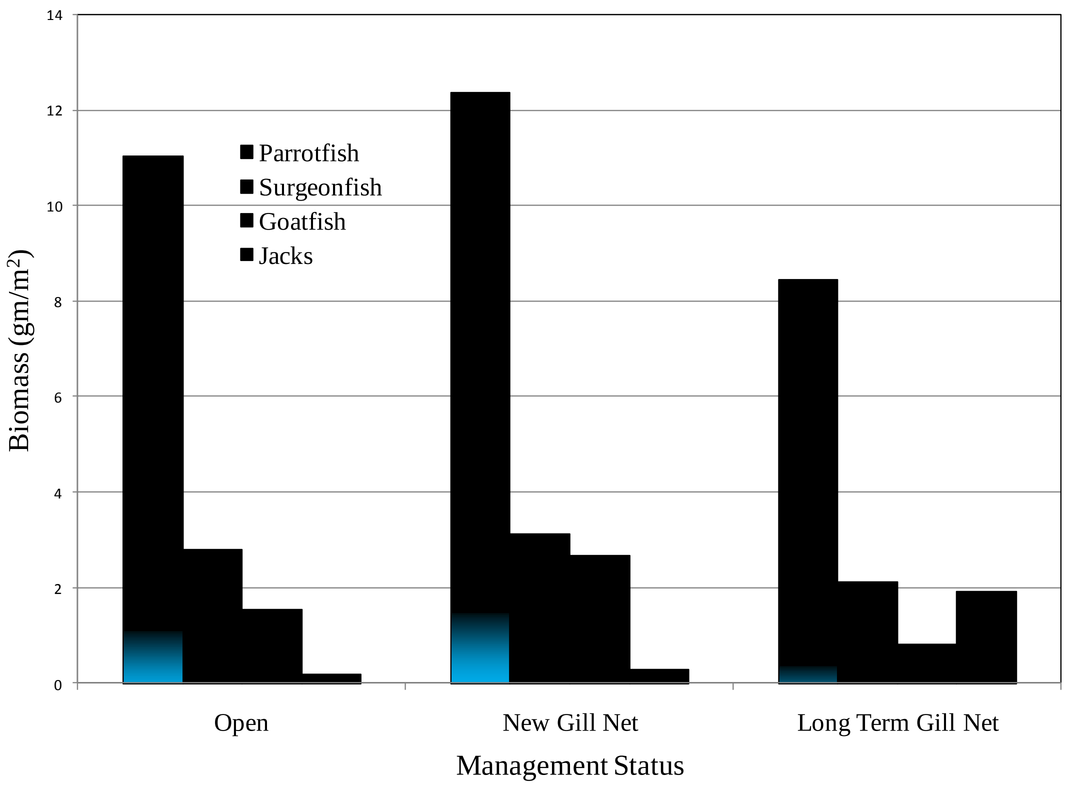

Figure 14. Biomass of 'Resource' (i.e. food) fish on shallow water transects. Only fish > 15 cm TL are censused. 'Open' denotes surveys (n=99) in areas where lay gill netting is permitted. 'New Gill Net' are survey areas (=32) which were closed to gill netting in 2005 and 'Long Term Gill Net' are survey sites (n=11) within MPAs which have prohibited netting for >10 years.

The reasons for the lack of differences between open and laynet protected areas may relate to one or more of several factors: (i) the newly protected areas haven't had sufficient time to work; (ii) the protected areas are not effectively enforced; (iii) the sites of many of the shallow water resource transects may be areas where netting is impractical (i.e. rocky shorelines, sharp reef drop-offs, etc.) and (iv) the overall level of laynet fishing is relatively low. This last factor is supported by the low number of lay gill nets registered in West Hawaiʻi as compared to the other islands (Figure 15).

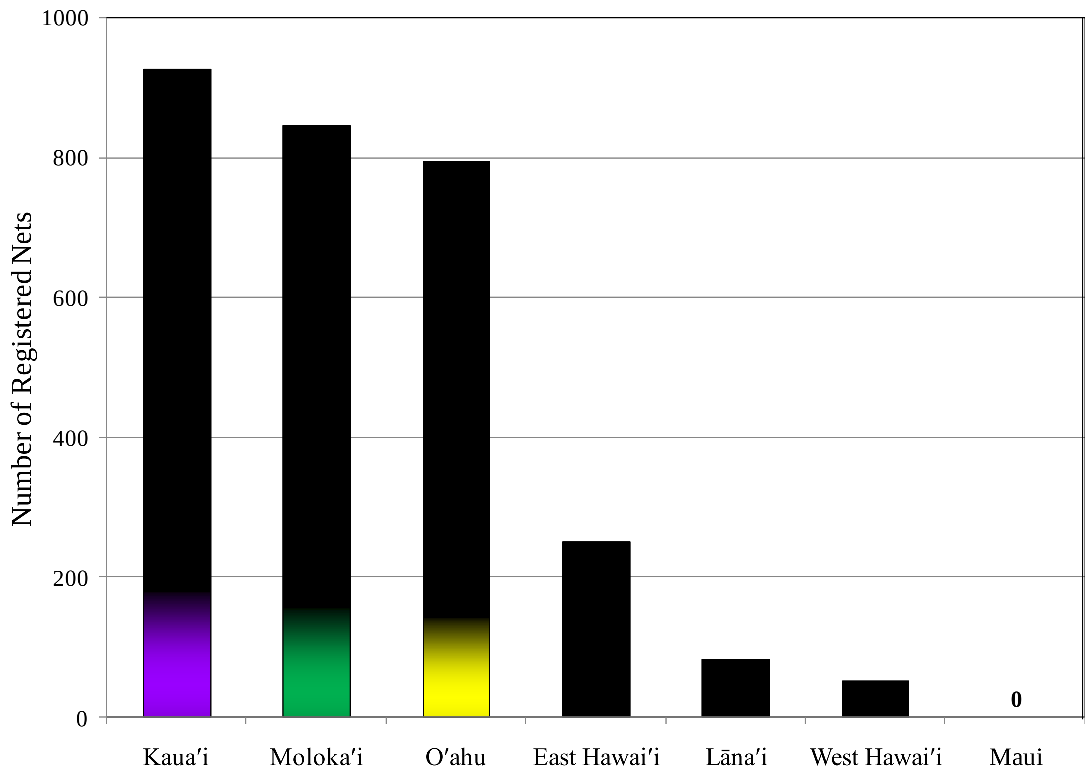

Figure 15. Number of registered lay gill nets in Hawaiʻi. Note that lay gill nets are prohibited on Maui and on Kauaʻi all types of nets are registered.

<u>Fish Reserves</u>

Unlike the other mandates of Act 306, SLH 1998, and resulting statute (Chapter 188f, HRS) and administrative rule (§13-60.3, HAR), the establishment of fish reserves where no fishing is allowed is an ongoing effort and has not yet been realized. This is due in part to a generalized resistance from some segments of the fishing community and overall government reluctance.

There are exceptions however. Beginning in 2001 an initiative developed within the South Kona community of Miloliʻi to develop rules which would allow management of their nearshore marine resources in a more traditional manner. In 2006, legislation was enacted which designated Miloliʻi a Subsistence Fishing Area (SFA). Rules for the SFA were to be subsequently developed by the community in conjunction with DAR. The following year a SFA rule package was proposed which limited fishing in the nearshore waters of Miloliʻi to subsistence purposes only. There were also a number of gear restrictions (e.g. nets and spears) and the establishment of a limited take refuge subzone

(Puʻuhonua). Unfortunately the proposed rule was scuttled at a public hearing in November 2007 when large numbers of offshore fishers objected to the subsistence only designation, fearing they would be prohibited from trolling through the area. A somewhat similar initiative is presently underway at Hoʻokena also in south Kona. In this area a one mile no-take zone (for 10 years) is proposed.

There are indications that public perceptions of marine protected areas are changing. In a 2009 DAR survey of West Hawaiʻi fishers and other ocean users (n=89) in 78% responded affirmatively to the question; should additional No-Take Marine Protected Areas be established in West Hawaiʻi? When queried about what type of management actions should be employed MPAs were most often indicated (Figure 16).

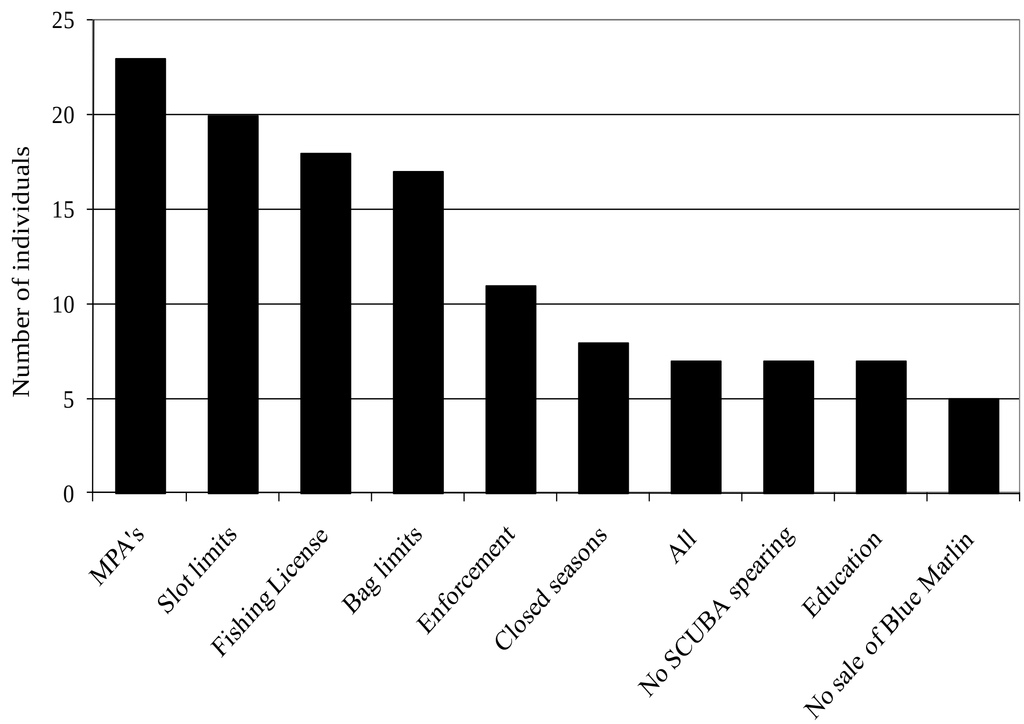

Figure 16. Top 10 methods for managing West Hawaiʻi Fisheries Resources as indicated in DAR size and bag limit questionnaire.

In response to this unfulfilled mandate, the WHFC convened a subcommittee in January 2009 to develop a strategy for working with communities to designate marine reserves within areas currently closed to aquarium collecting. Active members of the subcommittee include representatives from the commercial aquarium and SCUBA diving industries, educators, cultural advisors, and scientists.

The strategy outlined by this subcommittee has three phases:

Phase I: Compile relevant science from Hawai'i and elsewhere in the Pacific that demonstrates the benefits of properly designed and enforced marine reserves and marine reserve networks.

Phase II: Provide outreach to schools, community members, and the general public summarizing the benefits of marine reserves.

Phase III: Identify and support communities in designing and designating marine reserves in biologically viable areas by providing scientific and technical guidance and facilitating community education and outreach.

As a first step, the subcommittee has compiled scientific papers documenting marine reserve benefits to coral reef habitat, fish biomass, biodiversity, and fisheries yield in adjacent areas. Additionally, the subcommittee obtained studies that emphasize the importance of a network of marine reserves in combating the detrimental effects of natural disasters and climate change. This information will be used to develop a fact sheet highlighting reserve benefits to be made available to educators and concerned community members. Commercial aquarium collectors in West Hawai'i have pledged tentative support for the initiative provided it does not increase the percentage of coastline currently prohibiting aquarium collecting.

Kona school teachers at Kealakehe High School and Hualalai Academy have been approached to encourage their students to develop appropriate video and print media that explains the necessity of marine reserves. Verbal commitments have been made that such projects will be incorporated into their curriculums. The subcommittee is exploring re-activation of the West Hawaiʹi Youth Fisheries Council, which organized students to successfully lobby for a smoking prohibition at Kahaluʹu Beach Park.

A subcommittee member has identified a West Hawaiʹi community interested in the possibility of designating a marine reserve within their area of interest. This community has an existing advisory comprised of Hawaiian lineal descendents from the relevant geographic area, land owners and lessees, cultural advisors, educators, community coordinators and representatives from the Office of Hawaiian Affairs. Thus far, representatives from the WHFC have attended six advisory group meetings to provide information relevant to discussing designation of a Marine Reserve in an existing FRA.

Advisory group meetings have been attended by officers from DLNR’s Division of Conservation and Resources Enforcement (DOCARE) who have provided useful information related to enhancing compliance and enforcement, designating penalties, and building support for regulations. This community group is also dedicated to supporting education and outreach regarding this initiative and related coral reef topics at the Kalaemanō Interpretive Center at Kaʹupulehu.

The subcommittee has also responded to interest by the Puakō community related to amending existing FMA regulations to protect this coral reef from destructive and wasteful fishing practices and over-exploitation of existing stocks.

RECOMMENDATIONS

Based on the results of this review and evaluation the following recommendations are proposed:

1. Biological and fishery results to date indicate the FRAs are clearly working and are expected to increase in importance as time progresses. With one possible exception (Pebble Beach), there are no compelling reasons at present to alter the existing network of protected areas.

2. As monitoring and evaluation of the FRAs is required by law and necessary to further understand the dynamics of our coral reef ecosystem, a dedicated monitoring program similar to WHAP needs to be continued and supported.

3. Community input and co-management responsibility has proven to be critical in the establishment and legitimacy of the FRA network. Community advisory groups such as the WHFC should be encouraged and supported by DLNR.

4. Experienced facilitators preferably with training in environmental dispute resolution need to work with community advisory groups when addressing complex and contentious marine resource issues. This would also be desirable for DAR when holding particularly contentious community meetings and public hearings.

5. Strong community education/outreach efforts should be initiated and coordinated with “neutral” organizations already working in this capacity, for example: UH Sea Grant College Program, some branches of NOAA and the U.S. Fish and Wildlife Service.

6. While FRAs are an excellent strategy to manage the most abundant and heavily collected aquarium species, uncommon, rare or ecologically important species require species-specific harvesting limitations in open areas. An alternative, less data dependent, approach is to delimit what species can be collected (e.g. species of special concern initiative).

7. FRA boundary coordinates in the HARs do not all correspond to the shapefiles from which the maps are created for the published regulations. Some of these discrepancies are minimal while some are rather significant. A review and updating of the official MMA shapefiles and/or the HAR coordinates could prevent confusion and potential enforcement issues in the future.

8. A limited entry aquarium fishery should be established in West Hawaiʻi at the earliest possible date.

9. In order to protect and enhance aquarium stocks on other islands, especially Maui and Oʻahu, consideration should be given to establishing a system of FRAs on each island.

10. The existing aquarium catch report system needs to be revised to improve accuracy, remove ambiguities in fishing effort and provide for verification of catch.

11. A comprehensive verification of aquarium dealer and collector catch reports should be undertaken to determine reporting accuracy.

12. Collectors who continually fail to abide by the terms of their aquarium fish permit should be removed by DLNR from the fishery.

13. An effective DOCARE enforcement "presence" on the water and along coastal areas is essential for long term sustainability of our marine resources. Poaching can undermine monitoring results and make analyses of the effectiveness of protected areas problematic.

14. The effectiveness of the FRAs for aquarium fish suggests it would be prudent to establish MPAs for other resource species throughout Hawaiʻi as a precautionary measure against overfishing and for restoration of marine resources. Currently, less than 1% of the Main Hawaiian Islands is fully protected by MPAs (Clark and Gulko 1999).

15. MPAs should be large enough for self-recruitment of short distance dispersing propagules and spaced far enough apart that long distance dispersing propagules released from one reserve can settle in adjacent reserves.

16. An MPA network should encompass the proportion of the biomass necessary to sustain optimal yields of populations of concern.

17. Representative proportions of all habitat types should be included in MPAs, although rare and vulnerable habitats should be represented more fully. An initial step in this process would be to quantify/identify such habitats in West Hawaiʻi waters.

18. MPA efforts must recognize known ecological connections among habitat types, typically from shallow to deeper sites.

19. Diel movement patterns, such as from daytime foraging habitat to nocturnal resting areas must be considered in MPA establishment.

20. As recruitment is a key mechanism influencing the replenishment of nearshore populations, increased monitoring of recruitment and nearshore oceanography is necessary to better understand the dynamics of recruitment processes.

21. MPAs should have unambiguous and geographical distinct boundaries, as they are easier to recognize and enforce.

22. DAR staff should register lay gill nets at DAR offices on islands where such netting is allowed as this provides an excellent educational and net verification opportunity.

23. Support and implement co-management efforts at Miloliʻi, Hoʻokena and other interested communities.

24. A sustainable funding source for the day-use mooring buoy system needs to be established. Funds from coral damage related administrative fines and mitigation requirements could prove useful to this end.

25. Prohibit, by HAR, utilizing an illegally installed day-use mooring.

26. For continued safe and dependable operations, the DAR West Hawaiʻi vessel should be replaced. The 26' Glacier Bay catamaran used for all research and monitoring activities in West Hawaiʻi over the past 11 years has logged over 40,000 sea miles. Structural cracks have occurred on the deck and hull.

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West Hawai'i Fisheries Council – 1998-2009:

Members:
Edward Ahuna Jr., Pete Basabe, Scott Brien, Jody Bright, Ben Casuga Jr., Lisa Choquette, David Dart, Neil Dart, Fred Duerr, Michael Forcum Sr., Rick Gaffney, Doug Genovia, Glennon Gingo, Donna Goodale, Robert Hajek, Luanakanawai Hauanio, Mike Henshaw, Doug Herkes, David Hoopaugh, Kahana Itozaki, Josephine Kamoku, Ernest Kanehailua Jr., Junior Kanuha, Willie Kaupiko, Damien Kenison, Karen Klein, Guy Kitaoka, Matthias Kusch, Gerald Lange, Stan Lavine, Kawika Leicher, Gordon Leslie, Jeffery Lorance, Len Losalio, Paul Masterjohn, Ruby McDonald, Jim Medeiros Sr., Steven Meyer, Tony Nahacky, Mike Nakachi, Teresa Nakama, Cynthia Nazara, Frank Ota Jr., Bob Owens, Tina Owens, George Paleudis, Richard Prohoroff, William Rickards, Doug Robbins, JR Rosario, Dale Sarver, Robert Shallenberger, Hannah Springer, Joseph Stewart, Bill Stockley, William Talley III, Leonard Torricer, Paul Warren, Andrew West, Chad Wiggins, Vern Yamanaka, Charles Young

Alternates:
Scott Atkinson, Kater Bourdon, Zac Caldwell, Duane Erway, Ted Hardie, Jeffery Jarvis, Gilbert Kahele, Helen Lorance, Mark McGuffie, Gena Mendez, Dan Mersburgh, Pedro Padillo, Jim Passion, Dianne Yamaguchi, Caleb Yamanaka, Vern Yamanaka

Ex-officio/Agency:
Jeff Bearman, Sallie Beavers, Alex Cadang, Brent Carman, Lt. Mike Heisler, Pete Hendricks, Marnie Herkes, John Kahiapo, Reggie Lee, Laura Livnat, Wayne Leslie, Jan Marsh (KNA Jan Koo), Lt. Brian McCaul, Mark McGuffie, Nancy Murphy, Dickie Nelson, Robert Nishimoto, Robert Pacheco, Sara Peck, Scott Shero-Amba, David Tarnas, Justin Viezbicke, Ann Irene Wilcox, Bill Walsh

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APPENDIX A.

List of Aquarium collected species in West Hawai'i. Due to catch report confidentiality requirements 57 fish and 16 invertebrate species are not listed. They are included in total catch and value.

		FY05-FY09	FY05-FY09
Common Name	**Scientific Name**	**Total Caught**	**Total Value**
Fishes			
Yellow Tang	*Zebrasoma flavescens*	1,621,053	$5,035,883
Goldring Surgeonfish	*Ctenochaetus strigosus*	181,121	$376,253
Achilles Tang	*Acanthurus achilles*	42,383	$274,111
Clown Tang	*Naso lituratus*	29,859	$122,090
Black Surgeonfish	*Ctenochaetus hawaiiensis*	19,631	$309,808
Forcepsfish	*Forcipiger flavissimus*	13,216	$27,393
Multiband Butterflyfish	*Chaetodon multicinctus*	9,385	$7,127
Brown Surgeonfish	*Acanthurus nigrofuscus*	7,754	$6,833
Ornate Wrasse	*Halichoeres ornatissimus*	5,198	$11,415
Orangeband Surgeonfish	*Acanthurus olivaceus*	5,195	$9,654
Fourspot Butterflyfish	*Chaetodon quadrimaculatus*	4,909	$12,793
Moorish Idol	*Zanclus cornutus*	4,296	$9,492
Potter's Angelfish	*Centropyge potteri*	3,979	$23,343
Goldrim Surgeonfish	*Acanthurus nigricans*	3,969	$18,813
Saddle Wrasse	*Thalassoma duperrey*	3,831	$4,794
Yellowtail Coris	*Coris gaimard*	3,391	$13,049
Bird Wrasse	*Gomphosus varius*	2,559	$8,407
Hawaiian Cleaner Wrasse	*Labroides phthirophagus*	2,544	$9,550
Eye Stripe Surgeonfish	*Acanthurus dussumieri*	2,363	$3,753
Tinker's Butterflyfish	*Chaetodon tinkeri*	1,977	$156,240
Unicornfish	*Naso sp*	1,678	$6,348
Christmas Wrasse	*Thalassoma trilobatum*	1,190	$2,441
Arc-Eye Hawkfish	*Paracirrhites arcatus*	1,152	$1,426
Psychedelic Wrasse	*Anampses chrysocephalus*	1,146	$4,488
Thompson's Surgeonfish	*Acanthurus thompsoni*	1,143	$2,247
Teardrop Butterflyfish	*Chaetodon unimaculatus*	1,138	$2,930
Lei Triggerfish	*Sufflamen bursa*	1,106	$1,820
Bluelined Surgeonfish	*Acanthurus nigroris*	1,099	$1,453
Hawaiian Whitespotted Toby	*Canthigaster jactator*	932	$1,302
Smalltail Wrasse	*Pseudojuloides cerasinus*	876	$1,793
Shortnose Wrasse	*Macropharyngodon geoffroy*	849	$1,655
Hawaiian Dascyllus	*Dascyllus albisella*	821	$1,103
Fourline Wrasse	*Pseudocheilinus tetrataenia*	596	$3,419

Common Name	Scientific Name	Total Caught	Total Value
Eightline Wrasse	*Pseudocheilinus octotaenia*	588	$1,168
Spotted Boxfish	*Ostracion meleagris*	559	$2,076
Blacklip Butterflyfish	*Chaetodon kleinii*	491	$664
Flame Angelfish	*Centropyge loricula*	480	$5,969
Fisher's Angelfish	*Centropyge fisheri*	444	$1,810
Belted Wrasse	*Stethojulis balteata*	427	$713
Raccoon Butterflyfish	*Chaetodon lunula*	348	$1,732
Gilded Triggerfish	*Xanthichthys auromarginatus*	337	$2,414
Blackside Hawkfish	*Paracirrhites forsteri*	302	$712
Lantern Toby	*Canthigaster epilampra*	295	$1,300
Flame Wrasse	*Cirrhilabrus jordani*	270	$6,381
Milletseed Butterflyfish	*Chaetodon miliaris*	269	$414
Black Durgon	*Melichthys niger*	267	$1,189
Zebra Blenny	*Istiblennius zebra*	235	$248
Wrasse	Family Labridae	223	$470
Bandit Angelfish	*Desmoholacanthus arcuatus*	216	$16,784
Special Anthias	*Pseudoanthias hawaiiensis*	197	$3,210
Damselfish	Family Pomacentridae	195	$313
Pyramid Butterflyfish	*Hemitaurichthys polylepis*	193	$1,460
Reticulated Butterflyfish	*Chaetodon reticulatus*	159	$360
Disappearing Wrasse	*Pseudocheilinus evanidus*	158	$314
Rockmover Wrasse	*Novaculichthys taeniourus*	153	$858
Surgeonfish	Family Acanthuridae	143	$1,598
Ringtail Surgeonfish	*Acanthurus blochii*	134	$182
Oval Butterflyfish	*Chaetodon lunulatus*	133	$1,370
Bluestripe Snapper	*Lutjanus kasmira*	128	$149
Yellowfin Surgeonfish	*Acanthurus xanthopterus*	124	$321
Trumpetfish	*Aulostomus chinensis*	113	$471
Squirrelfish/Soldierfish	Family Holocentridae	95	$214
Ringtail Wrasse	*Oxycheilinus unifasciatus*	91	$84
Frogfish	*Antennarius sp.*	80	$1,463
Crown Toby	*Canthigaster coronata*	73	$194
Ornate Butterflyfish	*Chaetodon ornatissimus*	72	$118
Threadfin Butterflyfish	*Chaetodon auriga*	68	$372
Brick Soldierfish	*Myripristis amaena*	67	$149
Bluestripe Butterflyfish	*Chaetodon fremblii*	65	$82
Whitley's Boxfish	*Ostracion whitleyi*	62	$1,147
Blue-eye Damselfish	*Plectroglyphidodon johnstonianus*	62	$53
Longnose Hawkfish	*Oxycirrhites typus*	59	$1,100
Dragon Moray	*Enchelycore pardalis*	57	$14,550

Common Name	Scientific Name	Total Caught	Total Value
Fantail Filefish	*Pervagor spilosoma*	57	$205
Snowflake Moray	*Echidna nebulosa*	55	$629
Pearl Wrasse	*Anampses cuvier*	55	$267
Redbar Hawkfish	*Cirrhitops fasciatus*	54	$198
Yellowfin Goatfish	*Mulloidichthys vanicolensis*	51	$85
Stout Moray	*Gymnothorax eurostus*	49	$216
Hawaiian Squirrelfish	*Sargocentron xantherythrum*	49	$54
Pinktail Durgon	*Melichthys vidua*	48	$239
Bigscale Soldierfish	*Myripristis berndti*	48	$106
Whitebar Surgeonfish	*Acanthurus leucopareius*	47	$135
Bicolor Anthias	*Pseudanthias bicolor*	46	$380
Blenny	Family Blenniidae	44	$227
Parrotfish	Family Scaridae	42	$194
Manybar Goatfish	*Parupeneus multifasciatus*	42	$63
Whitemouth Moray	*Gymnothorax meleagris*	39	$246
Porcupine Fish	*Diodon hystrix*	34	$34
Reef Triggerfish	*Rhinecanthus rectangulus*	33	$210
Leaf Scorpionfish	*Taenianotus triacanthus*	32	$205
Blackfin Chromis	*Chromis vanderbilti*	27	$9
Shortbodied Blenny	*Exallias brevis*	24	$126
Bluespine Unicornfish	*Naso unicornis*	24	$68
Longnose Butterflyfish	*Forcipiger longirostris*	22	$55
Brighteye Damselfish	*Plectroglyphidodon imparipennis*	22	$2
Orangefin Filefish	*Cantherhines dumerilii*	19	$48
Hawaiian Hogfish	*Bodianus albotaeniatus*	19	$28
Speckled Butterflyfish	*Chaetodon citrinellus*	19	$18
Cardinalfish	Apogon sp.	18	$2
Surge Wrasse	*Thalassoma purpureum*	16	$96
Elegant Coris	*Coris venusta*	16	$76
Hawaiian Sergeant Major	*Abudefduf abdominalis*	16	$0
Hawaiian Turkeyfish	*Pterois sphex*	15	$570
Thompson's Anthias	*Pseudanthias thompsoni*	14	$66
Goatfish	Family Mullidae	13	$24
Threespot Damselfish	*Chromis verater*	13	$17
Ruby Cardinalfish	*Apogon erythrinus*	13	$0
Bay Cardinalfish	*Foa brachygrammus*	11	$0
Zebra Moray	*Gymnomuraena zebra*	10	$222
Twospot Hawkfish	*Amblycirrhitus bimacula*	10	$21
Thompson's Butterflyfish	*Hemitaurichthys thompsoni*	10	$15

Common Name	Scientific Name	Total Caught	Total Value
Invertebrates			
Opae ula	*Halocaridina rubra*	116,100	$6,670
Shrimp		56,384	$41,567
Hermit Crab	Family Diogenidae	12,074	$2,086
Sea Star	Class Asteroidea	616	$1,364
Common Linckia	*Linckia multifora*	455	$910
Urchin		243	$215
Sponge		274	$1,759
Coral-Banded Shrimp	*Stenopus hispidus*	153	$1,026
Spiny Lobster	Family Palinuridae	95	$475
Echinoderm		64	$43
Cowry	Family Cypraeidae	73	$92
Mann's Anemone	*Cladactella manni*	47	$610
Anemone Crab	*Dardanus gemmatus*	36	$35
Brittlestars	Family Ophiocomidae	21	$24
Yellow Hairy Crab	*Aniculus maximus*	22	$310
Cleaner Shrimp	*Lysmata amboinensis*	40	$199
Green Shrimp	Family Hippolytidae	25	$130
Ghost Shrimp	*Stenopus pyrsonotus*	24	$177
Miscellaneous Crab		19	$33
Sea Cucumber	Family Holothuroidea	16	$137
Bubble Shell	Order Cephalaspidea	14	$140
Harlequin Shrimp	*Hymenocera picta*	11	$174
	Grand Total	**2,179,361**	**$6,613,443**

APPENDIX B.

Summarized below are the changes (Δ) observed in each individual FRA over time. 'Before' density is the mean of 1999-2000 and 'After' is the mean of 2007-2009. 'Aquarium Fish' consist of the top 20 collected species (without yellow tangs since they account for the majority of the catch). The Figure shows Yellow Tang densities in each FRA relative to the closest MPA and Open area.

North Kohala FRA

Table A. Changes in fish groups in the North Kohala (Waiakailio Bay) FRA.

	Density (#/100m^2)					
Group	Before	After	Δ	ρ	R	ρ
Yellow Tang	16.34	11.77	**-28%**	0.01	**-57%**	0.01
Aquarium Fish w/o Yellow Tang	34.78	30.54	-12%	0.27	-26%	0.17
Non-aquarium fishes	46.37	34.52	-26%	0.14	+39%	0.07

Bold = statistically significant at ρ≤0.05

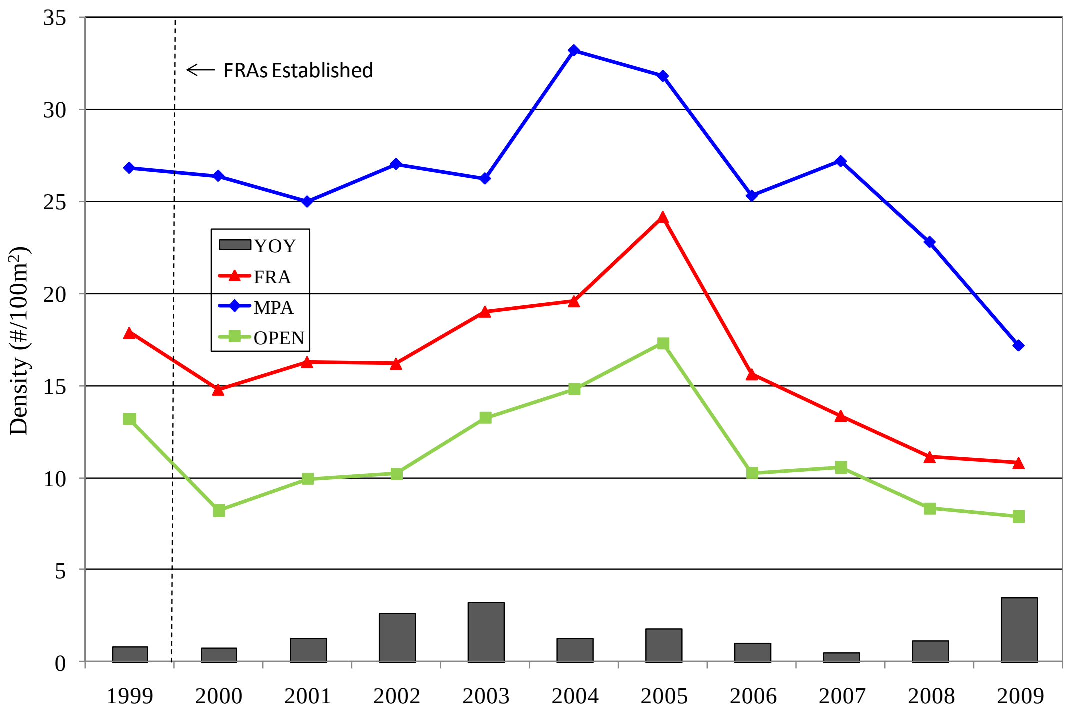

Figure 15. Changes in Yellow Tang abundance over time in FRA, MPA (Puakō) and Open (Kamilo Gulch) areas. Bars denote mean density (June-Nov) of Young- of-the-Year (YOY).

Puakō-ʻAnaehoʻomalu FRA

Table B. Changes in fish groups in the Puakō-ʻAnaehoʻomalu FRA.

Group	Density (#/100m²) Before	After	Δ	ρ	R	ρ
Yellow Tangs	11.59	14.62	**+26%**	0.04	**+33%**	0.01
Aquarium spp. w/o Yellow	45.70	42.35	-7%	0.52	-45%	0.24
Non-aquarium fishes	25.82	20.65	**-20%**	0.03	**+38%**	**0.03**

Bold = statistically significant at ρ≤ 0.05

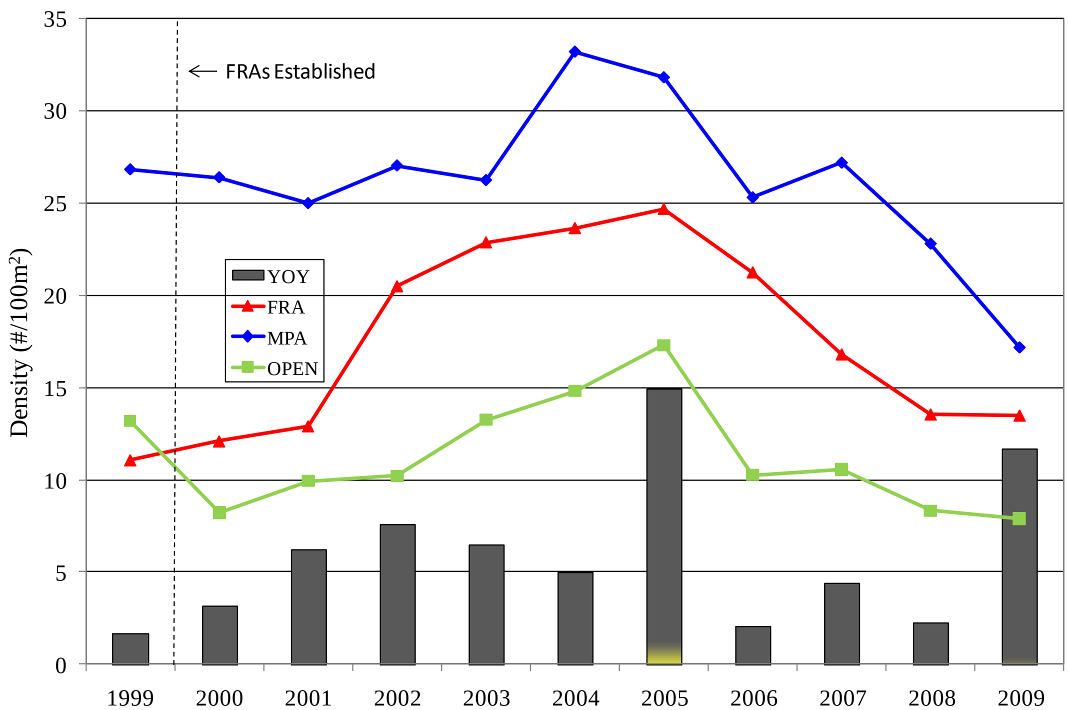

Figure 16. Changes in Yellow Tang abundance over time in FRA, MPA (Puakō) and Open (Keawaiki) areas. Bars denote mean density (June-Nov) of Young- of-the-Year (YOY).

Kaʻupulehu FRA

Table C. Changes in fish groups in the Kaʻupulehu FRA.

Group	Density (#/100m^2) Before	After	Δ	ρ	R	ρ
Yellow Tang	17.45	27.05	**+55%**	0.01	**+184%**	0.01
Aquarium spp. w/o Yellow Tang	55.69	59.98	+8%	0.32	+761%	0.26
Non-aquarium fishes	31.60	25.40	-20%	0.24	**+39**	0.05

Bold = statistically significant at ρ≤ 0.05

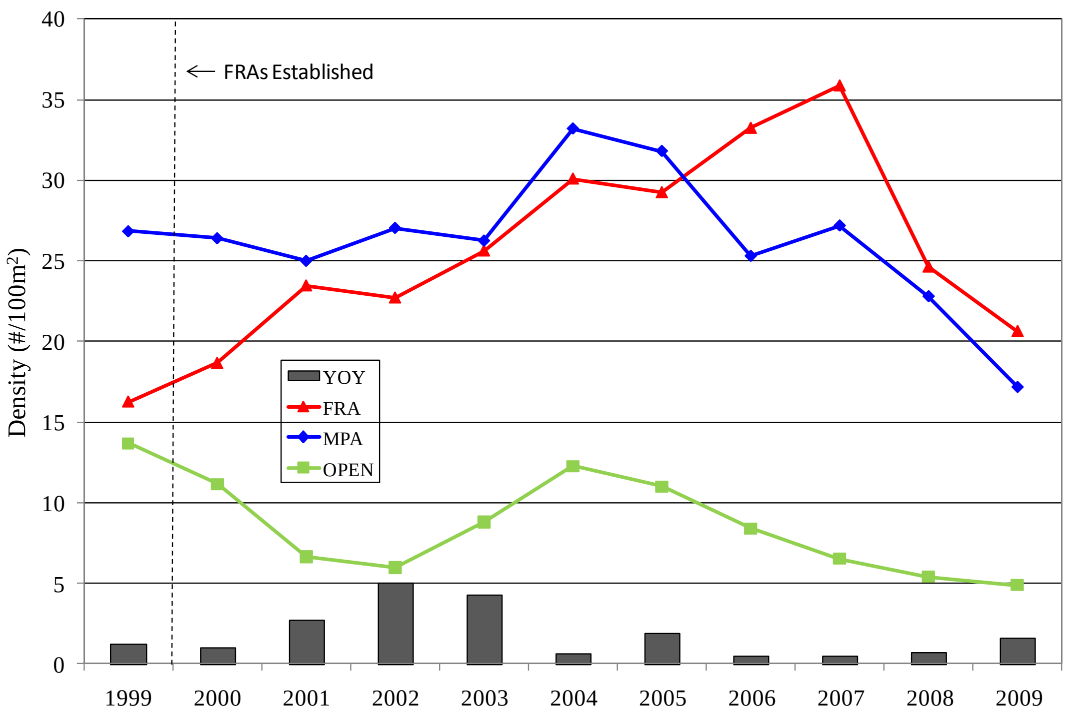

Figure 17. Changes in Yellow Tang abundance over time in FRA, MPA (Puakō) and Open (Makalawena) areas. Bars denote mean density (June-Nov) of Young- of-the-Year (YOY).

Kaloko-Honokōhau FRA

Table D. Changes in fish groups in the Kaloko-Honokohau FRA.

Group	Density (#/100m²) Before	Density (#/100m²) After	Δ	ρ	R	ρ
Yellow Tang	17.42	19.77	+14%	0.28	+55%	0.10
Aquarium spp. w/o Yellow Tang	59.45	44.15	-26%	0.11	**-493%**	0.02
Non-aquarium fishes	82.03	94.19	+15%	0.42	**+123%**	0.03

Bold = statistically significant at ρ≤0.05

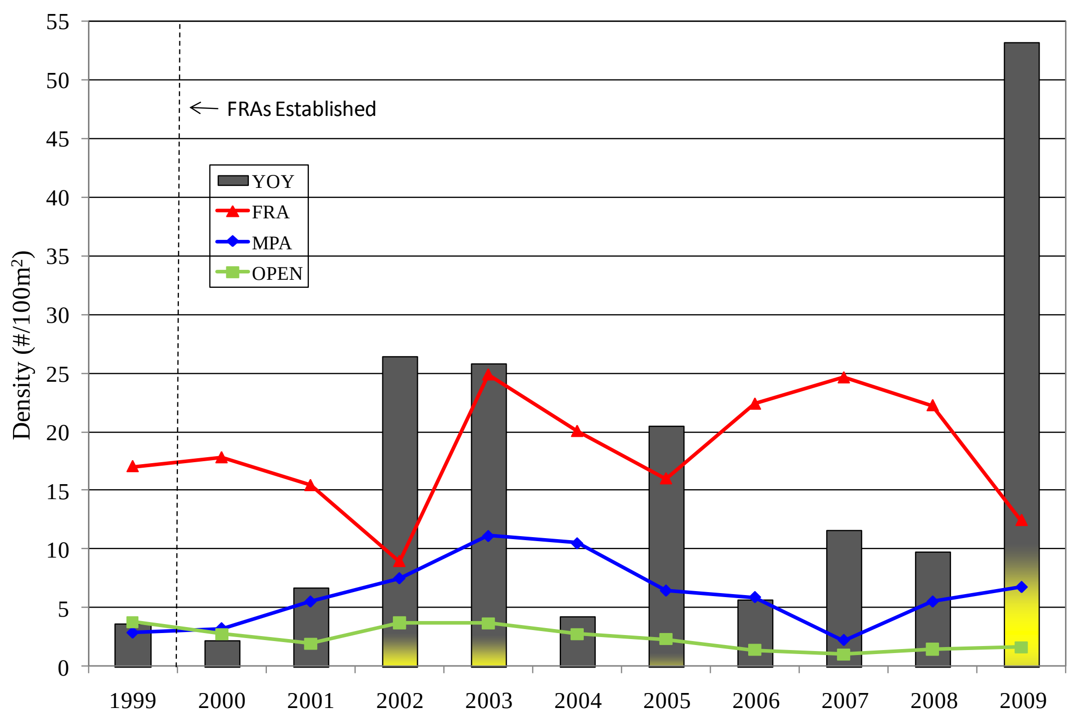

Figure 18. Changes in Yellow Tang abundance over time in FRA, MPA (Wawaloli) and Open (Wawaloli Beach) areas. Bars denote mean density (June-Nov) of Young- of-the-Year (YOY).

Kailua-Keauhou (South Oneo Bay) FRA

Table E. Changes in fish groups in the Kailua-Keauhou FRA.

	Density (#/100m²)					
Group	Before	After	Δ	ρ	R	ρ
Yellow Tang	11.77	13.04	+11%	0.53	+18%	0.33
Aquarium spp. w/o Yellow Tang	39.54	30.54	**-23%**	0.04	**-63%**	<0.01
Non-aquarium fishes	44.50	29.90	-33%	0.08	**+35%**	<0.01

Bold = statistically significant at ρ≤ 0.05

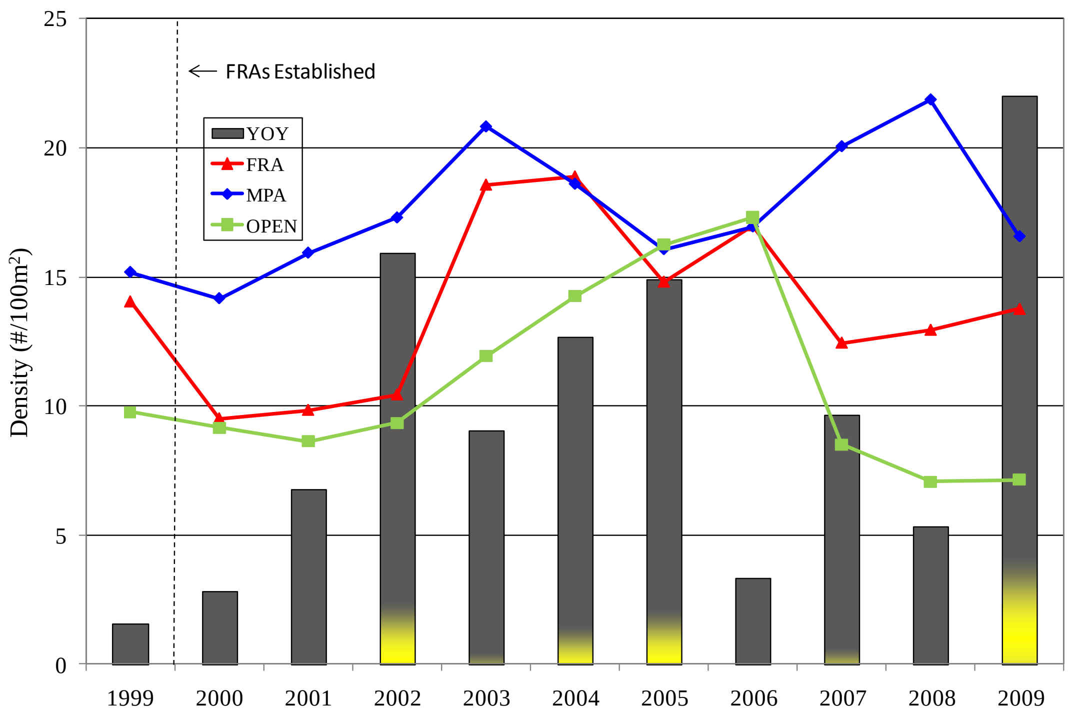

Figure 19. Changes in Yellow Tang abundance over time in FRA, MPA (Papawai) and Open (Kualanui Point) areas. Bars denote mean density (June-Nov) of Young- of-the-Year (YOY).

North Keauhou (Kailua-Keauhou) FRA

Table F. Changes in fish groups in the North Keauhou FRA.

Group	Density (#/100m²) Before	After	Δ	ρ	R	ρ
Yellow Tang	6.50	17.17	**+164%**	0.01	**+69%**	0.01
Aquarium spp. w/o Yellow Tang	48.25	34.25	**-29%**	0.02	**-196%**	0.04
Non-aquarium fishes	32.47	19.54	**-40%**	0.05	**+32%**	0.05

Bold = statistically significant at ρ≤ 0.05

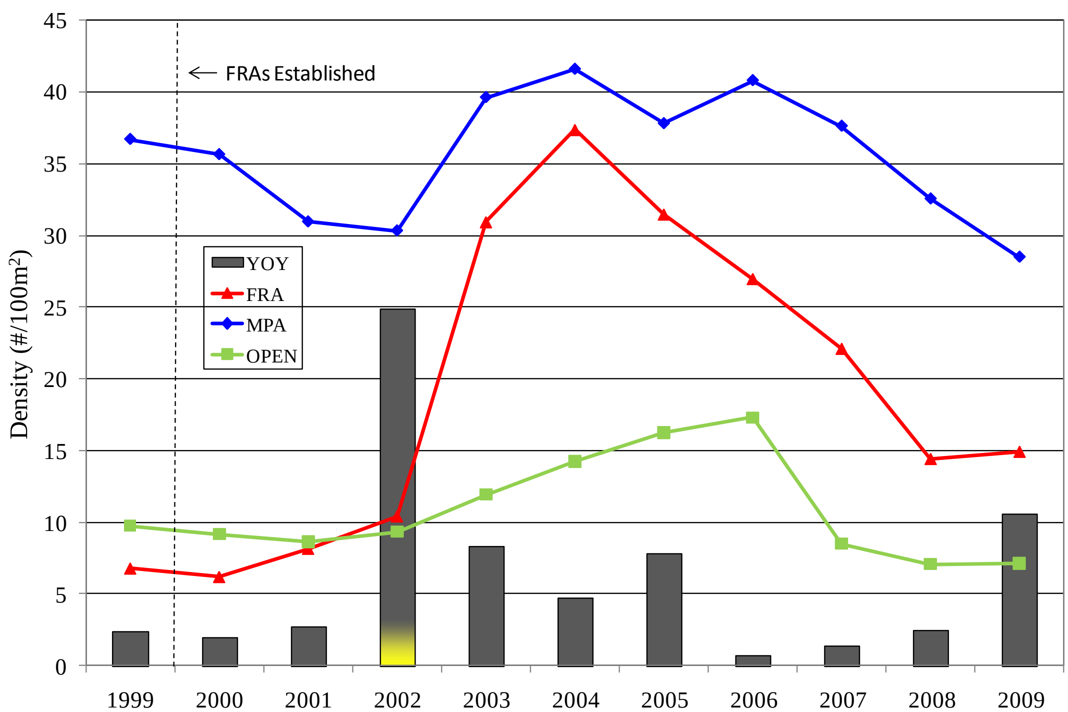

Figure 20. Changes in Yellow Tang abundance over time in FRA, MPA (Red Hill) and Open (Kualanui Point) areas. Bars denote mean density (June-Nov) of Young- of-the-Year (YOY).

Nāpoʻopoʻo-Hōnaunau (Keʻei) FRA

Table G. Changes in fish groups in the Nāpoʻopoʻo-Hōnaunau FRA.

	Density (#/100m^2)					
Group	Before	After	Δ	ρ	R	ρ
Yellow Tang	12.81	35.54	**+178%**	0.01	**+229%**	0.01
Aquarium spp. w/o Yellow Tang	48.34	49.10	+2%	0.88	-8%	0.71
Non-aquarium fishes	59.13	44.46	-25%	0.07	+42%	0.08

Bold = statistically significant at $\rho \leq 0.05$

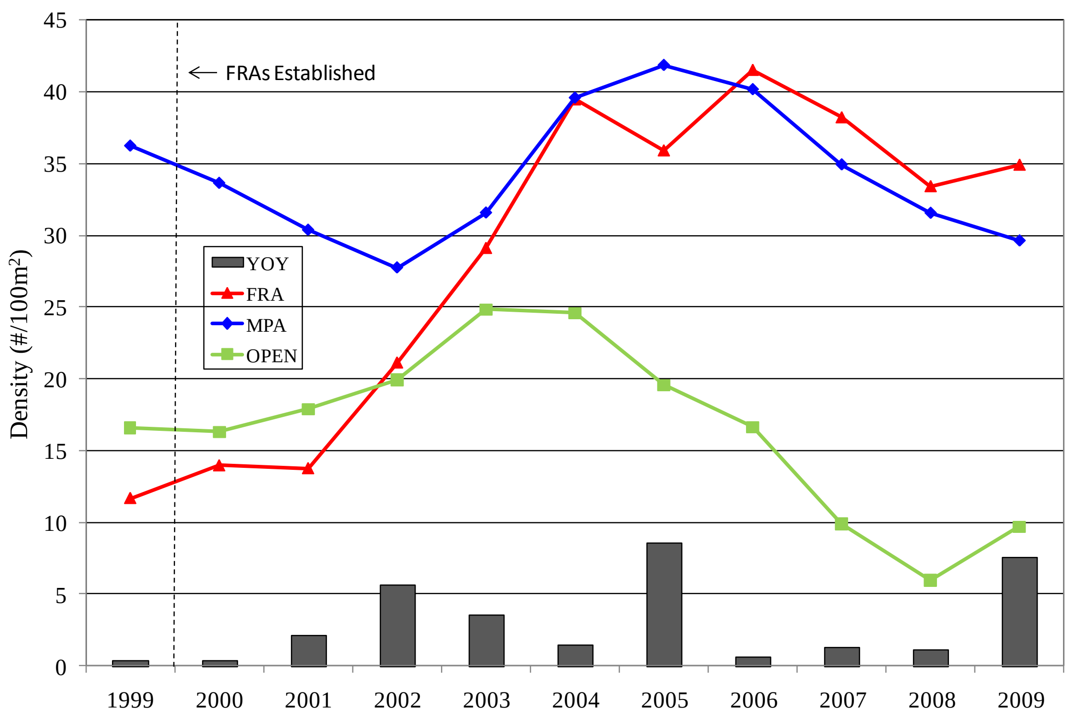

Figure 21. Changes in Yellow Tang abundance over time in FRA, MPA (Kealakekua Bay) and Open (Keopuka) areas. Bars denote mean density (June-Nov) of Young- of-the-Year (YOY).

<u>Hoʻokena (Kalahiki Beach) FRA</u>

Table H. Changes in fish groups in the Hoʻokena FRA.

	Density (#/100m²)					
Group	Before	After	Δ	ρ	R	ρ
Yellow Tang	11.91	26.46	**+122%**	0.01	**+137%**	0.01
Aquarium spp. w/o Yellow Tang	73.00	63.96	-12%	0.40	-61%	0.21
Non-aquarium fishes	49.61	42.29	-15%	0.14	**+47%**	0.03

Bold = statistically significant at $\rho \leq 0.05$

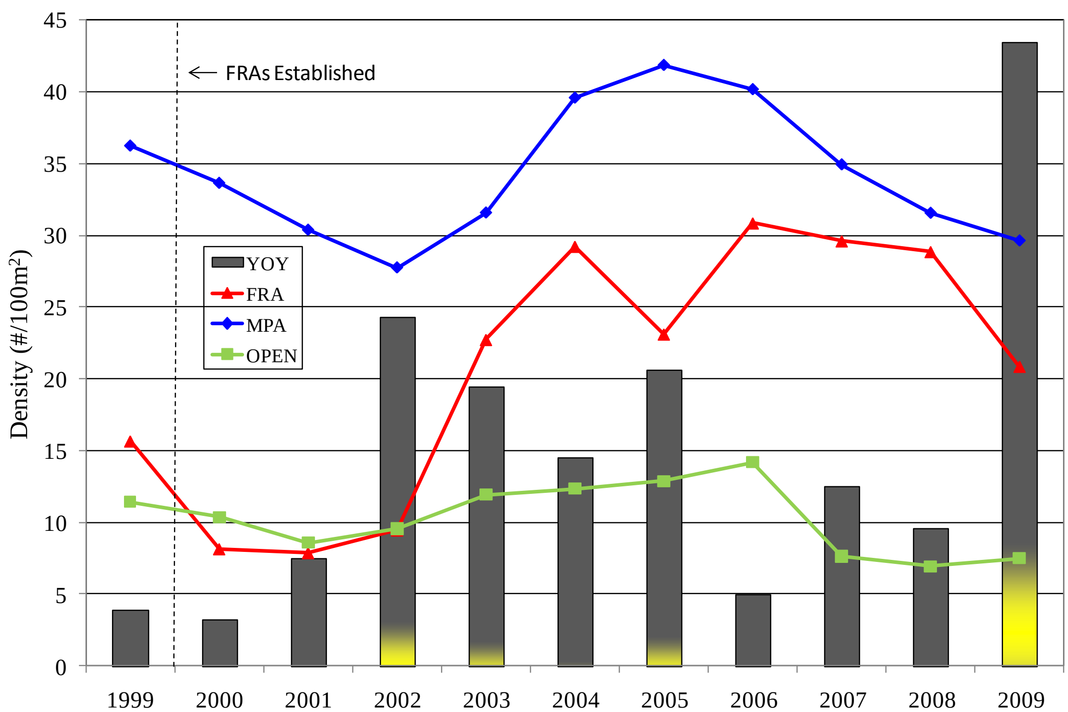

Figure 22. Changes in Yellow Tang abundance over time in FRA, MPA (Kealakekua Bay) and Open (Auʻau Crater) areas. Bars denote mean density (June-Nov) of Young- of-the-Year (YOY).

Miloliʻi FRA

Table I. Changes in fish groups in the Miloliʻi (Omakaʻa) FRA.

Group	Density (#/100m^2) Before	Density (#/100m^2) After	Δ	ρ	R	ρ
Yellow Tang	8.82	14.11	**60%**	0.01	**+42%**	0.01
Aquarium spp. w/o Yellow Tang	63.35	63.02	-1%	0.96	-23%	0.66
Non-aquarium fishes	103.16	78.38	-24%	0.14	+77%	0.38

Bold = statistically significant at ρ≤0.05

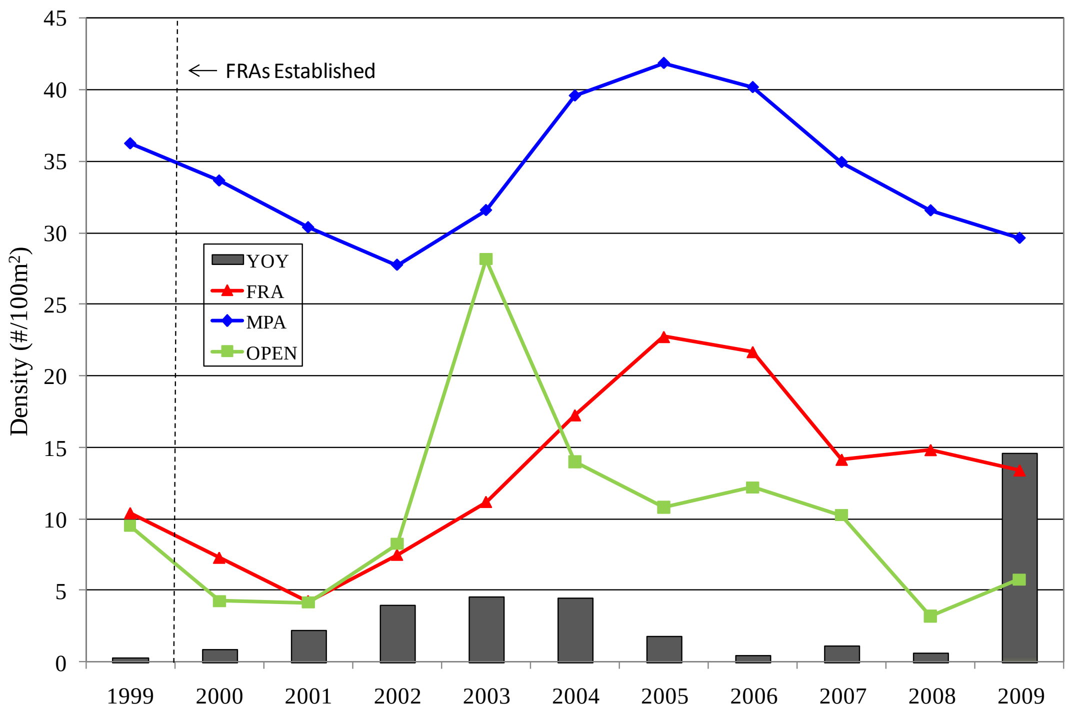

Figure 23. Changes in Yellow Tang abundance over time in FRA, MPA (Kealakekua Bay) and Open (Manuka) areas. Bars denote mean density (June-Nov) of Young- of-the-Year (YOY).

APPENDIX C

List of West Hawaiʻi day-use mooring buoys. Moorings in blue are installed but have not yet been written into Hawaii Administrative Rule. NR=not rigged (missing).

Name	Local Area Name	DM #	ft	N Latitude	W Longitude
Black Point (N)	Keawanui Bay	1	48	20° 6.775'	155° 53.177'
Black Point	Mala'e Pt (N)	2	55	20° 6.349'	155° 53.086'
Black Point (S)	Mala'e Pt (S)	3	53	20° 6.203'	155° 52.988'
Kei Kei Caverns (N) (Horseshoe)	Pōhakuloa Gulch (N)	4	51	20° 4.824'	155° 52.058'
Kei Kei Caverns (S)	Pōhakuloa Gulch (S)	5	42	20° 4.803'	155° 52.038'
Ulua Caverns	Waiakailio Bay	6	30	20° 4.462'	155° 51.861'
Frog Rock	Kapae Gulch	7	54	20° 3.895'	155° 51.266'
Lava Dome Rock	Kaiōpae	8	40	20° 3.654'	155° 51.058'
Crystal Cove	Honokoa	9	43	20° 3.220'	155° 50.749'
Puakō	Puakō	9A	40	19° 58.217'	155° 50.837'
Secrets	Waimā Pt (Puakō)	9B	35	19° 58.203'	155° 50.924'
Pine Tree	Kapuniau Pt	9C	18	19° 58.052'	155° 51.309'
Paniau N	Paniau N	9D	20	19° 56.590'	155° 51.595'
Paniau S	Paniau S	9E	40	19° 57.566'	155° 51.619'
Makaiwa Bay (Turtles)	Keanapukalua Pt	10	28	19° 56.957'	155° 52.259'
Haunted Cavern	Makaiwa Bay	11	34	19° 56.809'	155° 52.339'
Pentagon	ʻAnaehoʻomalu Bay	12	18	19° 54.940'	155° 53.940'
Kua Bay	Kua Bay	12.04	23	19° 48.776'	156° 0.487'
Hoover's Tower (Keahole) (3)	Unualoha	12A	35	19° 44.422'	156° 3.333'
Garden Eels (N)	Makako Bay	12A1	26	19° 44.230'	156° 3.240'
Garden Eels West	Makako Bay	12A2	27	19° 44.202'	156° 3.235'
Garden Eels East	Makako Bay	12A3	19	19° 44.198'	156° 3.215'
Garden Eels (S)	Makako Bay	12A4	23	19° 44.161'	156° 3.235'
Tako City (Keahole)	Hoʻona Bay	13	35	19° 43.955'	156° 3.467'
Keahole Wash Rock	Hoʻona Bay	14	32	19° 43.934'	156° 3.578'
Pipe Dreams	Keahole Pt.	14A	39	19° 43.747'	156° 3.735'
Black Hole	Wawaloli Beach	14B	55	19° 42.932'	156° 3.238'
Dotti's Reef	Pūhili Pt.	14C	28	19° 42.406'	156° 3.001'
Rabbi's Reef (Lionfish Arch)	Pūhili Pt.	14D	47	19° 42.359'	156° 3.056'
Phantom Ridge (High Rock)	Pūhili Pt.	15	38	19° 42.295'	156° 3.016'
Carpenter's House	Pūhili Pt.	16	34	19° 42.283'	156° 3.009'
Golden Arches (N)	Pūhili Pt.	17	40	19° 42.203'	156° 3.007'
Golden Arches (S)	Pūhili Pt.	17A	26	19° 42.176'	156° 2.991'
Pyramid Pinnacle 1	Wawahiwaʻa Pt.	18	65	19° 41.552'	156° 2.742'
Pyramid Pinnacle 2	Wawahiwaʻa Pt.	19	38	19° 41.551'	156° 2.775'
Skunk Hollow 1 (Inside)	Wawahiwaʻa Pt.	20	32	19° 41.483'	156° 2.582'

Skink Hollow 2 (Outside)	Wawahiwaʻa Pt.	21	40	19° 41.466'	156° 2.588'
Suck 'Em Up Cave	Wawahiwaʻa Pt.	22	35	19° 41.480'	156° 2.538'
Lone Tree	Wawahiwaʻa Pt.	23	40	19° 41.468'	156° 2.445'
Freeze-Face Cave	Wawahiwaʻa Pt.	23A	23	19° 41.425'	156° 2.365'
Windows	Kaloko Fishpond	23B	33	19° 41.154'	156° 2.099'
Kaloko Ledges (Kaloko Arches1)	Kaloko Pt	24	43	19° 40.991'	156° 2.192'
Kaloko Arches (Kaloko Arches2)	Kaloko Pt	24A	35	19° 41.019'	156° 2.152'
Terrapin Station	Honokōhau Bay	24A1	35	19° 40.330'	156° 1.875'
Turtle Pinnacle	Honokōhau Bay	24B	32	19° 40.305'	156° 1.830'
Turtle Pai	Honokōhau Bay	24C	21	19° 40.302'	156° 1.791'
Turtle Heaven	Maliu Pt.	24D	22	19° 40.223'	156° 1.750'
Honokohau Inside	Honokōhau Bay (S)	24E	18	19° 40.076'	156° 1.739'
Honokohau Middle	Honokōhau Bay (S)	24F	16	19° 40.072'	156° 1.747'
Honokohau Outside	Honokōhau Bay (S)	24G	20	19° 40.064'	156° 1.768'
Eel Cove (N)	Kaiwi Pt	25	33	19° 39.302'	156° 1.910'
Eel Cove (S)	Kaiwi Pt	26	15	19° 39.249'	156° 1.893'
Outhouse	??	26A	47	19° 39.002'	156° 1.806'
Kaiwi Wash Rock 1 (Pawai Bay)	Pawai Bay	27	40	19° 38.816'	156° 1.410'
Kaiwi Wash Rock 2 (Pawai Bay)	Pawai Bay	28	40	19° 38.830'	156° 1.403'
Kaiwi Arch Cave (Pawai Bay)	Pawai Bay	29	40	19° 38.840'	156° 1.375'
Kaiwi Sand Channel (Pawai Bay)	Pawai Bay	30	40	19° 38.849'	156° 1.348'
Kaiwi Kamanu (Pawai Bay)	Pawai Bay	31	45	19° 38.857'	156° 1.308'
Disneyland	??	32	33	19° 38.830'	156° 1.186'
Airtanks	??	32A	28	19° 38.802'	156° 1.108'
Old Airport	Pohakuloa Rock	33	40	19° 38.648'	156° 0.990'
Sharkfin Rock (Old Airport S)	Pohakuloa Rock	34	36	19° 38.620'	156° 0.940'
Casa Cave	Puapuaʻa Pt.	34A	38	19° 36.963'	155° 59.209'
Mano Point (Fantasy Reef)	Kualanui Pt.	35	42	19° 32.757'	155° 57.700'
Chimney	Kuamoʻo Pt.	36	41	19° 32.475'	155° 57.600'
Leinokano Point	Leinokano Pt.	37	NR	19° 32.180'	155° 57.520'
Paʻaoa Bay	Paʻaoa Bay	38	NR	19° 31.860'	155° 57.440'
Coral Domes	Keikiwaha Pt. (N)	39	33	19° 31.307'	155° 57.562'
Keikiwaha Point	Keikiwaha Pt. (S)	40	NR	19° 31.180'	155° 57.690'
Henry's Cave	Puʻu Ohau (N)	40A	43	19° 30.496'	155° 57.292'
Sharkey's (Bay of Pig)	Puʻu Ohau (S)	41	49	19° 30.371'	155° 57.305'
Nenue Point	Nenue Point	42	NR	19° 30.760'	155° 57.630'
Amphitheater (Long Lava Tube)	Nawawa Bay (N)	43	52	19° 30.239'	155° 57.183'
Amphitheater (Octocoral)	Nawawa Bay (S)	44	40	19° 30.185'	155° 57.145'
Driftwood	??	45	42	19° 29.929'	155° 57.088'
The Dome	Keawekaheka Bay (N)	45A	36	19° 29.823'	155° 57.002'
Ridges	Keawekaheka Bay (S)	46	32	19° 29.665'	155° 57.010'
A-Bay Arches	Kapalaoa	12.01	20	19° 54.919'	155° 54.001'
Black Coral Arch	??	12.02	40	19° 50.154'	155° 59.789'
Touch of Grey	??	12.03	58	19° 46.962'	156° 3.159'

Proposed Additional Moorings					
Puako Condos	Puakō Pt.		37	19° 58.405'	155° 50.615'
Puako Puffer Canyon	Puakō reef		37	19° 58.260'	155° 50.729'
Garden Eel Cove 1	Makako Bay		50	19° 44.186'	156° 3.260'
Garden Eel Cove 2	Makako Bay		85	19° 44.186'	156° 3.260'
Keauhou Manta 1	Kaukalaelae Pt.		25	19° 33.558'	155° 58.023'
Keauhou Manta 2	Kaukalaelae Pt.		35	19° 33.558'	155° 58.023'
Keauhou Manta 3	Kaukalaelae Pt.		40	19° 33.558'	155° 58.023'
Kealakekua Bay	Kaʻawaloa			TBD	TBD