Evaluation of the effectiveness of an MPA network in Hawai`i: ecological, economic and social dimensions

Tissot, Brian N.[1]; William J. Walsh[2]; Leon E. Hallacher[3]

[1] *Washington State University-Vancouver, 14204 NE Salmon Creek Avenue, Vancouver, Washington 98686, USA, tissot@vancouver.wsu.edu*

[2] *Division of Aquatic Resources, 88-1610 Mamalahoa Hwy, Captain Cook, HI 96704, USA, darkona@interpac.net*

[3] *Department of Biology, University of Hawaii Hilo, 200 W. Kawili St., Hilo, HI 96720, USA, leonh@hawaii.edu*

SUBMITTED*:* February 18, 2005

INTRODUCTION

The aquarium collecting industry in Hawai'i has had a long contentious history and is well know for its clashes between collectors and dive tour operators over shared resources and perceived declines in reef fishes targeted by collectors (Tissot and Hallacher 2003; Capitini et al., 2004; Tissot et al., 2004). As early as 1973, public concern over collecting activities were first addressed by the Hawai'i Division of Aquatic Resources (DAR). However, the industry has been largely unregulated since then despite dramatic increases in both the number of issued collecting permits and collected fishes. Further, increases in fish collecting combined with growing public perception of dwindling fish stocks eventually developed into a severe multiple use conflict between fish collectors and the dive tour industry (Capitini et al, 2004).

The network of nine Fish Replenishment Areas (FRAs, which are MPAs that prohibit collection of aquarium fish) cover 35% of the West Hawai'i coastline (Figure 1). The network was established during 1998-99 through Act 306 of the Hawai'i State Legislature after nearly a decade of ecological research and community collaboration (Walsh, 1999). Beginning in 1996, and working with legislators and other stakeholders, ecological studies were cooperatively designed and completed to identify the magnitude and effects of aquarium collection (Tissot and Hallacher, 2003) and other impacts to West Hawai'i reefs (Tissot and Hallacher, 2000). Simultaneously, concentrated, multi-level education and outreach efforts in the community resulted in collaborative reef management (Walsh, 1999) and volunteer monitoring groups (Tissot, 2005) aimed at developing a plan to resolve user conflicts, promote a sustainable aquarium fishery, and enhance reef fish populations. Act 306 formalized these ad hoc programs by mandating that a minimum of 30% of the West Hawai'i coastline be declared as FRAs in close consultation with the regional community, and that the FRAs be evaluated for effectiveness 5 yrs after their establishment (Tissot et al., 2004). Thus, two collaborative programs were launched to implement Act 306: (1) the West Hawai'i Fisheries Council (WHFC) was created in 1998 to develop and recommend community-based management plans; and (2) the West Hawai'i Aquarium Project (WHAP) was started in 1999 to study the effectiveness of the FRAs to replenish aquarium fish populations. This paper is aimed at describing the how an MPA network, such as the FRAs in Hawai`i, can simultaneously enhance ecological, economic and social aspects of the community and how the effectiveness of an MPA network is best gauged by the combined effects of these three dimensions.

West Hawai`i Fishery Council

In order to accomplish the mandates of Act 306, with substantive community input, a council approach was decided upon by the Hawai`i Department of Land and Natural Resources. 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. The WHFC consisted of 24 voting members and 6 ex-officio agency representatives. 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) (Capitini et al., 2004).

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 order to abide by the spirit and intent of the legislation, the WHFC were instructed the overall objective was to sustainably manage the aquarium fishery and not to dismantle or shut it down completely. Working under a very short 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 1) 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 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.

Within this context of social engagement, this paper further examines ecological changes in the FRAs after five years of closure in relation to changes in the associated aquarium fishery.

MATERIALS AND METHODS

The WHAP observational design compares FRA sites before and after closure to sites which remained open to aquarium fish collecting (open sites) and those that were not subjected to fish collecting (reference sites) (see Tissot et al., 2004 for a detailed description of methods and rationale). References sites included other MPAs (Marine Life Conservation Districts and Fishery Management Areas), both of which prohibit aquarium fish collecting, along with other activities. A total of 23 study sites were selected in early 1999. The sites were established in six existing reference areas, in eight open areas adjacent to FRAs, and in all nine of the FRAs (Figure 1)

Study sites were selected within an area of suitable habitat and depth for aquarium fishes and survey methods were developed specifically for the monitoring of fishes and benthic substrates in West Hawai'i (Tissot et al, 2004). Fish densities of all observed species were estimated by visual strip transect search along each permanent transect line. Two pairs of divers surveyed the lines, each pair searching two of the 25m lines in a single dive. The search of each line consists of two divers, swimming side-by-side on each side of the line, surveying a column 2m wide. On the outward-bound leg, larger planktivores and wide-ranging fishes within 4m 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. All sites were surveyed bi-monthly, weather permitting, for a total of six surveys per year (five in 2000 and 2002).

We tested the statistical significance of changes in FRAs using the Before-After-Control Impact (BACI) procedure (Osenberg and Schmidt 1996). 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 $\alpha=.10$ 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:

$$R = \left[\frac{\sum_{i=1}^{t_{after}} \overline{X}_{control} - \overline{X}_{\mathrm{FRA}}}{t_{after}}\right] - \left[\frac{\sum_{i=1}^{t_{before}} \overline{X}_{control} - \overline{X}_{\mathrm{FRA}}}{t_{before}}\right] \mathrm{X100} \qquad (1)$$

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:

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

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. 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.

We conducted the BACI procedure using a two-way, repeated measure analysis of variance with factors of before vs. after (FRA vs. reference or open vs. reference), locations, and before vs. after location interaction. We evaluated effectiveness in two ways: 1) by calculating the percent change in mean density from 1999 to 2004; and 2) by calculating the percent change in the FRA-reference or open-reference difference from 1999 to 2004.

Fishery data were obtained by analysis of monthly aquarium catch reports (form C-6). As has been noted previously, the reliability of these data is dependent upon the sincerity (and integrity) of the permittees. At present there is no provision for verification of submitted reports. Given there are indications of underreporting (Walsh et al., 2003)), catch numbers and dollar amounts should be regarded as minimum and not absolute values. Data from FY 74 and FY75 are not included in this analysis due to problems with early C-6 versions which produced data not comparable with that of subsequent years. Only commercial data are presented as non-commercial permit holders are not required to submit monthly catch reports. Non-commercial permit holders are also limited to a total take of five fish or aquatic specimens per person per day so their overall potential catch is considerably less than commercial collectors. In FY 2003, 108 non-commercial permits were issued in comparison to 116 commercial ones.

RESULTS

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.

Effectiveness of FRA network

The overall effectiveness of the FRA network to replenish fish stocks is listed in Table 1. 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.

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 2) 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. Chevron tangs (Figure 2) 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.

Effectiveness on 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 3). 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 (Tissot et al., 2004). 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. Catch per Unit effort (CPUE) among all aquarium fishes was also higher after FRA establishment than before (Figure 3).

DISCUSSION

Five years after their closure of FRAs there were significant increases in the overall abundance of fishes targeted by collectors, especially the top targeted fish the yellow tang.

Significant increases in yellow tangs indicate the widespread effectiveness of the FRAs to enhance aquarium fish populations. This recovery appears to be associated with strong interannual variation in the recruitment of all fishes in West Hawai'i (Tissot et al., 2004). Thus, although FRAs showed significant recovery in some species after only five years, the frequency of recruitment of protected species is likely to be an important factor determining the recovery of other species in reserves.

The effect of the FRAs on the aquarium fishery itself has also been positive. Total catch and the catch of the top species, yellow tang, 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. 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.

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. 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 (Capitini et al., 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 an increase in enforcement actions. 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.

The results of this study demonstrate the MPAs can effectively promote recovery of fish stocks depleted by fishing pressures in Hawai'i, without significant declines outside of reserves, and can result in enhancement of nearby fisheries. Moreover, substantial involvement in the community has resulted in reduced conflicts, greater support, and better enforcement of regulations. Clearly, acknowledgment and integration of ecological, economic and social dimensions helped resolve conflicts in West Hawai`i and promote sustainability in the aquarium fishery.

ACKNOWLEDGEMENTS

We thank David Tarnas and Sara Peck for instrumental roles in the development of FRAs and community support. Many assisted in diving and data management: Brent Carman, Steve Cotton, Ivor Williams Delisse Ortiz, Jonathan Hultquist, Kathy Greenwood, , 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. Funding was provided by NOAA-NOS through the Hawai`i Coral Reef Initiative Research Program Mike Hamnett, Christine Davidson and Risa Minato.

REFERENCES

Capitini, C. A. B. N. Tissot, M. Carroll, W. J. Walsh and S. Peck. 2004. Competing Perspectives in Resource Protection: the Case of Marine Protected Areas in West Hawai‘i. Society and Natural Resources 17: 763-778.

Tissot, B. N. 2005. Integral marine ecology: community-based fishery management in Hawaii. World Futures: the Journal of General Evolution. In press

Tissot, B. N. and L. E. Hallacher. 2000. Diver impacts on coral reef at Kealakekua Bay, Hawai`i. Hawaii Division of Aquatic Resources Technical Report: 10 pp.

Tissot, B. N. and L. E. Hallacher. 2004. Effects of aquarium collectors on reef fishes in Kona, Hawai`i. Conservation Biology 17(6): 1759-1768.

Tissot, B. N., Walsh, W. and L. E. Hallacher. 2004. Evaluating the effectiveness of a marine reserve network in Hawaii to increase the productivity of an aquarium fishery. Pacific Science 58(2): 175-188.

Tissot, B. N., Walsh, W. and L. E. Hallacher. 2003. Evaluating the effectiveness of a marine reserve network in Hawaii to improve management of the aquarium fishery. NOAA Technical Report. 20pp.

Walsh, W. J. 1999. Community-based management of a Hawai'i aquarium fishery. Marine Ornamentals '99, Waikoloa, Hawai'i. UNIHI-SEAGRANT-CP-00-04: 83-87.

Walsh, W.J., S.P. Cotton, J. Dierking and I.D. Williams. 2003. The Commercial Marine Aquarium Fishery in Hawai`i 1976-2003. In: Friedlander A.M. (ed) Status of Hawai`i's Coastal Fisheries in the New Millennium. Proceedings of a Symposium sponsored by the American Fisheries Society, Hawai`i Chapter. pp. 132-159.

Table 1. Overall effectiveness of Fishery Replenishment Areas (FRAs) for the top ten most aquarium collected fishes in West Hawai`i.

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 $P < 0.10$

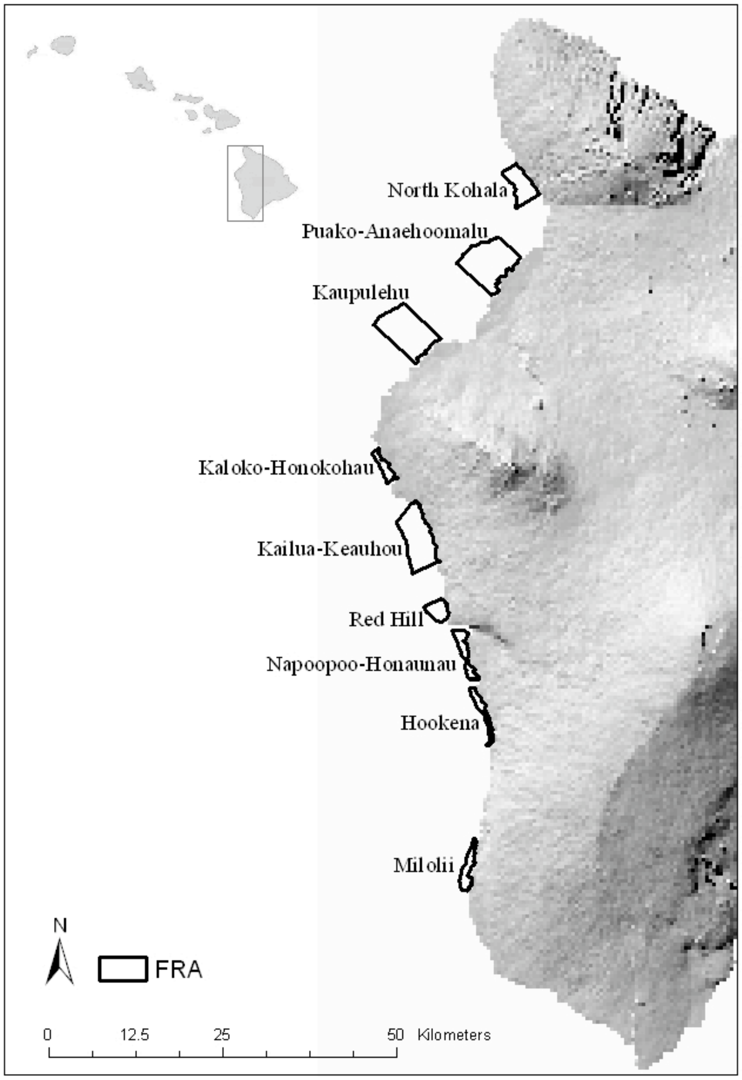
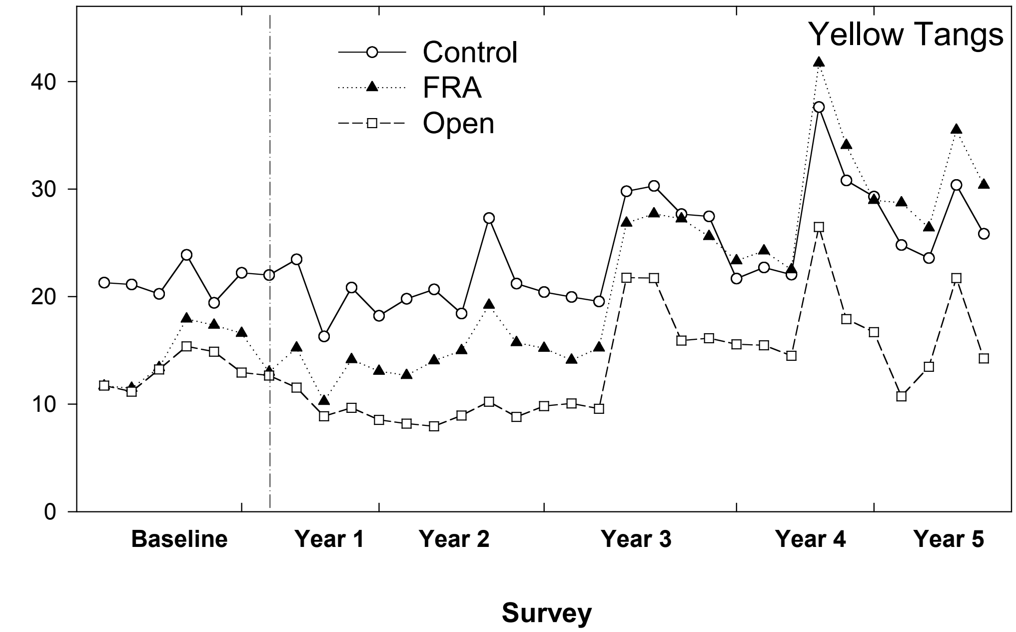


Figure 1. Locations of Fishery Replenishment Areas (FRAs) in West Hawai`i.



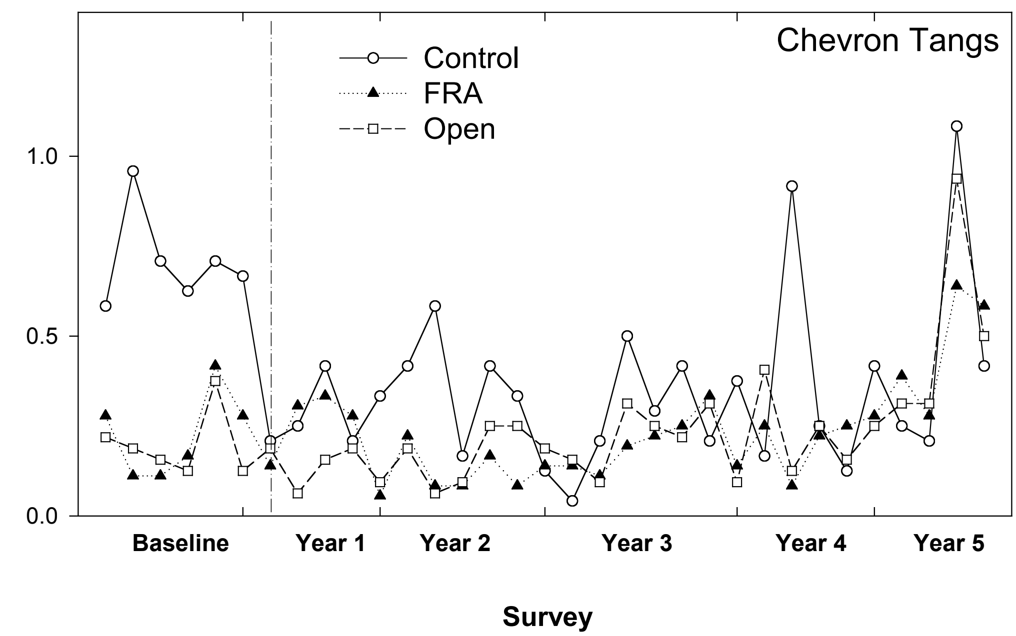
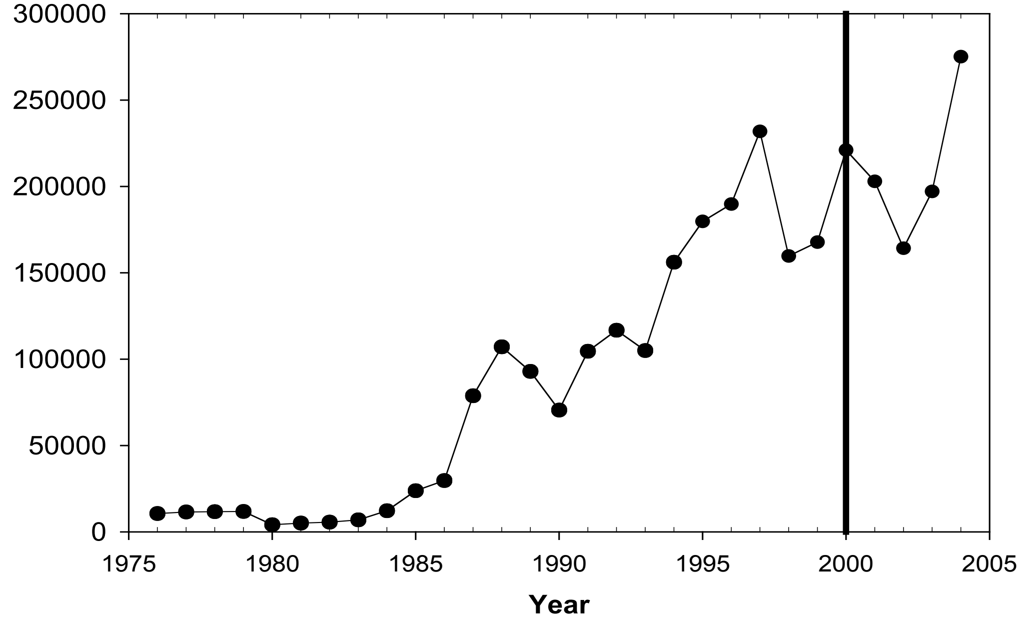


Figure 2. Overall changes in yellow tangs (top) and chevron tangs (bottom) in Fishery Replenishment Areas (FRAs) in West Hawai`i in comparison to Reference (control) and open sites



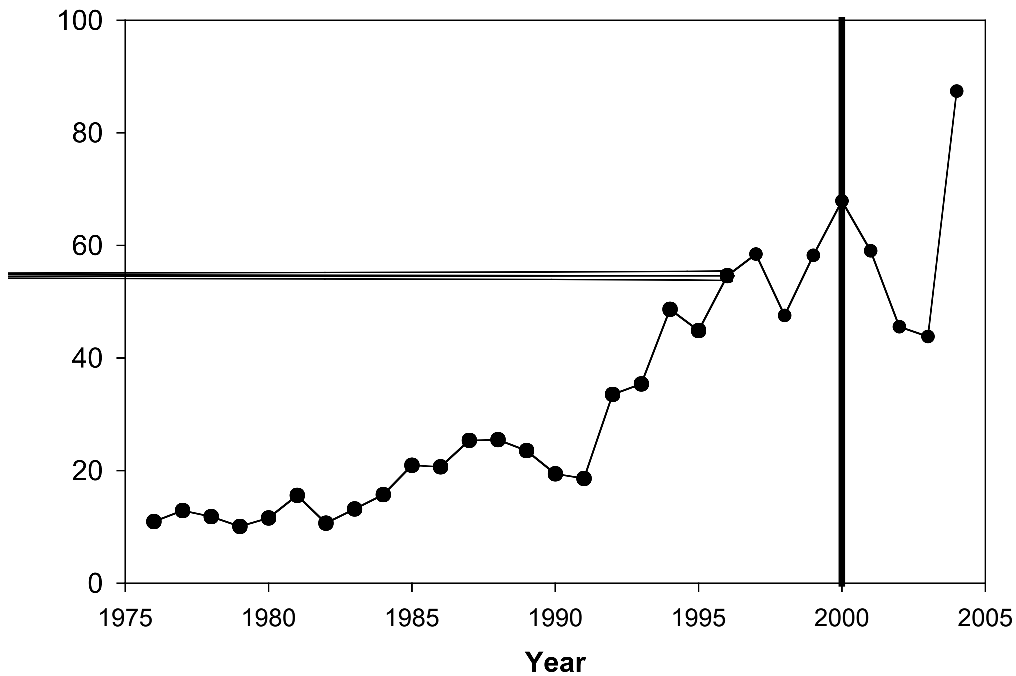


Figure 3. Total catch of yellow tangs (top) and Catch-per-unit-effort (CPUE) for aquarium fishes (bottom) in West Hawai`i before (1975-1999) and after (2000-2004) FRA establishment.