Report to the Twenty-Third Legislature
Regular Session of 2005
on

A Report on the Findings and Recommendations of Effectiveness of the West Hawai`i Regional Fishery Management Area

Prepared by

Division of Aquatic Resources
Department of Land and Natural Resources
State of Hawai`i

in response to

Hawai`i Revised Statutes (§188F-5)

December, 2004

SUMMARY OF FINDINGS

The West Hawai`i Regional Fisheries Management Area was created by Act 306, Session Laws of Hawaii (SLH) 1998. One of its major mandates was the designation of a minimum of 30% of West Hawai`i coastal waters as Fish Replenishment Areas (FRAs) where aquarium collecting is prohibited. A community advisory group, the West Hawai`i Fisheries Council (WHFC) developed an FRA plan which created a network of nine FRAs comprising 35.2% of the coastline. The FRAs became effective 31 December 1999.

Five years after closure of the FRAs, 7 of the 10 most heavily collected species (representing 94% of all collected fish) have increased in overall density. FRAs have been effective in significantly increasing the abundance of two species relative to already protected control sites (e.g. MLCDs). Yellow tangs which constitute 84% of all targeted fish increased 49% and chevron tangs increased 141%. Several others species, notably the longnose butterflyfish/forcepsfish, four-spot butterflyfish, ornate butterflyfish and Hawaiian cleaner wrasse showed high (>30%) but non-significant increases in FRAs relative to control sites. Four of the top 10 species; kole, Achilles tang, clown tang and multi-band butterflyfish showed insignificant decreases in FRAs relative to control sites.

While specific FRAs varied in their effectiveness in increasing fish stocks, overall 7 of 9 showed a positive effectiveness for yellow tangs with four having statistically significant increases in abundance. Effective replenishment has been linked to the moderately high levels of newly recruiting aquarium fishes observed in 2001-03. Previous work also indicates that habitat characteristics, FRA size, and density of adult fishes are important factors influencing the effectiveness of FRAs. The widespread occurrence of increases of aquarium fishes in FRAs, combined with a large and significant increase in the primary aquarium fish, the yellow tang, indicates that the FRAs are effectively replenishing aquarium fish stocks in West Hawai`i after almost five years of closure. This result is consistent with an earlier published analysis after three years of FRA closure.

The effect of the FRAs on the aquarium fishery itself has been positive. The average number of commercial aquarium collectors working in West Hawai`i during the four years after FRA establishment is higher than the comparable period before. Total catch and the catch of the top two species, yellow tang and kole, is presently the highest it has ever been. The price per fish received by collectors for yellow tangs has increased by an average of 33% subsequent to FRA establishment. Catch per Unit Effort (CPUE) of aquarium fish is higher in West Hawai`i than elsewhere in the State and is maintaining an upward trend. CPUE is the highest it has ever been in Fiscal Year (FY) ’04 and the total economic value of the of the West Hawai`i aquarium fishery has reached new heights. Compliance by collectors to the FRAs has generally been good and incidents of harassment and conflict between collectors and other ocean users has been markedly reduced. Noncompliance with catch report requirements remains problematic however.

Although not established by statute, the West Hawai`i community’s formation of the WHFC has been, and continues to be, invaluable and instrumental in achieving the objectives of Act 306, SLH 1998. The WHFC appears to be a model system for the

resolution of issues surrounding reef fisheries resources. Based on this review, a number of specific recommendations are proposed.

PURPOSE OF THIS REPORT

This report is submitted in compliance with Act 306, SLH 1998, "Relating to the West Hawai`i Regional Fishery Management Area" and subsequently established as Chapter 188F, Hawaii Revised Statutes (HRS). This Statute requires a review of the effectiveness of the West Hawai`i Regional Fishery Management Area Plan shall be conducted every five years by the Department of Land and Natural Resources (DLNR), in cooperation with the University of Hawai`i (§188F-5 HRS).

BACKGROUND

The West Hawai`i Regional Fishery Management Area Plan was conceived to have four separate but complementary components as follows (§188F-4, HRS):

(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.

Plan development and implementation of the various components has proceeded along differing time lines. A Hawai`i Island day-use mooring buoy system has been in place for almost 10 years (Hawaii Administrative Rules (HAR) 13-257). At present, 85 moorings have been permitted, installed and are in use in West Hawai`i. Five additional moorings are currently in the permit application process with DLNR's Division of Boating and Ocean Recreation (DOBOR) and the Army Corps of Engineers (ACOE). A no-anchoring zone exists within a 50 yd. radius of any day-use mooring.

A gill net management plan has been developed over the last three years by DLNR's Division of Aquatic Resources (DAR) in conjunction with a community advisory group, the WHFC. This plan provides for continued small-scale subsistence-level netting while effectively controlling large-scale commercial netting. Management recommendations include a number of provisions designed to encourage responsible net use and enhance enforcement. 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 will prohibit the use of such nets. The gill net management plan will be presented as an administrative rule amendment at public hearing in December, 2004.

The establishment of fish reserves where no fishing is allowed is an ongoing effort and has not been realized at present due largely to resistance from influential segments of the fishing community and government reluctance. Substantially increased outreach and education on the potential benefits of “no-take” areas as well as governmental commitment is necessary before this mandate can be achieved.

FRAs were mandated to address concerns over user conflict and localized resource depletion caused by aquarium fish collectors in West Hawai`i. To address this concern and the specific mandate of the statute, a network of 9 FRAs comprising 35.2% of coastal waters was established in December 1999 (HAR 13-60.3). Aquarium collecting and fish feeding are prohibited in these areas. Scientific research and monitoring on the effectiveness of the FRAs has been underway since 1998 under the aegis of the West Hawai`i Aquarium Project (WHAP). This Report presents a review of the effectiveness of the FRAs based upon WHAP monitoring data and commercial catch report information. An overview of the aquarium fishery and FRA development is also included.

The Aquarium Fishery in West Hawai`i

The marine aquarium fishery in the State of Hawai`i is one of the most economically valuable commercial inshore fisheries with FY 2004 reported landings of 557,673 specimens and a total reported value of $1.08 million. The reported value is considered to be underestimated by a factor of approximately 3 to 5X (Cesar et al. 2002 and Walsh et al. 2003, respectively). The fishery developed initially on O`ahu in the early 1950’s, went through a period of expansion in the 70’s and has subsequently been declining on O`ahu both in terms of fish catch and overall value.

In contrast to O`ahu, the aquarium fishery on the Island of Hawai`i has undergone substantial and sustained expansion over the past 20 years (Table 1). Presently 81% of fish caught in the State and 70% of the total aquarium catch value come from the Big Island and almost exclusively from West Hawai`i.

Table 1. Changes in West Hawai`i aquarium fishery over last twenty Years. Dollar value is adjusted for inflation.

	FY 1984	FY 2004	Δ
No. Permits	7	47	671% ↑
Total Catch	34,706	626,885	942% ↑
Total Value	$173,691	$757,278	436% ↑
% of State Fish Catch	23%	81%	58%↑
% of State Total Catch	19%	59%	40% ↑
% of State Value	30%	70%	40% ↑

The aquarium collecting industry in Hawai`i and especially West Hawai`i has long been a subject of controversy. As early as July 1973, public concern over collecting activities prompted DLNR’s then Division of Fish and Game to suspend the issuance of Aquarium Fish Permits. The suspension was lifted one week later. Shortly thereafter, the 10-

member State Animal Species Advisory Commission recommended restricting issuance of aquarium fish permits pending "full and extensive study." At a September 1973 meeting called by Fish & Game, a number of university marine scientists recommended the "careful selection of specified sanctuary areas of limited extent and the prohibition of collecting within their confines." It was at this time that aquarium permittees were first required to submit monthly fish catch reports. Unfortunately, no studies were conducted and sanctuary areas were never established.

Over subsequent years as the number of collectors in West Hawai`i began to rise and the numbers of animals collected increased markedly (Figure 1), conflict escalated along the coast, 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. The following year four of the areas from the Gentleperson's Agreement were incorporated into the Kona Coast Fisheries Management Area (FMA) which became effective in 1991.

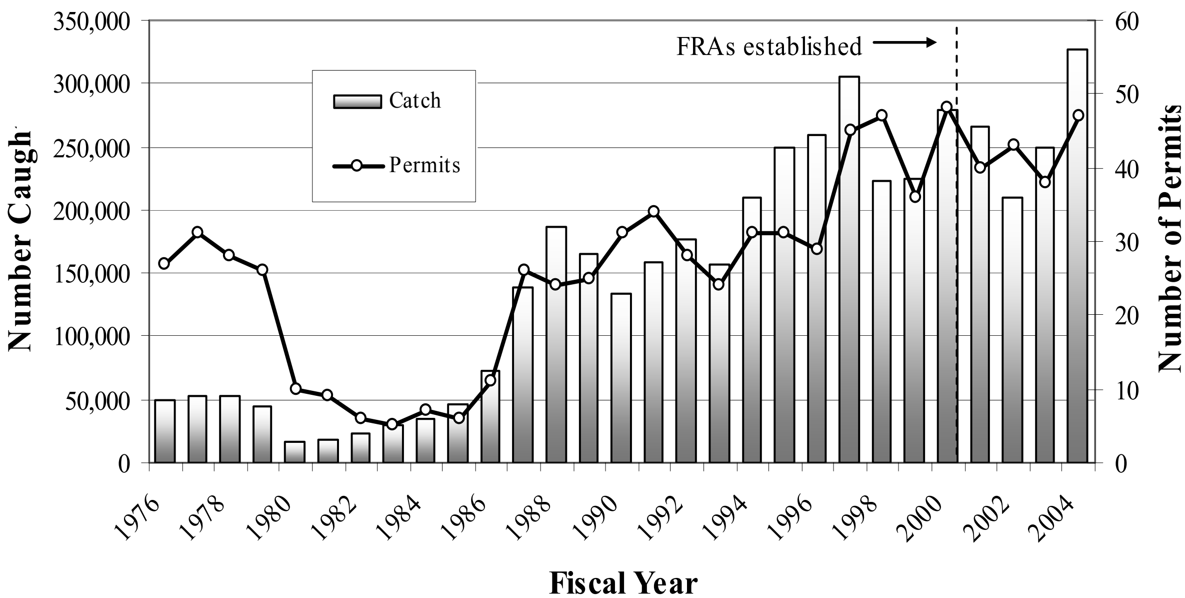

Figure 1. Number of aquarium animals collected and number of commercial aquarium permits in West Hawai`i for Fiscal years 1976-2004.

The West Hawai`i Reef Fish Working Group (WHRFWG)

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 as well as 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.

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 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 a West Hawai`i Regional Fishery Management Area (WHRFMA) along the entire 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 FRAs where aquarium collecting was prohibited. In February 1998, HB 3348 was killed. 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. It was passed by the Legislature and ultimately became Act 306, SLH 1998, taking effect 13 July 1998.

Act 306, SLH 1998, established a West Hawai`i Regional Fishery Management Area along the entire west coast (147 miles) of the Island of Hawai`i. Overall, the purposes of Act 306, SLH 1998, are to (1) Effectively manage fishery activities to ensure sustainability; (2) Enhance nearshore resources; and (3) Minimize conflicts of use in this coastal area. Included in the Act was a mandate to designate "a minimum of 30%" of West Hawai`i coastal waters as FRAs. Additionally, the Act also directed DLNR/DAR to identify these areas "after close consultation and facilitated dialogue with working groups of community members and resource users."

The West Hawai`i Fisheries Council (WHFC)

In order to accomplish the mandates of Act 306, SLH 1998, with substantive community input, a council approach was decided upon by DLNR. In conjunction with University of Hawai`i Sea Grant, DAR put together a council whose members come from diverse geographic areas and represent the various stakeholder, community and user groups in West Hawai`i. A working document of Operational Practices & Procedures was developed to serve as a vehicle for decision making. The West Hawai`i Fisheries Council (WHFC) was convened June 16, 1998. It consisted of 24 voting members and 6 ex-officio agency representatives (DAR, DOBOR, DLNR's Division of Conservation and Resources Enforcement (DOCARE), Sea Grant, and the Governor's Office). There were four aquarium representatives (three collectors, one aquarium shop owner), three commercial dive tour operators and one hotelier. The rest of WHFC consisted of a variety of overlapping and not easily definable interests. There were commercial and recreational fishermen (at least ten), shoreline gatherers, recreational divers, a LFC representative and several community representatives. Two members had degrees in marine or fishery science. Forty percent of the WHFC were Hawaiians, including one on the Board of the Office of Hawaiian Affairs (OHA). Twenty-three of the 30 members were on the WHRFWG with additional members added to expand expertise and/or representation.

Prior to the beginning of the Council's decision making process, pertinent information on marine protected areas, community-based resource management and scientific studies of Hawai`i's reefs and aquarium fish collecting was distilled for the Council into several specific site selection criteria. The group considered aspects of reserve design and function including minimum size, shape (e.g. single large or several small reserves?), location, enforceability and conflict reduction.

The importance of Council members conveying information during this process to their respective "constituents" was stressed repeatedly. It was emphasized they represented not only themselves but also more importantly, a particular user group or community.

After site selection criteria were established each Council member was given a set of coastal maps. They were tasked with gathering information from their respective communities or user groups and then designating specific FRA locations on their maps. The designations on each map were then compiled on master maps to provide a clear graphical indication of the group's selections. Consensus on certain areas was readily apparent. Aquarium representatives were further directed to demarcate areas that they considered essential to their fishery. In several instances community meetings were called by residents to request further information on the provisions of Act 306, SLH 1998 and to provide input for site selections to the WHFC.

In order to abide by the spirit and intent of the legislation, the WHFC was tasked to keep the total percentage of FRA mileage as close to 30% as possible. They were instructed the overall objective was to sustainably manage the aquarium fishery and not to dismantle or shut it down completely.

Fish Replenishment Areas (FRAs)

Working under a punishing deadline, the WHFC nevertheless persevered, and by determination, consensus and vote, worked out a FRA plan, which has proven to be biologically sound, enforceable, and conflict resolving. Nine separate areas along the coast (Figure 2) were demarcated comprising a total of 35.2% of the West Hawai`i coastline (including already protected areas). The areas specifically designated by the collectors showed a remarkable congruence with those selected by the Council as a whole. The FRAs prohibit all collecting of aquarium animals as well as fish feeding (not related to fishing). The seaward boundaries of the FRAs extend to a depth of 100 fathoms and distinctive signs mark the boundaries on shore.

The 28 April 1999 public hearing on the FRA Rule (HAR 13-60.3) 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. On 17 December 1999, the FRA administrative rule was signed by Governor Benjamin Cayetano, and became effective 31 December 1999.

West Hawai`i Aquarium Project (WHAP)

Although Act 306, SLH 1998 mandated review and evaluation (thus monitoring) of the FRAs in conjunction with the University of Hawai`i, no funding was provided to accomplish this. In order to estimate 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 each year of the Project through the Hawai`i Coral Reef Initiative Research Program (HCRI-RP – see Appendix A), a federal initiative under the aegis of the National Oceanic and Atmospheric Administration (NOAA). Additional funding was provided by 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. Mark Hixon, Oregon State University and Dr. Helen Fox, World Wildlife Fund. The following evaluation of the FRAs is a product of WHAP.

FINDINGS AND EVALUATION

WHAP established 23 study sites along the West Hawai`i coastline in early 1999 at 9 FRA sites, 8 open sites (aquarium fish collection areas) and 6 reference (i.e. 'control' sites) to collect baseline data both prior to and after the closure of the FRAs. Control sites are Marine Life Conservation Districts (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.

The overall goals of WHAP were two-fold: 1) To estimate FRA effectiveness by comparing targeted aquarium fishes in FRAs relative to adjacent control sites and, 2) To estimate changes in sites open to aquarium collectors by comparing targeted aquarium fishes in open sites relative to adjacent control sites.

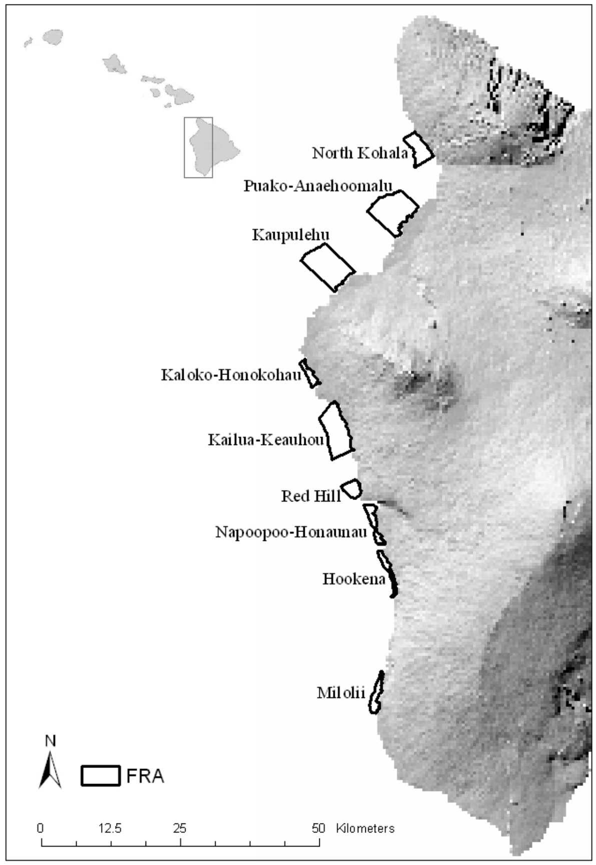

Figure 2. Locations of Fishery Replenishment Areas (FRAs) in West Hawai`i.

All study sites were selected within an area of suitable habitat and depth using a procedure which attempted to minimize among-site habitat variability yet selected unbiased locations within an area. A diver was towed behind a slow-moving vessel in the area of interest (open, FRA, or reference) to search for areas suitable as study sites. Criteria for acceptable sites included a substratum with abundant finger coral (*Porites compressa*) at 10-18 meter depths. Finger coral is an important habitat for juvenile aquarium fishes, particularly the yellow tang, *Zebrasoma flavescens*, and typically dominates many areas of the West Hawai`i coast at 10-18 m depths except along exposed headlands and on recent lava flows (Grigg and Maragos 1974; Dollar 1982). Within an area of suitable habitat and depth a float with an attached weight was haphazardly thrown off a moving vessel and the ocean-side center transect pin was established at the coral colony nearest to the weight on the bottom. Using five additional stainless-steel bolts cemented into the bottom, we established four permanent 25 m transects in an H-shaped pattern at each of the study sites. During field surveys, study sites were located by differential Global Positioning System (GPS) and the transect lines were deployed between the eyebolts.

Fish densities of all observed species were estimated by visual strip transect search along each permanent transect line. All divers either had extensive experience in conducting underwater fish surveys in Hawai`i or received training through the University of Hawai`i's Quantitative Underwater Ecological Survey Techniques (QUEST) training course prior to collecting any data (Hallacher and Tissot, 1999). Two pairs of divers surveyed the lines, each pair searching two of the 25 m lines in a single dive. The search of each line consisted of two divers, swimming side-by-side on each side of the line, surveying a column 2 m wide. On the outward-bound leg, larger planktivores and wide-ranging fishes within 4 m of the bottom were recorded. On the return leg, fishes closely associated with the bottom, new recruits, and fishes hiding in cracks and crevices were recorded. In addition to the transect surveys, a 10 minute 'free-swim' survey was also conducted by two divers in the areas surrounding the actual transects. The purpose of this survey was to increase the ability to 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 were surveyed bi-monthly, weather permitting, for a total of six surveys per year (five in 2000). Due to problems with the research vessel, surveys were not conducted during the summer of 2002.

As of Fall 2004, WHAP has completed a total of 34 surveys of all study sites, six of which were conducted prior to FRA closure in 1999 (the before- or baseline-surveys) and 28 over the past five years (2000-2004) subsequent to closure (the after-surveys). The surveys have counted a total of 549,019 fishes from 220 species on 3,128 transects.

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 geographically adjacent control areas 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 the most appropriate and statistically powerful method for examining FRA effectiveness.

FRA effectiveness is measured statistically as the change in the difference between each FRA and control site during each survey (control vs. impact) from baseline to post-baseline surveys (before vs. after). The statistical significant of this change is tested using a two-way repeated-measure analysis of variance. A statistical significant level of α=.10 is used in order to reduce the error level of β (the statistical mistake of concluding FRAs are non-effective when in fact they are). Thus, a statistically significant before vs. after effect in the analysis would indicate that overall fish abundance within FRAs has changed after closure relative to before closure. The degree of change is measured by the Index of FRA Effectiveness (R). R is defined by the following where t = no. of surveys:

$$\mathrm{R} = \left[\frac{\sum_{i=1}^{t_{after}} \overline{\mathrm{X}}_{control} - \overline{\mathrm{X}}_{\mathrm{FRA}}}{t_{after}} \right] - \left[\frac{\sum_{i=1}^{t_{before}} \overline{\mathrm{X}}_{control} - \overline{\mathrm{X}}_{\mathrm{FRA}}}{t_{before}} \right] \mathrm{X}100 \qquad (1)$$

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 'protective value' of the FRAs. That is, what effect is increased protection having on targeted fish?

Another measure of change in the FRAs is the absolute percent change in density of the baseline surveys relative to the post-closure surveys. These changes are presented as:

$$\text{Percent change in density} = \frac{\left(\overline{X}_{\text{FRA-}\mathit{After}} - \overline{X}_{\text{FRA-}\mathit{Before}\text{-}}\right)}{\overline{X}_{\text{FRA-}\mathit{Before}}} \times 100 \qquad (2)$$

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. If the population of a particular fish increases over time to the same extent within an FRA *and* its control, then the effectiveness (R) of the FRA would be zero even though the numbers of fish within have increased over time.

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 six years of study, it is extremely difficult to statistically detect changes in abundances except for the most common species that exhibit large changes (such as yellow tangs). Thus, the ability of this Study (and any other that we know of) is limited to only detecting large, significant changes (>50%) in common species, while less common species (99% of aquarium fishes) may still be increasing in abundance but not showing statistical significant changes. As a study such as WHAP continues over time, the ability to detect progressively smaller significant changes increases.

To illustrate the BACI method, presented below are two FRAs that have varied in their degree of effectiveness to replenish the most highly targeted aquarium fish in West Hawai`i, the yellow tang. Each graph illustrates the variable nature of yellow tang abundance through time and how changes in the FRAs and open areas occur *relative* to the control area. Thus, the Kailua-Kona FRA (Figure 3) has shown a statistically significant 146% increase in effectiveness (R) since FRA closure because yellow tang density in the FRA has increased in the last three years proportionally greater from the baseline period than the control has. Indeed, the numbers of yellow tangs within the FRA are presently quite comparable to the control which has been protected for 13 years.
In contrast, the Miloli`i FRA (Figure 4) had a non-significant 34% increase in effectiveness even though the number of yellow tangs in the FRA increased. The increase relative to the control area was modest however and therefore not significant.

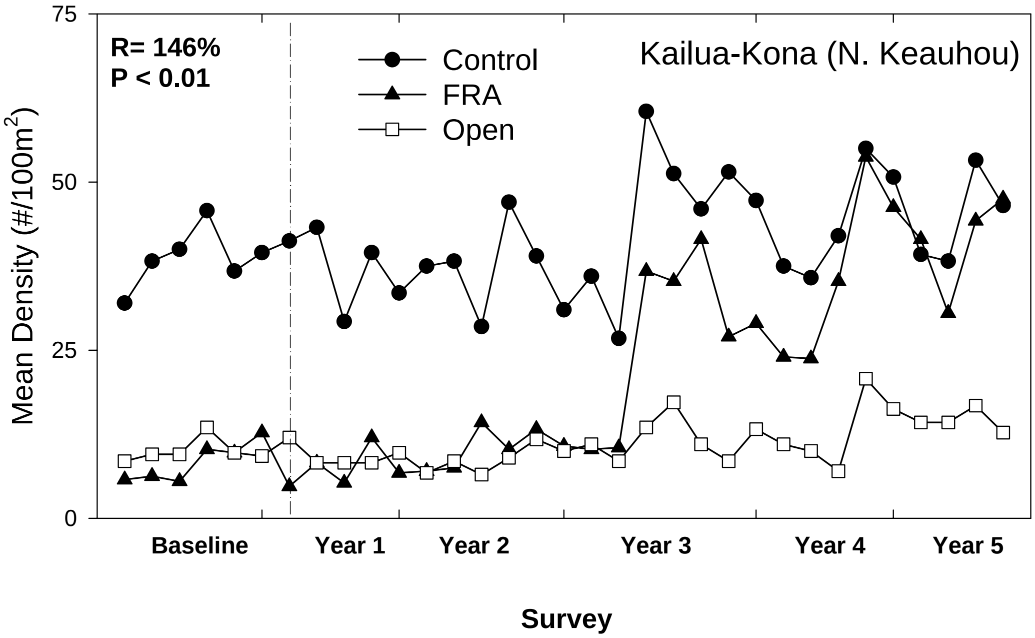

Figure 3. Changes in yellow tangs in the Kailua-Kona FRAs relative to control and open areas.

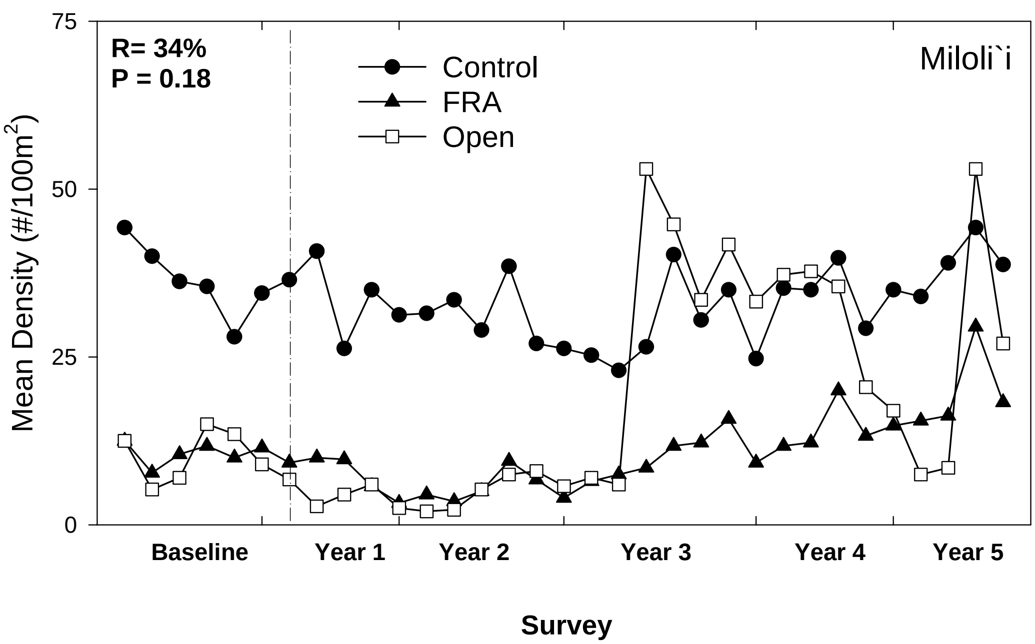

Figure 4. Changes in yellow tangs in the Miloli`i FRAs relative to control and open areas.

The overall effectiveness of the FRA network to replenish fish stocks is listed in Table 2. Aquarium fishes in general (65 species) have increased 7% and the top ten harvested fishes (listed individually below) have increased 8%. However, neither of these increases was statistically significant. In contrast, there has been a statistically significant -81% decrease in non-aquarium fishes (145 species) in the overall FRA network.

Table 2. Overall FRA Effectiveness for fishes.

Group	Overall % Change in Density	R	P
All aquarium fishes	+6%	+7%	0.28
Top 10 aquarium species	+16%	+8%	0.51
Resource fishes	+55%	+20%	0.79
Non-aquarium fishes	**+8%**	**-81%**	**0.01***

* Statistically significant at $P < 0.10$

Changes for the ten most collected aquarium fishes across all FRAs are shown in Table 3. Seven of the 10 most heavily collected species have increased overall along the West Hawai`i coast since the FRAs have been established. Two of these increases have been large enough to be statistically significant. There have been increases in FRAs relative to respective control site in six of the top ten collected species with two; yellow tangs (49%) and chevron tangs (141%) being significant. Collectively, these two species account for 85% of all collected fishes based on 2004 catch report data.

Table 3. Overall FRA effectiveness for the top ten most aquarium collected fishes.

Common name	Scientific name	Mean density (No/100m^2)		Overall % change in density	R
		Before	**After**		
Yellow Tang	*Zebrasoma flavescens*	14.7	21.8	**+48%**	**+49%***
Kole	*Ctenochaetus strigosus*	31.0	33.3	+7%	-3.8%
Achilles Tang	*Acanthurus achilles*	0.24	0.30	+26%	-46%
Clown Tang	*Naso lituratus*	0.75	0.84	+11%	-41%
Chevron Tang	*Ctenochaetus hawaiiensis*	0.22	0.23	**+2%**	**+141%***
Longnose and Forcepsfish	*Forcipiger spp.*	0.73	0.77	+6%	+65%
Fourspot Butterflyfish	*Chaetodon quadrimaculatus*	0.03	0.06	+100%	+116%
Ornate Butterflyfish	*Chaetodon ornatissimus*	0.87	0.75	-14%	+27%
Multiband Butterflyfish	*Chaetodon multicinctus*	5.71	5.02	-12%	-15%
Hawaiian Cleaner Wrasse	*Labroides phthirophagus*	0.88	0.73	-18%	+30%

* Statistically significant at $P < 0.10$

The top five species which account for 96% of total catch all increased in abundance since the FRAs were established. Each species however has shown variable changes in abundance through time in control, FRA and open areas. For example, of the top five most collected species, yellow tangs (Figure 4) have shown steady increases in abundance in all areas beginning in 2002 (year 3) when large recruitment of juvenile fishes first began occurring. Along with 58% increases in FRAs, control and open areas also increased 77% and 12% respectively, over the course of the Study.

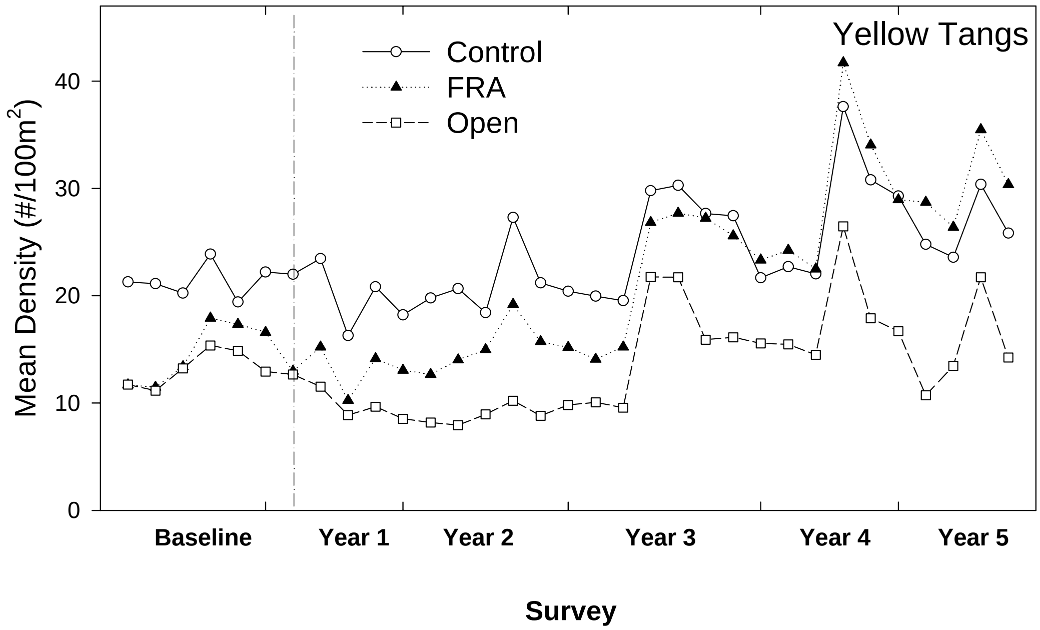

Figure 4. Overall changes in yellow tangs in FRAs, control and open areas, 1999-2004.

Kole (Figure 5) have also shown steady increases across all years. Along with 8% increases in FRAs, control and open areas increased 100% and 10%, respectively over the course of the Study.

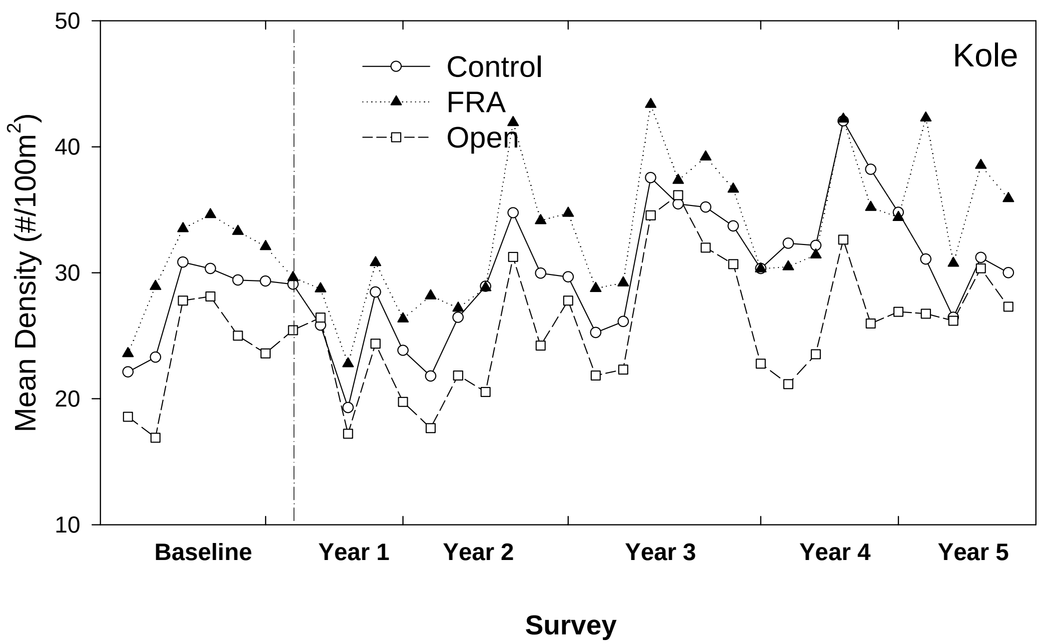

Figure 5. Overall changes in Kole in FRAs, control and open areas, 1999-2004.

Achilles tangs (Figure 6) have shown a highly variable pattern with a small gradual increase across years. Along with 34% increases in FRAs, control and open areas also increased 98% and 52%, respectively over the course of the Study.

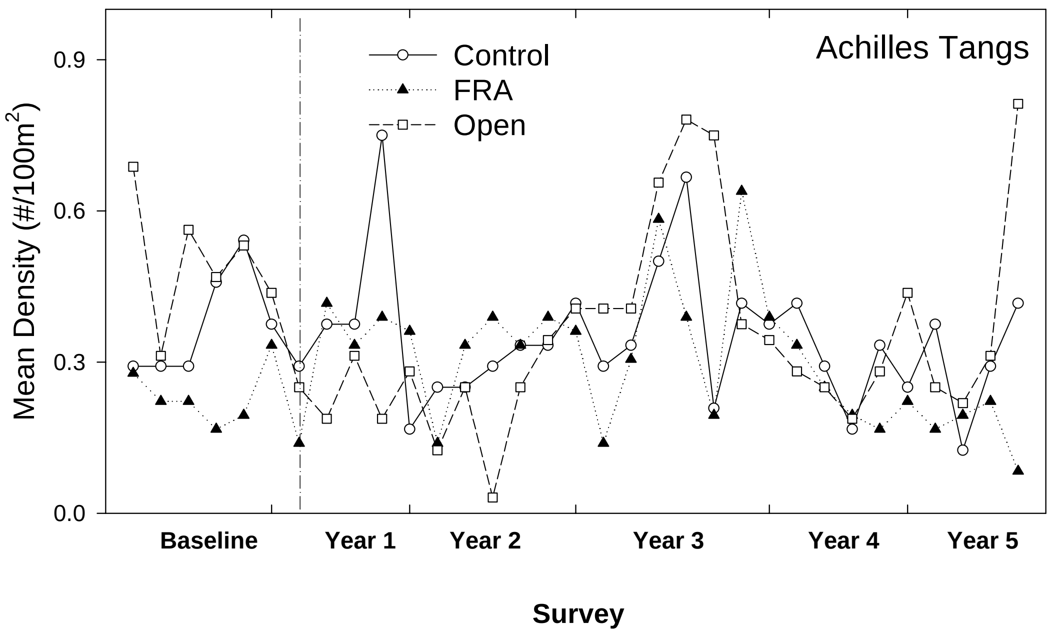

Figure 6. Overall changes in Achilles tangs in FRAs, control and open areas, 1999-2004.

Clown Tangs (Figure 7) have shown an increase in years 4-5. Along with 44% increases in FRAs, controls increased 16% while open areas decreased 1.2% during this time.

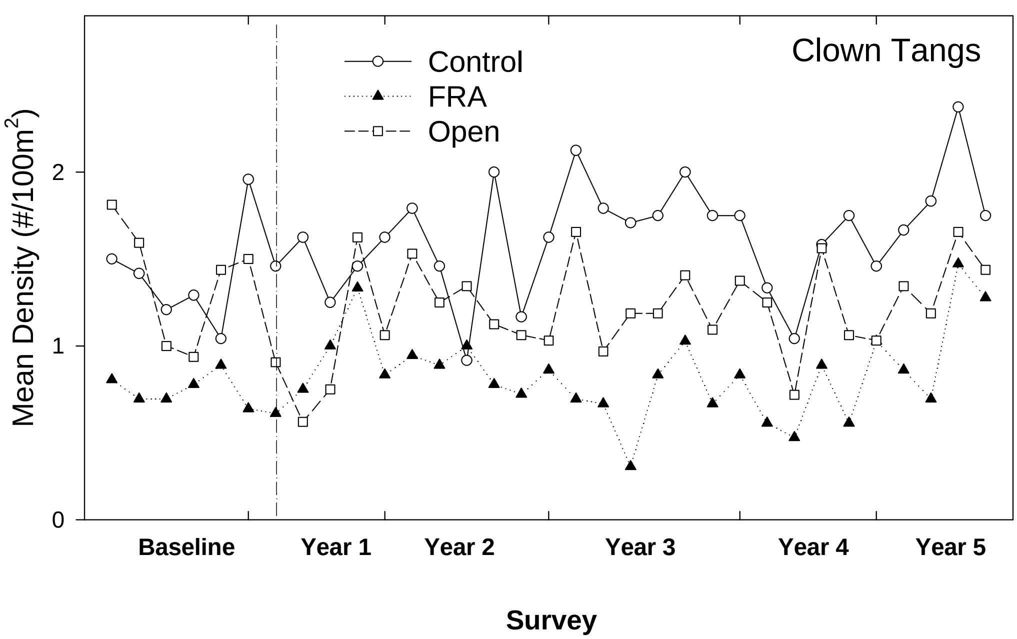

Figure 7. Overall changes in clown tangs in FRAs, control and open areas.

Chevron tangs (Figure 8) have only shown increases since 2003 (Year 4). However, FRAs increased 2%, controls decreased 35% and open areas increased 22% over the course of the Study. A large part of the relatively high effective value of the FRAs for this species is due to a marked decline in the control areas just prior to FRA establishment.

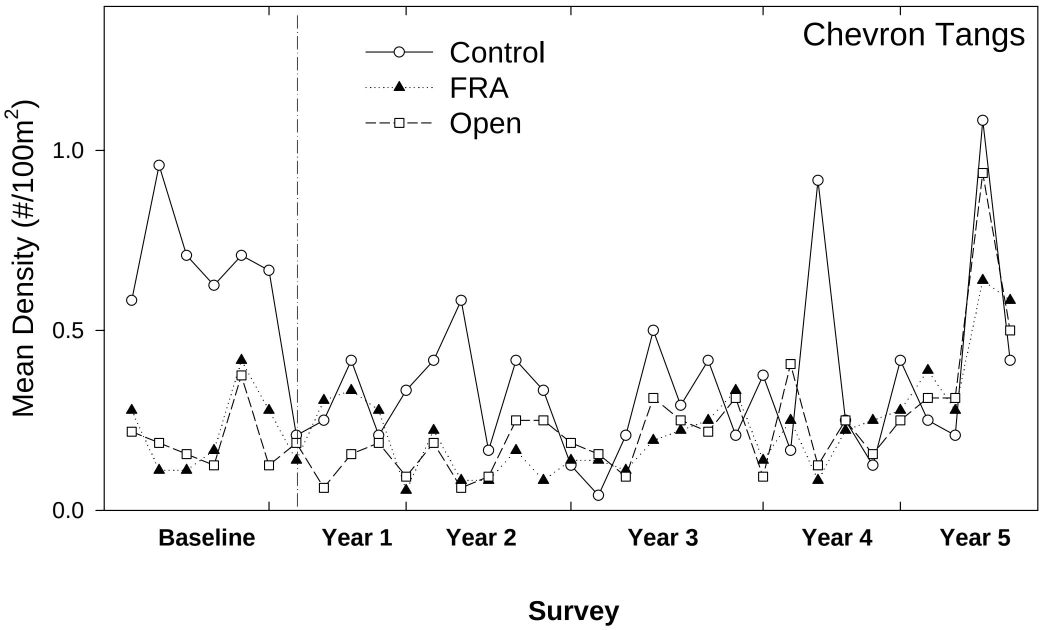

Figure 8. Overall changes in Chevron tangs in FRAs, control and open areas, 1999-2004.

FRAs have varied in their effectiveness at recovering aquarium fish stocks, as is illustrated for yellow tangs in Figure 9 and Appendix B. Overall, 7 of the 9 FRAs have shown a positive effectiveness with four having statistically significant increases in abundance. Given the relatively short time period of FRA existence, this is strong evidence for the widespread effectiveness of the FRAs to enhance aquarium fish populations.

An examination of multiple factors associated with effective FRAs (Tissot et al., 2003) indicates that habitat quality, the size of FRAs, and density of adult fishes are associated with significant recovery of fish stocks. This earlier study indicates two important conclusions from the data: 1) High numbers of juvenile tangs are associated with areas of high finger coral (*Porites compressa*) cover; and 2) Effective FRAs (ones with high positive before-after differences) are associated with high numbers of adult fish and large FRAs with wide reefs, that have high finger coral cover. Thus, based on a preliminary analysis of the FRAs the following factors may be important in influencing their effectiveness: 1) High finger coral cover, which is critical habitat for juvenile yellow tangs (and other fishes; Walsh, 1987); 2) Large FRAs with wide reefs; and 3) High densities of adult fish (Tissot et al., 2003).

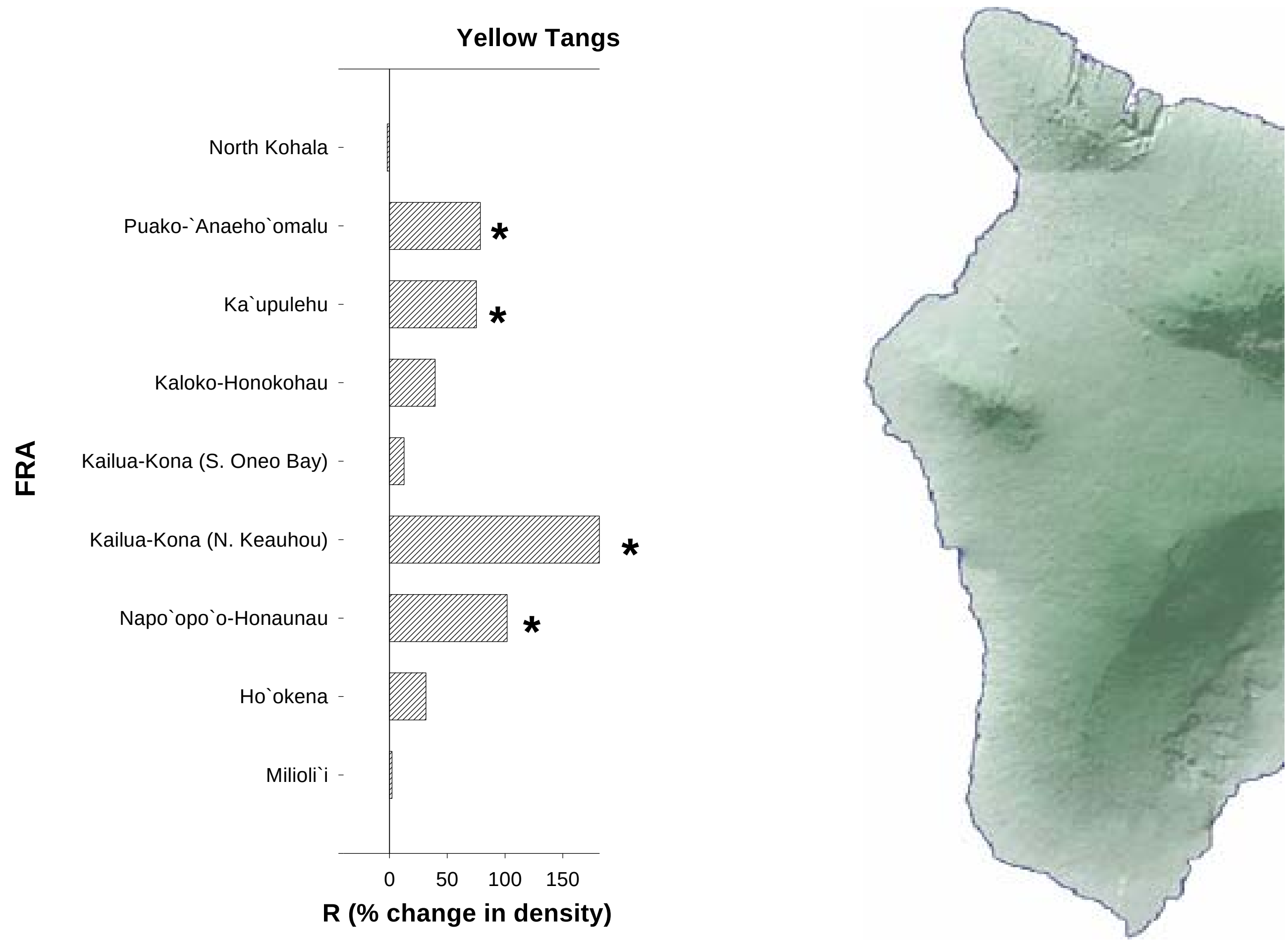

Figure 9. Effectiveness of individual FRAs to replenish yellow tangs, 1999-2004.
*** = Statistically significant**

Effects of FRAs on West Hawai`i Aquarium Fishery

Although there was overwhelming support within the West Hawai`i community for the establishment of the FRAs, a number of collectors expressed concern that the area closures would have negative effects on themselves as well as the fishery as a whole. Although almost 100 species are caught in the fishery, a relatively small handful constitute the bulk of the catch. The top five collected species constitute 96% of the total catch with yellow tangs alone comprising 84%. Yellow tangs are thus a key indicator of the health of the fishery.

After two years of declining yellow tang catch subsequent to the implementation of the FRAs, the catch has increased through 2004 (Figure 10). At this early stage of FRA establishment, this increase is due primarily to successful recruitment of this as well as several other species in the summers of 2002 and 2003 (Figure11). The price per fish received by collectors for yellow tangs has also increased by an average of 33% in the five years after FRA establishment as compared to the four years prior to the FRAs. The average number of commercial aquarium collectors working in West Hawai`i during these same time periods is also higher after the FRAs were established (Figure 1). The overall value of the West Hawai`i aquarium fishery in FY 2004 is the highest it has ever been.

There is some preliminary evidence (Walsh unpublished data) and anecdotal information that the numbers of yellow tangs in West Hawai`i just prior to FRA establishment were substantially lower than in earlier decades. This heavily collected species has been responding particularly well to FRA protection and given its long life (20+ years, Claisse, pers. comm.), it is likely that stocks will continue to increase in the coming years boding well for the reef community, the aquarium fishery and present and future generations of West Hawai`i.

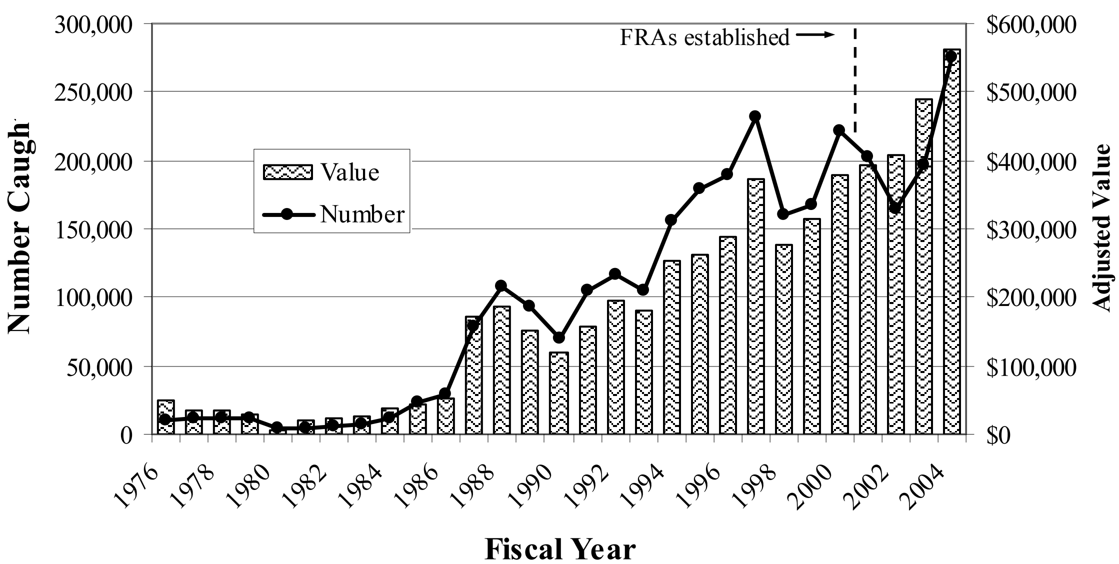

Figure 10. Number and value (adjusted for inflation) of yellow tangs caught in West Hawai'i per fiscal year.

The trends for the four next most heavily collected species are shown below. Kole (*Ctenochaetus strigosus*) catch (Figure 12) has been consistently increasing since the late 1980's and is now the ranks second in collected fishes both in West Hawai`i and statewide (Walsh et al. 2003). Catch in FY 2004 is the highest it has even been. This species has been increasing in recent years on West Hawai`i reefs and is one of the most common fishes on the reefs. Although it is also harvested somewhat for food, present indications are that with its large population, present collection trends for kole are not problematic.

In contrast, catch of the Achilles tang (*Acanthurus achilles*) has been in decline since FY 1990. This species is a favorite targeted species of both aquarium collectors as well as food fishers and is thus harvested at both ends of its size range. Although the achilles

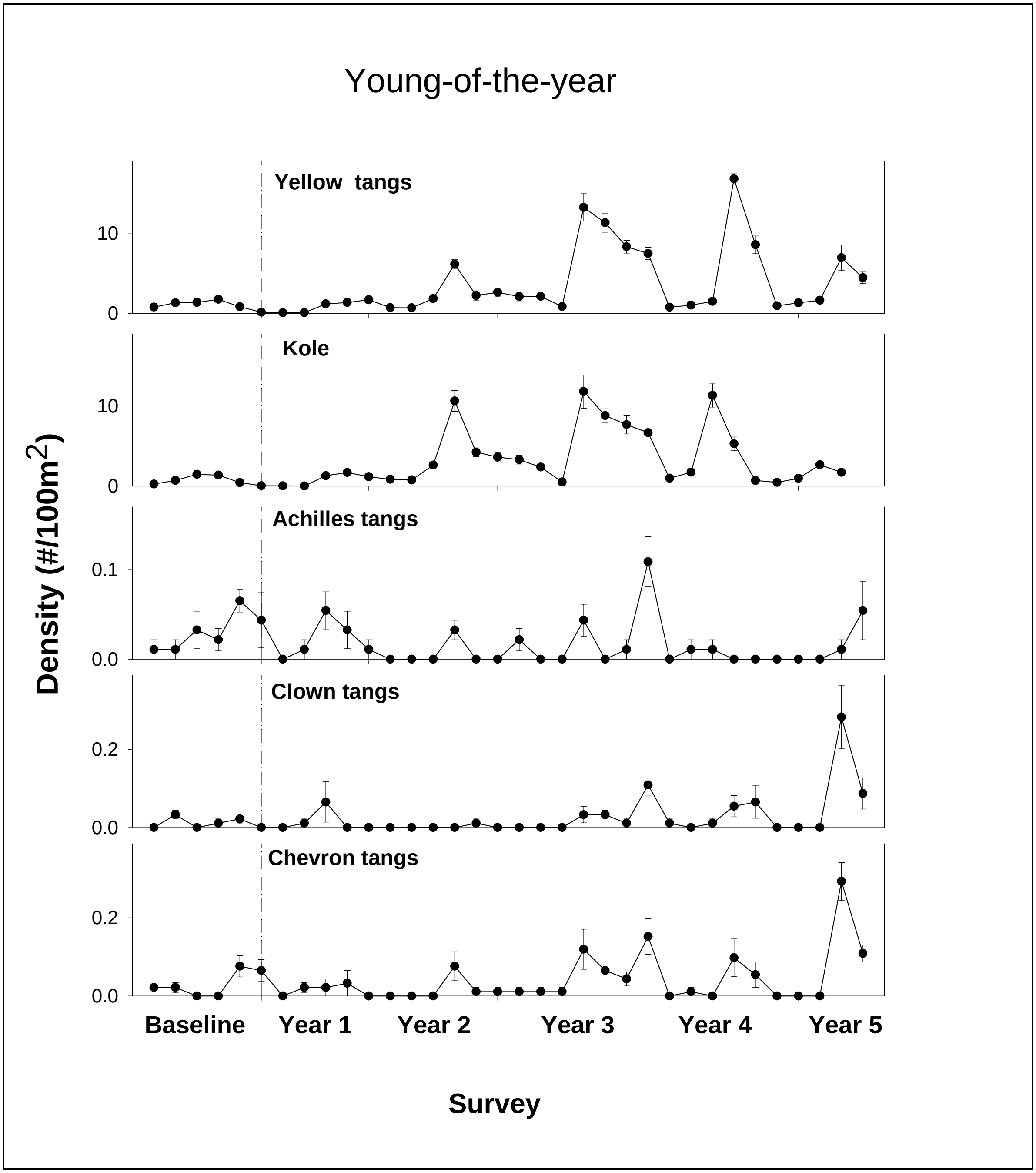

Figure 11. Recruitment trends for top 5 collected aquarium fish. Note: 'Young-of-the-Year' refers to fish which have recruited during each year's major summer recruitment period.

tang has increased somewhat overall on the reefs over the past five years; the FRAs have not yet been particularly effective in rebuilding populations in protected areas (Table 3).

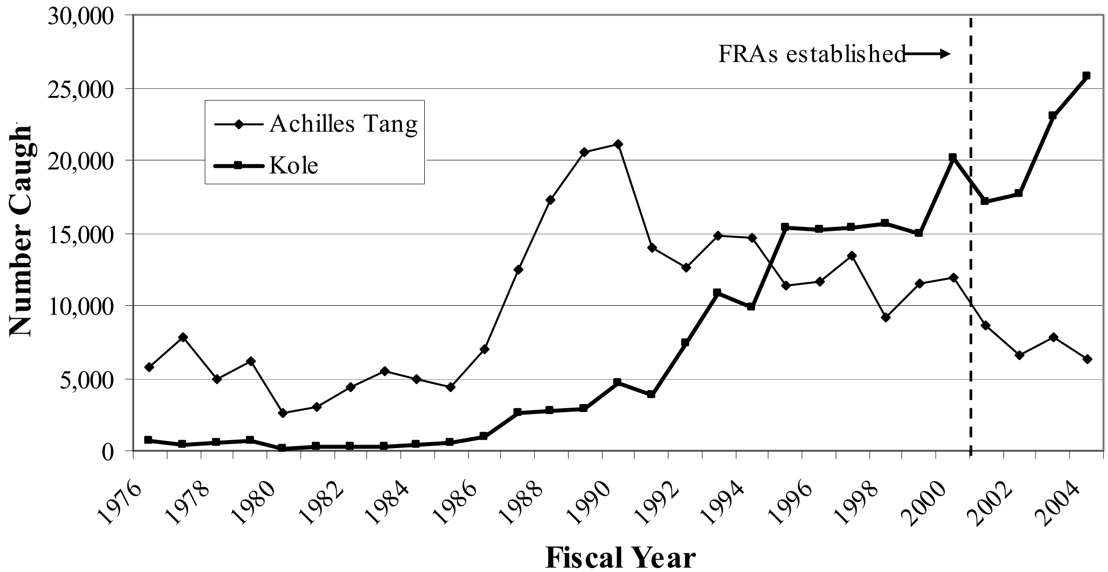

Figure 12. Number caught of top 2nd and 3rd West Hawai`i species per fiscal year.

The clown tang (*Naso lituratus*) catch appears to be following a pattern somewhat similar to the achilles tang (Figure 13). It reached a peak in the late 80's and then subsequently declined although there was a smaller secondary peak again in the late 90's. As with Achilles tangs, populations are increasing on the reefs but the FRAs have not yet been effective in most areas. Both these species point out the necessity for long term protection in order to maintain the progress of slowly increasing species.

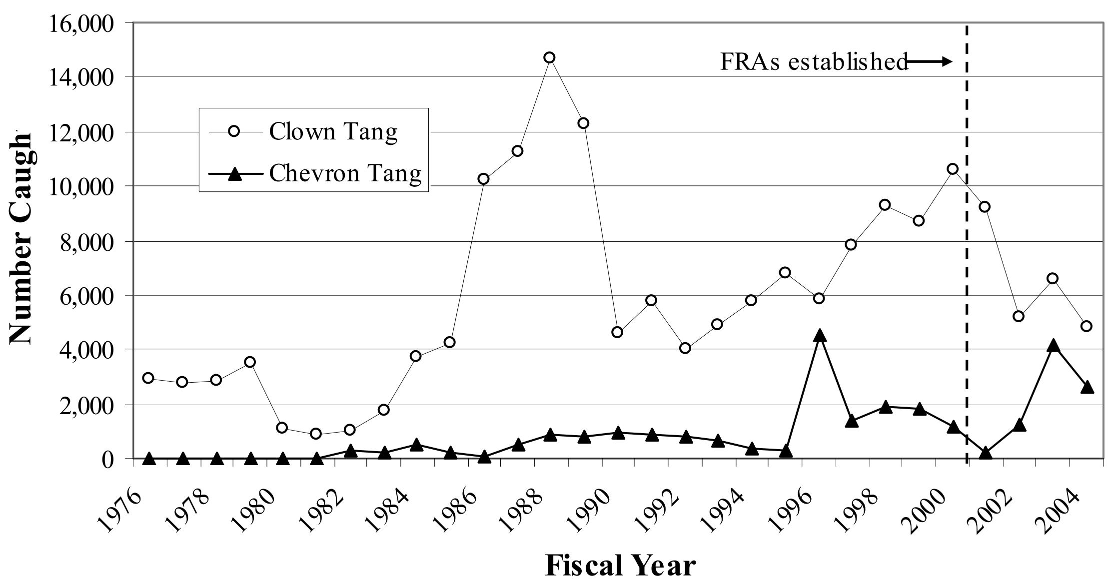

Figure 13. Number caught of top 4th and 5th West Hawai`i species per fiscal year.

Chevron tangs (*Ctenochaetus hawaiiensis*) were always a minor element of the catch up until 1996. Although the adults are rather inconspicuous, the young are spectacularly colored and highly desired in the aquarium trade with current wholesale prices around $16/fish (P. Masterjohn pers. comm). Recent strong recruitment (Figure 11) has increased populations and catch in recent years. If the market value of this species remains strong, the FRAs will play an increasingly important role over the years in maintaining healthy populations of this species.

Much the same can be said for many of the more uncommon and rare species that are targeted by collectors. Species such as flame angelfish, banded angelfish, Hawaiian lionfish, Tinker's butterfly and anthias species for example, are highly vulnerable to local depletion. While the FRAs will not provide protection for these species in open areas, they do provide a population reservoir to ensure continued presence of the species. Furthermore, since the FRAs encompass many of the areas most utilized by residents and dive/snorkel business, they help to maintain the biodiversity of our reefs people expect and are willing to pay for.

Catch per unit effort (CPUE) is a measure of the number of fish caught during a standard amount of fishing effort and it is often used as a measurement of relative abundance for a particular fish. For the State aquarium fishery, CPUE has historically been the highest in West Hawai`i (Figure 14) due in large part to the abundance of and relative collecting ease of commonly targeted surgeonfishes. The increasing trend in CPUE may be due to increasing expertise and efficiency of West Hawaii's full-time professional collectors as well as to increasing abundances of yellow tangs.

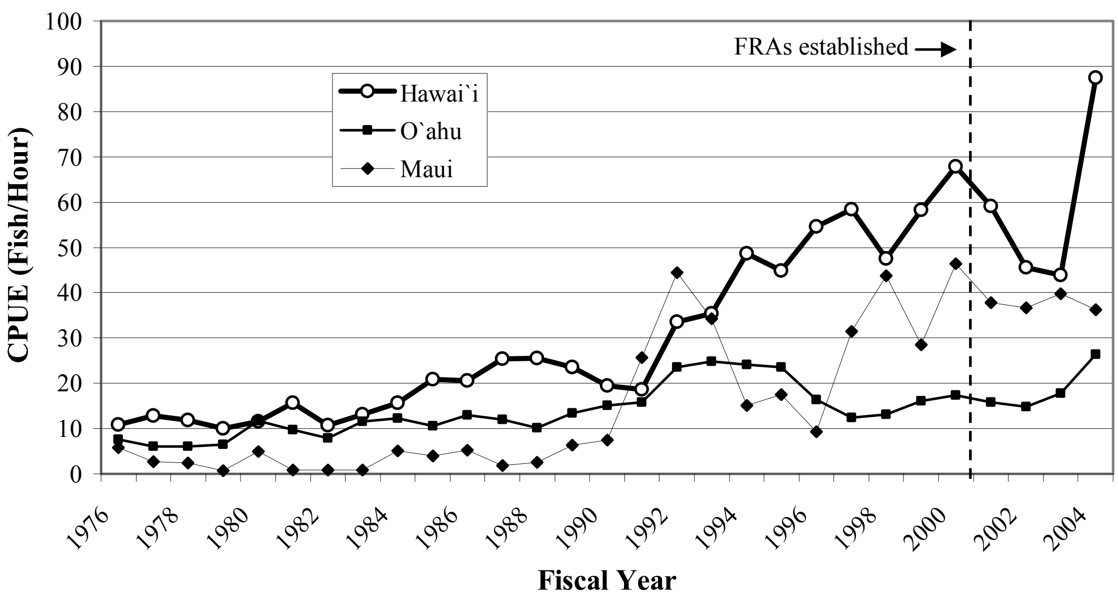

Figure 14. Catch per unit effort for Hawai`i collecting areas. Maui includes the islands of Maui, Moloka`i and Lana`i.

The average CPUE for West Hawai`i over the last ten years (56.7 ±13.3 SD fish/**hour**) is considerably higher than that reported for other areas such as Australia (20-45 fish/day), Cook Islands (24-36 fish/day), and Sri Lanka (30-50 fish/day) (Wood, 2001).

After an initial decrease coincident with FRA establishment, CPUE in West Hawai`i has once again continued a long-term upward trend. As with a number of other indicators of the status of the aquarium fishery, CPUE in 2004 was the highest it has ever has been. It is anticipated that this upward trend will level with time.

Due to uncertainties in the way collecting effort is reported by various fishers, CPUE data is considered to be the weakest component of the aquarium catch report data set and must be viewed cautiously. Indeed one of the caveats implicit with catch report analyses, aquarium or otherwise, is that reported catch accurately reflect what is actually being caught. At present there is no provision or means to verify this information. A recent analysis of the West Hawai`i aquarium catch report data (Walsh et. al. 2003) revealed a substantial number of collectors are not complying with the mandatory reporting requirement of the aquarium fish permit even though failing to comply is grounds for cancellation of the permit. Forty-seven percent of the required reports over the period January 1998 to July 2003 were not filed. Most of the delinquencies were due to short term and/or part time collectors but several of the more active collectors were included. Of all 97 collectors who fished over this period, only 14% filed every required monthly catch report. It is likely that report compliance is as poor or worse on the other islands which have had less attention paid to the fishery.

The Role of Community Co-Management

The current evaluation of monitoring and fisheries data indicates the FRAs are proving to be quite successful in accomplishing their management objectives. Given the longstanding and contentious nature of the aquarium issue in West Hawai`i, the importance of legislation in finally addressing the issue cannot be underestimated. Although DAR/DLNR made several attempts over the years to resolve conflict and local resource depletion by means of a 'gentleperson's agreement' and administrative rule, these efforts were not sufficient and were perceived by many in the community as wholly inadequate. 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, little progress would have been made in successfully managing this controversial fishery.

A unique and key aspect of the legislation which created the West Hawai`i Regional Fisheries Management Area and the FRA network was the requirement for "substantive involvement of the community in resource management decisions." Rather than a purely "top-down" (i.e. government-driven) approach which specified all the details of required management actions, the legislation instead directed the community to actively participate in the development of such actions. This approach was at once both innovative and far-reaching.

Due to the wide and overlapping range of mandates in Act 306, SLH 1998, a quasi-permanent council approach was taken by DAR/DLNR to accomplish specified mandates and fulfill the requirement for substantive community involvement. The West Hawai`i Fisheries Council (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).

Given the limitations of existing marine resource enforcement, it was recognized early on that widespread community involvement and 'buy in' were essential if rule recommendations developed by the WHFC and implemented by DLNR were to be effective. This active involvement is reflected in the increase in enforcement actions by DOCARE (Table 4). Many, if not most of these actions were initiated by members of the community. Overall, compliance by collectors has generally been good and by all accounts, incidents of harassment and conflict between collectors and other ocean users have been markedly reduced.

There is one exception however that has developed in recent years involving a community in South Kona (Pebble Beach-Ka`ohe Bay). This geographically isolated community, located outside of existing FRAs, increasingly finds itself in conflict with aquarium collectors working the area. Noting that the WHFC has been successful in addressing complex and contentious issues, the Chairperson of DLNR has requested that the WHFC consider developing recommendations for the long-term resolution of this conflict.

Table 4. Documented aquarium-related incidents which have occurred within the West Hawai`i Regional Fisheries Management Area (WHRFMA) as compiled by DOCARE.

Type of Incident	**Pre-FRA**				**Post-FRA**			
	1996	1997	1998	1999	2000	2001	2002	2003
Complaints	0	2	2	0	3	3	1	3
Warnings	0	0	1	0	2	2	0	1
Citations/Arrests	0	1	0	0	1	0	0	2

The WHFC has been and continues to be invaluable and instrumental in realizing the objectives of Act 306, SLH 1998. The 45 members of the community who have been members at one time or another of the WHFC have contributed over 2,300 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 the government in terms of its approach to and recommendations on marine resource management. The DLNR values the suggestions made from all segments of the community, whether they be from individuals, groups or organizations such as the WHFC.

The creation and functioning of the WHFC is entirely attributable to the volunteer commitment of time, energy and resources of its members. These efforts have been assisted by the support of community organizations such as the Hawaii Community Foundation, Coastal Zone Management, 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.

In addition to the members of the Council who attend monthly meetings, over 1,500 non-members have also attended, participated and been educated at WHFC meetings. Scientists, managers and other resource people have provided valuable information on topics germane to the Council's mission. Such information empowers the community, enhances involvement and facilitates the crafting of appropriate, sensitive and effective management advice and recommendations.

The WHFC has not been without challenges however. Sporadic attendance at Council meetings, especially by collector representatives during early deliberations, has proven to be an ongoing concern and some members have been dropped due to nonattendance. Maintaining people's continued commitment to such an advisory group is a challenge given the differences of interests and the often contentious and sometimes emotionally charged atmosphere of decision-making meetings.

Although Act 306, SLH 1998, specified that community involvement was to be through "facilitated dialogues", no facilitator was provided by DAR/DLNR during the critical 8 months of the Council's initial deliberations on the FRA plan. The role of group facilitator thus fell to the two main organizers of the WHFC, the West Hawai`i Sea Grant Extension Agent and the DAR West Hawai`i Biologist. As reported in a recent evaluation of the FRA/WHFC participatory process (Capitini, et al., 2004) they, and in particular the DAR Biologist/Resource Manager, functioned simultaneously as organizers, educators, scientific experts and advocates while managing and facilitating the Council. Their approach was generally from a relatively narrow scientific/regulatory perspective rather than from a broad-based conflict management perspective more desired in environmental dispute resolution (Bingham, 1985). The overlap in the roles played by the organizers was construed as threatening to the interest and values of the aquarium fish collectors who already perceived the process as being stacked against them. Furthermore, when the Biologist's position as Council coordinator/facilitator was defined, his perceived role as detached, unbiased scientific expert became problematic.

The WHFC has also faced resistance and outright obstruction from players both within and outside of government. For example, the FRA development process was partially undermined by an 'actor' in the government who scuttled a number of previously negotiated enforcement provisions (Capitini, et al., 2004). These provisions were key elements of the overall FRA plan and are only now, five years later, being brought back for inclusion. Nevertheless, the Capitini, et al. study concludes that the West Hawai`i conflict over FRA establishment appears to be a model system for the application of environmental dispute resolution in controversies over reef fisheries resources.

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 effectiveness as time progresses. With one possible exception, there are no compelling reasons at present to alter the existing network of protected areas.

2. Developing conflict between aquarium collectors and community members in the open area of Pebble Beach, South Kona needs to be addressed and resolved which could possibly involve relatively small boundary changes of one or more FRAs.

3. 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.

4. In order to have sufficient scientific robustness in a monitoring program, sites should be monitored at least 4 times a year with 2 of the surveys during summer recruitment period.

5. 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 West Hawai`i Fisheries Council should be encouraged and supported by DLNR.

6. Experienced facilitators preferably with training in environmental dispute resolution need to work with community advisory groups when addressing complex and contentious marine resource issues.

7. While FRAs are an excellent strategy to manage most aquarium species, certain rare or ecologically important species are likely to require species-specific harvesting limitations in open areas.

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

9. In order to enhance depleted aquarium stocks especially on O`ahu, consideration should be given to establishing a similar system of FRAs on that island.

10. Existing aquarium catch report system should be revised to improve accuracy, remove CPUE ambiguities and provide for verification of catch.

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

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

13. 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.

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

15. Representative proportions of all habitat types should be included in MPAs, although rare and vulnerable habitats should be represented more fully.

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

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

18. As recruitment appears to be an important mechanism influencing the replenishment of nearshore populations, increased monitoring of recruitment and nearshore oceanography is necessary to better understand the dynamics of recruitment processes.

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

ACKNOWLEDGEMENTS

Many people have played important roles in laying the groundwork for successful and adaptive marine resource co-management in West Hawai`i. David Tarnas is to be especially commended for his innovative and forward looking legislation. Sara Peck of Hawai`i Sea Grant has been involved from the beginning and is instrumental in ensuring community participation and education. Many other people have played and continue to play important roles in West Hawai`i resource co-management. Some of them are listed below:

<u>WHFC members past and present:</u>

Edward Ahuna Jr., Pete Basabe, Jody Bright, Ben Casuga Jr., Lisa Choquette, David Dart, Fred Duerr, Michael Forcum Sr., Rick Gaffney, Glennon Gingo, Luanakanawai Hauanio, David Hoopaugh, Kahana Itozaki, Josephine Kamoku, Ernest Kanehailua Jr., Junior Kanuha, Willie Kaupiko, Damien Kenison, Guy Kitaoka, Matthias Kusch, Gerald

Lange, Stan Lavine, Gordon Leslie, Jeffery Lorance, Len Losalio, Paul Masterjohn, Ruby McDonald, Jim Medeiros Sr., Steven Meyer, Tony Nahacky, Mike Nakachi, Teresa Nakama, Dickie Nelson, Frank Ota Jr., Bob Owens, Richard Prohoroff, Doug Robbins, Robert Shallenberger, Hannah Springer, Joseph Stewart, Bill Stockly, William Talley III, Leonard Torricer, Paul Warren, Andrew West, Charles Young, Jeff Bearman, Sallie Beavers, Alex Cadang, Lt. Mike Heisler, Marnie Herkes, John Kahiapo, Reggie Lee, Wayne Leslie, Lt. Brian McCaul, Nancy Murphy, Scott Shero-Amba

<u>WHAP Divers & Data Management</u>:

Brent Carman, Steve Cotton DAR, Ivor Williams DAR/HCRI-RP, Delisse Ortiz, Jonathan Hultquist, Kathy Greenwood, Washington State University Vancouver, Mark Albins, Josh Ballauer, Zachary Caldwell, Laura Campbell, Paul Clark, Steve Cotton, Brian Doo, Jeff Eble, Marc Hughes, Karen Geisler, Ranya Henson, Jackie Holbrook, Joe Laughlin, Sara McCutcheon, Scarlet Mraz, Jeff Muir, Shaun Norris, Daniel Okumura, Kara Osada, Richard Osada, Kim Page, Greg Polloi, Linda Preskitt, Noelani Puniwai, Chelsie Settlemier, Allison Suhr, Dan VanRavensway, Cecile Walsh, Todd Wass, Lisa Wedding, Darla White, Charles Wiggins, Rachael Younger, Brian Zyglicynski, University of Hawai'i Hilo

<u>Funding, logistical & other support</u>:

Mike Hamnett, Christine Davidson, Risa Minato HCRI-RP, Jan Marsh, Laura Livnat, Bob Nishimoto, Pete Hendricks, Athline Clark DAR, John Coney, Michael Childers University of Hawai'i Hilo, Dave Pence University of Hawai`i Manoa, Scott Atkinson Community Conservation Network, Larry Basch National Park Service, Eric Kawamoto DOCARE, Linda Paul, Kim Moffie Audubon Society, Virginia Isbell, Collins Tomei, Paul Whalen, Christin Walsh, Tina Owens.

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APPENDIX A.

The West Hawai`i Aquarium Project (WHAP) would not have been possible without continued support and funding by the Hawai`i Coral Reef Initiative Research Program (HCRI-RP). HCRI-RP was established in 1998 to support scientific research and monitoring to enhance the state's capacity to manage its coral reef resources. The Program is jointly managed by Hawai`i's Department of Land and Natural Resources/ Division of Aquatic Resources (DLNR/DAR) and the University of Hawai`i (UH) through a December 1998 Memorandum of Understanding. This partnership between resource managers and researchers is the foundation of HCRI-RP as it strives to become an innovative, results-driven, and science-based program.

Over its first four years, the program has received nearly $3 million in Congressional funding through the National Oceanic and Atmospheric Administration's Center for Sponsored Coastal Ocean Research (NOAA/CSCOR), home of the Coastal Ocean Program (NOAA/COP). NOAA/COP is part of the National Ocean Service (NOAA/NOS) and the National Centers for Coastal Ocean Science (NOAA/NCCOS).

APPENDIX B.

Summarized below are the changes observed in each individual FRA. Included are changes in yellow tangs, all aquarium fishes without yellow tangs (because they account for the majority of the catch), and as reference information changes in resource fishes (edible species such as surgeonfish, goatfish, triggerfish, parrotfish, etc.) and all non-aquarium species pooled. For yellow tangs a graph is included to show before vs. after changes in the FRAs relative to adjacent control and open areas.

North Kohala FRA

Table C. Changes in fish groups in the North Kohala FRA.

	Density (no/100m^2)			
Group	Before	After	% Change	R
Yellow tangs	18.5	18.2	-2%	-2%
Aquarium species (wo/yellow tangs)	52.0	49.5	-5%	+17%
Resource fishes	6.0	9.0	+90%	+30%
Non-aquarium fishes	40.7	40.5	-1%	-22%

* Statistically significant at $P < 0.10$

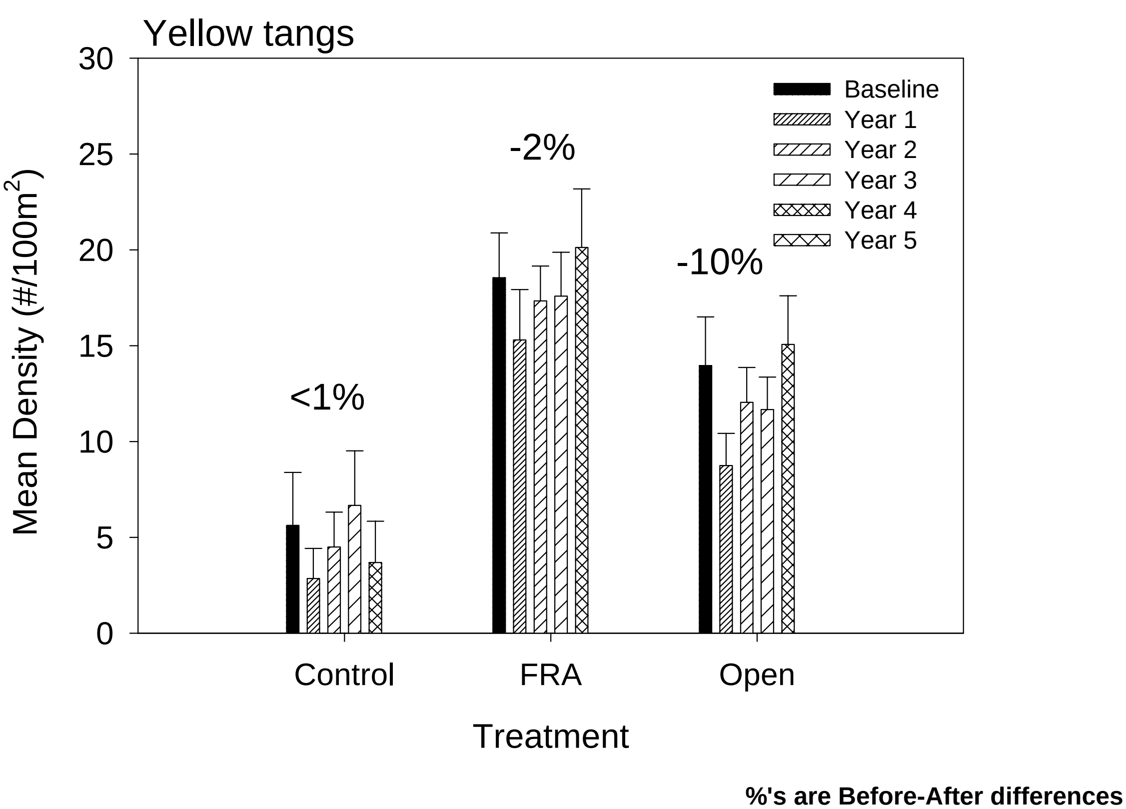

Figure 15. Before vs. after changes in yellow tangs in FRAs, control and open areas in the North Kohala FRA.

Puako-`Anaeho`omalu FRA

Table D. Changes in fish groups in the Puako-`Anaeho`omalu FRA.

Group	Density (no/100m²) Before	Density (no/100m²) After	% Change	R
Yellow tangs	12.4	22.1	**79%**	**54%***
Aquarium species (wo/yellow tangs)	61.0	54.4	**-11%**	**-20%***
Resource fishes	7.4	10.8	46%	-34%
Non-aquarium fishes	17.4	20.6	18%	-12%

* Statistically significant at P < 0.10

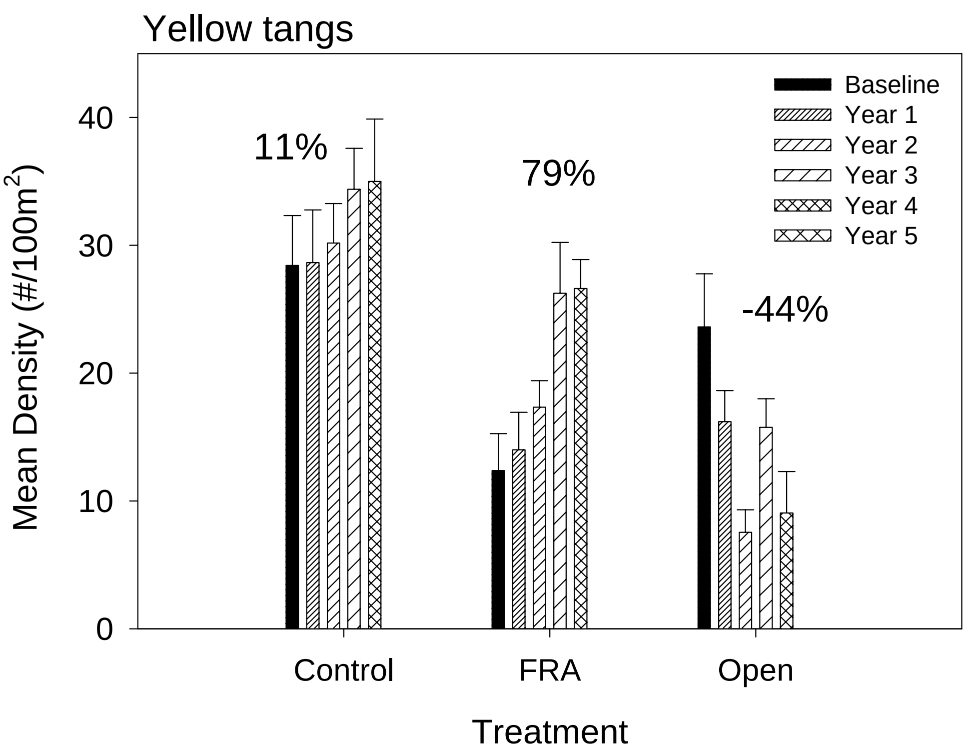

Figure 16. Before vs. after changes in yellow tangs in FRAs, control and open areas in the Puako-`Anaeho`omalu FRA.

Ka`upulehu FRA

Table F. Changes in fish groups in the Ka`upulehu FRA.

Group	Density ($no/100m^2$) Before	After	% Change	R
Yellow tangs	14.9	26.1	75%	-1%
Aquarium species (wo/yellow tangs)	59.1	78.1	32%	44%
Resource fishes	6.3	19.7	212%	144%
Non-aquarium fishes	23.1	31.1	**36%**	**-448%***

* Statistically significant at P < 0.10

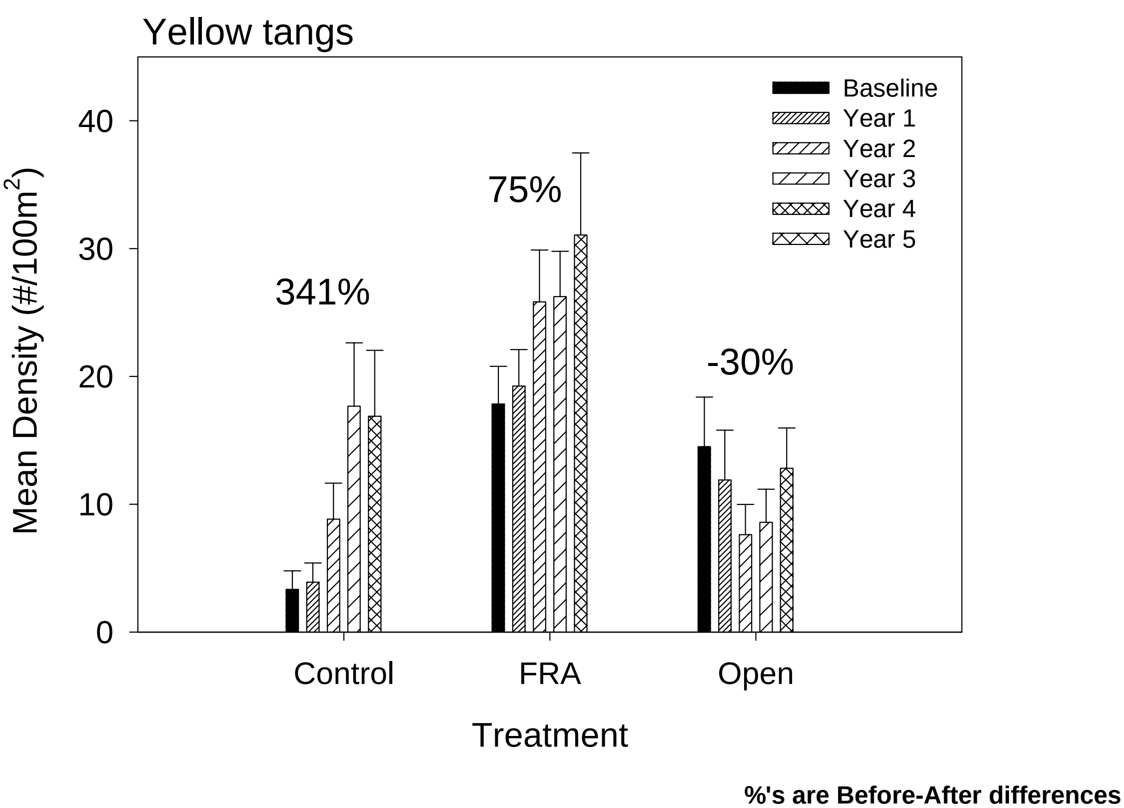

Figure 17. Before vs. after changes in yellow tangs in FRAs, control and open areas in the Ka`upulehu FRA.

Kaloko-Honokohau FRA

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

	Density (no/100m^2)			
Group	Before	After	% Change	R
Yellow tangs	19.6	27.4	40%	-18%
Aquarium species (wo/yellow tangs)	78.7	78.3	-1%	8%
Resource fishes	4.2	12.2	187%	86%
Non-aquarium fishes	68.0	76.2	**12%**	**-152%***

* Statistically significant at P < 0.10

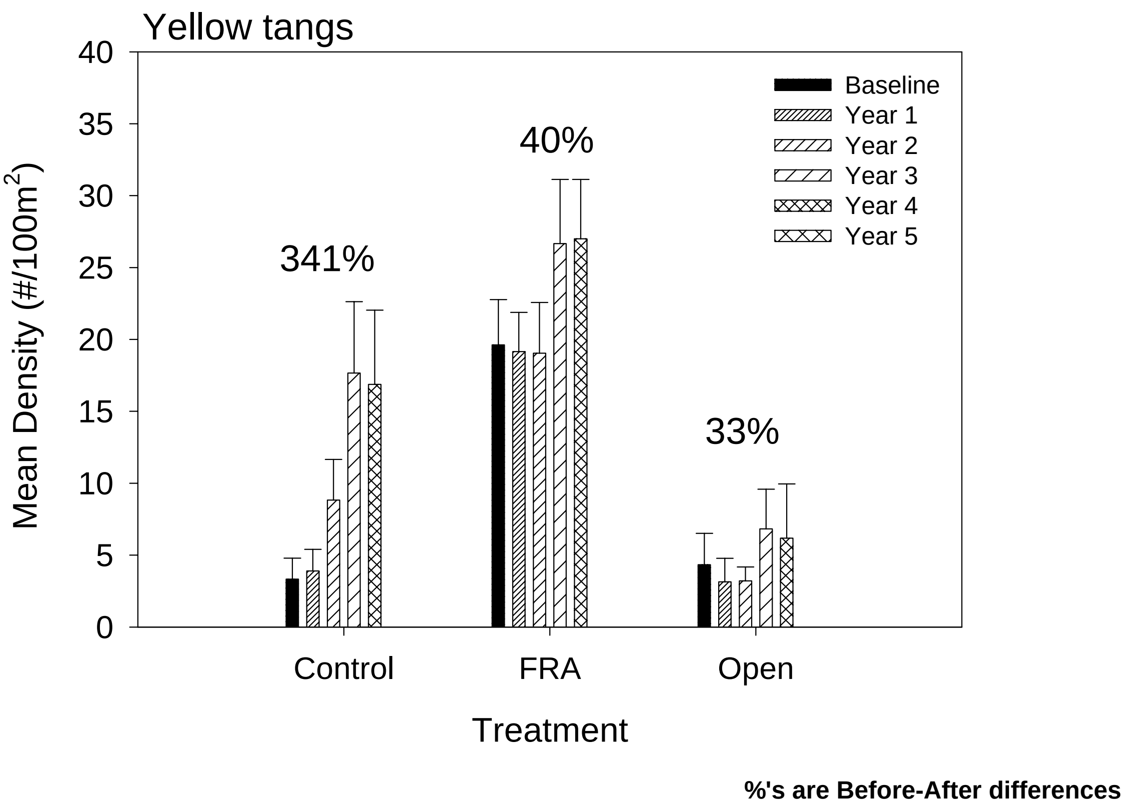

Figure 18. Before vs. after changes in yellow tangs in FRAs, control and open areas in the Kaloko-Honokohau FRA.

Kailua-Kona (S. Oneo Bay) FRA

Table H. Changes in fish groups in the Kailua-Kona (S. Oneo Bay) FRA.

	Density (no/100m^2)			
Group	Before	After	% Change	R
Yellow tangs	17.5	19.7	13%	-3%
Aquarium species (wo/yellow tangs)	64.1	55.1	-14%	-6%
Resource fishes	7.4	7.4	0.1%	-46%
Non-aquarium fishes	38.4	41.5	8%	-7%

* Statistically significant at P < 0.10

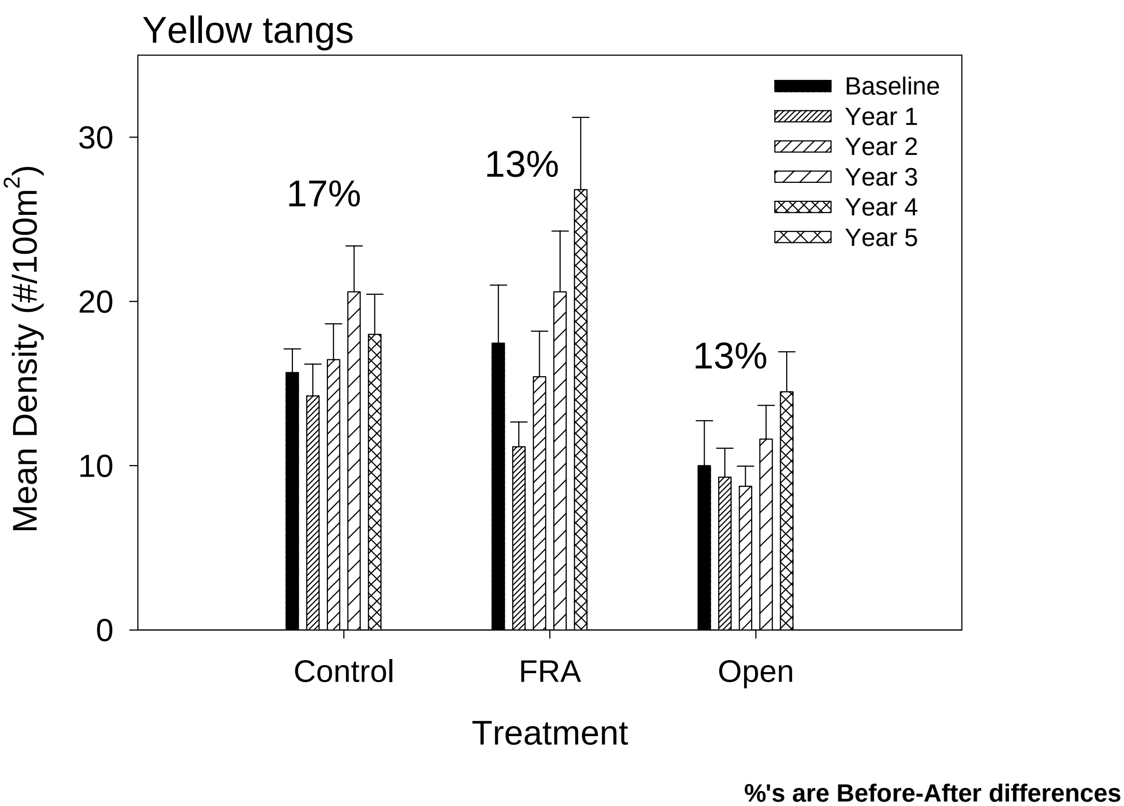

Figure 19. Before vs. after changes in yellow tangs in FRAs, control and open areas in the FRA.

Kailua-Kona (N. Keauhou) FRA

Table I. Changes in fish groups in the Kailua-Kona (N. Keauhou) FRA.

Group	Density (no/100m^2) Before	After	% Change	R
Yellow tangs	8.4	23.6	**182%**	**146%***
Aquarium species (wo/yellow tangs)	60.3	56.3	-7%	-4%
Resource fishes	2.5	6.3	**149%**	**201%***
Non-aquarium fishes	26.6	27.3	3%	-20%

* Statistically significant at P < 0.10

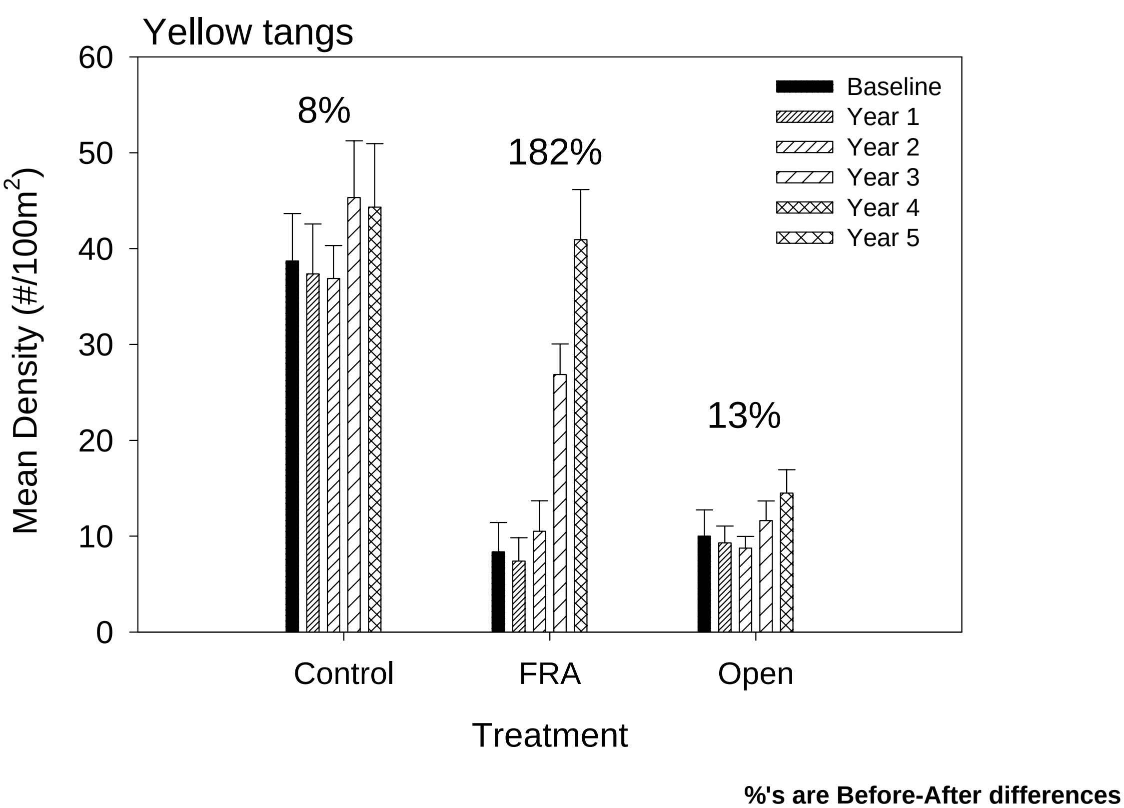

Figure 20. Before vs. after changes in yellow tangs in FRAs, control and open areas in the Kailua-Kona (N. Keauhou) FRA.

Napo`opo`o-Honaunau FRA

Table J. Changes in fish groups in the Napo`opo`o-Honaunau FRA.

Group	Density (no/100m^2) Before	After	% Change	R
Yellow tangs	11.9	24.1	**102%**	**130%***
Aquarium species (wo/yellow tangs)	63.5	57.8	-9%	-7%
Resource fishes	7.4	11.4	54%	-36%
Non-aquarium fishes	57.6	55.3	-4%	-6%

* Statistically significant at P < 0.10

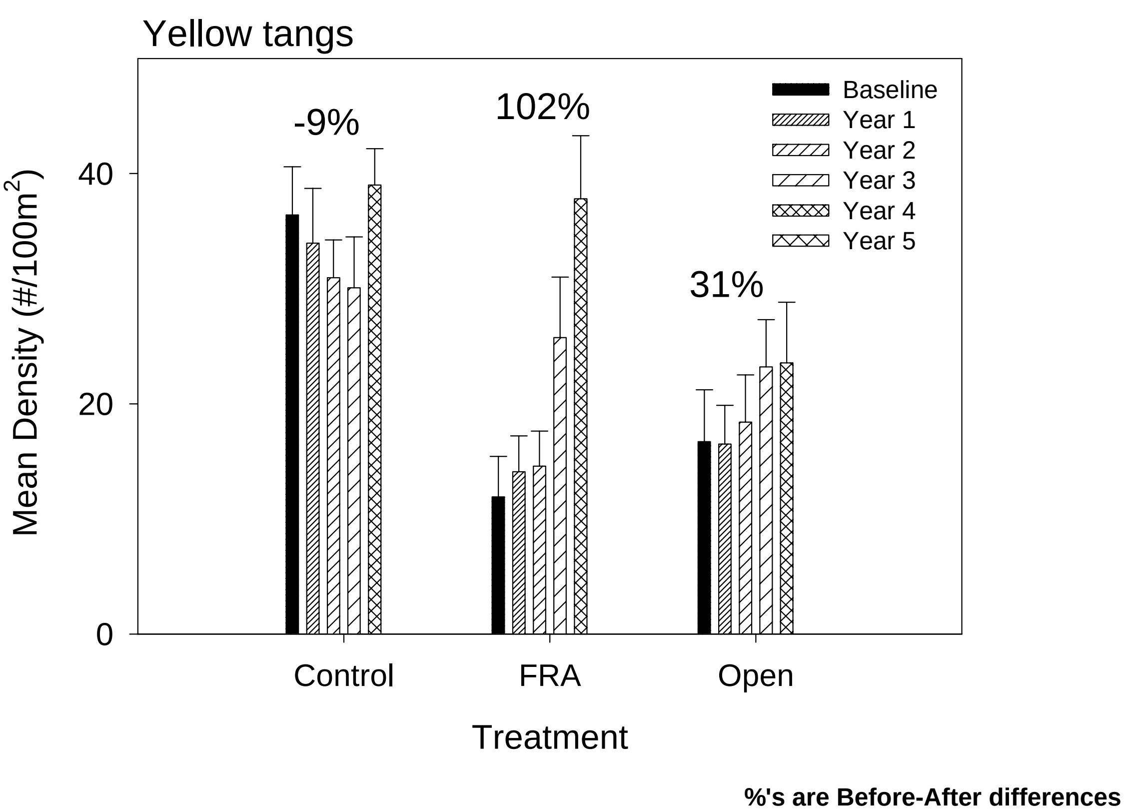

Figure 21. Before vs. after changes in yellow tangs in FRAs, control and open areas in the Napo`opo`o-Honaunau FRA.

<u>Ho`okena FRA</u>

Table K. Changes in fish groups in the Ho`okena FRA.

Group	Density (no/100m²) Before	After	% Change	R
Yellow tangs	18.7	24.7	**32%**	**50%***
Aquarium species (wo/yellow tangs)	108.2	95.2	-12%	-10%
Resource fishes	11.0	9.1	-17%	-78%
Non-aquarium fishes	35.6	38.6	9%	5%

* Statistically significant at $P < 0.10$

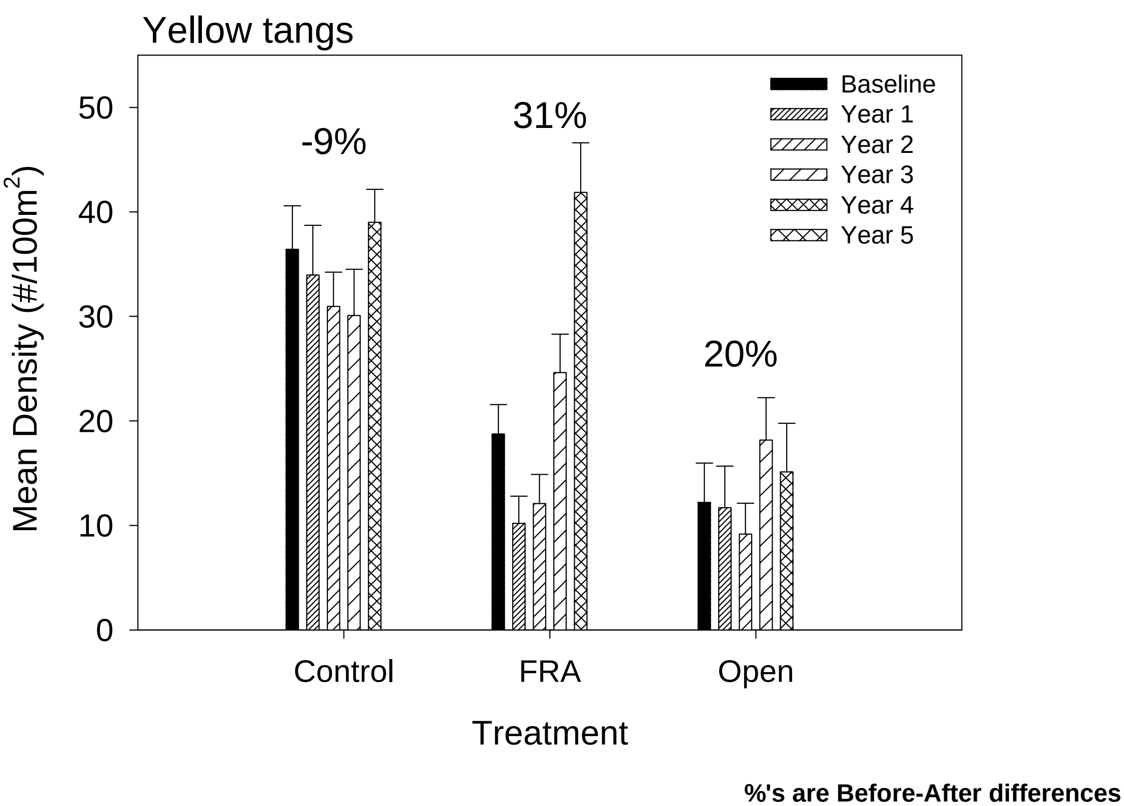

Figure 22. Before vs. after changes in yellow tangs in FRAs, control and open areas in the Ho`okena FRA.

<u>Miloli`i FRA</u>

Table L. Changes in fish groups in the Miloli`i FRA.

Group	Density (no/100m²) Before	After	% Change	R
Yellow tangs	10.7	10.9	2%	34%
Aquarium species (wo/yellow tangs)	91.0	88.9	-2%	-1%
Resource fishes	10.1	8.8	-13%	-79%
Non-aquarium fishes	98.3	92.8	-6%	-7%

* Statistically significant at P < 0.10

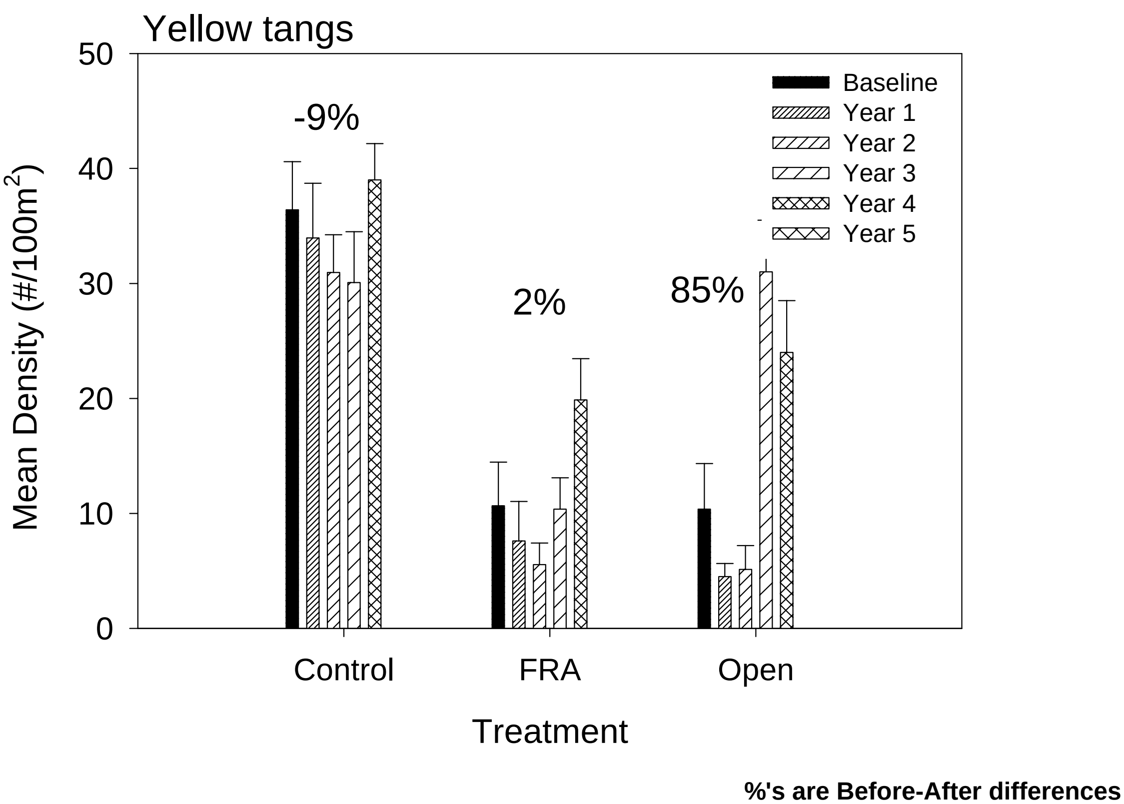

Figure 23. Before vs. after changes in yellow tangs in FRAs, control and open areas in the Miloli`i FRA.