

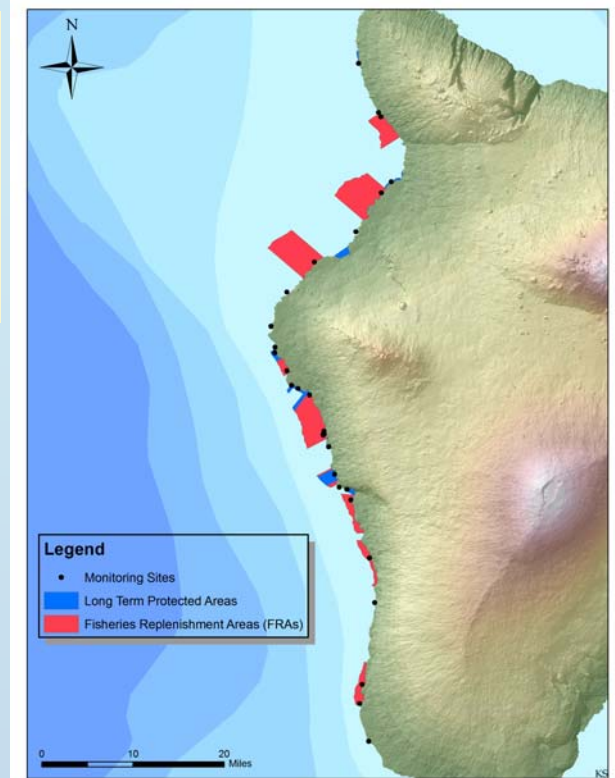


The West Hawaii Fish Replenishment Area Network

The West Hawaii Regional Fisheries Management Area was created in 1998 by Act 306. Act 306 also mandated the designation of a minimum of 30% of West Hawaii coastal waters as 'Fish Replenishment Areas' (FRAs) where aquarium collecting would be prohibited. A community group, the West Hawaii Fisheries Council, developed the plan for a network of 9 FRAs (see map →) which became effective on December 31st 1999. The FRAs encompass 27.8% of the West Hawaii coastline, bringing the total area closed to aquarium collecting, including already existing reserves, to 35.2% of the coastline.

Fish Monitoring and the West Hawaii Aquarium Project

In order to study the impacts of the FRA network, and of continuing aquarium fishing in the areas which remained open to collectors, DLNR-DAR and partners at the University of Hawaii at Hilo and Washington State University Vancouver initiated the 'West Hawaii Aquarium Project' (WHAP). As part of WHAP, 23 permanent monitoring sites were established (see map →): 9 in areas which were designated to become FRAs, but which were still open to fishing when monitoring began; 9 in areas which remained open to collectors throughout; and 5 in pre-existing reserves. Fishes at each of those sites have been surveyed 4-6 times every year since 1999. The WHAP monitoring program therefore has data from the 'FRA' sites before and after the FRAs were established, and allows trends at those sites to be compared with trends at sites where management status did not change (i.e. older reserves, and open areas). It is therefore possible to draw very powerful and statistically robust conclusions about the impacts of the FRA network on fish stocks.



W. Hawaii aquarium closure areas and monitoring sites.



Prime target size for yellow tangs is ~5-10 cm, which are fishes ~2 month to 2 years old. Maximum lifespan is >40 yrs

The Importance of Yellow Tang to the West Hawaii Aquarium Fishery

The West Hawaii aquarium fishery is very largely focused on small surgeonfishes. Just five species made up 95% by number and >93% by value of fish catches reported by West Hawaii collectors in fiscal years 2006-8. Of those, the yellow tang, *Zebrasoma flavescens*, is by some distance the most important single species, constituting 82% of the total catch and 78% of the value of the fishery over that time period.

As yellow tang are so important, and because young juveniles fishes are the prime targets of the fishery, the long-term health of the West Hawaii aquarium fishery very heavily depends on the continued supply of new generations of yellow tang to local reefs, which in turn means that maintaining healthy breeding stocks is essential to the long-term sustainability of the fishery.

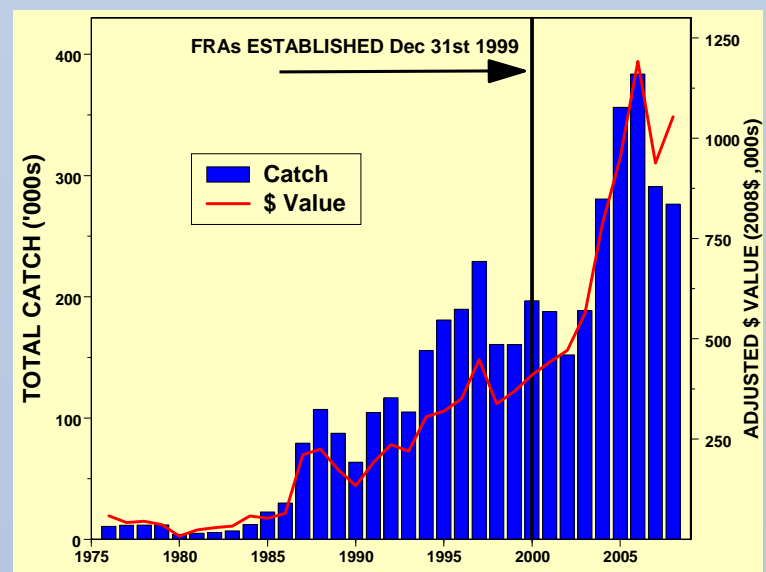
Catch Trends and Fishery Participation

Catch and value of yellow tang landings have been on an upward trend since 1976, when DLNR began collecting data on the fishery. West Hawaii reported catch increased from around 10,000 /yr between 1976-1985 to 280,000/yr or more since 2004 (see →). Inflation-adjusted value of landings has dramatically increased too — from around \$40,000/yr prior to 1985 to an average of more than \$1,000,000/yr since 2005.

Causes of increased catches include: more participants in the fishery; the concentration of effort on small surgeonfishes, particularly yellow tang, and away from other groups such as butterflyfishes; and the use of more intensive fishing methods.

Overall, since the FRAs were established:

- The number of West Hawaii collecting permits increased from 36 to 72. Many permit holders report little or no catch, but the number of 'active fishers' (those catching >1,000 yellow-tang /yr) more than doubled: from 16 in '99 to 37 in '07.
- Yellow tang catch has increased by 72% and inflation-adjusted \$ value by 170% (average of last 5 years [2004-8] compared to last 5 years prior to closure of FRAs: [1995-9]).



Catch and \$ value of yellow tang from West Hawaii. \$ values are inflation adjusted to 2008\$ using Honolulu consumer price index from hawaii.gov

An expanded version of the information presented here is available in 'Impacts of a Hawaiian marine protected area network on the abundance and fishery sustainability of the yellow tang, *Zebrasoma flavescens*', published in the journal Biological Conservation [Vol. 142:1066-1073, 2009]. Reprints of that article are available on request from ivor@hawaii.edu or darkona@hawaiiantel.net.

Yellow Tang Abundance Trends at Monitoring Sites

Monitoring sites are located in the mid-depth high coral cover zone which is the main habitat for juvenile yellow tang (the life-stage targeted by the fishery), and is consequently the most heavily-fished reef zone. Sites are therefore ideally situated to detect fishing and protection effects.

In 1999, before the FRAs were implemented, there was no difference in yellow tang density between 'open' sites (green squares →) and sites which were due to become FRAs (red circles). Both had about half the abundance of the established 'older reserves' (blue triangles). By 2003, and in all subsequent years, densities in FRAs had increased to levels similar to those in the older reserves (see →). Monitoring data therefore provides unequivocal evidence of population recovery within FRAs.

Densities at open sites remained about the same between 1999 and 2006 at around 10 per 100 m², but have declined steadily since, to < 5 per 100 m² in 2008. In addition to the decline in total abundance at open sites, there is other evidence that fishing impacts have increased in recent years. As described earlier, the fishery targets small juveniles—the preferred size being around 5 to 10 cm. In 2004, density of that size class in reserves was around 3 times that in open areas, but by 2008 fishes of that size were nearly 7 times as abundant in reserves.

As the prime-target sized fishes are mostly young juveniles (generally around 2 yrs old or younger), it will take a number of years before increased fishing impacts are reflected at the population level. However, there are already indications that fewer yellow tang in open areas are surviving through to reach sexual maturity (at approximately 5-6 yr old). Prior to 2006, FRAs had less than twice as many large juveniles/sub-adults as open areas, but they had more than four times as many in 2008.

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Effects on Breeding Stocks & Fishery Sustainability

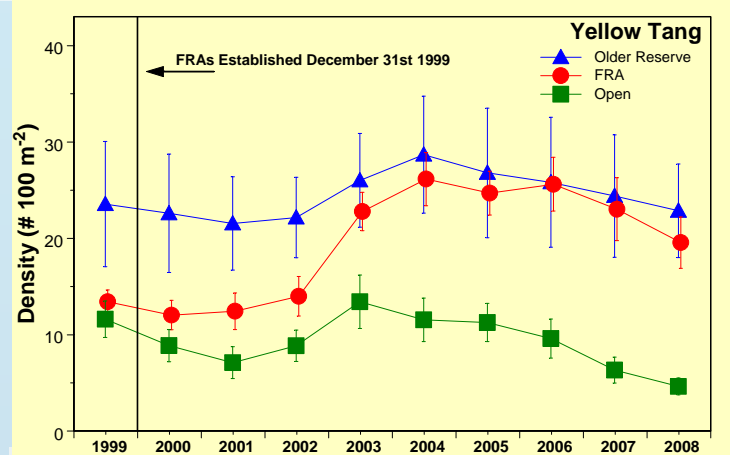
The fishing/reserve impacts described above are striking, but of greater significance to the role the FRAs have in enhancing or sustaining West Hawaii populations and the fishery which depends on those, are effects of the reserve network on yellow tang breeding stocks. Therefore, to supplement long-term monitoring of juvenile habitats, DAR initiated a series of surveys of the shallow reef habitats utilized by adult yellow tang. The first set of those was completed in 2006.

Adult densities were highest within reserves and in 'boundary' areas (open areas adjacent to reserves), and lowest in open areas far from reserves (see graph →). High densities in boundary areas are evidence of 'spillover' (outward movement from reserves into surrounding open areas) and indicate that reserves 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.

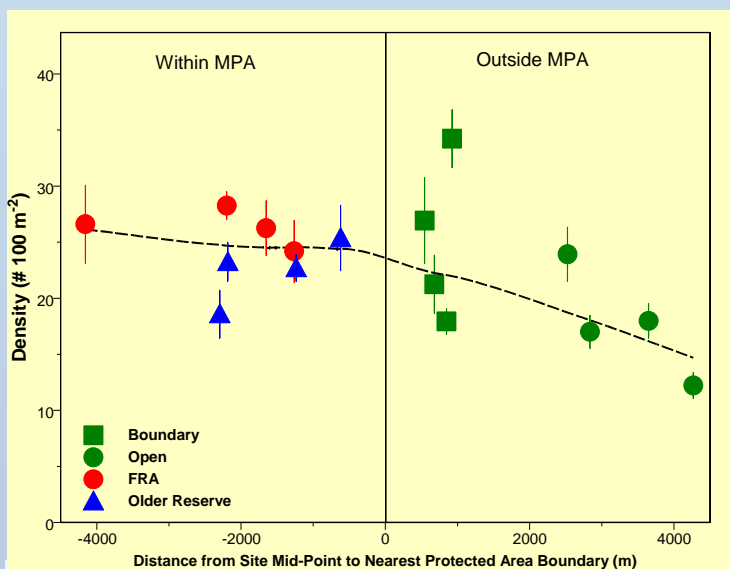
Although reserves are already important source areas for adult yellow tang (2006 densities were 48% higher in FRAs, and 41% higher in boundary areas than in open areas far from boundaries), the reduced supply of new adults from open areas following recent increases in effort and catch (above) mean that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

Conclusions—The Importance of West Hawaii Reserves

The West Hawaii reserve system has been shown to have a number of benefits above and beyond impacts on yellow tang. Those include greater numbers of other targeted species, reduced conflict between collectors, commercial ocean recreation operations, and community members, and greater numbers of attractive and conspicuous fishes in reef areas which are readily accessible to commercial and recreational divers and snorkelers. In addition, survey data provides clear evidence that the West Hawaii protected areas network, by sustaining adult stocks over large areas of the coastline, helps to ensure the long-term sustainability of yellow tang stocks in West Hawaii and of the fishery which depends heavily on this species. Increased fishing effort and catches in recent years demonstrate scope for severe overexploitation in the absence of reserves, and suggest that additional management, including perhaps limits on participation as well as specific additional protection of breeding stocks may be necessary to optimize future fishery benefits.



Mean density of yellow tang at W. Hawaii monitoring sites from 1999 to 2008. Error bars are ± 1 standard error. Excludes recently settled fishes.



Abundance of adult yellow tang in and out of reserves. High abundance in 'boundary' sites (open sites <1 km from nearest reserve) is indicative of 'spillover' of adult from reserves.