Continued long-term decline of the coral reef biota at Puakō and Pauoa, West Hawai'i (1979 – 2008)

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Cover photo: Aerial view of West Hawai'i coastline looking from just north of Pauoa to Puakō Bay.

EXECUTIVE SUMMARY

The coral reef ecosystem adjacent to Puakō, South Kohala, has long been recognized as one of the finest in the state, and is a prime location for subsistence/recreational fishing, dive tourism, and luxury shoreline residences. In this report, coral reef biota, including fish, invertebrates, and benthic communities, were surveyed at twelve sites at Puakō and Pauoa in 2007-2008, then compared to a reference study completed in 1979-1981 (Hayes et al. 1982). The more recent surveys indicated substantial declines in biota abundance, and included the following key findings:

- Striking declines in the abundance of fishes were observed between the two survey periods. At Puakō, the total relative decrease in fish abundance ranged from -43% to -69%, and at Pauoa, the total relative decrease ranged from -49% to -76%.
- Nine of the top ten most abundant fish families in the original study, representing more than 97% of all fishes, decreased in abundance at both Puakō and Pauoa.
- Of the 35 most abundant reef fish species at the Puakō site, comprising 92% of all fishes present in the 1978-1980 surveys, 31 declined in abundance, ranging from a slight relative decline in Yellow Tang, *Zebrasoma flavenscens* (- 9%), to an enormous relative decline in Achilles tang, *Acanthurus achilles* (-97%).
- Two popular aquarium fishes, the Blueline Butterflyfish (*Chaetodon fremblii*) and the Teardrop Butterflyfish (*C. unimaculatus*) were observed at Puakō sites during 1978-1981 surveys but were not detected in 2007- 2008. While still present at Pauoa sites during 2007-2008 resurveys, their abundance was substantially reduced.
- The number of fish species seen on transects was similar between the two studies.
- Only the family Scaridae (parrotfishes) increased in abundance between survey periods, primarily due to an increase in the abundance of the Bullethead Parrotfish, *Chlorurus spilurus*, at the Pauoa site, and to lesser extent by an increase in the PalenoseParrotfish, *Scarus psittacus*, at both sites.
- All trophic categories of fishes decreased in abundance, ranging from a 36% decline of piscivores at Puakō to a 65% decrease in herbivores/ detritivores at Pauoa.
- Both study areas were protected from lay net fishing during the recent surveys, although the duration of protection varied. However, with the exception of the Saddle Wrasse (*Thalasoma dupperey*), lay net targetted fish abundance was similar at the two study areas in the recent surveys but had declined substantially overall compared to the original survey.
- Similarly, both study areas were protected from commercial aquarium collection with a varying duration. The majority of the top ten most collected aquarium fish species declined at both sites. Notable exceptions were the most collected aquarium fish in Hawai'i, the Yellow Tang, *Zebrasoma flavescens*, and the Black Surgeonfish, *Ctenochaetus hawaiiensis*.

- The abundance of eight of the top ten most common resource fish species (i.e. food fishes), decreased markedly over time at both sites. Only the Bullethead Parrotfish, *Chlorurus spilurus*, increased at the two sites, despite being a targeted fishery species.
- Seven of the top ten fish species not targeted by food or aquarium fisheries also declined between the two survey periods.
- For the majority of fish species analyzed, the estimated maximum size observed in the 2007-2008 surveys decreased when compared to special survey data included in Hayes et al. (1982), particularly for parrotfishes.
- Hayes et al. (1982) predicted that certain species were highly susceptible to intensive fishing, including *Cirrhitus pinnulatus*, *Acanthurus triostegus*, *Mulloidichthys flavolineatus*, and *Parupeneus multifasciatus*, and general declines in abundance for at least one survey site were noted for each of these species listed during the more recent surveys.
- On average, total coral cover decreased by 35% at Puakō and by 21% at Pauoa when compared between the 1979-1981 and 2007-2008 surveys. A substantial coral bleaching and mortality event occurred in 2015, however, results of this survey indicate that corals were in decline during the prior decades.

Both top-down (e.g. fishing pressure, herbivory) and bottom-up (e.g. water quality characteristics) drivers are known to control coral reef community structure, and both are likely playing a role in shaping reef biota at Puakō and Pauoa. Fortunately, both sites have had multi-layered protective management in place for more than 10 years. However, the findings from this survey suggest that additional protective managment is likely required to promote both coral and reef fish recovery to previous abundances.

INTRODUCTION

The coral reef tract just offshore of Puakō and Pauoa in South Kohala, Hawai'i, comprises one of the most vibrant and structurally complex reef ecosystems on the island, popular for both dive tourism and recreational fishing. Notably, stony coral and reef fish communites in both areas are situated just meters from the shoreline, and in addition to shoreline fishing pressure, are subject to wastewater effluent from adjacent homes, transported via submarine groundwater dischange. In recent years, substantial declines in the reef community have been noted by the local community, prompting scientific investigation of community changes, water quality issues, and management options (Abaya et al. 2018a, 2018b, Weijerman et al. 2018).

In response to concerns about increasing shoreline commercial and residential development and associated fishing pressures and recreational use in the late 1970s, the University of Hawai'i Cooperative Fisheries Research Unit conducted a two-year study of the Puakō reef tract from 1979 to 1981. The study was designed to quantatively characterize the coral reef faunal community and examine the nature and effect of fisheries on reef resources (Hayes et al. 1982). In addition to surveying reef fish communities along the readily accessible reef at Puakō, reference sites at the much less fished reef area at Pauoa Bay, approximately 2.5 km south of Puakō were also surveyed.

In April and August of 1984 public meetings were held in North Kona, during which attendees pointed out the need to protect and manage Puakō's fishery resources, favoring a restriction on net fishing and a possible ban on spearfishing (Division of Aquatic Resources 1984). The following year, the Puakō Bay and Puakō Reef Fisheries Management Area (FMA) was established as a Marine Protected Area (MPA) by the State of Hawaii (Figure 1). The FMA prohibits the possession or use of nets, except throw nets. In 2000, Pauoa Bay was included as part of a larger Fish Replenishment Area (FRA), where commercial aquarium fish collection is prohibited (Figure 1). Fishing with hook and line and/or spear is permitted in both areas, and lay netting was permissible at Pauoa until the establishment of lay net restrictions in the area in 2005. SCUBA spearfishing was banned in all West Hawai'i waters in December 2013.

The primary intent of this study was to compare the abundances of reef fish species, selected benthic invertebrates, and reef fish functional groups with the 1979-1981 study and more recent surveys (2007-2008) conducted over a quarter century later. In addition, predictions from Hayes et al. (1982) regarding future coral reef fish stocks were investigated, and potential effects of the differing management regimes at the two sites were considered.

METHODS

1979-1981 Study

The initial fish transects at Puakō and Pauoa Bays were surveyed from November 1979 through June 1981 (Hayes et al. 1982). One or more fish surveys were conducted in each month of the year except for April and October. A total of twelve transect sites were established, six in the more accessible Puakō Reef area and six in the less accessible "control" area of Pauoa Bay (Figures 1 - 3).

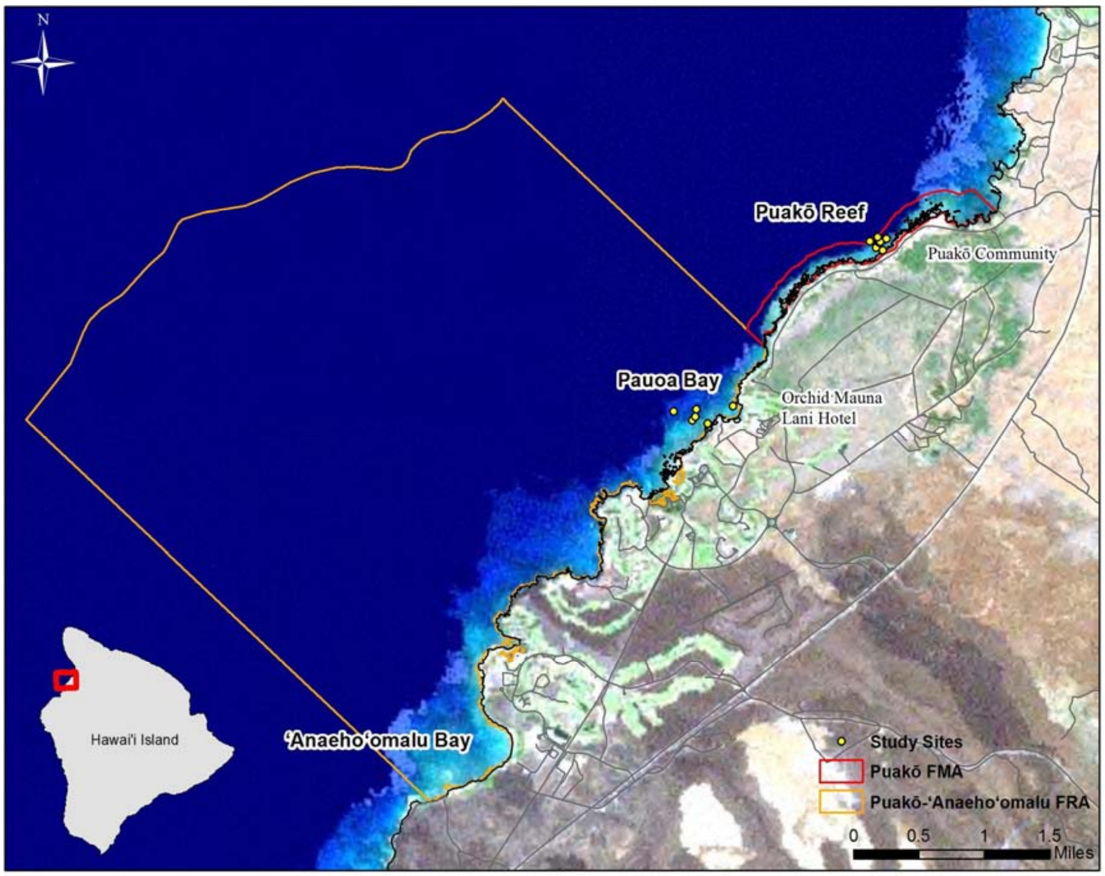

Figure 1. Location of Puakō and Pauoa study sites on Hawai'i Island. The red box on the island map indicates the general location of the study area and the yellow dots show the sites where each of six transects were located. The boundaries of the Puakō Bay and Puakō Reef Fisheries Management Area (FMA) and the Puakō - 'Anaeho'omalu Fish Replenishment Area (FRA) are outlined in red and amber respectively.

Puakō was designated as study area "A", and Pauoa as study area "B". Permanent 10 m x 50 m transects, marked in 5 m increments by small floats, were established in each of six different habitat zones at each site. The six habitat zones, proceeding from inshore to offshore, were designated as follows: Habitat Zone 1 – Surge Zone; Habitat Zone 2 – Shallow, Coral Rich Zone; Habitat Zone 3 – Shallow, Basalt reef platform; Habitat Zone 4 – Cliff Base Zone; Habitat Zone 5 – Deep, Coral Rich Zone; Habitat Zone 6 –

Sand-Coral Interface Zone. Transect names were a combination of the Habitat Zone designation and study area designation, so Puakō transects were named 1A-6A, and Pauoa transects were 1B-6B (Figures 2 and 3). In addition to fish, echinoderms and nocturnal crustaceans were also censused on the fixed transects.

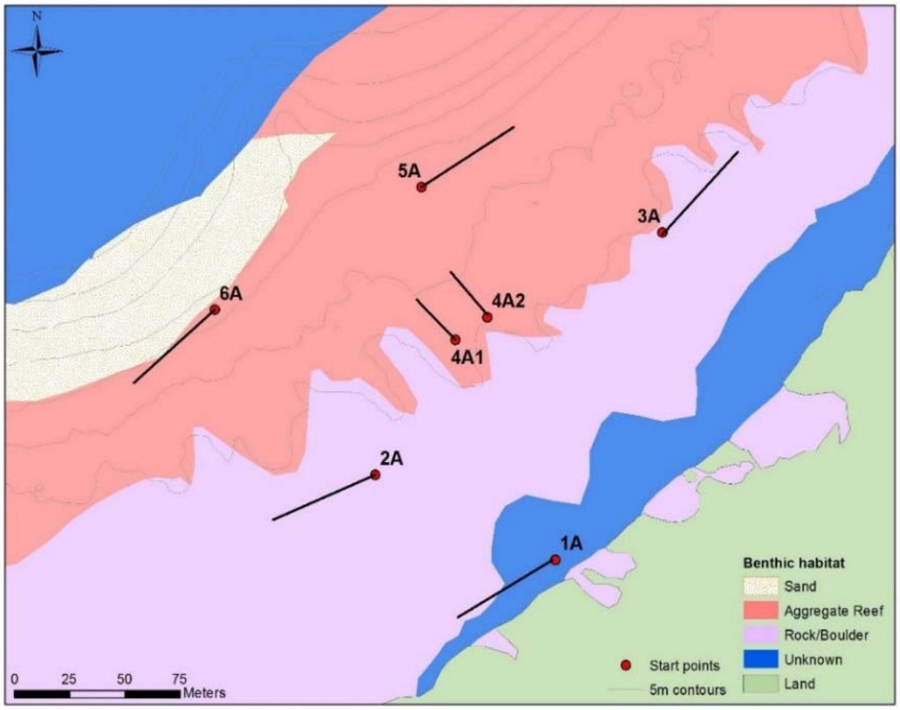

Figure 2. Location of transects at Puakō (Site "A"). Benthic habitat classifications based on NOAA data (Battista et al. 2007).

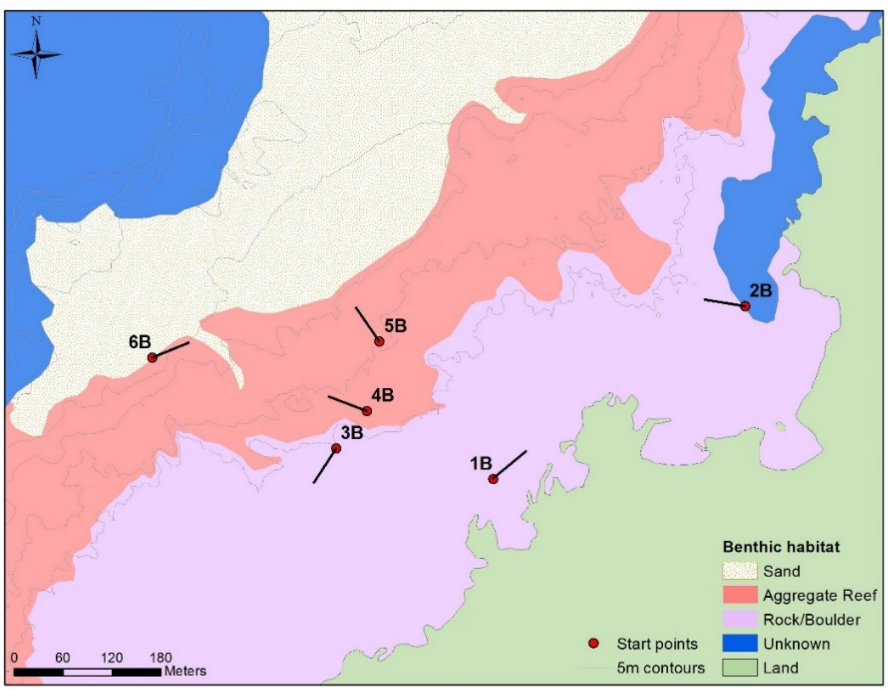

Figure 3. Location of transects at Pauoa (Site "B"). Benthic habitat classifications based on NOAA data.

For each fish transect survey in the original study, two divers swam abreast and counted all fish within each 5 m increment, in sequential "instantaneous" counts along the 50 m transect line. Two replicate surveys were performed, one day apart, within 1 or 2 hours of the same time of day. In the original study, transect 1B was surveyed 2 times, all other Pauoa transects were surveyed 8 times, and all Puakō transects were surveyed between 10 and 12 times.

Benthic surveys were performed on the same transects, by a diver who placed a 0.5 m^2 quadrat at 10 random locations along the transect line and recorded the substrate type under each of 36 equally spaced intersections of monofilament line strung within a quadrat frame.

2007-2008 Study

The 12 transect areas surveyed by Hayes et al. (1982) were relocated by Hawai'i State Division of Aquatic Resources (DAR) personnel in 2007, using maps and descriptive information contained in the original report. Descriptions of the transect locations are contained in Appendix 1.

In the 2008 study, DAR personnel repeated the fish transect surveys, using methodology identical to the original study, with the exception of the addition of size estimates (in 5 cm increments) for each fish counted. Each transect was surveyed 12 times, with six rounds of two surveys performed, when possible, one day apart, consistent with the methodology and seasonality of the original study design. For the benthic resurveys, percent cover estimates for benthic taxa were based on digital photo-quadrats, which were analyzed with CPCe random point-count software (Walsh et al. 2013).

Data analyses were conducted to the species level, and also on various groupings of fishes: trophic guilds, phylogenetic families, lay net species, resource (i.e. food) fish species, aquarium species and non-targeted species (i.e. neither aquarium nor resource fish species). Lay net species are defined as all species recorded as captured by gill net in Hayes et al. (1982), as well as those captured in lay nets in a more recent net study performed on Molokai (Puleloa 2012). We restricted lay net analyses to the shallower inshore transects accessible to lay net fishermen. "Aquarium fish species" are the top 20 most commonly collected fish species reported in the West Hawai'i commercial aquarium fishery. These 20 species account for well over 95% of the West Hawai'i fish commercially collected. "Resource fish species" included over 60 species targeted by recreational and commercial fishermen in Hawai'i, several of which are also targeted as juveniles by the aquarium fishery.

Notably, abundance data from the original study (numbers per 1000 m^2) are presented here in terms of numbers per 100 m^2. More importantly, the original study included no variance information (i.e. standard deviation) which precludes standard statistical comparisons between the two study periods. In an effort to address this methodological shortcoming, 95% confidence intervals are presented for the 2007-08 data when direct comparisons with the original study are made. The confidence interval provides a way of assessing whether original fish densities are outside the range of current fish densities and therefore highly likely to be real and meaningful.

RESULTS

Fish abundance and diversity

Striking differences between the abundance of fishes in the historical (1978-1981) and recent (2007-2008) surveys were observed. Overall, when compared with the historical surveys, fish abundances were substantially lower at both Puakō and Pauoa (Figure 4). At Puakō, the total relative decrease in fish abundance ranged from -43% to -69%, and at Pauoa, the total decrease ranged from -49% to -76%.

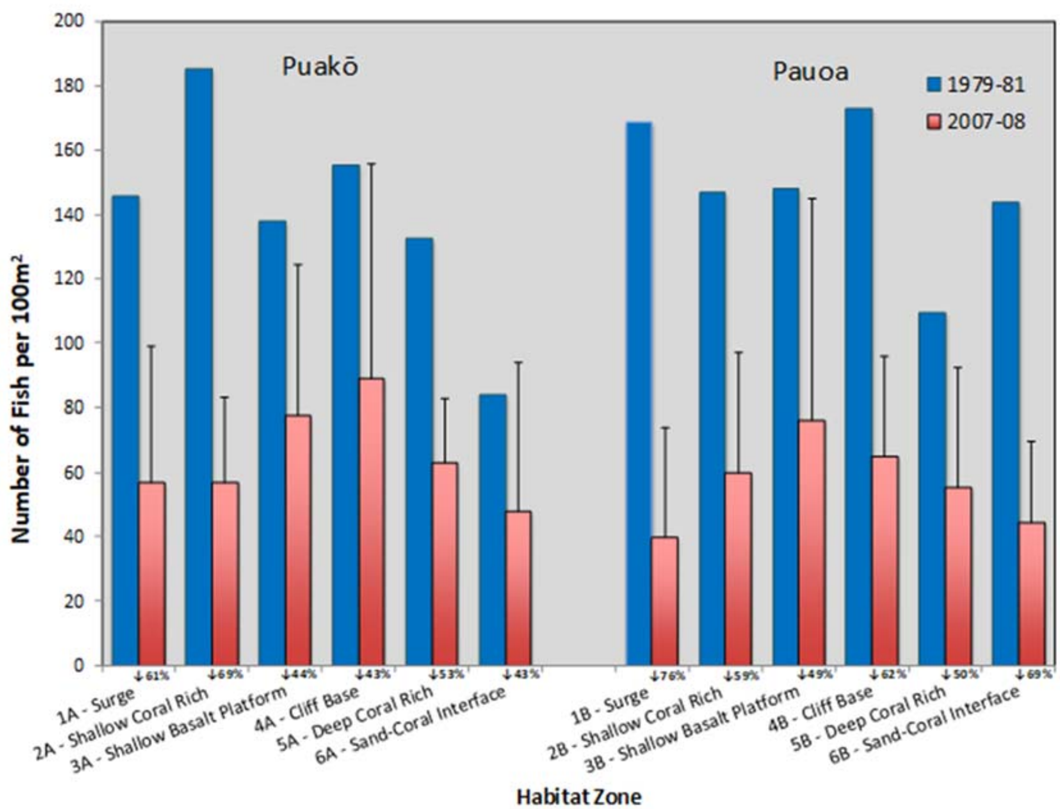

Figure 4: Average total abundance of reef fish communities at Puakō (transects 1A-6A) and Pauoa (transects 1B-6B) in number of per 100m^2. Error bars represent a 95% confidence interval of the mean (one tailed).

Of the 35 most abundant reef fish species at the Puakō sites, comprising 92% of all fishes present in the 1978-1981 surveys, 31 declined in abundance, ranging from a slight relative decline in Yellow Tang, *Zebrasoma flavenscens* (-9%), to an enormous relative decline in Achilles Tang, *Acanthurus achilles* (-97%) (Table 1). Other substantial declines were noted for Goldring Surgeonfish, *Ctenochaetus strigosus*, (-61%), Yellowstripe Goatfish, *Mulloidichthys vanicolensis* (-86%), and the Hawaiian Sergeant, *Abudefduf abdominalis* (- 98%). Only 4 of the top 35 fish species increased in abundance at Puakō, including Brighteye Damselfish, *Plectroglyphidodon imparipennis* (+51.0%), Blackfin Chromis, *Chromis vanderbilti* (+50.7%), Belted Wrasse, *Stethojulis balteata* (+16.7%), and Black Durgon, *Melichthyes niger* (+2.2%).

Table 1. Change in abundance from 1979-81 to 2007-08 for the 35 most abundant reef fish species at **Puakō**. Abundance values for each time period represent the mean number of fish per 100 m^2 on all transects combined. Δ is the numerical change in density and Δ (%) is the percent change in density between the two study periods.

Family	**Scientific Name**	**Common Name**	**1979-81 (#/100m²)**	**2007-08 (#/100m²)**	**Δ**	**Δ (%)**
Acanthuridae	*Acanthurus nigrofuscus*	Brown Surgeonfish	21.13	4.23	-16.90	-80.0%
Acanthuridae	*Ctenochaetus strigosus*	Kole	21.00	8.14	-12.86	-61.2%
Labridae	*Thalassoma duperrey*	Saddle Wrasse	17.99	8.37	-9.62	-53.5%
Acanthuridae	*Zebrasoma flavescens*	Yellow Tang	9.89	9.01	-0.88	-8.9%
Pomacentridae	*Stegastes marginatus*	Pacific Gregory	7.33	1.36	-5.97	-81.4%
Labridae	*Gomphosus varius*	Bird Wrasse	4.11	3.19	-0.92	-22.4%
Pomacentridae	*Abudefduf abdominalis*	Hawaiian Sergeant	4.08	0.10	-3.98	-97.5%
Chaetodontidae	*Chaetodon multicinctus*	Multiband Butterflyfish	3.56	0.49	-3.07	-86.2%
Cirrhitidae	*Paracirrhites arcatus*	Arc-Eye Hawkfish	3.39	1.34	-2.05	-60.5%
Labridae	*Stethojulis balteata*	Belted Wrasse	3.36	3.92	+0.56	+16.7%
Pomacentridae	*Chromis agilis*	Agile Chromis	3.08	2.52	-0.56	-18.2%
Pomacentridae	*Plectroglyphidodon johnstonianus*	Blue-Eye Damselfish	2.88	0.57	-2.31	-80.2%
Pomacanthidae	*Centropyge potteri*	Potter’s Angelfish	2.68	0.18	-2.50	-93.3%
Acanthuridae	*Naso lituratus*	Orangespine Unicornfish	2.54	0.43	-2.11	-83.1%
Pomacentridae	*Chromis vanderbilti*	Blackfin Chromis	2.11	3.18	+1.07	+50.7%
Pomacentridae	*Chromis hanui*	Chocolate-Dip Chromis	1.56	0.22	-1.34	-85.9%
Chaetodontidae	*Forcipiger flavissimus*	Forcepsfish	1.45	0.44	-1.01	-69.7%
Balistidae	*Melichthys niger*	Black Durgon	1.38	1.41	+0.03	+2.2%
Pomacentridae	*Dascyllus albisella*	Hawaiian Dascyllus	1.38	0.86	-0.52	-37.7%
Scaridae	*Scarus sp.*	Parrotfish	1.37	0.11	-1.26	-92.0%
Acanthuridae	*Acanthurus leucopareius*	Whitebar Surgeonfish	1.05	0.49	-0.56	-53.3%
Pomacentridae	*Plectroglyphidodon imparipennis*	Brighteye Damselfish	1.04	1.57	+0.53	+51.0%
Blenniidae	*Cirripectes vanderbilti*	Scarface Blenny	0.99	0.09	-0.90	-90.9%
Balistidae	*Sufflamen bursa*	Lei Triggerfish	0.95	0.36	-0.59	-62.1%
Acanthuridae	*Naso hexacanthus*	Sleek Unicornfish	0.94	0.55	-0.39	-41.5%

Acanthuridae	*Acanthurus achilles*	Achilles Tang	0.89	0.03	-0.86	-96.6%
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe Goatfish	0.86	0.12	-0.74	-86.0%
Mullidae	*Parupeneus multifasciatus*	Manybar Goatfish	0.84	0.33	-0.51	-60.7%
Cirrhitidae	*Cirrhitops fasciatus*	Redbarred Hawkfish	0.73	0.10	-0.63	-86.3%
Labridae	*Oxycheilinus unifasciatus*	Ringtail Wrasse	0.69	0.42	-0.27	-39.1%
Labridae	*Pseudocheilinus evanidus*	Disappearing Wrasse	0.66	0.48	-0.18	-27.3%
Balistidae	*Xanthichthys auromarginatus*	Gilded Triggerfish	0.64	0.07	-0.57	-89.1%
Tetraodontidae	*Canthigaster jactator*	HI Whitespotted Toby	0.61	0.30	-0.31	-50.8%
Chaetodontidae	*Chaetodon ornatissimus*	Ornate Butterflyfish	0.60	0.38	-0.22	-36.7%
Chaetodontidae	*Chaetodon quadrimaculatus*	Fourspot Butterflyfish	0.60	0.05	-0.55	-91.7%

A similar, and even more pronounced downward trend in fish abundance was apparent at the Pauoa sites (Table 2). Of the 35 most abundant fish species, 31 declined in abundance, ranging from a slight relative decline in Bird Wrasse, *Gomphosus varius* (-6%), to a total absence of the Threespot Chromis, *Chromis verater* (-100%). Similar to the Puakō sites, Goldring Surgeonfish, *Ctenochaetus strigosus*, decreased by 71% and the Hawaiian Sergeant, *Abudefduf abdominalis*, decreased by 99%. Of the top 35 species, the only 4 that increased in abundance at Pauoa were Yellow Tang, *Zebrasoma flavenscens* (+14.8%), Bullethead Parrotfish, *Chlorurus spilurus* (+186.2%), Brighteye Damselfish, *Plectroglyphidodon imparipennis* (+43.1%), and Blackfin Chromis, *Chromis vanderbilti* (+203.4%).

Table 2. Change in fish abundance from 1979-81 to 2007-08 of Top 35 Species at **Pauoa**. Numbers for each time period represent the mean number of fish per 100m^2 on all transects combined. Δ is the numerical change in density and Δ (%) is the percent change in density between the two study periods.

Family	**Scientific Name**	**Common Name**	**1979-81 (#/100m^2)**	**2007-08 (#/100m^2)**	**Δ**	**Δ (%)**
Acanthuridae	Acanthurus nigrofuscus	Brown Surgeonfish	31.68	5.63	-26.05	-82.2%
Acanthuridae	*Ctenochaetus strigosus*	Kole	29.04	8.53	-20.51	-70.6%
Labridae	*Thalassoma duperrey*	Saddle Wrasse	16.53	6.76	-9.77	-59.1%
Labridae	*Stethojulis balteata*	Belted Wrasse	7.50	3.83	-3.67	-48.9%
Acanthuridae	*Zebrasoma flavescens*	Yellow Tang	5.86	6.73	+0.87	+14.8%
Pomacentridae	*Stegastes marginatus*	Pacific Gregory	4.79	1.57	-3.22	-67.2%
Chaetodontidae	*Chaetodon multicinctus*	Multiband Butterflyfish	4.22	0.46	-3.76	-89.1%
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe Goatfish	3.56	0.08	-3.48	-97.8%
Cirrhitidae	*Paracirrhites arcatus*	Arc-Eye Hawkfish	3.46	1.34	-2.12	-61.3%
Labridae	*Gomphosus varius*	Bird Wrasse	2.39	2.25	-0.14	-5.9%

Pomacanthidae	*Centropyge potteri*	Potter's Angelfish	2.33	0.04	-2.29	-98.3%
Pomacentridae	*Chromis agilis*	Agile Chromis	2.12	0.79	-1.33	-62.7%
Pomacentridae	*Chromis hanui*	Chocolate-Dip Chromis	1.91	0.24	-1.67	-87.4%
Pomacentridae	*Plectroglyphidodon johnstonianus*	Blue-Eye Damselfish	1.77	0.54	-1.23	-69.5%
Scaridae	*Scarus sp.*	Parrotfish	1.74	0.30	-1.44	-82.8%
Pomacentridae	*Plectroglyphidodon imparipennis*	Brighteye Damselfish	1.53	2.19	+0.66	+43.1%
Chaetodontidae	*Forcipiger flavissimus*	Forcepsfish	1.24	0.21	-1.03	-83.1%
Pomacentridae	*Chromis vanderbilti*	Blackfin Chromis	1.19	3.61	+2.42	+203.4%
Mullidae	*Parupeneus multifasciatus*	Manybar Goatfish	1.13	0.39	-0.74	-65.5%
Mullidae	*Mulloidichthys vanicolensis*	Yellowfin Goatfish	1.00	0.04	-0.96	-96.0%
Labridae	*Oxycheilinus unifasciatus*	Ringtail Wrasse	0.93	0.23	-0.70	-75.3%
Acanthuridae	*Naso lituratus*	Orangespine Unicornfish	0.91	0.29	-0.62	-68.1%
Acanthuridae	*Acanthurus triostegus*	Convict Surgeonfish	0.90	0.49	-0.41	-45.6%
Balistidae	*Sufflamen bursa*	Lei Triggerfish	0.89	0.17	-0.72	-80.9%
Balistidae	*Melichthys niger*	Black Durgon	0.87	0.20	-0.67	-77.0%
Pomacentridae	*Abudefduf abdominalis*	Hawaiian Sergeant	0.85	0.01	-0.84	-98.8%
Pomacentridae	*Dascyllus albisella*	Hawaiian Dascyllus	0.85	0.12	-0.73	-85.9%
Cirrhitidae	*Cirrhitops fasciatus*	Redbarred Hawkfish	0.84	0.05	-0.79	-94.0%
Scaridae	*Scarus dubius*	Regal Parrotfish	0.84	0.28	-0.56	-66.7%
Tetraodontidae	*Canthigaster jactator*	HI Whitespotted Toby	0.71	0.53	-0.18	-25.4%
Acanthuridae	*Naso hexacanthus*	Sleek Unicornfish	0.70	0.14	-0.56	-80.0%
Scaridae	*Chlorurus spilurus*	Bullethead Parrotfish	0.58	1.66	+1.08	+186.2%
Labridae	*Halichoeres ornatissimus*	Ornate Wrasse	0.57	0.39	-0.18	-31.6%
Pomacentridae	*Chromis verater*	Threespot Chromis	0.55	0.00	-0.55	-100.0%
Balistidae	*Rhinecanthus rectangulus*	Reef Triggerfish	0.53	0.36	-0.17	-32.1%

The diversity of fish species seen on transects was similar between the two studies. The original study (1979-81) documented 29 families and 138 species of fish at Puakō, whereas the more recent DAR resurveys observed a total of 29 families and 148 species of fish at Puakō (Appendices 2 and 3). At Pauoa, 138 species comprising 29 families were found in the original surveys, and 148 species from 29 families were documented during the resurveys (Appendices 4 and 5).

A small number of fish species were noted in the original Hayes et al. (1982) study outside of the transects that were never seen by DAR divers on resurveys. Among these were the reef sharks, *Carcharhinus amblyrhinchos* and *Triaenodon obesus,* and the Thornback Cowfish, *Lactornia fornasini*.

Seventy-five fish species were recorded during only one survey period and/or only one site during each round of surveys ("unique species") (Appendix 6). Interestingly, more unique species were seen during the 2007-2008 surveys than during the earlier 1979-1981 surveys at Puako (27 vs. 21 spp.) and Pauoa (33 vs. 19 spp.). The abundance of most of these unique species was very low, precluding formal analysis of changes in density. Eight of these species were recorded at a moderately high density (> 20 individuals) during only one survey but were not observed in any other survey (Table 3).

Two popular aquarium fishes, the Blueline Butterflyfish (*Chaetodon fremblii*) and the Teardrop Butterflyfish (*C. unimaculatus*) were observed at Puakō sites during 1978-1981 surveys but were not detected in 2007- 2008. While still present at Pauoa sites during 2007-2008 resurveys, their abundance was substantially reduced. The Fantail Filefish (*Pervagor spilosoma*) was present at both sites in the original surveys, but not the more recent ones. Their earlier presence was likely a remnant of a large recruitment event that occurred in 1975 (Hutchins 1986). Notably, from 1999 to 2014, this species was not recorded at any of the DAR long-term monitoring sites. Additionally, three Holocentrid species and the Palenose Parrotfish (*Scarus psittacus*) were recorded only during the 2007-2008 surveys. *S. psittacus*, in particular, was quite abundant at both sites (> 0.70 individuals/100m^2). Previously, *S. psittacus* was known in Hawai'i by other names until a review by Randall and Ormond (1978). The name most frequently used was *Scarus forsteri*. Other names used were *Scarus gilberti*, *Scarus brunneus*, *Scarus jenkinsi*, *Callyodon gilberti*, *Callydon brunneus*, *Callyodon jenkinsi*, *Callyodon bataviensis*, *Callyodon forsteri*, *Scarus hornbosteli*, and *Scarus teniurus* (Bruce Mundy, personal communication). None of these species names were reported on the 1979-1981 surveys, so *S. psittacus* was likely recorded as *Scarus spp.*

Table 3. Relatively abundant fish species (>20 fish on all transects combined), which were recorded during only one survey period at one or both sites, presented as the mean number of fish/100 m^2 on all transects combined. Grayed-out numbers indicate that a species was recorded during both survey periods at a site but was "unique" between survey periods at the other site.

Family	Species	Puakō Site Mean (#/100m^2)		Pauoa Site Mean (#/100m^2)	
		1978-81	2007-08	1978-81	2007-08
Chaetodontidae	*Chaetodon fremblii*	0.06	-	0.12	<0.01
Chaetodontidae	*Chaetodon unimaculatus*	0.23	-	0.34	0.05
Holocentridae	*Myripristis berndti*	-	0.09	-	0.11
Holocentridae	*Myripristis kuntee*	-	0.38	-	0.13
Holocentridae	*Neoniphon sammara*	<0.01	0.13	-	0.11
Monacanthidae	*Pervagor spilosoma*	0.13	-	0.16	-
Pomacentridae	*Chromis verater*	0.11	-	0.55	-
Scaridae	*Scarus psittacus*	-	0.73	-	1.02

Trends by Fish Family

Nine of the top ten most abundant fish families in the original study, representing more than 97% of all fishes, decreased in abundance at both Puakō and Pauoa (Table 4). Only the family Scaridae (parrotfishes) increased between survey periods, primarily due to an increase in the abundance of Bullethead Parrotfish, *Chlorurus spilurus*, at the Pauoa site (Table 2) and to lesser extent by an increase in Palenose Parrotfish, *Scarus psitticus*, at both sites (Table 3).

Table 4: Mean fish abundance (#/100m^2 (SE)) for the top ten most abundant fish families at the six transects/habitat types at each site. Δ is the numerical change in fish density and Δ (%) is the percent change between the two study periods. Families whose abundances have increased at one or both sites are shown in bold.

Family	**Puakō**					**Pauoa**			
	1979-81 (#/100m^2)	**2007-08 (#/100m^2)**	**Δ**	**Δ (%)**		**1979-81 (#/100m^2)**	**2007-08 (#/100m^2)**	**Δ**	**Δ (%)**
Acanthuridae	58.56	22.44(2.65)	-36.12	-61.68%		70.46	22.40(1.51)	-48.06	-68.21%
Balistidae	3.48	2.28(0.63)	-1.20	-34.48%		2.57	0.88(0.04)	-1.69	-65.76%
Blenniidae	1.42	0.29(0.05)	-1.13	-79.58%		0.93	0.44(0.05)	-0.49	-52.69%
Chaetodontidae	7.33	1.63(0.14)	-5.70	-77.76%		7.50	1.21(0.13)	-6.29	-83.87%
Cirrhitidae	4.43	1.44(0.06)	-2.99	-67.49%		4.61	1.51(0.19)	-3.10	-67.25%
Labridae	29.25	17.00(1.18)	-12.25	-41.88%		30.48	14.76(1.09)	-15.72	-51.57%
Mullidae	2.56	0.55(0.08)	-2.01	-78.52%		6.60	0.61(0.09)	-5.99	-90.76%
Pomacanthidae	2.68	0.19(0.03)	-2.49	-92.91%		2.30	0.05(0.01)	-2.25	-97.83%
Pomacentridae	23.66	9.92(0.81)	-13.74	-58.07%		15.55	9.30(1.30)	-6.25	-40.19%
Scaridae	**2.36**	**3.27(0.30)**	**+0.91**	**38.56%**		**3.45**	**3.74(0.25)**	**+0.29**	**8.41%**

A drastic decline in abundance was observed for the family Pomacanthidae (Angelfishes), which was the result of a sharp reduction in a single species, the Potter's Angelfish *(Centropyge potteri)*, which is by far, the most common angelfish in Hawai'i (Randall 2007) (Tables 1, 2, and 4). The more recent surveys also documented the presence of two other angelfish species, Fisher's Angelfish (*C. fisheri*) and Flame Angelfish (*C. loricula*), which were absent during the 1978-1981 surveys (Appendix 6). The abundance of these two species in the more recent survey was very low, however.

Trends by Trophic Group

The extensive, long-term decline in fish abundance at both South Kohala sites was not limited only to fishes that eat a certain kind of food. All trophic categories of fishes decreased in abundance, ranging from a 36% decline of piscivores (species that consume fish) at Puakō to a 65% decrease in herbivores/detritivores at Pauoa (Table 5). Additionally, herbivores/detritivores had the largest decline in abundance at Pauoa (-54%) compared to the other trophic groups. Observed declines in herbivores/detritivores at both study sites was driven largely by the loss of surgeonfishes (Table 4), as parrotfish abundances have remained relatively constant (Pauoa), or increased (Puakō), over the course of the study (Table 4).

Piscivores, the least abundant trophic group, declined over time at both sites despite increases of the Peacock Grouper, *Cephalopholis argus* or "roi", which was introduced to West Hawai'i in 1956. During all of the original 111 surveys conducted in 1979-1981, only seven *C. argus* individuals were counted, whereas in the subsequent 144 surveys completed in 2007-2008, 182 *C. argus* individuals were counted. At Puakō, the abundance of *C. argus* increased 26-fold between survey periods while at Pauoa they increased 12-fold. The increase in *C. argus* has been tempered by a more recent widespread decline in abundance in West Hawai'i, likely associated with an unexplained die-off around 2005-2006. At nearby DAR permanent monitoring sites (part of the West Hawai'i Aquarium Project – WHAP), *C. argus* has decreased by 66% at Puakō and by 74% at Pauoa over the last decade (DAR data).

Table 5: Mean abundance (#/100m^2 (SE) of fishes by trophic group averaged for all six sites (habitat types) at Puakō and Pauoa. Δ is the numerical change in density and Δ (%) is the percent change between the two study periods.

Trophic Group	Puakō				Pauoa			
	1979-81 (#/100m^2)	2007-08 (#/100m^2)	Δ	Δ (%)	1979-81 (#/100m^2)	2007-08 (#/100m^2)	Δ	Δ (%)
Herbivores/ Detritivores	73.58	31.92 (3.56)	-41.66	-56.62%	83.18	28.74 (2.70)	-54.44	-65.45%
Invertivores	49.36	25.08 (2.25)	-24.28	-49.19%	53.93	21.56 (1.99)	-32.37	-60.02%
Planktivores	15.00	8.17 (1.37)	-6.83	-45.53%	9.17	5.44 (1.27)	-3.73	-40.68%
Piscivores	2.14	1.37 (0.44)	-0.77	-35.98%	1.99	0.99 (0.17)	-1.00	-50.25%

Individuals of 13 other piscivorous species were observed during both the initial and more recent surveys (Appendices 7 and 8). Individuals of two species, Bluefin Trevally (*Caranx melampygus*) and Island Jack (*Carangoides orthogrammus*) were present on transects only during the resurveys in 2007-2008. Both species were noted as present at Puakō and Pauoa during the 1979-1981 surveys but were not recorded on the transects.

Potential fishing impacts

One major difference between Puakō and Pauoa is that lay net fishing and aquarium collecting were prohibited at Puakō considerably earlier than at Pauoa. Puakō has been protected from all forms of net fishing (with the exception of thow nets) since 1985, thus effectively prohibiting aquarium fish collecting. In contrast, Pauoa received protection from aquarium collecting recently in 2000 and lay net fishing in 2005. Both sites allow most other types of recreational fishing, excluding SCUBA spearfishing which was prohibited coastwide in 2013.

Generally, considerably fewer fish of lay net targeted species are found on shallow reef areas today, versus the original study (Figure 5). During the more recent surveys in 2007-2008, no difference was found between Puakō and Pauoa for transects in habitat zones 2 and 3 (t-tests, both $p > 0.3$), but transect 1A (Puakō) had a higher mean abundance of lay net fishery species than transect 1B ($t = 4.9$, $p < 0.001$), representing the shallow surge zone (Figure 5). Examination of the raw data, however, reveals that a single species, Saddle Wrasse (*Thalassoma duperrey*), significantly influences this result (Appendices 7 and 8). While *T. duperrey* is taken by lay net and other fishing methods, and is sometimes kept by fishermen, it is not a highly valued resource fish in Hawai'I (Demartini et al. 2010). If *T. duperrey* is removed from the analysis, there is no significance difference in the abundance of lay net species between transects Puakō 1A (17.80/100m^2) and Pauoa 1B (11.28/100m^2) in the most recent surveys ($t= 0.6$, $p > 0.6$). The duration of protection from lay nets thus does not seem to be an important factor at these sites.

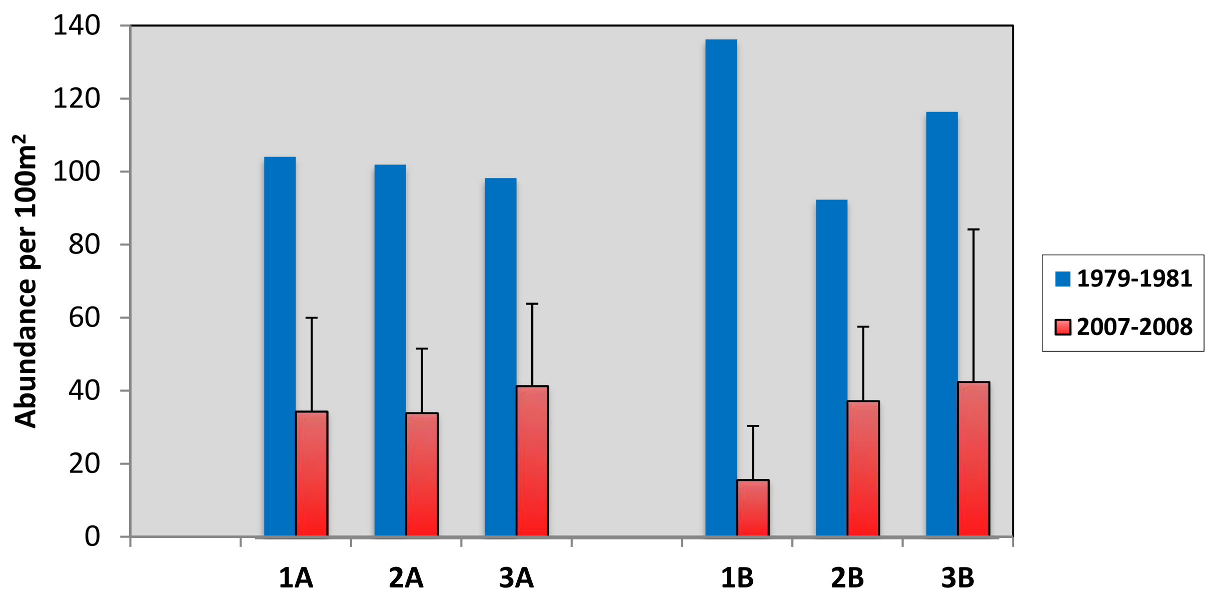

Figure 5: Average abundance of lay net species on shallow transects at Puakō (1A-3A) and Pauoa (1B-3B). Error bars represent 95% confidence interval of the mean (one tailed).

Most of the top ten most collected aquarium fish species declined at both sites between survey periods (Table 6). A notable exception was the number one collected aquarium fish in Hawai'i, the Yellow Tang, *Zebrasoma flavescens*, which increased by almost 15% at Pauoa while decreasing slightly at Puakō (- 8.9 %). The Black Surgeonfish, *Ctenochaetus hawaiiensis,* was the only other species that increased in abundance, and only at the Puakō site. The remaining eight species declined in abundance, with the largest absolute decreases occurring in the Goldring Surgeonfish, *C. strigosus*, and the Brown Surgeonfish, *Acanthurus nigrofuscus* (Table 6). The former (aka Kole) is also a popular food fish while the latter is not. *A. nigrofuscus* was ranked seventh for aquarium catch with 2,476 fish collected in FY 2008 in West Hawai'i, representing only 0.7% of all aquarium fish taken. Additional aquarium fish species are not included, because their abundances are less than 0.03/100m^2, making it nearly impossible to detect any meaningful change in abundance over time.

Table 6: Abundance (#/100m^2) of the top ten most abundant aquarium fish species at Puakō and Pauoa. Collection rankings were based on FY 2009 aquarium catch data. Standard error for 2007-2008 surveys is included in Appendices 3 and 5. Δ is the numerical change in density and Δ (%) is the percent change between the two study periods. Species whose abundances have increased at one or both sites are shown in bold.

Species	Puakō				Pauoa			
	1979-81	2007-08	Δ	% (Δ)	1979-81	2007-08	Δ	Δ (%)
Zebrasoma flavescens	9.89	9.01	-0.88	-8.9%	**5.86**	**6.73**	**+0.87**	**+14.8%**
Ctenochaetus strigosus	21.00	8.14	-12.86	-61.2%	29.04	8.53	-20.51	-70.6%
Naso lituratus	2.54	0.43	-2.11	-83.1%	0.91	0.29	-0.62	-68.1%
Acanthurus achilles	0.89	0.03	-0.86	-96.6%	0.36	0.06	-0.30	-83.3%
Forcipiger flavissimus	1.45	0.44	-1.01	-69.7%	1.24	0.21	-1.03	-83.1%
Acanthurus nigrofuscus	21.13	4.23	-16.9	-80.0%	31.68	5.63	-25.93	-82.2%
Chaetodon multicinctus	3.56	0.49	-3.07	-86.2%	4.22	0.46	-3.76	-89.1%
Zanclus cornutus	0.52	0.04	-0.48	-92.3%	0.52	0.05	-0.47	-90.4%
Ctenochaetus hawaiiensis	**0.03**	**0.04**	**+0.01**	**+33.3%**	**0.00**	**0.03**	**+0.03**	na
Centropyge potteri	2.68	0.18	-2.50	-93.3%	2.33	0.04	-2.29	-98.3%

The abundance of eight of the top ten most common resource fish species (i.e. food fishes), decreased markedly over time (Table 7). While decreases occurred at both sites, they were of greater magnitude at Pauoa than Puakō. This may indicate that the net fishing ban confers some protection to reef fish species, or perhaps the length of time each site has been protected influenced this result. Only the Bullethead Parrotfish, *Chlorurus spilurus*, increased substantially, despite the fact that they are a targeted fishery species (Giddens 2010). *C. spilurus* increased in all surveyed habitats, but the increase in abundance was particularly evident for Zone 4, the cliff base zone (Figure 6).

Table 7: Abundance (#/100m^2) of the top ten most abundant resource fishery species (not including species that are both aquarium fishery and resource fishery species). Standard error for 2007-2008 surveys is included in Appendices 3 and 5. Δ is the numerical change in density and Δ (%) is the percent change between the two study periods. Species whose abundances have increased at one or both sites are shown in bold.

Species	Puakō				Pauoa			
	1979-81	2007-08	Δ	Δ (%)	1979-81	2007-08	Δ	Δ (%)
Abudefduf abdominalis	4.08	0.10	-3.98	-97.4	0.85	0.01	-0.74	-98.8
Melichthys niger	**1.38**	**1.41**	**+0.03**	**+2.2**	0.87	0.20	-0.67	-77.0
Acanthurus leucopareius	1.05	0.49	-0.56	-53.3	0.48	0.01	-0.47	-97.9
Naso hexacanthus	0.94	0.55	-0.39	-41.4	0.70	0.14	-0.56	-80.0
Mulloidichthys flavolineatus	0.86	0.12	-0.74	-86.0	3.56	0.08	-3.48	-97.7
Parupeneus multifasciatus	0.84	0.33	-0.51	-60.7	1.13	0.39	-0.74	-65.5
Oxycheilinus unifasciatus	0.69	0.42	-0.27	-39.1	0.93	0.23	-0.70	-75.3
Chlorurus spilurus	**0.51**	**1.88**	**+1.37**	**+268.6**	**0.58**	**1.66**	**+1.08**	**+186.2**
Aulostomus chinensis	0.46	0.13	-0.33	-71.7	0.24	0.02	-0.22	-91.7
Mulloidichthys vanicolensis	0.36	0.03	-0.33	-91.7	1.00	0.04	-0.96	-96.0

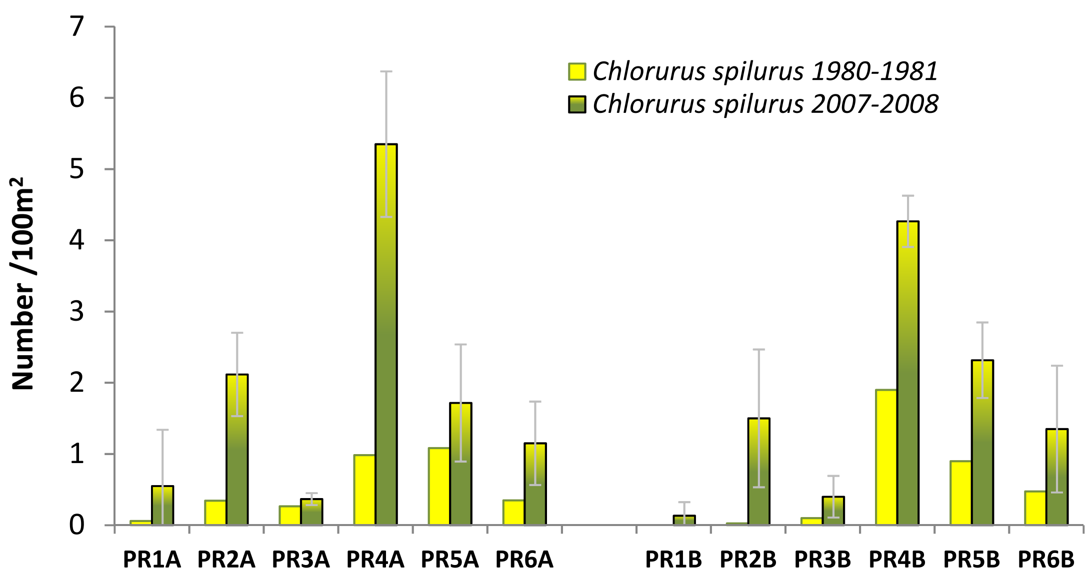

Figure 6: Abundance of the bullethead parrotfish, *Chlorurus spilurus*, at Puakō and Pauoa.

Even fish species which were not targeted by food or aquarium fishers declined over the decades. Of the top ten most abundant non-targeted fish species, only three did not decrease in abundance at either of the sites (Table 8). All three were small bodied species which feed on small invertebrates or plankton: Blackfin Chromis (*Chromis vanderbilti)*, Brighteye Damselfish (*Plectroglyphidodon imparipennis)*, and Belted Wrasse (*Stethojulis balteata*).

Table 8: Abundance (#/100m^2) of the top ten non-aquarium, non-fishery target species. Standard error for 2007-2008 surveys is included in Appendices 3 and 5. Δ is the numerical change in density and Δ (%) is the percent change between the two study periods. Species whose abundances have increased at one or both sites are shown in bold.

Species	Puakō				Pauoa			
	1979-81	2007-08	Δ	Δ (%)	1979-81	2007-08	Δ	Δ (%)
Chromis agilis	3.08	2.52	-0.56	-18.2	2.12	0.79	-1.33	-62.7
Chromis hanui	1.56	0.22	-1.34	-85.9	1.91	0.24	-1.67	-87.4
Plectroglyphidodon imparipennis	**1.04**	**1.57**	**+0.53**	**+51.0**	**1.53**	**2.19**	**+0.66**	**+43.1**
Chromis vanderbilti	**2.11**	**3.18**	**+1.07**	**+50.7**	**1.19**	**3.61**	**+2.42**	**+203.4**
Gomphosus varius	4.11	3.19	-0.92	-22.4	2.39	2.25	-0.14	-5.9
Plectroglyphidodon johnstonianus	2.92	0.52	-2.40	-82.2	1.77	0.54	-1.23	-69.5
Stegastes marginatus	7.33	1.36	-5.97	-81.4	4.79	1.57	-3.22	-67.2
Stethojulis balteata	**3.36**	**3.92**	**+0.56**	**+16.7**	7.50	3.83	-3.67	-48.9
Thalassoma duperrey	18.0	8.37	-9.62	-53.5	16.5	6.76	-9.77	-59.1
Paracirrhites arcatus	3.39	1.34	-2.05	-60.5	3.46	1.34	-2.12	-61.3

The magnitude of decline in abundances of resource fishes (targeted food fish species), aquarium species, and other species was fairly similar in scope across the various surveyed habitat zones at Puakō (Table 9). Overall, declines at Pauoa appeared to be greater than they were at Puakō (overall site average declines: -45.5% at Puakō and -64.5% at Pauoa). Shallow transect 1B at Pauoa declined most precipitously, which may indicate an effect of lay net fishing, which was allowed at this site until 2005 (and prohibited at Puakō since 1985). However, due to relative difficulty of access, only two surveys were performed at transect 1B during the 1979-1981 study, which precludes conclusive statistical comparison to the more recent surveys at this site.

Table 9: Overall percentage change in abundance by transect (i.e. habitat) for resource fishes, aquarium species, and all other species at Puakō and Pauoa.

Site	Transect					
Puakō	**1A**	**2A**	**3A**	**4A**	**5A**	**6A**
Resource Species	-55.0	-46.3	-57.9	-30.6	-28.3	-55.6
Aquarium Species	-57.6	-41.7	-52.7	-25.0	-36.9	-31.8
Other Species	-47.7	-60.8	-48.6	-27.8	-51.3	-63.8
Pauoa	**1B**	**2B**	**3B**	**4B**	**5B**	**6B**
Resource Species	-94.6	-52.6	-83.6	-85.0	-61.1	-66.3
Aquarium Species	-95.7	-33.3	-87.2	-97.9	-67.4	-76.2
Other Species	-92.0	-2.8	-76.5	-47.7	-63.4	-44.7

For the majority of fish species analyzed, the estimated maximum fish size in total length observed in the 2007-2008 surveys decreased when compared to special survey data included in Hayes et al. (1982) (Table 10). The estimated maximum fish sizes recorded by DAR divers during 2007-2008 surveys, align fairly closely with maximum measured lengths observed in the recent creel survey by The Nature Conservancy of Hawai'i (Giddens 2010). Notably, popularly targeted goatfish species, the Yellowstripe Goatfish, *Mulloidichthys flavolineatus*, and the Manybar Goatfish, *Parupeneus multifasciatus*, did not decrease in size since the original study. However, overall abundance for both species decreased at both study sites (Table 4).

Table 10: Estimated maximum sizes (cm) for eight reef fish species. Data are maximum total length measurements from collections for a size-at-maturity study (Hayes 1982), 2010 creel surveys by The Nature Conservancy (Giddens 2010), and underwater visual census estimates of fish recorded by Division of Aquatic Resources divers (DAR 2007-2008). Data is adapted from Minton et al. (2012). For smaller fishes, DAR estimates size in 5 cm categorical bins, and fishes over 25 cm are estimated to the nearest 5 cm total length. The Brick Soldierfish, *Myripristis amaena*, was not observed by DAR divers during the recent re-surveys. Species in bold do not appear to have decreased in size over time.

Species	Hayes et al. 1982	TNC 2010	DAR 2007-2008	~Δ (%)
Acanthurus nigrofuscus	**17.6**	**21**	**15-20**	**-14.8 to 13.6**
Abudefduf sordidus	23.6	25	15-20	-36.4 to -15.3
Myripristis amaena	26.5	20	N/A	N/A
Myripristis berndti	27.9	23	25	-10.4
Cirrhites pinnulatus	27.6	23	20-25	-27.5 to -9.4
Naso lituratus	47.8	40	35	-26.8
Mulloidichthys flavolineatus	**33.5**	**33**	**40**	**19.4**
Parupeneus multifasciatus	**25.9**	**30**	**30**	**15.8**

Only the 2007-2008 resurvey included specific fish size during belt transect surveys (Appendices 7 and 8), and notably, the parrotfishes observed in the resurveys were relatively small. For the Bullethead Parrotfish, *C. spilurus*, maximum length is reported to be 40 cm, length at reproduction is 14.4 cm, and a "prime spawner" would be 28.8 cm (Williams et al. 2008, Taylor and Choat 2014). A prime spawner is a fish with a size ~ 70% of the maximum total length, and contributes disproportionately more to reproductive output (Birkeland and Dayton 2005). The size frequency distribution for all *C. spilurus* observed in the 2007-2008 resurveys (Figure 7) indicates that size frequency peaked at 10-15 cm total length, which according to the sources above, would be minimally fecund. Individuals > 28.8 cm total length (prime spawners) were present at Puakō and Pauoa, but at a relatively low frequency.

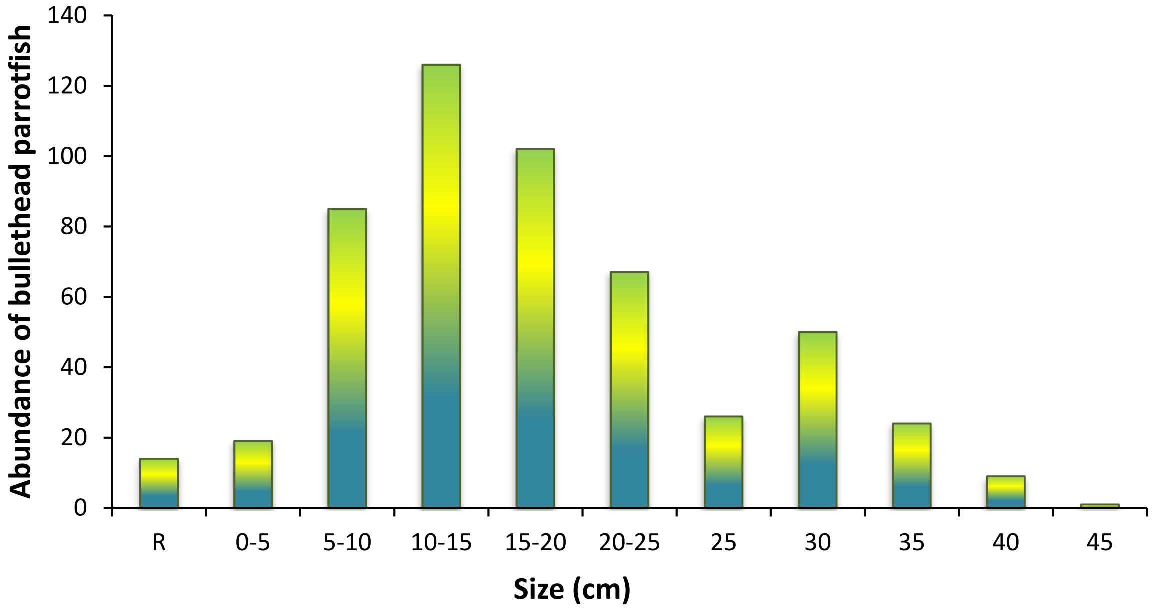

Figure 7: Size frequency distribution of the Bullethead Parrotfish*, Chlorurus spilurus*, observed during 2007-2008 surveys at Puakō and Pauoa sites combined. Abundance is the total number counted during all re-surveys, and "R" indicates a very recently recruited fish.

Similar patterns were observed for the three other common parrotfish species: Stareye Parrotfish *Calotomus carolinus*, Palenose Parrotfish *Scarus psittacus*, and Redllip Parrotfish *Scarus rubroviolaceus* (Figure 8). According to Taylor and Choat (2014) who surveyed parrotfish assemblages in Guam, the length at maturity for *Calotomus carolinus* is 16.8 cm, *Scarus psittacus* is 10.3 cm, and *Scarus rubroviolaceus* is 27.1 cm. Importantly, life history patterns of parrotfishes can vary according to fishing pressures and local conditions (Hawkins and Roberts 2003, Taylor and Choat 2014). The "prime spawner" size for highly targeted resource fishes *C. carolinus* and *S. rubroviolaceus* are 37.8 and 49.0 cm, respectively, and *S. psittacus*, which is a less desirable species, has a prime spawner length of 23.1 cm. Very few *C. carolinus* were observed above the length of maturity, whereas *S. psittacus* and *S. rubroviolaceus* stocks were more right distributed, with larger individuals indivduals observed at a low frequency.

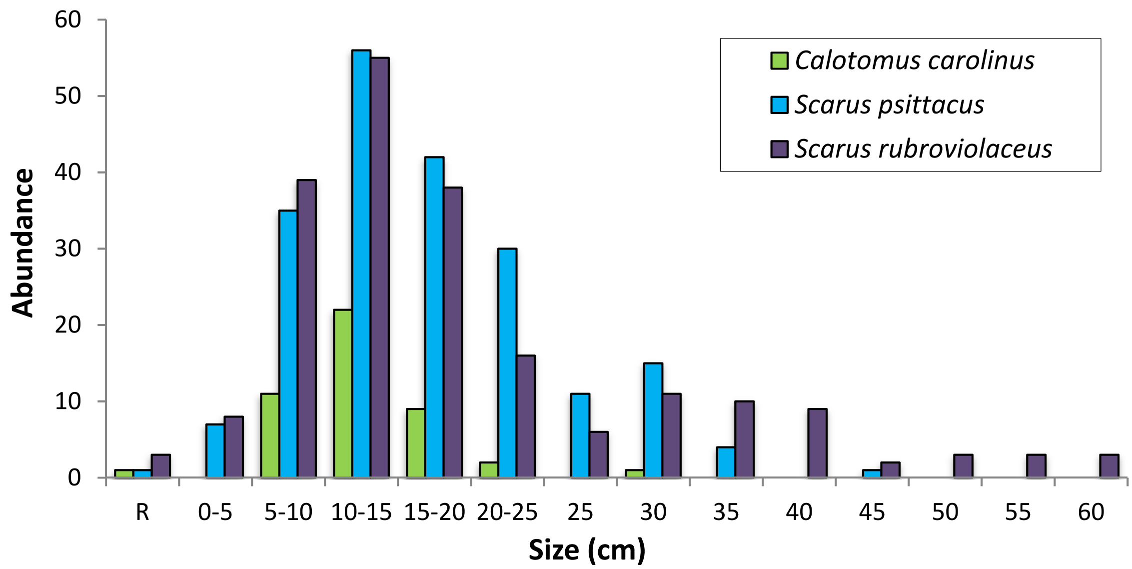

Figure 8: Size frequency distributions for three common parrotfish species at Puakō and Pauoa, with site data combined for each species. Abundance is the total number of indivduals counted over all resurveys, and "R" indicates that a fish recruited very recently.

Hayes et al. (1982) predictions and outcomes

Hayes et al. (1982) predicted that, of the common fish species found in creel surveys, *Cirrhitus pinnulatus* and *Acanthurus triostegus* were the most *unlikely* to be able to withstand the high level of fishing effort. For the Stocky Hawkfish, *C. pinnulatus*, these predictions appear to have come to fruition. The original study reported 25 *C. pinnulatus* in 69 transect surveys at Puakō, and 20 individuals in 42 transect surveys at Pauoa. The more recent study documented a total of only 3 individuals at Puakō during 72 transect surveys, and 0 individuals were observed in 72 transect surveys at Pauoa.

In contrast to the declines in hawkfish abundance, Convict Tang or manini, *Acanthurus triostegus*, abundance has remained stable at the Puakō site, estimated at 0.3/100m^2 in the original surveys, and 0.36/ 100m^2 (± 0.11) in the more recent surveys. At the Pauoa site however, the abundance of this species has declined over time, with abundance estimated at 0.9/100m^2 originally, and 0.49/100m^2 (±1.07) more recently. Manini is a highly desired species for throw-net fishers along the shoreline, an activity which is permitted at both Puakō and Pauoa. Giddens (2010) noted that the average size of *A. triostegus* kept by fishermen was one inch smaller than the legal limit of 5 inches (12.7 cm). The majority of *A. triostegus* caught and measured in the original creel census (Hayes et al. 1982) were between 11 and 13 cm, or approximately 1-3 cm larger than those measured by Giddens (2010).

Two additional species of concern cited in the original study were the Yellowstripe Goatfish, *Mulloidichthys flavolineatus*, and the Manybar Goatfish, *Parupeneus multifasciatus*, which were both predicted to be unable to offset fishing mortality with local productivity. Both of these, and particularly *M. flavolineatus*, appear to have declined in abundance at both Puakō and Pauoa (Table 3). The average size at capture, however, does not seem to have decreased over time (Table 10).

Hayes et al. (1982) also predicted that some species were likely to be able to withstand the current levels of fishing mortality, among these, *Stethojulis balteata*, *Thalassoma duperrey*, and *Acanthurus nigrofuscus*. All three of these species have declined in numbers at both sites (Tables 1, 3, Appendices 1-4), though we cannot be certain that fishing pressure, environmental degradation, or other factors contributed to these declines. Despite their declines in abundance, these species were three of the most common on the reef at both sites, and both sites retain similar abundances.

Benthic Organisms

The only benthic organisms re-surveyed in the 2007-2008 surveys were sea urchins, and all five surveyed species decreased in abundance at both sites, particularly *Diadema paucispinum* and *Heterocentrotus mammillatus* (Table 11). The magnitude of decline was similar at each site.

Table 11: Sea urchin abundance (#/100 m^2). Standard error, in parentheses, is the average of six calculated transect-level standard errors.

Species	Puakō				Pauoa			
	1979-81	2007-08	Δ	Δ (%)	1979-81	2007-08	Δ	Δ (%)
Diadema paucispinum	0.09	0.01 (0.0)	-0.08	-88.9%	0.47	0.01 (0.0)	-0.46	-97.9%
Echinothrix calamaris	1.13	0.48 (0.2)	-0.65	-57.5%	5.57	0.38 (0.1)	-5.19	-93.2%
Echinothrix diadema	8.73	5.71 (0.6)	-3.02	-34.6%	8.93	7.44 (1.1)	-1.49	-16.7%
Heterocentrotus mammillatus	24.7	4.98 (0.7)	-19.7	-79.8%	38.4	3.49 (0.4)	-34.9	-90.9%
Tripneustes gratilla	42.8	25.5 (2.5)	-17.3	-40.4%	70	22.5 (3.0)	-47.5	-67.9%

Benthic Cover

Overall, total coral cover decreased 35% at Puakō and 21% at Pauoa between the 1979-1981 and 2007-2008 surveys. Crustose coralline algae also decreased 64% at Puakō and 87% at Pauoa (Figure 9).

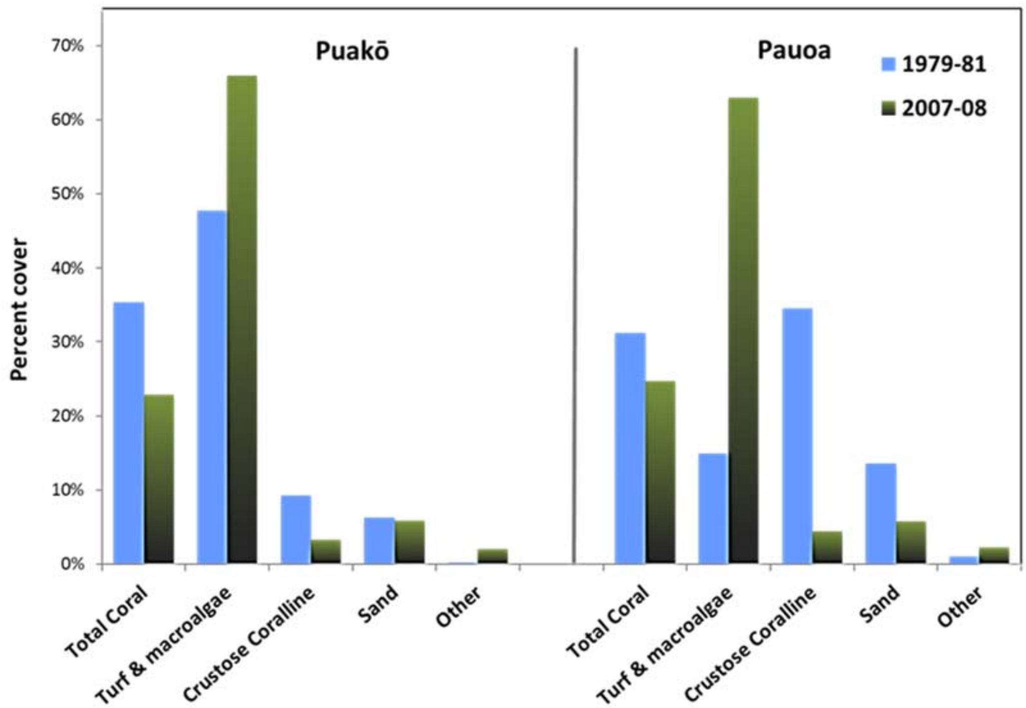

Figure 9: Benthic cover by category observed at Puakō and Pauoa in 1979-1981 and 2007-2008 surveys.

Total coral cover at Puakō showed varying patterns by habitat zone (Tables 12 and 13). Coral cover declined dramatically on transects 1, 4, and 5, remained stable or slightly increased on transects 2 and 3, and increased on transect 6. Crustose coralline algal cover decreased precipitously on transects 1 and 2, increased or remained stable on transects 3, 4, and 5, and decreased considerably on transect 6. Overall, turf and macroalgal cover increased on all transects except transect 6. Because the original study did not separate algae into categories, only broad comparisons were possible.

Table 12: Benthic cover (%) on each transect at **Puakō**, **1979-1981**. Values for “Other” and “Turf and macroalgae” have been corrected for Transect 1A per the footnote in Hayes et al. (1982), Table 3. As noted in the footnote, due to an error in defining the “Other” category on this transect it was reduced by 95%, and that percentage was added to “Turf and Macroalgae”.

Transect	Coral	Algal turf/ macroalgae	Crustose coralline algae	Sand	Other
Puakō 1A	13.2%	70.6%	15.9%	0.0%	1.0%
Puakō 2A	31.9%	47.5%	18.3%	2.3%	0.0%
Puakō 3A	16.0%	73.0%	0.0%	10.4%	0.6%
Puakō 4A	65.2%	29.4%	4.8%	0.0%	0.6%
Puakō 5A	63.1%	30.7%	6.2%	0.0%	0.0%
Puakō 6A	22.8%	41.7%	10.3%	25.2%	0.0%

Table 13: Benthic cover (%) on each transect at **Puakō**, **2007-2008**. NCC Macroalgae is non-calcifying, crustose macroalgae such as *Peyssonnelia* or *Lobophora spp*.

Transect	Coral	Algal turf/ bare	Crustose coralline algae	Sand	Other	Macroalgae	NCC Macroalgae
Puakō 1A	0.6%	93.1%	0.5%	3.4%	0.6%	1.7%	0.1%
Puakō 2A	32.2%	56.2%	3.9%	5.6%	1.8%	0.3%	0.0%
Puakō 3A	18.5%	77.6%	0.4%	0.0%	2.8%	0.7%	0.0%
Puakō 4A	24.8%	64.1%	7.1%	0.2%	3.4%	0.0%	0.4%
Puakō 5A	30.7%	56.0%	6.4%	0.0%	3.1%	1.9%	1.9%
Puakō 6A	30.3%	41.3%	1.7%	25.9%	0.7%	0.0%	0.1%

In contrast to the Puakō site, coral cover at the Pauoa inshore transects (1B and 2B) declined only slightly between surveys while cover on transect 3 increased substantially (Tables 14 and 15). In contrast, coral cover along all the offshore transects (4B, 5B, and 6B) declined. Across all transects at Pauoa, crustose coralline algae cover declined dramatically and the percent cover of algae (turf and macroalgae) increased.

Table 14: Benthic cover (%) at **Pauoa**, **1979-1981**. Values for "Other" and "Turf and macroalgae" have been corrected for Transects 1B and 2B per the footnote in Hayes et al (1982), Table 3. As noted in the footnote, due to an error in defining the "Other" category on this transect it was reduced by 95%, and that percentage was added to "Turf and Macroalgae".

Transect	Coral	Algal turf/ macroalgae	Crustose coralline algae	Sand	Other
Pauoa 1B	6.6%	60.6%	11.9%	19.9%	1.0%
Pauoa 2B	31.8%	35.7%	20.0%	11.9%	0.6%
Pauoa 3B	13.2%	65.7%	10.0%	7.2%	3.9%
Pauoa 4B	42.2%	40.0%	13.7%	4.1%	0.0%
Pauoa 5B	52.3%	14.4%	24.8%	8.5%	0.0%
Pauoa 6B	40.8%	20.6%	9.0%	29.6%	0.0%

Table 15: Percent cover of benthos at **Pauoa**, **2007-2008**. NCC Macroalgae is non-calcifying, crustose macroalgae such as *Peyssonnelia* sp. or *Lobophora* spp.

Transect	Coral	Algal turf/ bare	Crustose coralline algae	Sand	Other	Macroalgae	NCC Macroalgae
Pauoa 1B	2.3%	91.4%	2.2%	0.5%	3.5%	0.0%	0.1%
Pauoa 2B	25.0%	64.2%	4.3%	4.4%	1.4%	0.3%	0.3%
Pauoa 3B	44.7%	52.5%	1.2%	0.2%	1.4%	0.0%	0.0%
Pauoa 4B	24.8%	64.1%	7.1%	0.2%	3.4%	0.0%	0.4%
Pauoa 5B	26.1%	43.3%	7.9%	19.1%	2.8%	0.1%	0.7%
Pauoa 6B	25.1%	59.7%	3.6%	10.2%	0.9%	0.1%	0.4%

At the Puakō site, *Porites lobata* cover decreased dramatically at transects 1, 4, and 5, compared to the original survey (Tables 16 and 17), with a relative change ranging from -77.7 % to -95.4 % loss. Meanwhile, *Porites compressa* coverage remained stable on transect 5, and increased on transects 4 and 6. Coverage of *Montipora* spp., while never particularly high at this site, haD decreased to nearly zero by 2007-2008.

Table 16: Percent cover of corals by species on each transect at **Puakō**, **1979-1981** and **2007-2008**.

Species	**Puakō**				
	Transect	**1979-81**	**2007-08**	**Δ**	**% (Δ)**
Porites lobata	1A	13.2%	0.6%	-12.6%	-95.5%
	2A	28.2%	30.4%	2.2%	7.8%
	3A	12.6%	12.7%	0.1%	0.8%
	4A	55.6%	12.4%	-43.2%	-77.7%
	5A	41.9%	10.5%	-31.4%	-74.9%
	6A	16.3%	21.9%	5.6%	34.4%
Porites compressa	1A	0.0%	0.0%	-	-
	2A	0.0%	0.8%	0.8%	n/a
	3A	0.0%	0.0%	-	-
	4A	4.8%	11.8%	7.0%	145.8%
	5A	20.0%	20.1%	0.1%	0.5%
	6A	4.9%	8.0%	3.1%	63.3%
Pocillopora meandrina	1A	0.0%	0.0%	-	-
	2A	3.7%	0.3%	-3.4%	-91.9%
	3A	3.4%	5.9%	2.5%	73.5%
	4A	2.4%	0.2%	-2.2%	-91.7%
	5A	0.0%	0.1%	0.1%	n/a
	6A	0.0%	0.0%	-	-95.5%
Montipora sp.	1A	0.0%			
	2A	0.0%			
	3A	0.0%			
	4A	2.4%			
	5A	1.2%			
	6A	1.6%			
Montipora capitata	1A		0.0%		
	2A		0.1%		
	3A		0.0%		
	4A		0.3%		
	5A		0.0%		

	6A		0.4%		
Montipora patula	1A		0.0%		
	2A		0.1%		
	3A		0.0%		
	4A		0.0%		
	5A		0.0%		
	6A		0.0%		
Pavona varians	1A		0.0%		
	2A		0.3%		
	3A		0.0%		
	4A		0.1%		
	5A		0.0%		
	6A		0.0%		
Porites evermanni	1A		0.0%		
	2A		0.1%		
	3A		0.0%		
	4A		0.0%		
	5A		0.0%		
	6A		0.0%		
Other	1A		0.0%		
	2A		0.1%		
	3A		0.0%		
	4A		0.1%		
	5A		0.0%		
	6A		0.0%		

At the Pauoa site, coral cover declined on the two inshore transects (1B and 2B), which was driven by declines in *P. lobata* and *Pocillopora meandrina* (Tables 18 and 19). The increase in coral cover observed for transect 3B is due to a large increase in percent cover of *P. lobata*, as well as an increase in percent cover of *P. meandrina*. The three deeper transects (4B, 5B, and 6B) all showed decreased percent cover of *P. lobata*, and cover of *P. compressa* and *Montipora* sp. varied inconsistently between the two surveys.

Table 17: Percent cover of corals by species on each transect at **Pauoa**, **1979-1981** and **2007-2008**.

Species	Pauoa				
	Transect	1979-81	2007-08	Δ	% (Δ)
Porites lobata	1A	5.2%	1.4%	-3.8%	-73.1%
	2A	23.8%	20.8%	-3.0%	-12.6%
	3A	11.5%	37.2%	25.7%	223.5%
	4A	35.6%	12.4%	-23.2%	-65.2%
	5A	29.0%	13.0%	-16.0%	-55.2%
	6A	30.9%	19.0%	-11.9%	-38.5%
Porites compressa	1A	0.6%	0.0%	-0.6%	-100.0%
	2A	0.0%	0.7%	0.7%	n/a
	3A	0.0%	0.0%	-	-
	4A	4.1%	11.8%	7.7%	187.8%
	5A	22.2%	9.6%	-12.6%	-56.8%
	6A	9.3%	5.1%	-4.2%	-45.2%
Pocillopora meandrina	1A	0.8%	0.8%	0.0%	0.0%
	2A	4.7%	0.8%	-3.9%	-83.0%
	3A	1.7%	6.4%	4.7%	276.5%
	4A	0.0%	0.2%	0.2%	n/a
	5A	0.3%	0.0%	-0.3%	-100.0%
	6A	0.0%	0.1%	0.1%	n/a
Montipora sp.	1A	0.0%			
	2A	3.3%			
	3A	0.0%			
	4A	2.5%			
	5A	0.8%			
	6A	0.6%			
Montipora capitata	1A		0.0%		
	2A		0.9%		
	3A		0.3%		
	4A		0.3%		
	5A		0.7%		
	6A		0.8%		
Montipora patula	1A		0.0%		
	2A		1.7%		
	3A		0.7%		
	4A		0.0%		
	5A		2.6%		
	6A		0.1%		

Pavona varians	1A		0.1%		
	2A		0.1%		
	3A		0.1%		
	4A		0.1%		
	5A		0.2%		
	6A		0.0%		
Porites evermanni	1A		0.0%		
	2A		0.0%		
	3A		0.0%		
	4A		0.0%		
	5A		0.0%		
	6A		0.0%		
Other	1A		0.0%		
	2A		0.0%		
	3A		0.0%		
	4A		0.0%		
	5A		0.0%		
	6A		0.0%		

DISCUSSION

The coral reef ecosystem fringing Puakō and Pauoa within the South Kohala region of Hawai'i Island has long been recognized as an invaluable natural resource, and is currently a focal point for recreational use, numerous scientific research studies, and protective management. Because of its recognized importance, special management of the area began decades ago with the establishment of the Puakō Reef Fisheries Management Area (FMA) in 1985, which prohibited the possession and use of nets, except for throw nets (DAR 1984). In 2000, the Pauoa Bay area was included within a larger existing Fish Replenishment Area (FRA), prohibiting aquarium fish collection, and a lay net restriction went into effect in 2005. Spearfishing using SCUBA was common at both sites until a ban was established in December 2013. In 2014, the South Kohala region of West Hawai'i was designated as a NOAA Habitat Blueprint area for prioritized management, one of only ten areas selected nationwide (www.habitatblueprint.noaa.gov)

Despite this multi-layer focused management, this study documents sharp declines in reef biota communites from 1978-1979 to 2007-2008, suggesting that certain drivers of reef degradation are still having an impact. The majority of surveyed fishes, invertebrates, corals, and crustose coralline algae analyzed in this study declined at both survey sites when compared to Hayes et al. (1982). Also, despite differences in the duration of management regulations at each survey site, both declined similarly, with minimal clear differences related to protective management.

Results of fish surveys conducted by TNC corroborated the findings in this study; though they were slightly higer than what was reported in this study, they were strikingly lower than the 1979-1981 study. TNC surveyys were conducted in habitat zones 4 and 5, within a broad area surrounding the original transects in Hayes et al. (1982). Average fish abundances were 130 ind/100m^2 (± 10, n=47 sites) and 110 ind/100m^2 (± 10, n=40 sites). Here, we documented resurvey abundances in habitat zones 3A, 4A and 6A that were closest to the original survey abundances documented by Hayes et al (1982). More pronounced differences in fish abundance were documented for the other surveyed habitat zones.

Fishing pressure has long been known to dictate shallow water reef fish community structure in the Hawaiian Islands (Hobson 1984, Friedlander and Demartini 2002), and the varying duration of protection from lay netting, recreational fishing, commercial aquarium collection, as well as other land-use issues could certainly influence the findings of this study. In addition to altering target fish abundance, net fishing is known to decrease habitat complexity in coral reef ecosystems (Kaiser et al. 2000), a key factor in sustaining healthy reef fish populations (Pratchett et al. 2008). Several popular fishery species, including *Aphareus furca*, *Monotaxis grandoculis, Scarus rubroviolaceous, Naso lituratus,* and *Naso brevirostris*, were deemed "relatively numerous" around the island of Hawaiʻi over the course of a five year study, which was conducted from 1977 to 1982 (Hobson 1984). In this study, a lack of large, predatory fishes such as *Caranx ignobilis* and *Carcharhinus amblyrhynchos* was noted, as compared to abundances in the previous study and surveys conducted in the Northwestern Hawaiian Islands. Large predatory fish species, in general, have decreased in abundance, with the exception of the introduced grouper, *Cephalopholis argus*. Reef sharks were not observed during the 2007-2008 DAR resurveys, however two jack species, *Caranx melampygus* and *Carangoides orthogrammus,* were only recorded during the resurveys and not in the original study. These species are not, however, restricted in range and tag-recapture studies have demonstrated that they can travel at least two miles and as many as 37 miles (Tagawa and Clayward 2009). Declines in fish predator abundances can be driven by loss of prey species as well as by fishing pressure (Williams et al. 2008, Wilson et al. 2008).

Most aquarium collected species had declined since the original surveys, in particular the angelfish *Centropyge potteri* and the Multiband Butterflyfish, *Chaetodon multicinctus*. Hobson (1984) listed both species among the ten most abundant along West Hawaiʻi (Hobson 1984). Pratchett et al. (2008) noted that corallivores such as *C. multicinctus* were more likely to decline with decreasing coral cover, which was noted on certain transects. Also troubling were the great declines in abundance of the the surgeonfish species, *Acanthurus nigrofuscus* and *Ctenochaetus strigosus*, which previously occurred at > 20-30 / 100 m^2 (Hayes et al. 1982) and were reduced to ~ 4-8 / 100 m^2 in this resurvey.

Yellow Tang surgeonfish, *Zebrasoma flavescens*, which account for over 80% of the aquarium catch in Hawaiʻi (Williams et al. 2009), increased at Pauoa (+14.8%) and decrease slightly at Puako (-8.9%) even though aquarium collecting had been effectively prohibited there (i.e. no nets permitted except throw nets) for over a decade. Yellow Tang can live to be 41 years or more of age (Claisse et al. 2009). There is minimal take of Yellow Tang for human consumptive purposes in Hawaiʻi, compared to certain surgeonfish species that are targeted for both aquarium and food fish purposes. Also, the establishment of a network of Fish Replenishment Areas (FRAs) and Marine Life Conservation Districts (MLCDs) along > 35% of the coastline, has prohibited aquarium collecting and very likely contributed to both juvenile and adult fish spillover. Williams et al. (2009) showed that populations of adult Yellow Tang were more abundant within and along the boundaries of FRAs, compared to open areas, indicative of both take in open sites and recovery within FRAs.

Spearfishing has been noted to be particularly detrimental to shallow reef fish communities, particularly if SCUBA spearfishing is allowed, and/or if fishing occurs at night (Nevill 2005, Gillett and Moy 2006, Lindfield et al. 2014). Gillet and Moy (2006) concluded that the single most important management measure for the preservation of reef fish communities in the western Pacific was to ban spearfishing with SCUBA and ensure adequate enforcement. Prior to the ban, SCUBA spearfishing was allowed in both Puakō and Pauoa, and became increasingly popular over the course of this study until December 2013 when it was prohibited throughout West Hawai'i. SCUBA spearfishing promotes the capture of larger fishes than spearfishing on snorkel gear (Lindfield et al. 2014), and therefore reduces reproductive potential and decreases spawning biomass (Birkeland and Dayton 2005). There is, however, the possibility of depth refugia when spearfishing is a method of capture (Lindfield et al. 2014) although the maximum depths of all but two of the sites surveyed (<14 m)) are well within the range of many free-divers and certainly SCUBA spearfishers.

Another surgeonfish species, *Naso unicornis*, was resilient to fishing pressure in Guam (Lindfield et al. 2014), but declined in this study, likely due to removal from both recreational and aquarium fisheries. Lindfield et al. (2014) suggested that the resilience of *N. unicornis* was due to replenishment from outside stocks, which may be less available as a replenishment method for the Hawaiian Islands. A close congener, *N. hexacanthus*, also declined in abundance between survey periods, (-41% at Puakō and -80% at Pauoa) suggesting intensive take is also occurring for this species.

The surgeonfish *Acanthurus triostegus* maintained its abundance over the course of the study, but the size at capture for this fish was often 4 inches, approximately one inch below the legal size limit, as documented by Giddens (2010). Given that the estimated minimum size of first reproduction for this species is 11.5 - 12 cm (Hayes et al. 1982), over-harvest of 10 cm (4 inch) fishes on average likely has important reproductive consequences for the population, contributing to an unsustainable recreational fishery. Productivity within the local population is likely impeded by this practice, suggesting that these sites may be receiving recruit stock from elsewhere. Surgeonfish larvae are known to be long-lived (Rocha et al. 2002), and repopulation of surgeonfishes on the shallow reef habitats at Puakō and Pauoa could be driven by larvae from fully protected, adjacent reef areas.

This study documented an increase in abundance of the Bullethead Parrotfish*, Chlorurus spilurus*, at both sites, contributing to a general maintenance of overall parrotfish abundance since the Hayes et al. 1982 study. Small parrotfishes are thought to be resilient to overfishing impacts (Bellwood et al. 2012, Taylor and Choat 2014), and that theory was corroborated here. A recent pan Indo-Pacific study demonstrated that small *Chlorurus* spp. individuals paradoxically increase with increasing human population density and presumed fishing pressure (Bellwood et al. 2012). Moreover, Bellwood et al. (2012) demonstrated no relationship between *Scarus* spp. and human population density. During this study, the Redlip Parrotfish, *Scarus rubroviolaceus*, also increased in abundance compared to the original survey. However, very few large individuals remained at either site. Parrotfishes play a key role in controlling macroalgal cover on coral reefs, and have been shown to enhance the rate of coral recruitment in the Caribbean (Mumby et al. 2007), with larger parrotfishes being more critical as major reef excavators.

In terms of size class structure, both Puakō and Pauoa showed a paucity of parrotfishes over 25 cm in total length across species, which for some species (e.g. *S. rubroviolaceous*) is well below the maximum size. Four hypotheses potentially explain the increase of small parrotfishes in reef habitats associated with high human population density: 1) small species and/or individuals are targeted less by fishers; 2) small, short-lived species have a higher turnover rate and higher recruitment rate; 3) trophic cascade effects allow small parrotfish to proliferate in the absence of large, targeted predators (Kramer and Heck 2007); and 4) the high species richness of small parrotfishes is likely to afford some functional redundancy that promotes resilience (Bellwood et al. 2012). Evidence suggests that the smallest species are at greatest risk of predation and in the absence of predators, small parrotfishes may be able to increase their foraging rates and expand their home ranges (Madin et al. 2010a, Madin et al. 2010b). In contrast to the hypothesis of Bellwood et al. (2012), we did not find that surgeonfishes follow the same pattern of proliferation with human population, probably because many surgeonfishes such as *Ctenochaetus strigosus* are highly sought after as food fish in the Hawaiian Islands.

Particularly germane to fishery management issues at Puakō and other areas of West Hawaiʻi are the findings of a recent study (Weijerman et al. 2018) which evaluated the efficacy of current and alternative management scenarios to improve (1) ecosystem structure and resilience; (2) non-commercial fisheries; and (3) dive/snorkel tourism at Puakō. Modeling results showed that nearly all ecosystem indicators decrease or show no meaningful change under the current management regime. Key fish-related indicators such as total fish biomass, fish community trophic level and fish diversity show the most substantive increases under scenarios that limit gear such as hook and line fishing only and/or no-take MPAs. Reducing land-based pollution was the only scenario where coral cover increased. The tradeoff of stricter fishery regulations (MPAs including herbivore replenishment areas) is that total fish catch within the protected area declines somewhat. The study concludes that line fishing only represented the most balanced trade-off with positive gains in both ecosystem structure and resilience and dive tourism with only moderate losses in fishery ecosystem service.

Non-targeted fish species also showed drastic declines in abundance over the course of the study period. The widespread declines in families of fish not typically targeted either for food use or for the aquarium fishery suggest that other, more widespread factors are additionally contributing to the overall long-term declines in fish abundance at Puakō and Pauoa. Factors aside from fisheries pressure, such as water quality degradation or climate change impacts (e.g. thermal stress, ocean acidification) may have played a role in fish declines directly or drove declines by reducing habitat.

Water quality threats have been recently well-documented at Puakō and Pauoa, for both "natural" sources of increased submarine groundwater discharge of dissolved nutrients, including nitrogen and phosphate (Kay et al. 1977, Street et al. 2008, Knee et al. 2010), and increased discharge of wastewater and sewage-associated nutrients (Abaya et al. 2018a, 2018b). Elevated nutrient influx to nearshore reef areas can drive algal blooms and coral reef phase shifts to algal-dominated states, and the negative impacts related to unregulated shoreline development and nutrient pollution are well-documented (van Beukering and Cesar 2004, Dailer et al. 2010). Numerous studies, including the recently released DAR Coral Bleaching Recovery Plan (Univ. of Hawaiʻi Social Science Research Institute 2017), emphasize the importance of local watershed management for controlling eutrophication on coral reef ecosystems. In addition to enhancing algal growth, elevated nutrients have been linked to other adverse effects on coral reef health, including increased disease susceptibility of corals (Couch et al. 2014, Vega-Thurber et al.

2014), increased coral skeletal brittleness (Dunn et al. 2012), and reduced coral recruitment due to algal overgrowth of available substrate (Ward and Harrison 2000).

Herbivory is widely recognized as a crucial ecosystem function on coral reefs for controlling algal growth and competition with corals (Williams et al. 2008, Smith et al. 2010, Univ. of Hawai'i Social Science Research Institute 2017). The over-harvesting of herbivorous fishes, which are known to eat both native and non-native algal species (Okano 2011), is of particular concern, as lack of herbivores can also drive phase shifts to algal dominance on reefs (Hughes 1994). In addition, a recent meta-analysis found that the effects of herbivory are larger than those of eutrophication (Burkepile and Hay 2006), and on Puakō reef in Hawaiʻi, the return of herbivores after experimental exclusion was shown to reverse the growth of fleshy macroalgae after only two months of exposure (Smith et al. 2010). Herbivorous fishes also contribute to the increased presence of crustose coralline algae by controlling macroalgal growth.

While urchins at Puakō and Pauoa were still relatively abundant, they decreased by an order of magnitude at certain sites for *Heterocentrotus mamillatus*, and by at least half for *Tripneustes gratilla*. *Echinothrix* spp. abundance decreased slightly, and almost no *Diadema paucispinum* were observed in recent surveys. After the mass mortality of *Diadema antillarum* in the Caribbean, it was noted that reefs that were not overfished did not exhibit quite as strong a coral to macroalgal shift as reefs that were heavily overfished (Lessios 1988), suggesting that urchins play a secondary role to herbivorous fish in controlling algal overgrowth.

Importantly, an increase in macroalgal cover was not observed during the resurvey of benthic assemblages, suggesting that fish and invertebrate grazers are adequately consuming available macroalgae, and reducing the likelihood of a phase-shift (Hughes et al. 2007, Hughes et al. 2010). However, a decline in coral cover was observed at certain sites in this study, particularly within the shallow surge zone, and the deeper "coral-rich" habitat zone. Since the completion of this study, a severe coral bleaching and mortality occurred in late 2015 as a result of very high water temperatures, driving further catastrophic declines in coral cover at Puakō and Pauoa. For the DAR long-term monitoring site at Puakō, average relative coral cover loss was estimated at -64.2% ± 4.3 % (Kramer et al. 2016). Importantly however, this study indicates that both reef fish and certain coral species were in decline prior to 2015.

Additionally, crustose coralline algae (CCA) cover decreased by an order of magnitude at certain sites from 1979 to 2008, which has negative implications for available space for coral recruitment (Mumby et al. 2007, Vermeij et al. 2010). Furthermore, some species of CCA are known to provide specific settlement cues for both larval fish and corals (Harrington et al. 2004). CCA at Puakō declined precipitously on the two most inshore transects, which may be related to nearshore eutrophication coupled with intensive fish grazer removal at shallow sites. Importantly, the common herbicide ingredient, Diuron, has been shown to inhibit photosynthesis in CCA and drive mortality (Harrington et al. 2005), and although water quality was not specifically quantified in this study, pollutants associated with nearshore residences likely played an important role in shaping shallow reef communites (Abaya et al. 2018a, 2018b). The decreases observed for urchins and surgeonfishes may also contribute to the decreasing abundance of CCA at these sites.

The biota of coral reef ecosystems at Puakō and Pauoa in West Hawaiʻi demonstrated degradation for both fish and benthic communities over a span of thirty years, with a few notable exceptions. While the specific and/or synergistic causes for these declines cannot be conclusively determined by this study, the observed declines are likely driven by a combination of anthropogenic stressors, requiring both local and global management.

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APPENDICES

Appendix 1: Transect descriptions and survey dates. Depths represent beginning and end depths.

Transect #	Bearing	Depths (m)	Latitude	Longitude	Surveyed
Puakō					
1A	235°	0.9 – 1.2	19.96956° N	-155.84490° W	**2007:** 5/8, 5/9, 8/21, 8/22, 11/20, 11/21
2A	205°	1.9 – 3.4	19.96988° N	-155.84567° W	
3A	30°	2.4 – 3.4	19.97073° N	-155.84447° W	
4A1*	325°	8.4 – 10.0	19.97052° N	-155.84529° W	**2008:** 2/5, 2/7, 5/14, 5/15, 8/12, 8/13
4A2*	325°	8.4 – 10.0	19.97044° N	-155.84538° W	
5A	40°	12.8 – 13.7	19.97114° N	-155.84547° W	
6A	220°	18.3 – 17.7	19.97067° N	-155.84642° W	
Pauoa					
1B	220°	1.2 –1.5	19.95125° N	-155.86465° W	**2007:** 5/1, 5/2, 8/28, 8/29, 11/27, 12/12
2B	170°	3.0 – 3.7	19.95249° N	-155.86230° W	
3B	237°	3.7 – 4.6	19.95082° N	-155.86709° W	
4B	340°	9.1 – 10.1	19.95140° N	-155.86692° W	**2008:** 2/12, 3/4, 5/6, 5/7, 8/19, 8/20
5B	320°	10.7 – 13.4	19.95210° N	-155.86655° W	
6B	30°	20.7 – 22.0	19.95171° N	-155.86918° W	

Appendix 2: Fish species abundance (#/100 m^2) at **Puakō** sites during **1979-1981** surveys**.** Ten surveys were performed on transect 1A, eleven were performed on transect 2A, and twelve surveys were performed at transects 3A through 6A. Site mean is the average of all six sites/ habitat zones. Species listed in gray were not observed at Puakō sites during the surveys.

Family	Taxa	1A	2A	3A	4A	5A	6A	Site mean
Acanthuridae	*Acanthurus achilles*	0.36	1.09	-	3.42	0.50	-	0.89
Acanthuridae	*Acanthurus dussumieri*	-	-	0.02	0.02	-	-	0.01
Acanthuridae	*Acanthurus leucopareius*	0.60	0.05	0.02	5.58	0.02	-	1.05
Acanthuridae	*Acanthurus nigricans*	0.02	-	-	0.05	-	-	0.01
Acanthuridae	*Acanthurus nigrofuscus*	49.66	23.55	47.25	6.25	0.03	0.02	21.13
Acanthuridae	*Acanthurus nigroris*	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus olivaceus*	-	0.27	-	0.03	0.12	0.50	0.15
Acanthuridae	*Acanthurus triostegus*	0.98	0.18	0.07	0.57	-	-	0.30
Acanthuridae	*Acanthurus xanthopterus*	-	0.91	-	0.07	-	-	0.16
Acanthuridae	*Ctenochaetus hawaiiensis*	-	-	-	-	0.05	0.10	0.03
Acanthuridae	*Ctenochaetus strigosus*	1.60	33.04	6.20	37.45	36.83	10.90	21.00
Acanthuridae	*Naso brevirostris*	0.28	-	-	0.28	0.92	0.07	0.26
Acanthuridae	*Naso hexacanthus*	-	0.04	-	-	4.03	1.60	0.94
Acanthuridae	*Naso lituratus*	0.60	1.76	1.00	2.48	8.63	0.77	2.54
Acanthuridae	*Naso unicornis*	0.38	0.36	-	0.03	0.17	-	0.16
Acanthuridae	*Zebrasoma flavescens*	0.84	3.84	5.23	29.95	13.03	6.45	9.89
Acanthuridae	*Zebrasoma veliferum*	-	-	0.03	0.20	0.03	-	0.04
Apogonidae	*Apogon sp.*	-	0.49	-	0.82	0.92	0.68	0.48

Aulostomidae	*Aulostomus chinensis*	0.06	0.51	0.05	0.65	0.75	0.77	0.46
Balistidae	*Canthidermis maculatus*	0.04	0.04	0.03	-	-	-	0.02
Balistidae	*Melichthys niger*	0.50	1.85	1.38	4.05	0.23	0.28	1.38
Balistidae	*Melichthys vidua*	0.12	0.38	0.10	0.40	0.23	-	0.21
Balistidae	*Rhinecanthus rectangulus*	0.80	0.07	0.62	-	-	-	0.25
Balistidae	*Sufflamen bursa*	-	0.07	0.02	1.07	1.83	2.68	0.95
Balistidae	*Sufflamen fraenatus*	-	-	-	-	-	0.18	0.03
Balistidae	*Xanthichthys auromarginatus*	-	-	-	0.10	0.48	3.27	0.64
Blenniidae	*Cirripectes vanderbilti*	1.14	4.55	0.23	0.05	-	-	0.99
Blenniidae	*Exallias brevis*	0.16	1.47	0.17	0.32	0.38	0.05	0.42
Blenniidae	*Plagiotremus goslinei*	0.08	-	-	-	-	-	0.01
Carangidae	*Alectis ciliaris*	-	-	-	-	-	-	-
Carangidae	*Decapterus macarellus*	-	-	-	0.10	0.05	-	0.03
Carangidae	*Scomberoides lysan*	-	-	0.03	-	-	-	0.01
Chaetodontidae	*Chaetodon auriga*	-	-	-	0.02	0.03	-	0.01
Chaetodontidae	*Chaetodon fremblii*	0.02	0.05	0.13	0.10	-	0.05	0.06
Chaetodontidae	*Chaetodon kleinii*	-	-	-	-	0.05	1.77	0.30
Chaetodontidae	*Chaetodon lunula*	0.26	0.18	0.10	0.62	0.08	-	0.21
Chaetodontidae	*Chaetodon lunulatus*	-	0.22	0.20	-	-	-	0.07
Chaetodontidae	*Chaetodon miliaris*	-	-	-	-	-	0.30	0.05
Chaetodontidae	*Chaetodon multicinctus*	0.82	2.04	3.05	8.35	5.03	2.10	3.56
Chaetodontidae	*Chaetodon ornatissimus*	0.12	0.49	0.13	1.87	0.37	0.60	0.60
Chaetodontidae	*Chaetodon quadrimaculatus*	0.58	0.80	1.73	0.35	0.10	0.03	0.60
Chaetodontidae	*Chaetodon unimaculatus*	0.36	0.05	0.57	0.28	0.07	0.05	0.23
Chaetodontidae	*Forcipiger flavissimus*	0.20	0.25	0.85	1.87	2.03	3.52	1.45
Chaetodontidae	*Forcipiger longirostris*	0.02	0.02	-	0.30	0.38	0.38	0.18
Chaetodontidae	*Hemitaurichthys polylepis*	-	-	-	0.02	0.02	-	0.01
Cirrhitidae	*Amblycirrhitus bimacula*	-	-	-	-	-	-	-
Cirrhitidae	*Cirrhitops fasciatus*	2.32	0.49	1.52	0.03	-	-	0.73
Cirrhitidae	*Cirrhitus pinnulatus*	0.02	0.33	0.02	0.08	-	-	0.07
Cirrhitidae	*Paracirrhites arcatus*	2.32	7.38	7.32	2.33	0.52	0.45	3.39
Cirrhitidae	*Paracirrhites forsteri*	0.14	0.05	0.07	0.65	0.38	0.13	0.24
Diodontidae	*Diodon holocanthus*	0.02	0.02	0.02	-	-	-	0.01
Diodontidae	*Diodon hystrix*	-	-	-	-	-	-	-
Fistulariidae	*Fistularia commersonii*	0.64	0.25	0.52	-	-	0.12	0.25
Hemiramphidae	*Hyporhamphus acutus pacificus*	-	-	-	-	-	-	-
Holocentridae	*Myripristis sp.*	0.02	-	-	0.82	1.55	-	0.40
Holocentridae	*Neoniphon sammara*	-	-	-	-	0.02	-	<0.01
Holocentridae	*Sargocentron sp.*	0.02	0.44	-	0.07	0.05	0.22	0.13
Labridae	*Anampses chrysocephalus*	-	-	-	-	0.02	-	<0.01
Labridae	*Anampses cuvier*	0.02	-	-	-	-	-	<0.01

Labridae	*Bodianus albotaeniatus*	-	-	-	-	0.02	-	<0.01
Labridae	*Coris flavovittata*	0.06	-	-	-	-	-	0.01
Labridae	*Coris gaimard*	0.66	0.78	0.03	0.22	0.05	0.67	0.40
Labridae	*Gomphosus varius*	7.28	9.55	5.52	1.30	0.97	0.07	4.11
Labridae	*Halichoeres ornatissimus*	0.26	0.87	0.93	0.67	-	-	0.46
Labridae	*Labroides phthirophagus*	0.02	0.49	0.13	0.13	0.10	0.02	0.15
Labridae	Labridae sp.	0.18	0.24	0.03	0.03	0.03	-	0.09
Labridae	*Macropharyngodon geoffroy*	0.04	0.33	0.13	-	0.07	0.20	0.13
Labridae	*Novaculichthys taeniourus*	0.02	-	-	-	-	-	<0.01
Labridae	*Oxycheilinus unifasciatus*	0.02	0.09	0.07	1.13	1.22	1.60	0.69
Labridae	*Pseudocheilinus evanidus*	-	0.13	-	0.18	0.95	2.68	0.66
Labridae	*Pseudocheilinus octotaenia*	-	0.04	-	0.87	0.60	0.35	0.31
Labridae	*Pseudocheilinus tetrataenia*	0.08	0.44	0.37	0.82	0.47	0.07	0.37
Labridae	*Pseudojuloides cerasinus*	-	-	-	-	0.05	0.02	0.01
Labridae	*Stethojulis balteata*	8.74	6.65	4.00	0.47	0.10	0.22	3.36
Labridae	*Thalassoma ballieui*	0.58	0.84	0.20	0.63	0.12	0.08	0.41
Labridae	*Thalassoma duperrey*	32.56	25.44	25.53	10.35	9.23	4.83	17.99
Labridae	*Thalassoma trilobatum*	0.36	0.11	0.12	-	-	-	0.10
Lethrinidae	*Monotaxis grandoculis*	-	-	-	-	0.05	-	0.01
Lutjanidae	*Aphareus furca*	-	0.02	-	0.08	0.32	0.02	0.07
Lutjanidae	*Aprion virescens*	-	-	0.02	-	-	-	<0.01
Lutjanidae	*Lutjanus kasmira*	-	-	-	-	-	0.02	<0.01
Monacanthidae	*Cantherhines dumerilii*	0.04	-	0.02	0.07	-	-	0.02
Monacanthidae	*Cantherhines sandwichiensis*	0.24	0.31	0.40	-	0.02	-	0.16
Monacanthidae	*Pervagor aspricaudus*	0.26	0.51	0.47	0.05	-	0.02	0.22
Monacanthidae	*Pervagor spilosoma*	0.06	0.24	0.10	0.12	0.15	0.10	0.13
Mullidae	*Mulloidichthys flavolineatus*	0.18	0.09	-	0.08	-	4.83	0.86
Mullidae	*Mulloidichthys vanicolensis*	-	-	-	0.03	0.05	2.10	0.36
Mullidae	*Parupeneus cyclostomus*	0.02	0.04	0.08	0.10	0.05	0.43	0.12
Mullidae	*Parupeneus insularis*	0.48	0.07	0.22	0.42	0.05	-	0.21
Mullidae	*Parupeneus multifasciatus*	1.16	0.38	0.58	0.88	0.67	1.35	0.84
Mullidae	*Parupeneus pleurostigma*	-	-	-	-	-	1.00	0.17
Mullidae	*Parupeneus porphyreus*	-	-	-	-	-	-	-
Muraenidae	*Echidna nebulosa*	0.02	-	-	0.02	-	-	0.01
Muraenidae	*Gymnomuraena zebra*	0.04	0.02	0.02	-	-	0.02	0.02
Muraenidae	*Gymnothorax eurostus*	0.02	-	-	-	-	-	<0.01
Muraenidae	*Gymnothorax flavimarginatus*	-	0.02	-	-	0.05	0.02	0.01
Muraenidae	*Gymnothorax meleagris*	0.02	0.05	0.12	0.08	0.05	-	0.05
Muraenidae	*Gymnothorax sp.*	0.02	-	0.05	0.02	0.02	-	0.02
Muraenidae	*Gymnothorax steindachneri*	-	-	-	-	-	-	-
Muraenidae	*Gymnothorax undulatus*	-	-	-	-	-	0.02	<0.01

Ostraciidae	*Lactoria fornasini*	-	-	-	0.03	0.02	0.02	0.01
Ostraciidae	*Ostracion meleagris*	0.32	0.33	0.55	0.07	0.05	0.13	0.24
Ostraciidae	*Ostracion whitleyi*	-	-	-	0.07	0.02	0.02	0.02
Pomacanthidae	*Centropyge potteri*	-	-	-	5.65	6.33	4.10	2.68
Pomacentridae	*Abudefduf abdominalis*	0.72	8.95	-	2.85	10.03	1.93	4.08
Pomacentridae	*Abudefduf sordidus*	0.28	-	-	-	-	-	0.05
Pomacentridae	*Chromis agilis*	-	-	-	0.60	11.33	6.53	3.08
Pomacentridae	*Chromis hanui*	-	-	-	5.65	2.73	0.97	1.56
Pomacentridae	*Chromis ovalis*	-	-	0.17	0.03	0.02	-	0.04
Pomacentridae	*Chromis vanderbilti*	2.14	0.13	10.20	0.20	-	-	2.11
Pomacentridae	*Chromis verater*	-	-	-	0.15	0.53	-	0.11
Pomacentridae	*Dascyllus albisella*	0.04	0.51	-	-	-	7.72	1.38
Pomacentridae	*Plectroglyphidodon imparipennis*	5.54	0.04	0.67	-	-	-	1.04
Pomacentridae	*Plectroglyphidodon johnstonianus*	1.46	6.65	0.42	4.50	3.03	1.23	2.88
Pomacentridae	*Stegastes marginatus*	10.04	30.16	2.35	1.45	-	-	7.33
Priacanthidae	*Priacanthus sp.*	-	-	-	-	-	-	-
Scaridae*	*Calotomus sp.*	0.02	0.04	0.23	0.20	0.22	0.07	0.13
Scaridae	*Chlorurus perspicillatus*	-	0.02	0.05	0.40	0.17	-	0.11
Scaridae	*Chlorurus spilurus*	0.06	0.35	0.27	0.98	1.03	0.35	0.51
Scaridae	*Scarus dubius*	0.92	0.04	0.30	0.05	-	0.07	0.23
Scaridae	*Scarus rubroviolaceus*	-	-	-	0.13	-	-	0.02
Scaridae	*Scarus sp.***	2.04	0.40	3.32	0.93	0.88	0.65	1.37
Scorpaenidae	*Pterois sphex*	-	-	-	-	0.02	-	<0.01
Scorpaenidae	*Scorpaenopsis diabolus*	0.02	0.09	-	0.02	-	-	0.02
Scorpaenidae	*Sebastapistes coniorta*	0.58	0.05	0.05	-	-	-	0.11
Scorpaenidae	*Taenianotus triacanthus*	-	0.22	-	-	-	-	0.04
Serranidae	*Cephalopholis argus*	-	-	-	0.05	-	-	0.01
Sphyraenidae	*Sphyraena barracuda*	-	0.02	-	-	-	-	<0.01
Sphyraenidae	*Sphyraena helleri*	-	-	-	-	-	0.35	0.06
Synodontidae	*Synodus sp.*	-	0.05	-	0.27	0.07	0.10	0.08
Tetraodontidae	*Arothron hispidus*	-	-	-	-	-	-	-
Tetraodontidae	*Arothron meleagris*	-	-	-	-	0.02	-	<0.01
Tetraodontidae	*Canthigaster amboinensis*	0.32	0.11	0.12	-	-	-	0.09
Tetraodontidae	*Canthigaster coronata*	0.02	-	-	-	-	0.02	0.01
Tetraodontidae	*Canthigaster epilampra*	-	-	-	-	-	0.03	0.01
Tetraodontidae	*Canthigaster jactator*	1.06	1.44	1.17	-	-	-	0.61
Tetraodontidae	*Canthigaster rivulata*	-	-	-	-	-	-	-
Zanclidae	*Zanclus cornutus*	0.54	0.33	0.20	0.67	0.57	0.82	0.52

*Note: Scaridae are now commonly referred to as scarine labrids (subfamily Scarinae, family Labridae) but some authorities (e.g. Randall 2007) and FishBase maintain parrotfishes as a family-level taxon.
**Note: *Scarus sp.* Recorded as Scarus juveniles in Hayes et al. 1982.

Appendix 3. Mean fish abundance (#/100 m^2) meters observed at **Puakō** during **2007-2008** resurveys. Standard error is listed in parenthesis. Twelve surveys were performed at each site. Site mean is the average abundance of all six sites/ habitat zones. Species listed in gray were not observed at Puakō sites during the surveys.

Family	**Taxa**	**1A**	**2A**	**3A**	**4A**	**5A**	**6A**	**Site mean**	**SE**
Acanthuridae	Acanthuridae sp.	0.02 (0.08)	-	-	-	-	-	<0.01	0.00
Acanthuridae	*Acanthurus achilles*	-	0.12 (0.23)	-	0.03 (0.17)	-	-	0.03	0.01
Acanthuridae	*Acanthurus blochii*	-	0.05 (0.13)	0.02 (0.08)	0.02 (0.08)	-	0.08 (0.34)	0.03	0.02
Acanthuridae	*Acanthurus dussumieri*	-	-	-	-	-	0.02 (0.08)	<0.01	0.00
Acanthuridae	*Acanthurus leucopareius*	0.07 (0.19)	0.45 (0.55)	0.32 (0.99)	2.13 (2.39)	-	-	0.49	0.06
Acanthuridae	*Acanthurus nigricans*	-	-	-	0.15 (0.33)	-	-	0.03	0.01
Acanthuridae	*Acanthurus nigrofuscus*	0.02 (0.08)	10.85 (7.27)	8.10 (8.75)	5.97 (11.86)	0.42 (2.08)	0.02 (0.08)	4.23	0.60
Acanthuridae	*Acanthurus nigroris*	-	0.48 (1.31)	0.15 (0.51)	0.02 (0.08)	-	-	0.11	0.07
Acanthuridae	*Acanthurus olivaceus*	-	1.30 (1.79)	0.92 (1.58)	0.03 (0.11)	0.02 (0.08)	0.27 (0.66)	0.42	0.12
Acanthuridae	*Acanthurus thompsoni*	-	-	-	0.02 (0.08)	-	0.02 (0.08)	0.01	0.00
Acanthuridae	*Acanthurus triostegus*	1.23 (2.47)	0.57 (1.48)	0.10 (0.50)	0.22 (0.45)	-	0.03 (0.17)	0.36	0.11
Acanthuridae	*Acanthurus xanthopterus*	-	-	-	-	-	-	-	-
Acanthuridae	*Ctenochaetus hawaiiensis*	-	-	-	0.07 (0.19)	0.07 (0.19)	0.10 (0.23)	0.04	0.01
Acanthuridae	*Ctenochaetus strigosus*	0.02 (0.08)	0.97 (1.25)	0.02 (0.08)	18.17 (8.77)	19.23 (3.59)	10.45 (5.06)	8.14	0.46
Acanthuridae	*Naso brevirostris*	-	-	-	-	0.12 (0.36)	-	0.02	0.01
Acanthuridae	*Naso hexacanthus*	-	-	-	-	0.08 (0.23)	3.22 (10.72)	0.55	0.33
Acanthuridae	*Naso lituratus*	0.02 (0.08)	0.75 (1.09)	0.50 (1.36)	0.92 (0.94)	0.23 (0.37)	0.13 (0.36)	0.43	0.06
Acanthuridae	*Naso unicornis*	-	0.15 (0.66)	0.05 (0.18)	0.18 (0.50)	-	-	0.06	0.02
Acanthuridae	*Zebrasoma flavescens*	0.10 (0.50)	3.73 (2.03)	5.47 (3.07)	22.67 (11.43)	13.2 (2.68)	8.90 (4.25)	9.01	0.71
Acanthuridae	*Zebrasoma veliferum*	-	0.23 (0.27)	-	0.20 (0.37)	-	0.02 (0.08)	0.08	0.02
Apogonidae	*Pristiapogon kallopterus*	-	-	-	0.03 (0.11)	0.03 (0.11)	0.10 (0.42)	0.03	0.02
Aulostomidae	*Aulostomus chinensis*	0.05 (0.25)	-	0.02 (0.08)	0.07 (0.14)	0.58 (0.93)	0.07 (0.14)	0.13	0.05
Balistidae	*Canthidermis maculatus*	0.03 (0.17)	-	-	-	-	-	0.01	0.01
Balistidae	*Melichthys niger*	0.02 (0.08)	0.77 (1.05)	1.40 (2.28)	1.50 (2.23)	3.03 (7.27)	1.72 (5.63)	1.41	0.56
Balistidae	*Melichthys vidua*	0.05 (0.18)	0.13 (0.22)	0.40 (0.51)	0.63 (0.30)	0.20 (0.25)	0.28 (0.38)	0.28	0.02
Balistidae	*Rhinecanthus aculeatus*	-	-	-	-	-	-	-	-

Balistidae	*Rhinecanthus rectangulus*	0.97 (0.72)	0.35 (0.48)	0.65 (0.48)	-	-	-	0.33	0.01
Balistidae	*Sufflamen bursa*	-	0.07 (0.19)	0.53 (0.47)	0.60 (0.49)	0.33 (0.41)	0.63 (0.44)	0.36	0.04
Balistidae	*Sufflamen fraenatus*	-	-	-	-	0.02 (0.08)	0.10 (0.23)	0.02	0.01
Balistidae	*Xanthichthys auromarginatus*	-	0.02 (0.08)	-	0.05 (0.13)	0.15 (0.45)	0.18 (0.38)	0.07	0.02
Blenniidae	*Blenniella gibbifrons*	-	-	-	-	-	-	-	-
Blenniidae	*Cirripectes vanderbilti*	0.35 (0.52)	0.08 (0.23)	0.08 (0.15)	-	-	-	0.09	0.02
Blenniidae	*Exallias brevis*	0.02 (0.08)	0.02 (0.08)	-	0.05 (0.13)	0.10 (0.19)	0.03 (0.11)	0.04	0.01
Blenniidae	*Plagiotremus ewaensis*	0.02 (0.08)	-	0.07 (0.14)	-	-	-	0.01	0.01
Blenniidae	*Plagiotremus goslinei*	0.52 (0.80)	0.18 (0.40)	0.37 (0.53)	-	-	-	0.18	0.05
Carangidae	*Carangoides orthogrammus*	0.03 (0.17)	-	-	-	-	-	0.01	0.01
Carangidae	*Caranx melampygus*	0.02 (0.08)	-	-	-	0.02 (0.08)	0.02 (0.08)	0.01	0.00
Carangidae	*Decapterus macarellus*	-	-	-	-	-	-	-	-
Carangidae	*Scomberoides lysan*	-	-	0.02 (0.08)	-	-	-	<0.01	0.00
Chaetodontidae	*Chaetodon auriga*	0.03 (0.11)	0.02 (0.08)	0.07 (0.22)	0.07 (0.14)	-	0.07 (0.22)	0.04	0.01
Chaetodontidae	*Chaetodon fremblii*	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon kleinii*	0.02 (0.08)	-	-	-	0.02 (0.08)	-	0.01	0.00
Chaetodontidae	*Chaetodon lineolatus*	-	-	-	0.05 (0.18)	-	-	0.01	0.01
Chaetodontidae	*Chaetodon lunula*	-	0.05 (0.13)	0.07 (0.19)	0.27 (0.51)	-	0.03 (0.17)	0.07	0.01
Chaetodontidae	*Chaetodon lunulatus*	-	-	-	0.03 (0.17)	-	-	0.01	0.01
Chaetodontidae	*Chaetodon miliaris*	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon multicinctus*	0.02 (0.08)	0.03 (0.17)	0.07 (0.22)	1.82 (1.52)	0.33 (0.38)	0.68 (0.60)	0.49	0.07
Chaetodontidae	*Chaetodon ornatissimus*	0.02 (0.08)	0.22 (0.43)	0.22 (0.47)	0.85 (0.76)	0.43 (0.52)	0.53 (0.79)	0.38	0.05
Chaetodontidae	*Chaetodon quadrimaculatus*	0.03 (0.11)	0.02 (0.08)	0.18 (0.36)	0.05 (0.18)	-	-	0.05	0.02
Chaetodontidae	*Chaetodon unimaculatus*	-	-	-	-	-	-	-	-
Chaetodontidae	*Forcipiger flavissimus*	-	-	-	0.37 (0.39)	1.23 (0.59)	1.05 (1.14)	0.44	0.04
Chaetodontidae	*Forcipiger longirostris*	-	-	-	0.40 (0.73)	0.53 (0.53)	0.75 (0.66)	0.28	0.03
Cirrhitidae	*Cirrhitops fasciatus*	0.08 (0.23)	0.25 (0.28)	0.25 (0.25)	-	-	-	0.10	0.01
Cirrhitidae	*Cirrhitus pinnulatus*	-	0.03 (0.11)	-	0.02 (0.08)	-	-	0.01	0.01
Cirrhitidae	*Paracirrhites arcatus*	1.05 (0.94)	1.20 (0.71)	4.33 (2.36)	1.15 (0.77)	-	0.30 (0.42)	1.34	0.07
Cirrhitidae	*Paracirrhites forsteri*	-	0.05 (0.13)	-	0.22 (0.26)	0.12 (0.19)	0.10 (0.15)	0.08	0.02
Diodontidae	*Diodon holocanthus*	-	-	0.02 (0.08)	-	-	-	<0.01	0.00

Diodontidae	*Diodon hystrix*	-	0.02 (0.08)	0.02 (0.08)	-	-	-	0.01	0.00
Echeneidae	*Echeneis naucrates*	0.02 (0.08)	-	-	-	-	-	<0.01	0.00
Fistulariidae	*Fistularia commersonii*	-	0.08 (0.29)	0.30 (0.65)	0.03 (0.17)	-	-	0.07	0.04
Gobiidae	*Coryphopterus sp.*	-	-	-	-	-	0.02 (0.08)	<0.01	0.00
Gobiidae	Gobiidae sp.	-	-	-	-	-	-	-	-
Holocentridae	*Myripristis berndti*	-	-	-	0.22 (0.67)	0.23 (0.41)	0.08 (0.26)	0.09	0.03
Holocentridae	*Myripristis kuntee*	-	-	-	0.12 (0.29)	1.10 (1.75)	1.08 (1.82)	0.38	0.12
Holocentridae	*Neoniphon sammara*	-	-	-	-	0.75 (0.64)	0.03 (0.11)	0.13	0.03
Holocentridae	*Sargocentron diadema*	-	0.02 (0.08)	-	-	-	0.03 (0.11)	0.01	0.00
Holocentridae	*Sargocentron spiniferum*	-	-	-	-	-	-	-	-
Holocentridae	*Sargocentron tiere*	-	-	-	0.02 (0.08)	0.03 (0.11)	0.02 (0.08)	0.01	0.01
Kyphosidae	*Kyphosus sp.*	0.02 (0.08)	-	-	-	-	-	<0.01	0.00
Labridae	*Anampses chrysocephalus*	-	-	-	0.10 (0.29)	-	-	0.02	0.01
Labridae	*Anampses cuvier*	0.02 (0.08)	-	-	-	0.05 (0.13)	-	0.01	0.01
Labridae	*Bodianus albotaeniatus*	-	-	-	0.02 (0.08)	-	0.02 (0.08)	0.01	0.00
Labridae	*Coris flavovittata*	-	0.02 (0.08)	-	-	-	-	<0.01	0.00
Labridae	*Coris gaimard*	1.55 (1.25)	0.35 (0.55)	0.80 (0.66)	0.75 (0.69)	0.03 (0.11)	0.07 (0.19)	0.59	0.08
Labridae	*Coris venusta*	0.05 (0.13)	0.10 (0.15)	0.05 (0.25)	0.02 (0.08)	-	-	0.04	0.01
Labridae	*Gomphosus varius*	1.98 (1.33)	5.83 (1.87)	7.23 (3.31)	2.20 (2.32)	1.27 (1.53)	0.60 (0.52)	3.19	0.16
Labridae	*Halichoeres ornatissimus*	0.23 (0.55)	0.30 (0.42)	1.07 (1.00)	0.87 (0.59)	-	-	0.41	0.04
Labridae	Labridae sp.	0.15 (0.75)	-	-	-	-	-	0.03	0.03
Labridae	*Labroides phthirophagus*	0.03 (0.17)	0.48 (0.40)	0.15 (0.35)	0.12 (0.19)	0.17 (0.27)	0.10 (0.23)	0.18	0.04
Labridae	*Macropharyngodon geoffroy*	0.02 (0.08)	0.07 (0.14)	0.02 (0.08)	-	-	-	0.02	0.01
Labridae	*Novaculichthys taeniourus*	0.23 (0.30)	-	-	-	-	-	0.04	0.00
Labridae	*Oxycheilinus unifasciatus*	-	-	0.02 (0.08)	1.20 (0.90)	0.68 (0.54)	0.60 (0.56)	0.42	0.04
Labridae	*Pseudocheilinus evanidus*	-	0.03 (0.11)	-	0.47 (0.90)	0.47 (0.77)	1.88 (1.72)	0.48	0.10
Labridae	*Pseudocheilinus octotaenia*	0.02 (0.08)	-	0.03 (0.11)	0.43 (0.32)	0.18 (0.45)	0.12 (0.19)	0.13	0.02
Labridae	*Pseudocheilinus tetrataenia*	0.03 (0.11)	0.08 (0.15)	0.10 (0.15)	0.32 (0.58)	0.23 (0.39)	0.37 (0.72)	0.19	0.03
Labridae	*Pseudojuloides cerasinus*	-	-	-	-	-	-	-	-
Labridae	*Stethojulis balteata*	14.92 (7.78)	4.65 (2.20)	2.48 (2.14)	0.87 (0.73)	0.43 (0.63)	0.17 (0.27)	3.92	0.35

Labridae	*Thalassoma ballieui*	0.03 (0.11)	0.05 (0.13)	-	-	-	-	0.01	0.01
Labridae	*Thalassoma duperrey*	16.48 (6.18)	7.90 (3.39)	19.13 (6.93)	2.67 (2.64)	2.00 (2.56)	2.03 (2.5)	8.37	0.42
Labridae	*Thalassoma purpureum*	0.08 (0.23)	-	-	-	-	-	0.01	0.01
Labridae	*Thalassoma quinquevittatum*	-	-	0.03 (0.17)	-	-	-	0.01	0.01
Labridae	*Thalassoma trilobatum*	0.22 (0.45)	-	-	-	-	-	0.04	0.02
Lethrinidae	*Monotaxis grandoculis*	-	-	-	-	-	-	-	-
Lutjanidae	*Aphareus furca*	-	0.02 (0.08)	-	0.08 (0.23)	-	-	0.02	0.01
Lutjanidae	*Lutjanus fulvus*	-	-	-	0.02 (0.08)	-	-	<0.01	0.00
Lutjanidae	*Lutjanus kasmira*	-	-	-	0.03 (0.17)	0.02 (0.08)	-	0.01	0.01
Monacanthidae	*Cantherhines dumerilii*	-	0.03 (0.11)	0.03 (0.11)	0.15 (0.33)	-	0.03 (0.11)	0.04	0.01
Monacanthidae	*Cantherhines sandwichiensis*	0.07 (0.26)	0.10 (0.26)	0.05 (0.13)	0.02 (0.08)	-	-	0.04	0.02
Monacanthidae	*Pervagor aspricaudus*	-	-	-	0.07 (0.19)	0.05 (0.13)	-	0.02	0.01
Mullidae	*Mulloidichthys flavolineatus*	0.07 (0.26)	0.05 (0.18)	-	-	0.05 (0.25)	0.53 (1.21)	0.12	0.04
Mullidae	*Mulloidichthys vanicolensis*	-	-	-	-	0.13 (0.67)	0.02 (0.08)	0.03	0.02
Mullidae	*Parupeneus cyclostomus*	-	0.05 (0.25)	-	0.02 (0.08)	0.02 (0.08)	0.22 (0.23)	0.05	0.01
Mullidae	*Parupeneus insularis*	-	0.08 (0.19)	0.05 (0.25)	0.15 (0.35)	-	0.02 (0.08)	0.05	0.01
Mullidae	*Parupeneus multifasciatus*	0.03 (0.11)	0.58 (0.63)	0.23 (0.46)	0.45 (0.54)	0.17 (0.34)	0.50 (0.42)	0.33	0.06
Mullidae	*Parupeneus pleurostigma*	-	-	-	-	-	0.02 (0.08)	<0.01	0.00
Muraenidae	*Echidna nebulosa*	0.03 (0.11)	-	-	-	-	-	0.01	0.00
Muraenidae	*Gymnomuraena zebra*	-	-	0.02 (0.08)	-	-	-	<0.01	0.00
Muraenidae	*Gymnothorax eurostus*	-	-	-	-	-	-	-	-
Muraenidae	*Gymnothorax flavimarginatus*	0.10 (0.19)	-	0.02 (0.08)	0.03 (0.11)	0.02 (0.08)	-	0.03	0.00
Muraenidae	*Gymnothorax melatremus*	-	-	-	-	0.02 (0.08)	-	<0.01	0.00
Muraenidae	*Gymnothorax meleagris*	0.03 (0.11)	0.10 (0.15)	0.03 (0.11)	0.07 (0.14)	0.07 (0.19)	0.03 (0.11)	0.06	0.02
Ostraciidae	*Ostracion meleagris*	0.67 (0.73)	0.37 (0.39)	0.17 (0.27)	0.13 (0.22)	-	0.08 (0.19)	0.24	0.03
Ostraciidae	*Ostracion whitleyi*	-	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge fisheri*	-	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge loricula*	-	-	-	0.13 (0.22)	-	-	0.02	0.01
Pomacanthidae	*Centropyge potteri*	-	-	-	0.43 (0.52)	0.50 (0.51)	0.13 (0.28)	0.18	0.03
Pomacentridae	*Abudefduf abdominalis*	0.25 (0.68)	-	-	0.20 (0.54)	0.05 (0.18)	0.12 (0.6)	0.10	0.04

Pomacentridae	*Abudefduf sordidus*	0.12 (0.19)	-	-	-	-	-	0.02	0.01
Pomacentridae	*Abudefduf vaigiensis*	0.02 (0.08)	-	-	0.03 (0.17)	-	-	0.01	0.01
Pomacentridae	*Chromis agilis*	0.07 (0.33)	-	-	4.43 (2.22)	6.05 (5.14)	4.55 (2.64)	2.52	0.17
Pomacentridae	*Chromis hanui*	-	-	-	0.98 (0.51)	0.17 (0.27)	0.17 (0.27)	0.22	0.02
Pomacentridae	*Chromis ovalis*	0.53 (1.86)	-	-	-	-	-	0.09	0.09
Pomacentridae	*Chromis vanderbilti*	4.20 (4.83)	2.12 (4.73)	12.78 (12.80)	-	-	-	3.18	0.66
Pomacentridae	*Dascyllus albisella*	0.25 (0.28)	-	-	-	3.40 (2.39)	1.50 (2.70)	0.86	0.11
Pomacentridae	*Plectroglyphidodon imparipennis*	6.15 (4.83)	0.95 (0.85)	2.32 (1.84)	0.02 (0.08)	-	-	1.57	0.27
Pomacentridae	*Plectroglyphidodon johnstonianus*	0.10 (0.36)	0.40 (0.54)	0.20 (0.33)	0.73 (0.62)	0.87 (0.51)	0.82 (0.56)	0.52	0.04
Pomacentridae	*Stegastes marginatus*	1.55 (1.58)	3.37 (1.81)	0.52 (0.72)	2.65 (1.11)	0.10 (0.36)	-	1.36	0.12
Scaridae	*Calotomus carolinus*	0.02 (0.08)	0.08 (0.15)	0.07 (0.14)	0.35 (0.62)	0.10 (0.34)	0.03 (0.11)	0.11	0.04
Scaridae	*Chlorurus perspicillatus*	-	0.17 (0.83)	-	0.05 (0.25)	0.07 (0.26)	0.05 (0.25)	0.06	0.03
Scaridae	*Chlorurus spilurus*	0.55 (1.52)	2.12 (1.49)	0.37 (0.49)	5.35 (2.66)	1.72 (1.77)	1.15 (1.19)	1.88	0.23
Scaridae	*Scarus dubius*	-	0.27 (0.99)	0.47 (0.92)	0.15 (0.43)	0.23 (0.59)	0.02 (0.08)	0.19	0.05
Scaridae	*Scarus psittacus*	-	1.13 (1.85)	1.72 (2.08)	1.20 (2.28)	0.22 (0.50)	0.08 (0.29)	0.73	0.18
Scaridae	*Scarus rubroviolaceus*	0.37 (1.26)	0.70 (1.27)	1.37 (1.49)	0.98 (1.50)	0.12 (0.34)	0.10 (0.34)	0.61	0.10
Scaridae	*Scarus sp.*	0.15 (0.59)	0.30 (1.12)	0.12 (0.58)	0.07 (0.22)	-	0.02 (0.08)	0.11	0.06
Scorpaenidae	*Dendrochirus barberi*	0.02 (0.08)	-	-	-	-	-	<0.01	0.00
Scorpaenidae	*Sebastapistes coniorta*	0.07 (0.26)	-	-	-	-	-	0.01	0.01
Scorpaenidae	*Taenianotus triacanthus*	-	-	-	-	-	-	-	-
Serranidae	*Cephalopholis argus*	-	0.13 (0.14)	0.05 (0.18)	0.38 (0.43)	0.50 (0.47)	0.52 (0.51)	0.26	0.02
Synodontidae	*Saurida flamma*	-	-	-	-	0.02 (0.08)	-	<0.01	0.00
Synodontidae	*Saurida gracilis*	-	0.02 (0.08)	-	-	-	-	<0.01	0.00
Synodontidae	*Synodus sp.*	-	-	0.02 (0.08)	-	-	0.02 (0.08)	0.01	0.00
Synodontidae	*Synodus variegatus*	-	-	-	-	-	0.07 (0.19)	0.01	0.01
Tetraodontidae	*Arothron hispidus*	-	-	-	-	-	-	-	-
Tetraodontidae	*Arothron meleagris*	0.02 (0.08)	0.02 (0.08)	0.03 (0.11)	0.03 (0.17)	-	0.03 (0.11)	0.02	0.01
Tetraodontidae	*Canthigaster amboinensis*	0.18 (0.26)	0.05 (0.13)	0.25 (0.37)	-	-	-	0.08	0.01
Tetraodontidae	*Canthigaster coronata*	-	0.02 (0.08)	-	-	-	-	<0.01	0.00

Tetraodontidae	*Canthigaster jactator*	0.33 (0.40)	0.55 (0.64)	0.87 (1.14)	0.03 (0.11)	-	-	0.30	0.09
Zanclidae	*Zanclus cornutus*	-	-	0.03 (0.17)	0.15 (0.28)	0.03 (0.17)	0.03 (0.17)	0.04	0.01

Appendix 4: Fish species abundance (#/100 m^2) at **Pauoa** sites during **1979-1981** surveys**.** Ten surveys were performed on transect 1A, eleven were performed on transect 2A, and twelve surveys were performed at transects 3A through 6A. Site mean is the average of all six sites/ habitat zones. Species listed in gray were not observed at Pauoa sites during the surveys.

Family	**Taxa**	**1B**	**2B**	**3B**	**4B**	**5B**	**6B**	**Site mean**
Acanthuridae	*Acanthurus achilles*	0.10	-	0.08	1.55	0.43	0.03	0.36
Acanthuridae	*Acanthurus dussumieri*	-	-	-	-	-	0.03	<0.01
Acanthuridae	*Acanthurus leucopareius*	0.50	-	0.13	2.15	0.03	0.05	0.48
Acanthuridae	*Acanthurus nigricans*	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus nigrofuscus*	63.60	29.95	56.45	34.65	1.53	3.90	31.68
Acanthuridae	*Acanthurus nigroris*	0.30	-	-	0.13	-	-	0.07
Acanthuridae	*Acanthurus olivaceus*	-	-	-	0.13	0.08	0.28	0.08
Acanthuridae	*Acanthurus triostegus*	1.30	0.20	0.10	3.83	-	-	0.90
Acanthuridae	*Acanthurus xanthopterus*	-	-	-	-	-	-	-
Acanthuridae	*Ctenochaetus hawaiiensis*	-	-	-	-	-	-	-
Acanthuridae	*Ctenochaetus strigosus*	2.60	29.45	17.75	50.05	47.05	27.35	29.04
Acanthuridae	*Naso brevirostris*	-	-	-	0.05	0.10	1.23	0.23
Acanthuridae	*Naso hexacanthus*	-	-	-	-	0.15	4.05	0.70
Acanthuridae	*Naso lituratus*	0.20	0.70	0.83	1.45	1.43	0.88	0.91
Acanthuridae	*Naso unicornis*	-	0.18	-	0.18	0.28	-	0.10
Acanthuridae	*Zebrasoma flavescens*	-	0.63	1.65	13.20	11.85	7.83	5.86
Acanthuridae	*Zebrasoma veliferum*	-	-	-	0.25	-	-	0.04
Apogonidae	*Apogon sp.*	-	0.08	0.05	0.10	0.08	0.05	0.06
Aulostomidae	*Aulostomus chinensis*	-	0.18	0.08	0.58	0.40	0.23	0.24
Balistidae	*Canthidermis maculatus*	-	0.25	0.03	-	-	-	0.05
Balistidae	*Melichthys niger*	-	1.03	2.25	0.30	1.65	-	0.87
Balistidae	*Melichthys vidua*	-	0.05	0.10	0.08	0.08	0.30	0.10
Balistidae	*Rhinecanthus rectangulus*	1.20	0.30	0.83	0.88	-	-	0.53
Balistidae	*Sufflamen bursa*	-	0.40	0.38	1.33	0.65	2.60	0.89
Balistidae	*Sufflamen fraenatus*	-	-	-	-	-	0.03	<0.01
Balistidae	*Xanthichthys auromarginatus*	-	-	-	-	0.03	0.73	0.13
Blenniidae	*Cirripectes vanderbilti*	1.00	1.40	0.50	0.23	0.05	-	0.53
Blenniidae	*Exallias brevis*	-	0.25	0.13	0.83	0.50	0.25	0.33
Blenniidae	*Plagiotremus goslinei*	0.40	-	0.03	-	-	-	0.07
Carangidae	*Alectis ciliaris*	-	0.10	-	-	-	-	0.02
Carangidae	*Decapterus macarellus*	-	-	0.13	0.10	0.30	1.00	0.25

Carangidae	*Scomberoides lysan*	-	-	-	0.03	-	-	<0.01
Chaetodontidae	*Chaetodon auriga*	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon fremblii*	0.20	0.20	0.15	0.15	-	0.03	0.12
Chaetodontidae	*Chaetodon kleinii*	-	-	-	-	-	0.70	0.12
Chaetodontidae	*Chaetodon lunula*	0.60	-	0.08	0.20	0.13	-	0.17
Chaetodontidae	*Chaetodon lunulatus*	-	0.30	-	0.15	-	-	0.08
Chaetodontidae	*Chaetodon miliaris*	0.30	0.20	-	0.03	-	0.30	0.14
Chaetodontidae	*Chaetodon multicinctus*	0.80	3.53	3.28	5.55	7.55	4.63	4.22
Chaetodontidae	*Chaetodon ornatissimus*	0.60	0.63	0.35	0.85	0.13	0.30	0.48
Chaetodontidae	*Chaetodon quadrimaculatus*	0.20	0.73	0.88	0.68	-	-	0.41
Chaetodontidae	*Chaetodon unimaculatus*	0.20	1.05	0.15	0.20	0.43	-	0.34
Chaetodontidae	*Forcipiger flavissimus*	-	1.75	0.75	1.70	0.80	2.45	1.24
Chaetodontidae	*Forcipiger longirostris*	-	0.03	0.03	0.33	0.18	0.63	0.20
Chaetodontidae	*Hemitaurichthys polylepis*	-	-	-	-	-	-	-
Cirrhitidae	*Amblycirrhitus bimacula*	-	0.10	0.03	-	-	-	0.02
Cirrhitidae	*Cirrhitops fasciatus*	1.00	2.65	1.08	0.30	-	-	0.84
Cirrhitidae	*Cirrhitus pinnulatus*	-	0.18	0.05	0.28	-	-	0.08
Cirrhitidae	*Paracirrhites arcatus*	3.10	8.83	4.75	0.88	1.20	2.03	3.46
Cirrhitidae	*Paracirrhites forsteri*	0.20	0.10	0.08	0.35	0.38	0.18	0.21
Diodontidae	*Diodon holocanthus*	-	-	-	-	0.03	-	<0.01
Diodontidae	*Diodon hystrix*	0.10	-	-	-	-	0.05	0.03
Fistulariidae	*Fistularia commersonii*	0.20	0.10	0.15	0.03	-	-	0.08
Hemiramphidae	*Hyporhamphus acutus pacificus*	-	-	1.93	-	-	-	0.32
Holocentridae	*Myripristis sp.*	-	0.15	0.05	0.10	0.08	0.05	0.07
Holocentridae	*Neoniphon sammara*	-	-	-	-	-	-	-
Holocentridae	*Sargocentron sp.*	-	0.28	-	0.10	-	0.03	0.07
Labridae	*Anampses chrysocephalus*	-	-	-	-	-	-	-
Labridae	*Anampses cuvier*	-	-	-	-	-	-	-
Labridae	*Bodianus albotaeniatus*	-	-	-	0.08	0.05	0.08	0.03
Labridae	*Coris flavovittata*	-	-	-	-	-	-	-
Labridae	*Coris gaimard*	1.20	0.25	0.40	0.45	0.18	0.60	0.51
Labridae	*Gomphosus varius*	6.40	2.80	2.68	0.73	1.43	0.30	2.39
Labridae	*Halichoeres ornatissimus*	-	0.88	0.88	0.70	0.75	0.23	0.57
Labridae	*Labroides phthirophagus*	-	0.53	0.03	0.43	0.05	0.10	0.19
Labridae	Labridae sp.	1.00	0.03	0.03	0.03	-	0.05	0.19
Labridae	*Macropharyngodon geoffroy*	0.40	0.05	0.15	0.05	-	0.45	0.18
Labridae	*Novaculichthys taeniourus*	-	-	-	-	-	-	-
Labridae	*Oxycheilinus unifasciatus*	-	0.48	0.08	1.13	1.43	2.45	0.93
Labridae	*Pseudocheilinus evanidus*	-	0.03	-	-	0.25	1.60	0.31
Labridae	*Pseudocheilinus octotaenia*	-	-	-	0.25	0.68	0.78	0.28
Labridae	*Pseudocheilinus tetrataenia*	0.10	1.00	0.13	0.08	0.43	0.23	0.33

Labridae	*Pseudojuloides cerasinus*	-	-	-	-	0.10	0.13	0.04
Labridae	*Stethojulis balteata*	28.20	5.90	7.70	1.50	0.75	0.98	7.50
Labridae	*Thalassoma ballieui*	0.70	0.35	0.25	0.90	0.05	0.23	0.41
Labridae	*Thalassoma duperrey*	27.70	19.35	21.75	8.15	5.70	16.55	16.53
Labridae	*Thalassoma trilobatum*	0.20	0.20	0.13	-	-	-	0.09
Lethrinidae	*Monotaxis grandoculis*	-	-	-	-	-	-	-
Lutjanidae	*Aphareus furca*	-	-	-	0.20	0.03	-	0.04
Lutjanidae	*Aprion virescens*	-	-	-	-	-	0.10	0.02
Lutjanidae	*Lutjanus kasmira*	-	-	-	-	-	-	-
Monacanthidae	*Cantherhines dumerilii*	-	0.03	-	0.05	-	-	0.01
Monacanthidae	*Cantherhines sandwichiensis*	-	0.40	0.08	-	-	-	0.08
Monacanthidae	*Pervagor aspricaudus*	-	0.33	0.35	0.20	0.10	-	0.16
Monacanthidae	*Pervagor spilosoma*	0.20	0.60	0.05	0.03	0.03	0.05	0.16
Mullidae	*Mulloidichthys flavolineatus*	-	0.33	-	1.43	0.55	19.05	3.56
Mullidae	*Mulloidichthys vanicolensis*	-	0.25	-	0.95	0.18	4.63	1.00
Mullidae	*Parupeneus cyclostomus*	0.30	0.05	0.15	0.45	0.08	0.10	0.19
Mullidae	*Parupeneus insularis*	1.60	0.28	0.13	0.20	0.03	-	0.37
Mullidae	*Parupeneus multifasciatus*	1.40	0.98	1.00	1.05	0.65	1.73	1.13
Mullidae	*Parupeneus pleurostigma*	-	-	0.03	0.43	-	0.15	0.10
Mullidae	*Parupeneus porphyreus*	-	-	-	1.50	-	-	0.25
Muraenidae	*Echidna nebulosa*	-	-	-	-	-	-	-
Muraenidae	*Gymnomuraena zebra*	-	-	-	-	-	0.03	<0.01
Muraenidae	*Gymnothorax eurostus*	0.10	-	-	0.03	-	-	0.02
Muraenidae	*Gymnothorax flavimarginatus*	-	0.13	0.03	0.03	-	-	0.03
Muraenidae	*Gymnothorax meleagris*	-	0.15	0.05	0.03	0.03	0.05	0.05
Muraenidae	*Gymnothorax sp.*	0.10	0.05	-	0.05	0.05	-	0.04
Muraenidae	*Gymnothorax steindachneri*	-	-	-	-	0.03	0.05	0.01
Muraenidae	*Gymnothorax undulatus*	-	-	-	-	-	-	-
Ostraciidae	*Lactoria fornasini*	-	-	-	-	-	0.03	<0.01
Ostraciidae	*Ostracion meleagris*	0.40	0.80	0.48	0.20	-	0.03	0.32
Ostraciidae	*Ostracion whitleyi*	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge potteri*	-	-	-	2.15	5.80	6.05	2.33
Pomacentridae	*Abudefduf abdominalis*	1.10	0.13	-	2.78	-	1.13	0.85
Pomacentridae	*Abudefduf sordidus*	-	-	-	-	-	-	-
Pomacentridae	*Chromis agilis*	-	-	-	3.13	2.63	6.95	2.12
Pomacentridae	*Chromis hanui*	-	0.20	-	4.85	3.50	2.90	1.91
Pomacentridae	*Chromis ovalis*	-	-	-	-	-	-	-
Pomacentridae	*Chromis vanderbilti*	0.40	2.35	3.85	0.53	-	-	1.19
Pomacentridae	*Chromis verater*	-	-	-	-	-	3.33	0.55
Pomacentridae	*Dascyllus albisella*	-	-	-	-	-	5.08	0.85
Pomacentridae	*Plectroglyphidodon imparipennis*	7.70	0.20	1.28	-	-	-	1.53

Pomacentridae	*Plectroglyphidodon johnstonianus*	0.10	2.95	0.58	1.90	2.63	2.45	1.77
Pomacentridae	*Stegastes marginatus*	0.80	6.25	4.45	4.85	2.40	-	4.79
Priacanthidae	*Priacanthus sp.*	-	-	0.13	-	-	0.03	0.03
Scaridae	*Calotomus sp.*	0.10	0.08	0.23	0.13	0.15	0.08	0.13
Scaridae	*Chlorurus perspicillatus*	-	0.03	0.15	0.23	0.03	-	0.07
Scaridae	*Chlorurus spilurus*	-	0.03	0.10	1.95	0.90	0.48	0.58
Scaridae	*Scarus dubius*	2.90	0.03	1.75	0.28	-	0.10	0.84
Scaridae	*Scarus rubroviolaceus*	-	-	0.18	0.43	-	-	0.10
Scaridae	*Scarus sp.***	3.00	0.53	1.78	3.48	0.13	1.55	1.74
Scorpaenidae	*Pterois sphex*	-	-	-	-	-	-	-
Scorpaenidae	*Scorpaenopsis diabolus*	-	0.03	-	-	-	-	<0.01
Scorpaenidae	*Sebastapistes coniorta*	-	0.38	0.60	-	-	-	0.16
Scorpaenidae	*Taenianotus triacanthus*	-	-	-	-	-	-	-
Serranidae	*Cephalopholis argus*	-	-	-	0.08	0.03	-	0.02
Sphyraenidae	*Sphyraena barracuda*	-	-	-	-	-	-	-
Sphyraenidae	*Sphyraena helleri*	-	-	-	-	-	-	-
Synodontidae	*Synodus sp.*	0.20	0.13	0.03	0.08	0.05	0.13	0.10
Tetraodontidae	*Arothron hispidus*	-	-	-	0.05	-	-	0.01
Tetraodontidae	*Arothron meleagris*	-	-	0.03	0.08	-	-	0.02
Tetraodontidae	*Canthigaster amboinensis*	0.60	0.18	0.03	-	-	-	0.13
Tetraodontidae	*Canthigaster coronata*	-	-	-	-	-	-	-
Tetraodontidae	*Canthigaster epilampra*	-	-	-	-	-	-	-
Tetraodontidae	*Canthigaster jactator*	2.20	0.95	0.80	0.33	-	-	0.71
Tetraodontidae	*Canthigaster rivulata*	-	-	-	0.03	-	-	<0.01
Zanclidae	*Zanclus cornutus*	0.80	0.43	0.43	0.63	0.23	0.60	0.52

**Note: *Scarus sp.* Recorded as *Scarus* juveniles in Hayes et al. 1982.

Appendix 5: Mean fish abundance (#/100 m^2) observed at **Pauoa** during **2007-2008** resurveys. Standard error is listed in parenthesis. Twelve surveys were performed at each site. Site mean is the average abundance of all six sites/ habitat zones. Species listed in gray were not observed at Pauoa sites during the surveys.

Family	**Taxa**	**1B**	**2B**	**3B**	**4B**	**5B**	**6B**	**Site mean**	**SE**
Acanthuridae	*Acanthurus sp.*	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus achilles*	-	-	0.25 (1.25)	0.08 (0.29)	0.02 (0.08)	-	0.06	0.27
Acanthuridae	*Acanthurus blochii*	-	-	0.37 (1.22)	0.02 (0.08)	-	-	0.06	0.22
Acanthuridae	*Acanthurus dussumieri*	-	-	0.05 (0.25)	-	0.03 (0.17)	-	0.01	0.07
Acanthuridae	*Acanthurus leucopareius*	-	-	0.08 (0.23)	-	-	-	0.01	0.04
Acanthuridae	*Acanthurus nigricans*	-	-	-	-	-	-	-	-

Acanthuridae	*Acanthurus nigrofuscus*	0.02 (0.08)	19.33 (6.73)	6.98 (7.36)	5.90 (4.09)	1.33 (1.16)	0.23 (0.42)	5.63	3.31
Acanthuridae	*Acanthurus nigroris*	-	-	0.05 (0.13)	0.15 (0.43)	0.07 (0.14)	-	0.04	0.12
Acanthuridae	*Acanthurus olivaceus*	0.05 (0.18)	0.10 (0.19)	0.72 (0.89)	0.33 (0.75)	0.07 (0.19)	0.37 (0.9)	0.27	0.52
Acanthuridae	*Acanthurus thompsoni*	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus triostegus*	0.08 (0.23)	0.03 (0.11)	1.97 (4.19)	0.83 (1.73)	0.02 (0.08)	0.02 (0.08)	0.49	1.07
Acanthuridae	*Acanthurus xanthopterus*	-	-	0.02 (0.08)	-	-	-	-	0.01
Acanthuridae	*Ctenochaetus hawaiiensis*	-	-	-	-	-	0.20 (0.28)	0.03	0.05
Acanthuridae	*Ctenochaetus strigosus*	-	-	0.17 (0.51)	17.93 (5.71)	21.02 (7.31)	12.08 (5.82)	8.53	3.22
Acanthuridae	*Naso brevirostris*	-	-	-	0.07 (0.33)	0.08 (0.42)	0.13 (0.67)	0.05	0.24
Acanthuridae	*Naso hexacanthus*	-	-	-	-	0.02 (0.08)	0.82 (3.64)	0.14	0.62
Acanthuridae	*Naso lituratus*	0.18 (0.29)	0.20 (0.37)	0.58 (0.98)	0.32 (0.38)	0.35 (0.43)	0.12 (0.29)	0.29	0.46
Acanthuridae	*Naso unicornis*	0.03 (0.11)	-	0.03 (0.17)	-	-	0.05 (0.25)	0.02	0.09
Acanthuridae	*Zebrasoma flavescens*	0.53 (0.57)	0.07 (0.19)	2.85 (5.90)	12.63 (2.88)	14.93 (6.75)	9.38 (2.51)	6.73	3.13
Acanthuridae	*Zebrasoma veliferum*	-	-	0.07 (0.33)	-	-	-	0.01	0.06
Apogonidae	*Pristiapogon kallopterus*	0.05 (0.13)	-	-	-	0.03 (0.11)	-	0.01	0.04
Aulostomidae	*Aulostomus chinensis*	-	-	-	-	0.05 (0.13)	0.05 (0.13)	0.02	0.04
Balistidae	*Canthidermis maculatus*	-	-	-	-	-	-	-	-
Balistidae	*Melichthys niger*	0.23 (0.39)	0.03 (0.11)	0.73 (0.86)	0.07 (0.19)	0.10 (0.36)	0.03 (0.17)	0.20	0.34
Balistidae	*Melichthys vidua*	-	0.05 (0.18)	0.28 (0.31)	0.20 (0.39)	0.07 (0.14)	0.12 (0.19)	0.12	0.20
Balistidae	*Rhinecanthus aculeatus*	-	0.17 (0.24)	-	-	-	-	0.03	0.04
Balistidae	*Rhinecanthus rectangulus*	0.85 (0.63)	0.67 (0.50)	0.67 (0.54)	-	-	-	0.36	0.28
Balistidae	*Sufflamen bursa*	-	-	0.10 (0.26)	0.20 (0.30)	0.30 (0.51)	0.43 (0.52)	0.17	0.27
Balistidae	*Sufflamen fraenatus*	-	-	-	-	-	-	-	-
Balistidae	*Xanthichthys auromarginatus*	-	-	-	-	-	-	-	-
Blenniidae	*Blenniella gibbifrons*	0.03 (0.11)	-	-	-	-	-	0.01	0.02
Blenniidae	*Cirripectes vanderbilti*	0.15 (0.35)	0.47 (0.57)	0.43 (0.53)	0.05 (0.13)	-	-	0.18	0.26
Blenniidae	*Exallias brevis*	0.03 (0.17)	0.02 (0.08)	-	0.17 (0.17)	0.10 (0.15)	-	0.05	0.09
Blenniidae	*Plagiotremus ewaensis*	0.05 (0.13)	0.02 (0.08)	0.05 (0.13)	-	-	-	0.02	0.06
Blenniidae	*Plagiotremus goslinei*	0.65 (1.04)	0.12 (0.19)	0.28 (0.58)	-	-	-	0.18	0.30
Carangidae	*Carangoides orthogrammus*	-	-	-	-	-	-	-	-

Carangidae	*Caranx melampygus*	0.07 (0.33)	-	-	-	-	-	0.01	0.06
Carangidae	*Decapterus macarellus*	-	-	-	0.05 (0.25)	0.05 (0.25)	-	0.02	0.08
Carangidae	*Scomberoides lysan*	0.03 (0.11)	-	0.02 (0.08)	-	-	-	0.01	0.03
Chaetodontidae	*Chaetodon auriga*	0.22 (0.26)	0.13 (0.38)	-	0.02 (0.08)	-	0.07 (0.22)	0.07	0.16
Chaetodontidae	*Chaetodon fremblii*	-	0.02 (0.08)	-	-	-	-	<0.01	0.01
Chaetodontidae	*Chaetodon kleinii*	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon lineolatus*	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon lunula*	-	0.10 (0.34)	-	0.05 (0.18)	-	0.08 (0.23)	0.04	0.12
Chaetodontidae	*Chaetodon lunulatus*	-	0.08 (0.19)	-	0.07 (0.22)	-	-	0.03	0.07
Chaetodontidae	*Chaetodon miliaris*	-	-	-	0.02 (0.08)	-	-	<0.01	0.01
Chaetodontidae	*Chaetodon multicinctus*	-	-	-	0.87 (0.71)	0.97 (0.89)	0.95 (0.80)	0.46	0.40
Chaetodontidae	*Chaetodon ornatissimus*	0.07 (0.19)	0.10 (0.19)	0.17 (0.30)	0.08 (0.34)	0.35 (0.43)	0.37 (0.49)	0.19	0.32
Chaetodontidae	*Chaetodon quadrimaculatus*	-	0.13 (0.36)	0.05 (0.18)	0.03 (0.11)	-	-	0.04	0.11
Chaetodontidae	*Chaetodon unimaculatus*	-	0.20 (0.44)	-	0.10 (0.23)	-	-	0.05	0.11
Chaetodontidae	*Forcipiger flavissimus*	-	0.07 (0.26)	-	0.20 (0.41)	0.23 (0.41)	0.78 (0.77)	0.21	0.31
Chaetodontidae	*Forcipiger longirostris*	-	0.02 (0.08)	-	0.12 (0.29)	0.17 (0.41)	0.38 (0.69)	0.11	0.24
Cirrhitidae	*Cirrhitops fasciatus*	0.12 (0.19)	0.03 (0.11)	0.15 (0.28)	-	-	-	0.05	0.10
Cirrhitidae	*Cirrhitus pinnulatus*	-	-	-	-	-	-	-	-
Cirrhitidae	*Paracirrhites arcatus*	0.92 (0.86)	1.00 (0.39)	4.15 (2.47)	1.00 (0.73)	0.20 (0.41)	0.77 (0.56)	1.34	0.90
Cirrhitidae	*Paracirrhites forsteri*	-	0.03 (0.11)	0.27 (0.98)	0.13 (0.19)	0.13 (0.28)	0.13 (0.22)	0.12	0.30
Diodontidae	*Diodon holocanthus*	0.02 (0.08)	0.03 (0.11)	-	-	-	-	0.01	0.03
Diodontidae	*Diodon hystrix*	-	0.03 (0.11)	-	-	-	-	0.01	0.02
Echeneidae	*Echeneis naucrates*	0.02 (0.08)	-	-	-	-	-	<0.01	0.01
Fistulariidae	*Fistularia commersonii*	0.02 (0.08)	0.02 (0.08)	0.22 (0.48)	0.02 (0.08)	-	-	0.04	0.12
Gobiidae	*Coryphopterus sp.*	-	-	-	0.02 (0.08)	-	-	<0.01	0.01
Gobiidae	*Gobiidae sp.*	0.08 (0.19)	-	-	-	-	-	0.01	0.03
Holocentridae	*Myripristis berndti*	-	-	-	-	-	0.68 (3.33)	0.11	0.55
Holocentridae	*Myripristis kuntee*	-	-	-	0.07 (0.33)	-	0.68 (1.63)	0.13	0.33
Holocentridae	*Neoniphon sammara*	-	-	-	0.15 (0.75)	-	0.53 (1.36)	0.11	0.35
Holocentridae	*Sargocentron diadema*	-	-	-	-	-	-	-	-

Holocentridae	*Sargocentron spiniferum*	-	-	-	-	-	0.02 (0.08)	-	0.01
Holocentridae	*Sargocentron tiere*	-	-	-	0.03 (0.17)	-	0.02 (0.08)	0.01	0.04
Kyphosidae	*Kyphosus sp.*	-	-	-	-	-	-	-	-
Labridae	*Anampses chrysocephalus*	-	-	-	-	0.03 (0.11)	-	0.01	0.02
Labridae	*Anampses cuvier*	-	0.03 (0.11)	-	-	-	-	0.01	0.02
Labridae	*Bodianus albotaeniatus*	-	-	-	-	-	-	-	-
Labridae	*Coris flavovittata*	-	-	-	-	-	-	-	-
Labridae	*Coris gaimard*	0.03 (0.11)	0.72 (0.57)	0.23 (0.37)	0.30 (0.31)	0.30 (1.06)	0.48 (0.53)	0.34	0.49
Labridae	*Coris venusta*	0.08 (0.15)	0.13 (0.43)	0.02 (0.08)	-	-	-	0.04	0.11
Labridae	*Gomphosus varius*	0.32 (0.45)	2.73 (1.35)	7.17 (3.37)	1.30 (0.98)	1.25 (1.39)	0.75 (0.48)	2.25	1.34
Labridae	*Halichoeres ornatissimus*	0.28 (0.62)	0.17 (0.44)	1.25 (1.02)	0.35 (0.71)	0.28 (0.34)	-	0.39	0.52
Labridae	Labridae sp	0.30 (1.25)	-	-	-	-	-	0.05	0.21
Labridae	*Labroides phthirophagus*	-	0.03 (0.34)	0.07 (0.19)	0.08 (0.23)	0.07 (0.14)	0.02 (0.08)	0.09	0.16
Labridae	*Macropharyngodon geoffroy*	0.03 (0.11)	-	0.25 (0.57)	-	-	0.08 (0.23)	0.06	0.15
Labridae	*Novaculichthys taeniourus*	0.18 (0.40)	0.02 (0.08)	-	0.02 (0.08)	-	-	0.04	0.09
Labridae	*Oxycheilinus unifasciatus*	-	-	-	0.45 (0.54)	0.37 (0.30)	0.58 (0.54)	0.23	0.23
Labridae	*Pseudocheilinus evanidus*	-	-	0.02 (0.08)	0.12 (0.19)	0.08 (0.19)	1.28 (2.11)	0.25	0.43
Labridae	*Pseudocheilinus octotaenia*	-	-	-	0.12 (0.29)	0.20 (0.43)	0.08 (0.23)	0.07	0.16
Labridae	*Pseudocheilinus tetrataenia*	0.02 (0.08)	0.20 (0.74)	0.18 (0.26)	0.58 (0.57)	0.33 (0.53)	0.12 (0.15)	0.24	0.39
Labridae	*Pseudojuloides cerasinus*	-	-	0.02 (0.08)	-	-	0.15 (0.28)	0.03	0.06
Labridae	*Stethojulis balteata*	8.47 (8.12)	5.07 (2.74)	5.22 (3.02)	1.58 (0.78)	1.35 (0.97)	1.32 (2.20)	3.83	2.97
Labridae	*Thalassoma ballieui*	-	-	-	-	-	-	-	-
Labridae	*Thalassoma duperrey*	4.23 (1.98)	8.88 (2.90)	20.1 (6.26)	3.45 (1.28)	2.15 (1.37)	1.72 (0.93)	6.76	2.45
Labridae	*Thalassoma purpureum*	0.03 (0.11)	-	-	-	-	-	0.01	0.02
Labridae	*Thalassoma quinquevittatum*	0.02 (0.08)	0.07 (0.22)	-	-	-	-	0.01	0.05
Labridae	*Thalassoma trilobatum*	0.37 (0.32)	-	-	-	-	-	0.06	0.05
Lethrinidae	*Monotaxis grandoculis*	-	-	-	0.05 (0.25)	-	0.05 (0.18)	0.02	0.07
Lutjanidae	*Aphareus furca*	-	-	-	-	-	0.02 (0.08)	<0.01	0.01
Lutjanidae	*Lutjanus fulvus*	-	-	-	-	-	0.02 (0.08)	<0.01	0.01
Lutjanidae	*Lutjanus kasmira*	-	-	-	-	-	-	-	-

Monacanthidae	*Cantherhines dumerilii*	0.02 (0.08)	0.05 (0.18)	-	0.05 (0.18)	0.03 (0.17)	-	0.03	0.10
Monacanthidae	*Cantherhines sandwichiensis*	0.05 (0.18)	-	0.10 (0.15)	-	-	-	0.03	0.06
Monacanthidae	*Pervagor aspricaudus*	-	-	-	-	0.02 (0.08)	-	<0.01	0.01
Mullidae	*Mulloidichthys flavolineatus*	-	0.02 (0.08)	-	0.03 (0.17)	0.10 (0.23)	0.35 (0.69)	0.08	0.19
Mullidae	*Mulloidichthys vanicolensis*	-	-	-	-	-	0.27 (1.33)	0.04	0.22
Mullidae	*Parupeneus cyclostomus*	-	0.03 (0.11)	-	0.08 (0.15)	0.05 (0.13)	0.18 (0.38)	0.06	0.13
Mullidae	*Parupeneus insularis*	-	0.02 (0.08)	0.03 (0.11)	0.05 (0.18)	0.02 (0.08)	0.02 (0.08)	0.02	0.09
Mullidae	*Parupeneus multifasciatus*	0.02 (0.08)	0.52 (0.53)	0.08 (0.15)	0.50 (0.45)	0.40 (0.51)	0.85 (1.27)	0.39	0.50
Mullidae	*Parupeneus pleurostigma*	-	-	-	-	-	0.05 (0.18)	0.01	0.03
Muraenidae	*Echidna nebulosa*	-	-	-	-	-	-	-	-
Muraenidae	*Gymnomuraena zebra*	-	-	-	-	-	-	-	-
Muraenidae	*Gymnothorax eurostus*	0.02 (0.08)	-	-	0.02 (0.08)	-	-	0.01	0.03
Muraenidae	*Gymnothorax flavimarginatus*	0.02 (0.08)	-	-	-	0.02 (0.08)	0.03 (0.11)	0.01	0.05
Muraenidae	*Gymnothorax melatremus*	-	-	-	-	-	0.02 (0.08)	<0.01	0.01
Muraenidae	*Gymnothorax meleagris*	0.02 (0.08)	-	0.07 (0.14)	0.05 (0.13)	0.03 (0.11)	0.02 (0.08)	0.03	0.09
Ostraciidae	*Ostracion meleagris*	0.42 (0.60)	0.18 (0.29)	0.05 (0.13)	0.15 (0.25)	0.07 (0.14)	0.13 (0.19)	0.17	0.27
Ostraciidae	*Ostracion whitleyi*	-	-	-	-	-	0.02 (0.08)	<0.01	0.01
Pomacanthidae	*Centropyge fisheri*	-	-	0.02 (0.08)	-	-	-	<0.01	0.01
Pomacanthidae	*Centropyge loricula*	-	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge potteri*	-	-	-	0.02 (0.08)	0.05 (0.13)	0.20 (0.37)	0.04	0.10
Pomacentridae	*Abudefduf abdominalis*	0.03 (0.11)	-	-	-	-	-	0.01	0.02
Pomacentridae	*Abudefduf sordidus*	-	-	-	-	-	-	-	-
Pomacentridae	*Abudefduf vaigiensis*	-	-	-	-	-	-	-	-
Pomacentridae	*Chromis agilis*	0.03 (0.11)	0.02 (0.08)	-	0.57 (0.58)	1.35 (1.27)	2.78 (2.67)	0.79	0.79
Pomacentridae	*Chromis hanui*	-	-	-	0.47 (0.50)	0.62 (0.53)	0.33 (0.38)	0.24	0.23
Pomacentridae	*Chromis ovalis*	0.33 (0.84)	0.92 (2.47)	-	-	0.22 (1.00)	-	0.24	0.72
Pomacentridae	*Chromis vanderbilti*	5.28 (3.66)	6.65 (10.72)	9.70 (10.63)	-	-	-	3.61	4.17
Pomacentridae	*Chromis verater*	-	-	-	-	-	-	-	-
Pomacentridae	*Plectroglyphidodon imparipennis*	9.43 (6.56)	0.8 (0.51)	2.93 (1.76)	-	-	-	2.19	1.47
Pomacentridae	*Plectroglyphidodon johnstonianus*	0.05 (0.18)	0.38 (0.60)	0.68 (0.71)	0.65 (0.37)	0.75 (0.66)	0.73 (0.68)	0.54	0.53
Pomacentridae	*Stegastes marginatus*	2.22 (2.09)	2.62 (1.94)	1.42 (1.78)	2.27 (1.04)	0.88 (0.71)	-	1.57	1.26

Scaridae	*Calotomus carolinus*	-	-	0.05 (0.18)	0.05 (0.13)	0.13 (0.26)	0.05 (0.25)	0.05	0.14
Scaridae	*Chlorurus perspicillatus*	-	-	-	0.13 (0.43)	0.03 (0.11)	-	0.03	0.09
Scaridae	*Chlorurus spilurus*	0.13 (0.50)	1.50 (1.88)	0.40 (0.74)	4.27 (1.23)	2.32 (1.64)	1.35 (1.52)	1.66	1.25
Scaridae	*Scarus dubius*	-	0.47 (0.93)	0.87 (2.04)	0.28 (0.71)	0.03 (0.17)	0.02 (0.08)	0.28	0.66
Scaridae	*Scarus psittacus*	0.17 (0.83)	1.32 (1.57)	1.43 (2.51)	2.77 (4.12)	0.38 (0.78)	0.07 (0.14)	1.02	1.66
Scaridae	*Scarus rubroviolaceus*	0.08 (0.42)	0.78 (1.08)	0.72 (1.02)	0.65 (1.02)	0.13 (0.22)	0.07 (0.19)	0.41	0.66
Scaridae	*Scarus sp.*	0.58 (1.99)	0.23 (0.82)	0.08 (0.34)	0.83 (2.20)	-	0.05 (0.25)	0.30	0.93
Scorpaenidae	*Dendrochirus barberi*	-	-	-	-	-	-	-	-
Scorpaenidae	*Sebastapistes coniorta*	0.27 (0.77)	-	-	-	-	-	0.04	0.13
Scorpaenidae	*Taenianotus triacanthus*	-	-	-	-	0.02 (0.08)	-	<0.01	0.01
Serranidae	*Cephalopholis argus*	-	0.23 (0.17)	0.02 (0.08)	0.42 (0.38)	0.40 (0.49)	0.38 (0.48)	0.24	0.27
Synodontidae	*Saurida flamma*	-	-	-	-	-	0.02 (0.08)	<0.01	0.01
Synodontidae	*Saurida gracilis*	-	-	-	-	-	0.02 (0.08)	<0.01	0.01
Synodontidae	*Synodus sp.*	-	-	-	-	-	-	-	-
Synodontidae	*Synodus variegatus*	0.02 (0.08)	-	-	-	-	0.05 (0.13)	0.01	0.04
Tetraodontidae	*Arothron hispidus*	0.02 (0.08)	0.03 (0.11)	-	-	0.02 (0.08)	-	0.01	0.05
Tetraodontidae	*Arothron meleagris*	0.05 (0.13)	0.05 (0.13)	-	0.02 (0.08)	0.02 (0.08)	0.02 (0.08)	0.03	0.09
Tetraodontidae	*Canthigaster amboinensis*	0.38 (0.43)	0.18 (0.31)	0.05 (0.13)	-	-	-	0.10	0.15
Tetraodontidae	*Canthigaster coronata*	-	-	-	-	-	0.08 (0.23)	0.01	0.04
Tetraodontidae	*Canthigaster jactator*	0.53 (0.74)	1.05 (1.06)	1.28 (1.92)	0.28 (0.47)	0.02 (0.08)	-	0.53	0.71
Zanclidae	*Zanclus cornutus*	0.17 (0.27)	0.05 (0.13)	-	0.02 (0.08)	0.02 (0.08)	0.03 (0.17)	0.05	0.12

Appendix 6. Species observed during transect surveys during only one round of the survey period for Puakō or Pauoa. Grayed-out numbers indicate that a fish species was observed during both 1978-1981 and 2007-2008 surveys at a site.

Family	**Species**	**Puakō**		**Pauoa**	
		1978-81	**2007-08**	**1978-81**	**2007-08**
		Site Mean (#/100m^2)		**Site Mean (#/100m^2)**	
Acanthuridae	*Acanthurus blochii*	-	-	-	0.06
Acanthuridae	*Acanthurus nigroris*	-	0.11	-	-
Acanthuridae	Acanthurus thompsoni	-	0.01	-	-
Acanthuridae	Acanthurus xanthopterus	0.16	-	-	<0.01

Acanthuridae	Ctenochaetus hawaiiensis	-	-	-	0.03
Apogonidae	Pristiapogon kallopterus	-	0.03	-	-
Balistidae	*Canthidermis maculatus*	-	-	0.05	-
Balistidae	*Rhinecanthus aculeatus*	-	-	-	0.03
Balistidae	*Sufflamen fraenatus*	-	-	<0.01	-
Balistidae	*Xanthichthys auromarginatus*	-	-	0.13	-
Blenniidae	*Blenniella gibbifrons*	-	-	-	0.01
Blenniidae	*Plagiotremus ewaensis*	-	0.01	-	0.02
Carangidae	*Alectis ciliaris*	-	-	0.02	-
Carangidae	*Carangoides orthogrammus*	-	0.01	-	-
Carangidae	*Caranx melampygus*	-	0.01	-	0.01
Carangidae	*Decapterus macarellus*	0.03	-	-	-
Chaetodontidae	*Chaetodon auriga*	-	-	-	0.07
Chaetodontidae	*Chaetodon fremblii*	0.06	-	0.12	<0.01
Chaetodontidae	*Chaetodon kleinii*	-	-	0.12	-
Chaetodontidae	*Chaetodon lineolatus*	-	0.01	-	-
Chaetodontidae	*Chaetodon miliaris*	0.05	-	0.14	<0.01
Chaetodontidae	*Chaetodon unimaculatus*	0.23	-	0.34	0.05
Chaetodontidae	*Hemitaurichthys polylepis*	0.01	-	-	-
Cirrhitidae	*Amblycirrhitus bimacula*	-	-	0.02	-
Cirrhitidae	*Cirrhitus pinnulatus*	-	-	0.08	-
Diodontidae	*Diodon hystrix*	-	0.01	0.03	0.01
Echeneidae	*Echeneis naucrates*	-	<0.01	-	<0.01
Hemiramphidae	*Hyporhamphus acutus*	-	-	0.32	-
Holocentridae	*Myripristis berndti*	-	0.09	-	0.11
Holocentridae	*Myripristis kuntee*	-	0.38	-	0.13
Holocentridae	*Neoniphon sammara*	<0.01	0.13	-	0.11
Holocentridae	*Sargocentron diadema*	-	0.01	-	-
Holocentridae	*Sargocentron spiniferum*	-	-	-	<0.01
Holocentridae	*Sargocentron tiere*	-	0.01	-	0.01
Labridae	*Anampses chrysocephalus*	-	-	-	0.01
Labridae	*Anampses cuvier*	-	-	-	0.01
Labridae	*Bodianus albotaeniatus*	-	-	0.03	-
Labridae	*Coris venusta*	-	0.04	-	0.04
Labridae	*Novaculichthys taeniourus*	-	-	-	0.04
Labridae	*Pseudojuloides cerasinus*	0.01	-	0.04	0.03
Labridae	*Thalassoma ballieui*	-	-	0.41	-
Labridae	*Thalassoma purpureum*	-	0.01	-	0.01
Labridae	*Thalassoma quinquevittatum*	-	0.01	-	0.01
Lethrinidae	*Monotaxis grandoculis*	0.01	-	-	0.02
Lutjanidae	*Aprion virescens*	<0.01	-	0.02	-
Lutjanidae	*Lutjanus fulvus*	-	<0.01	-	<0.01

Monacanthidae	*Pervagor spilosoma*	0.13	-	0.16	-
Mullidae	*Parupeneus porphyreus*	-	-	0.25	-
Monacanthidae	*Gymnomuraena zebra*	-	<0.01	<0.01	-
Monacanthidae	*Gymnothorax eurostus*	<0.01	-	0.02	0.01
Muraenidae	*Gymnothorax melatremus*	-	<0.01	-	<0.01
Muraenidae	*Gymnothorax undulatus*	<0.01	-	-	-
Muraenidae	*Gymnothorax steindachneri*	-	-	0.01	-
Ostraciidae	*Lactoria fornasini*	0.01	-	0.01	-
Ostraciidae	*Ostracion whitleyi*	0.02	-	-	<0.01
Pomacanthidae	*Centropyge fisheri*	-	-	-	<0.01
Pomacanthidae	*Centropyge loricula*	-	0.02	-	-
Pomacentridae	*Abudefduf vaigiensis*	-	0.01	-	-
Pomacentridae	*Chromis ovalis*	-	-	-	0.24
Pomacentridae	*Chromis verater*	0.11	-	0.55	-
Scaridae	*Calotomus carolinus*	-	0.11	-	0.05
Scaridae	*Scarus psittacus*	-	0.73	-	1.02
Scorpaenidae	*Pterois sphex*	<0.01	-	-	-
Scorpaenidae	*Dendrochirus barberi*	-	<0.01	-	-
Scorpaenidae	*Scorpaenopsis diabolus*	0.02	-	<0.01	-
Scorpaenidae	*Taenianotus triacanthus*	0.04	-	-	<0.01
Sphyraenidae	*Sphyraena barracuda*	<0.01	-	-	-
Sphyraenidae	*Sphyraena helleri*	0.06	-	-	-
Synodontidae	*Saurida flamma*	-	<0.01	-	<0.01
Synodontidae	*Saurida gracilis*	-	<0.01	-	<0.01
Synodontidae	*Synodus variegatus*	-	0.01	-	0.01
Tetraodontidae	*Arothron hispidus*	-	-	0.01	0.01
Tetraodontidae	*Canthigaster epilampra*	0.01	-	-	-
Tetraodontidae	*Canthigaster coronata*	-	-	-	0.01
Tetraodontidae	*Canthigaster rivulata*	-	-	<0.01	-
Number of unique species		**21**	**27**	**19**	**33**

Appendix 7: Mean fish abundance (#/1000 m^2) by size class for total fish length (cm) observed at **Puakō** during **2007-2008** resurveys. For fishes less than 25 cm in total length, sizes were binned in 5 cm increments. For fishes greater than 25 cm in total length, sizes were estimated to the nearest 5 cm. Species listed in gray were not observed at Puakō sites during the surveys.

Family	**Taxa**	**Mean abundance (#/1000 m^2) by size class (cm)**											
		0-5	**5-10**	**10-15**	**15-20**	**20-25**	**25**	**30**	**35**	**40**	**45**	**50**	**>50**
Acanthuridae	Acanthuridae sp.	0.03	-	-	-	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus achilles*	0.03	0.11	0.06	0.06	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus blochii*	-	0.06	0.03	-	-	-	0.14	0.06	-	-	-	-
Acanthuridae	*Acanthurus dussumieri*	-	-	-	-	-	-	-	0.03	-	-	-	-
Acanthuridae	*Acanthurus leucopareius*	0.14	0.47	0.53	3.19	0.31	-	0.31	-	-	-	-	-
Acanthuridae	*Acanthurus nigricans*	-	0.14	0.11	-	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus nigrofuscus*	0.94	9.42	28.50	3.42	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus nigroris*	0.17	0.25	0.28	0.28	0.08	-	0.03	-	-	-	-	-
Acanthuridae	*Acanthurus olivaceus*	-	0.08	0.06	0.08	0.53	0.28	2.47	0.67	0.06	-	-	-
Acanthuridae	*Acanthurus thompsoni*	0.03	-	0.03	-	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus triostegus*	1.69	0.36	0.75	0.61	-	-	0.17	-	-	-	-	-
Acanthuridae	*Acanthurus xanthopterus*	-	-	-	-	-	-	-	-	-	-	-	-
Acanthuridae	*Ctenochaetus hawaiiensis*	-	0.03	0.19	0.14	0.03	-	-	-	-	-	-	-
Acanthuridae	*Ctenochaetus strigosus*	1.92	33.89	44.36	1.19	0.06	-	-	-	-	-	-	-
Acanthuridae	*Naso brevirostris*	-	-	-	-	-	0.03	0.17	-	-	-	-	-
Acanthuridae	*Naso hexacanthus*	-	-	-	0.36	4.75	-	0.31	0.06	0.03	-	-	-
Acanthuridae	*Naso lituratus*	0.14	0.36	0.31	1.22	1.06	0.25	0.28	0.64	-	-	-	-
Acanthuridae	*Naso unicornis*	-	-	-	-	0.17	-	0.22	0.14	0.06	0.03	0.03	-
Acanthuridae	*Zebrasoma flavescens*	4.72	27.86	47.11	10.36	0.06	-	-	-	-	-	-	-
Acanthuridae	*Zebrasoma veliferum*	-	-	-	0.14	0.31	0.08	0.19	0.03	-	-	-	-
Apogonidae	*Apogon kallopterus*	-	0.06	0.22	-	-	-	-	-	-	-	-	-
Aulostomidae	*Aulostomus chinensis*	-	-	0.08	0.28	0.06	0.14	0.42	0.14	0.08	0.03	-	0.08
Balistidae	*Canthidermis maculatus*	-	-	-	-	0.06	-	-	-	-	-	-	-
Balistidae	*Melichthys niger*	-	-	0.08	6.08	6.56	0.25	1.08	-	-	-	-	-
Balistidae	*Melichthys vidua*	-	-	0.08	0.69	1.58	0.06	0.31	0.08	0.03	-	-	-
Balistidae	*Rhinecanthus aculeatus*	-	-	-	-	-	-	-	-	-	-	-	-

Balistidae	*Rhinecanthus rectangulus*	0.03	0.03	0.22	2.81	0.19	-	-	-	-	-	-	-
Balistidae	*Sufflamen bursa*	0.33	0.56	0.86	1.81	0.06	-	-	-	-	-	-	-
Balistidae	*Sufflamen fraenatus*	-	-	-	0.06	0.08	0.03	0.03	-	-	-	-	-
Balistidae	*Xanthichthys auromarginatus*	-	-	0.17	0.42	0.08	-	-	-	-	-	-	-
Blenniidae	*Blenniella gibbifrons*	-	-	-	-	-	-	-	-	-	-	-	-
Blenniidae	*Cirripectes vanderbilti*	0.25	0.58	0.03	-	-	-	-	-	-	-	-	-
Blenniidae	*Exallias brevis*	0.03	0.25	0.06	0.03	-	-	-	-	-	-	-	-
Blenniidae	*Plagiotremus ewaensis*	0.06	0.08	-	-	-	-	-	-	-	-	-	-
Blenniidae	*Plagiotremus goslinei*	0.28	1.47	0.03	-	-	-	-	-	-	-	-	-
Carangidae	*Carangoides orthogrammus*	-	-	-	-	0.06	-	-	-	-	-	-	-
Carangidae	*Caranx melampygus*	-	-	-	-	-	-	-	0.03	-	-	-	0.06
Carangidae	*Decapterus macarellus*	-	-	-	-	-	-	-	-	-	-	-	-
Carangidae	*Scomberoides lysan*	-	-	-	-	-	-	0.03	-	-	-	-	-
Chaetodontidae	*Chaetodon auriga*	0.06	-	0.17	0.14	0.06	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon fremblii*	-	-	-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon kleinii*	0.03	-	0.03	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon lineolatus*	-	-	-	0.03	0.06	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon lunula*	-	0.03	0.61	0.06	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon lunulatus*	-	-	0.06	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon miliaris*	-	-	-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon multicinctus*	0.69	3.78	0.44	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon ornatissimus*	-	0.44	1.86	1.47	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon quadrimaculatus*	0.28	0.08	0.11	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon unimaculatus*	-	-	-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Forcipiger flavissimus*	0.03	1.67	2.72	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Forcipiger longirostris*	-	0.08	2.11	0.61	-	-	-	-	-	-	-	-
Cirrhitidae	*Cirrhitops fasciatus*	0.06	0.81	0.11	-	-	-	-	-	-	-	-	-
Cirrhitidae	*Cirrhitus pinnulatus*	-	-	0.03	0.03	0.03	-	-	-	-	-	-	-
Cirrhitidae	*Paracirrhites arcatus*	0.69	11.75	0.94	-	-	-	-	-	-	-	-	-
Cirrhitidae	*Paracirrhites forsteri*	-	-	0.36	0.44	-	-	-	-	-	-	-	-
Diodontidae	*Diodon holocanthus*	-	-	-	-	0.03	-	-	-	-	-	-	-
Diodontidae	*Diodon hystrix*	-	-	-	-	0.03	-	0.03	-	-	-	-	-

Echeneidae	*Echeneis naucrates*	-	-	-	0.03	-	-	-	-	-	-	-	-
Fistulariidae	*Fistularia commersonii*	-	-	-	-	0.03	-	0.22	0.22	0.06	-	0.06	0.11
Gobiidae	*Coryphopterus sp.*	-	0.03	-	-	-	-	-	-	-	-	-	-
Gobiidae	*Gobiidae sp.*	-	-	-	-	-	-	-	-	-	-	-	-
Holocentridae	*Myripristis berndti*	-	-	-	0.69	0.17	0.03	-	-	-	-	-	-
Holocentridae	*Myripristis kuntee*	-	-	0.86	2.92	0.06	-	-	-	-	-	-	-
Holocentridae	*Neoniphon sammara*	-	-	0.03	0.92	0.33	-	0.03	-	-	-	-	-
Holocentridae	*Sargocentron diadema*	-	-	0.08	-	-	-	-	-	-	-	-	-
Holocentridae	*Sargocentron spiniferum*	-	-	-	-	-	-	-	-	-	-	-	-
Holocentridae	*Sargocentron tiere*	-	0.03	-	0.03	0.06	-	-	-	-	-	-	-
Kyphosidae	*Kyphosus sp.*	-	-	-	-	-	-	-	0.03	-	-	-	-
Labridae	*Anampses chrysocephalus*	0.08	0.08	-	-	-	-	-	-	-	-	-	-
Labridae	*Anampses cuvier*	-	0.03	0.08	-	-	-	-	-	-	-	-	-
Labridae	*Bodianus albotaeniatus*	0.03	-	-	-	-	-	-	0.03	-	-	-	-
Labridae	*Coris flavovittata*	-	-	-	-	-	-	-	-	0.03	-	-	-
Labridae	*Coris gaimard*	0.67	2.64	1.97	0.36	0.08	-	0.06	0.11	0.03	-	-	-
Labridae	*Coris venusta*	0.06	0.22	0.08	-	-	-	-	-	-	-	-	-
Labridae	*Gomphosus varius*	4.78	13.39	11.11	2.53	0.06	-	-	-	-	-	-	-
Labridae	*Halichoeres ornatissimus*	0.67	2.25	1.17	0.03	-	-	-	-	-	-	-	-
Labridae	Labridae sp.	0.25	-	-	-	-	-	-	-	-	-	-	-
Labridae	*Labroides phthirophagus*	0.56	1.19	-	-	-	-	-	-	-	-	-	-
Labridae	*Macropharyngodon geoffroy*	0.06	0.11	-	-	-	-	-	-	-	-	-	-
Labridae	*Novaculichthys taeniourus*	0.14	0.08	0.11	0.06	-	-	-	-	-	-	-	-
Labridae	*Oxycheilinus unifasciatus*	0.61	1.72	0.89	0.47	0.31	-	0.17	-	-	-	-	-
Labridae	*Pseudocheilinus evanidus*	0.92	3.72	0.11	-	-	-	-	-	-	-	-	-
Labridae	*Pseudocheilinus octotaenia*	0.11	0.78	0.42	-	-	-	-	-	-	-	-	-
Labridae	*Pseudocheilinus tetrataenia*	0.92	0.97	-	-	-	-	-	-	-	-	-	-
Labridae	*Pseudojuloides cerasinus*	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	*Stethojulis balteata*	14.94	21.00	3.17	0.08	-	-	-	-	-	-	-	-
Labridae	*Thalassoma ballieui*	-	0.06	0.08	-	-	-	-	-	-	-	-	-
Labridae	*Thalassoma duperrey*	17.11	39.39	23.39	3.75	0.06	-	-	-	-	-	-	-
Labridae	*Thalassoma purpureum*	-	0.03	0.08	0.03	-	-	-	-	-	-	-	-

Labridae	*Thalassoma quinquevittatum*	-	0.03	0.03	-	-	-	-	-	-	-	-	-
Labridae	*Thalassoma trilobatum*	0.03	0.08	0.22	0.03	-	-	-	-	-	-	-	-
Lethrinidae	*Monotaxis grandoculis*	-	-	-	-	-	-	-	-	-	-	-	-
Lutjanidae	*Aphareus furca*	-	-	-	0.03	-	0.03	0.06	0.06	-	-	-	-
Lutjanidae	*Lutjanus fulvus*	-	-	-	-	0.03	-	-	-	-	-	-	-
Lutjanidae	*Lutjanus kasmira*	-	-	-	0.08	-	-	-	-	-	-	-	-
Monacanthidae	*Cantherhines dumerilii*	-	-	-	0.14	0.08	0.03	0.17	-	-	-	-	-
Monacanthidae	*Cantherhines sandwichiensis*	0.03	0.06	0.19	0.11	-	-	-	-	-	-	-	-
Monacanthidae	*Pervagor aspricaudus*	-	0.19	-	-	-	-	-	-	-	-	-	-
Mullidae	*Mulloidichthys flavolineatus*	-	-	0.03	0.11	0.53	-	0.28	0.11	0.11	-	-	-
Mullidae	*Mulloidichthys vanicolensis*	-	-	0.03	0.22	-	-	-	-	-	-	-	-
Mullidae	*Parupeneus cyclostomus*	-	0.03	0.17	0.14	0.14	0.03	-	-	-	-	-	-
Mullidae	*Parupeneus insularis*	-	0.06	0.14	0.14	0.17	-	-	-	-	-	-	-
Mullidae	*Parupeneus multifasciatus*	-	0.31	0.67	1.56	0.72	-	0.03	-	-	-	-	-
Mullidae	*Parupeneus pleurostigma*	-	-	-	-	-	-	-	0.03	-	-	-	-
Muraenidae	*Echidna nebulosa*	-	-	-	-	-	-	0.03	-	-	0.03	-	-
Muraenidae	*Gymnomuraena zebra*	-	-	-	-	-	-	-	-	-	-	0.03	-
Muraenidae	*Gymnothorax eurostus*	-	-	-	-	-	-	-	-	-	-	-	-
Muraenidae	*Gymnothorax flavimarginatus*	-	-	-	-	0.03	-	-	0.06	0.03	-	-	0.17
Muraenidae	*Gymnothorax melatremus*	-	-	-	-	0.03	-	-	-	-	-	-	-
Muraenidae	*Gymnothorax meleagris*	-	-	-	-	0.08	-	0.06	0.03	-	0.03	0.11	0.25
Ostraciidae	*Ostracion meleagris*	0.44	1.47	0.42	-	-	-	-	0.03	-	-	-	-
Ostraciidae	*Ostracion whitleyi*	-	-	-	-	-	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge fisheri*	-	-	-	-	-	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge loricula*	0.03	0.19	-	-	-	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge potteri*	0.03	1.39	0.31	-	-	-	0.03	-	0.03	-	-	-
Pomacentridae	*Abudefduf abdominalis*	0.36	0.39	0.22	0.06	-	-	-	-	-	-	-	-
Pomacentridae	*Abudefduf sordidus*	-	-	0.08	0.11	-	-	-	-	-	-	-	-
Pomacentridae	*Abudefduf vaigiensis*	0.03	-	0.06	-	-	-	-	-	-	-	-	-
Pomacentridae	*Chromis agilis*	3.64	21.28	0.25	-	-	-	-	-	-	-	-	-
Pomacentridae	*Chromis hanui*	1.11	1.08	-	-	-	-	-	-	-	-	-	-
Pomacentridae	*Chromis ovalis*	0.89	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	*Chromis vanderbilti*	27.83	4.00	-	-	-	-	-	-	-	-	-	-

Pomacentridae	*Dascyllus albisella*	0.36	4.67	3.56	-	-	-	-	-	-	-	-	-
Pomacentridae	*Plectroglyphidodon imparipennis*	13.31	2.39	0.03	-	-	-	-	-	-	-	-	-
Pomacentridae	*Plectroglyphidodon johnstonianus*	0.56	4.53	0.11	-	-	-	-	-	-	-	-	-
Pomacentridae	*Stegastes marginatus*	2.53	10.50	0.61	-	-	-	-	-	-	-	-	-
Scaridae	*Calotomus carolinus*	0.03	0.19	0.61	0.17	0.06	-	0.03	-	-	-	-	-
Scaridae	*Chlorurus perspicillatus*	-	0.06	0.33	0.14	0.03	-	-	-	-	-	-	-
Scaridae	*Chlorurus spilurus*	1.14	4.19	7.86	3.06	0.83	0.42	0.69	0.33	0.22	-	-	-
Scaridae	*Scarus dubius*	0.25	0.53	0.31	0.33	0.42	0.06	-	-	-	-	-	-
Scaridae	*Scarus psittacus*	0.03	2.03	2.44	1.06	0.86	0.31	0.39	0.11	-	0.03	-	-
Scaridae	*Scarus rubroviolaceus*	0.75	1.50	1.64	0.67	0.17	0.08	0.22	0.36	0.31	0.06	0.19	0.11
Scaridae	*Scarus sp.*	0.36	0.47	0.06	-	0.17	0.03	-	-	-	-	-	-
Scorpaenidae	*Dendrochirus barberi*	-	0.03	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	*Sebastapistes coniorta*	0.11	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	*Taenianotus triacanthus*	-	-	-	-	-	-	-	-	-	-	-	-
Serranidae	*Cephalopholis argus*	-	-	-	0.17	0.31	0.06	0.69	0.69	0.58	0.14	-	-
Synodontidae	*Saurida flamma*	-	-	-	-	-	0.03	-	-	-	-	-	-
Synodontidae	*Saurida gracilis*	-	0.03	-	-	-	-	-	-	-	-	-	-
Synodontidae	*Synodus sp.*	-	-	0.06	-	-	-	-	-	-	-	-	-
Synodontidae	*Synodus variegatus*	-	0.03	0.08	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Arothron hispidus*	-	-	-	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Arothron meleagris*	0.03	0.08	-	0.03	0.06	0.03	-	-	-	-	-	-
Tetraodontidae	*Canthigaster amboinensis*	0.14	0.58	0.08	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Canthigaster coronata*	-	0.03	-	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Canthigaster jactator*	2.36	0.61	-	-	-	-	-	-	-	-	-	-
Zanclidae	*Zanclus cornutus*	-	-	0.11	0.25	0.06	-	-	-	-	-	-	-

Appendix 8. Mean fish abundance (#/1000 m^2) by size class for total fish length (cm) observed at **Pauoa** during **2007-2008** resurveys. For fishes less than 25 cm in total length, sizes were binned in 5 cm increments. For fishes greater than 25 cm in total length, sizes were estimated to the nearest 5 cm. Species listed in gray were not observed at Pauoa sites during the surveys.

Family	**Taxa**	**Mean abundance (#/1000 m^2) by size class (cm)**											
		0-5	**5-10**	**10-15**	**15-20**	**20-25**	**25**	**30**	**35**	**40**	**45**	**50**	**>50**
Acanthuridae	Acanthuridae sp.	-	-	-	-	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus achilles*	-	0.08	0.06	0.25	0.19	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus blochii*	-	-	-	-	0.06	0.08	0.42	0.08	-	-	-	-
Acanthuridae	*Acanthurus dussumieri*	-	-	-	-	-	-	-	-	0.08	-	0.06	-
Acanthuridae	*Acanthurus leucopareius*	-	0.03	0.06	-	-	-	0.06	-	-	-	-	-
Acanthuridae	*Acanthurus nigricans*	-	-	-	-	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus nigrofuscus*	1.14	13.81	37.44	3.94	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus nigroris*	-	0.03	0.06	0.14	0.22	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus olivaceus*	0.06	-	0.03	0.19	0.50	0.08	1.19	0.67	-	-	-	-
Acanthuridae	*Acanthurus thompsoni*	-	-	-	-	-	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus triostegus*	0.25	0.17	2.25	2.00	0.25	-	-	-	-	-	-	-
Acanthuridae	*Acanthurus xanthopterus*	-	-	-	-	-	-	-	-	-	0.03	-	-
Acanthuridae	*Ctenochaetus hawaiiensis*	-	-	0.03	0.25	0.06	-	-	-	-	-	-	-
Acanthuridae	*Ctenochaetus strigosus*	3.28	33.53	46.94	1.58	-	-	-	-	-	-	-	-
Acanthuridae	*Naso brevirostris*	-	-	-	-	0.33	-	0.14	-	-	-	-	-
Acanthuridae	*Naso hexacanthus*	-	-	-	0.78	0.53	0.08	-	-	-	-	-	-
Acanthuridae	*Naso lituratus*	-	0.06	0.08	0.61	0.89	0.06	0.72	0.50	-	-	-	-
Acanthuridae	*Naso unicornis*	0.03	0.03	-	0.08	-	-	0.06	-	-	-	-	-
Acanthuridae	*Zebrasoma flavescens*	5.06	20.78	31.44	9.89	0.17	-	-	-	-	-	-	-
Acanthuridae	*Zebrasoma veliferum*	-	-	0.03	0.03	-	-	0.03	0.03	-	-	-	-
Apogonidae	*Apogon kallopterus*	-	0.14	-	-	-	-	-	-	-	-	-	-
Aulostomidae	*Aulostomus chinensis*	-	-	-	-	0.06	-	0.06	0.03	-	0.03	-	-
Balistidae	*Canthidermis maculatus*	-	-	-	-	-	-	-	-	-	-	-	-
Balistidae	*Melichthys niger*	-	-	-	0.92	0.89	0.11	0.08	-	-	-	-	-
Balistidae	*Melichthys vidua*	-	-	0.03	0.47	0.58	-	0.11	-	-	-	-	-
Balistidae	*Rhinecanthus aculeatus*	-	-	-	0.19	0.06	-	0.03	-	-	-	-	-
Balistidae	*Rhinecanthus rectangulus*	-	-	0.31	2.94	0.22	-	0.11	0.06	-	-	-	-
Balistidae	*Sufflamen bursa*	0.03	0.08	0.33	1.25	0.03	-	-	-	-	-	-	-

Balistidae	*Sufflamen fraenatus*	-	-	-	-	-	-	-	-	-	-	-	-
Balistidae	*Xanthichthys auromarginatus*	-	-	-	-	-	-	-	-	-	-	-	-
Blenniidae	*Blenniella gibbifrons*	-	0.06	-	-	-	-	-	-	-	-	-	-
Blenniidae	*Cirripectes vanderbilti*	0.08	1.64	0.11	-	-	-	-	-	-	-	-	-
Blenniidae	*Exallias brevis*	0.06	0.36	0.11	-	-	-	-	-	-	-	-	-
Blenniidae	*Plagiotremus ewaensis*	0.03	0.14	0.03	-	-	-	-	-	-	-	-	-
Blenniidae	*Plagiotremus goslinei*	0.17	1.58	-	-	-	-	-	-	-	-	-	-
Carangidae	*Carangoides orthogrammus*	-	-	-	-	-	-	-	-	-	-	-	-
Carangidae	*Caranx melampygus*	-	-	-	-	-	-	0.06	0.06	-	-	-	-
Carangidae	*Decapterus macarellus*	-	-	-	-	0.17	-	-	-	-	-	-	-
Carangidae	*Scomberoides lysan*	-	-	-	-	-	-	0.03	0.06	-	-	-	-
Chaetodontidae	*Chaetodon auriga*	-	-	0.11	0.53	0.08	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon fremblii*	-	-	0.03	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon kleinii*	-	-	-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon lineolatus*	-	-	-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon lunula*	-	-	0.25	0.14	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon lunulatus*	-	-	0.25	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon miliaris*	-	0.03	-	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon multicinctus*	0.03	4.19	0.42	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon ornatissimus*	-	-	0.56	1.28	0.06	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon quadrimaculatus*	0.11	-	0.22	0.03	-	-	-	-	-	-	-	-
Chaetodontidae	*Chaetodon unimaculatus*	-	0.17	0.33	-	-	-	-	-	-	-	-	-
Chaetodontidae	*Forcipiger flavissimus*	-	0.47	1.53	0.14	-	-	-	-	-	-	-	-
Chaetodontidae	*Forcipiger longirostris*	-	0.06	0.58	0.47	0.03	-	-	-	-	-	-	-
Cirrhitidae	*Cirrhitops fasciatus*	-	0.47	0.03	-	-	-	-	-	-	-	-	-
Cirrhitidae	*Cirrhitus pinnulatus*	-	-	-	-	-	-	-	-	-	-	-	-
Cirrhitidae	*Paracirrhites arcatus*	0.33	11.67	1.39	-	-	-	-	-	-	-	-	-
Cirrhitidae	*Paracirrhites forsteri*	-	0.44	0.44	0.22	0.06	-	-	-	-	-	-	-
Diodontidae	*Diodon holocanthus*	-	-	-	-	0.03	-	0.06	-	-	-	-	-
Diodontidae	*Diodon hystrix*	-	-	-	-	-	-	0.06	-	-	-	-	-
Echeneidae	*Echeneis naucrates*	-	-	-	-	-	-	-	-	0.03	-	-	-
Fistulariidae	*Fistularia commersonii*	-	-	-	-	0.03	-	-	-	0.06	0.03	0.08	0.25
Gobiidae	*Coryphopterus sp.*	-	0.03	-	-	-	-	-	-	-	-	-	-
Gobiidae	Gobiidae sp.	0.14	-	-	-	-	-	-	-	-	-	-	-

Holocentridae	*Myripristis berndti*	-	-	0.56	0.42	0.17	-	-	-	-	-	-	-
Holocentridae	*Myripristis kuntee*	-	-	0.19	0.89	0.17	-	-	-	-	-	-	-
Holocentridae	*Neoniphon sammara*	-	-	0.03	0.81	0.31	-	-	-	-	-	-	-
Holocentridae	*Sargocentron diadema*	-	-	-	-	-	-	-	-	-	-	-	-
Holocentridae	*Sargocentron spiniferum*	-	-	-	0.03	-	-	-	-	-	-	-	-
Holocentridae	*Sargocentron tiere*	-	-	-	-	0.03	0.03	0.03	-	-	-	-	-
Kyphosidae	*Kyphosus sp.*	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	*Anampses chrysocephalus*	-	0.06	-	-	-	-	-	-	-	-	-	-
Labridae	*Anampses cuvier*	-	0.03	0.03	-	-	-	-	-	-	-	-	-
Labridae	*Bodianus albotaeniatus*	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	*Coris flavovittata*	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	*Coris gaimard*	0.19	1.50	1.03	0.31	0.17	0.11	0.11	0.03	-	-	-	-
Labridae	*Coris venusta*	-	0.31	0.08	-	-	-	-	-	-	-	-	-
Labridae	*Gomphosus varius*	2.31	11.36	7.72	1.00	0.14	-	-	-	-	-	-	-
Labridae	*Halichoeres ornatissimus*	0.78	2.44	0.67	-	-	-	-	-	-	-	-	-
Labridae	Labridae sp	0.50	-	-	-	-	-	-	-	-	-	-	-
Labridae	*Labroides phthirophagus*	0.03	0.78	0.08	-	-	-	-	-	-	-	-	-
Labridae	*Macropharyngodon geoffroy*	0.06	0.56	-	-	-	-	-	-	-	-	-	-
Labridae	*Novaculichthys taeniourus*	0.06	0.17	0.06	0.08	-	-	-	-	-	-	-	-
Labridae	*Oxycheilinus unifasciatus*	0.06	0.58	1.06	0.39	0.22	-	0.03	-	-	-	-	-
Labridae	*Pseudocheilinus evanidus*	0.69	1.78	0.03	-	-	-	-	-	-	-	-	-
Labridae	*Pseudocheilinus octotaenia*	0.06	0.53	0.08	-	-	-	-	-	-	-	-	-
Labridae	*Pseudocheilinus tetrataenia*	1.06	1.31	0.03	-	-	-	-	-	-	-	-	-
Labridae	*Pseudojuloides cerasinus*	0.06	0.17	0.06	-	-	-	-	-	-	-	-	-
Labridae	*Stethojulis balteata*	10.31	23.75	4.17	0.11	-	-	-	-	-	-	-	-
Labridae	*Thalassoma ballieui*	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	*Thalassoma duperrey*	10.97	35.14	18.19	3.19	0.06	-	-	-	-	-	-	-
Labridae	*Thalassoma purpureum*	-	-	0.06	-	-	-	-	-	-	-	-	-
Labridae	*Thalassoma quinquevittatum*	-	0.08	0.06	-	-	-	-	-	-	-	-	-
Labridae	*Thalassoma trilobatum*	0.03	0.28	0.31	-	-	-	-	-	-	-	-	-
Lethrinidae	*Monotaxis grandoculis*	-	-	0.03	0.06	-	-	0.03	-	0.06	-	-	-
Lutjanidae	*Aphareus furca*	-	-	-	-	0.03	-	-	-	-	-	-	-
Lutjanidae	*Lutjanus fulvus*	-	-	-	-	-	-	-	0.03	-	-	-	-
Lutjanidae	*Lutjanus kasmira*	-	-	-	-	-	-	-	-	-	-	-	-

Monacanthidae	*Cantherhines dumerilii*	-	-	0.03	0.03	0.08	-	0.11	-	-	-	-	-
Monacanthidae	*Cantherhines sandwichiensis*	0.03	0.03	0.06	0.11	0.03	-	-	-	-	-	-	-
Monacanthidae	*Pervagor aspricaudus*	-	0.03	-	-	-	-	-	-	-	-	-	-
Mullidae	*Mulloidichthys flavolineatus*	-	-	-	0.14	0.39	0.11	0.14	0.06	-	-	-	-
Mullidae	*Mulloidichthys vanicolensis*	-	-	0.22	0.22	-	-	-	-	-	-	-	-
Mullidae	*Parupeneus cyclostomus*	0.03	-	0.19	0.28	0.03	0.03	0.03	-	-	-	-	-
Mullidae	*Parupeneus insularis*	-	0.03	0.11	0.03	0.03	0.03	-	-	-	-	-	-
Mullidae	*Parupeneus multifasciatus*	-	0.25	1.14	1.94	0.50	0.06	0.06	-	-	-	-	-
Mullidae	*Parupeneus pleurostigma*	-	-	0.03	0.06	-	-	-	-	-	-	-	-
Muraenidae	*Echidna nebulosa*	-	-	-	-	-	-	-	-	-	-	-	-
Muraenidae	*Gymnomuraena zebra*	-	-	-	-	-	-	-	-	-	-	-	-
Muraenidae	*Gymnothorax eurostus*	-	-	-	-	-	-	-	0.03	-	-	-	0.03
Muraenidae	*Gymnothorax flavimarginatus*	-	-	-	-	-	-	-	-	-	-	0.03	0.08
Muraenidae	Gymnothorax melatremus	-	-	-	-	0.03	-	-	-	-	-	-	-
Muraenidae	Gymnothorax meleagris	-	-	-	-	-	0.03	0.06	0.03	0.8	-	-	0.11
Ostraciidae	*Ostracion meleagris*	0.25	1.17	0.25	-	-	-	-	-	-	-	-	-
Ostraciidae	*Ostracion whitleyi*	-	0.03	-	-	-	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge fisheri*	0.03	-	-	-	-	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge loricula*	-	-	-	-	-	-	-	-	-	-	-	-
Pomacanthidae	*Centropyge potteri*	-	0.33	0.11	-	-	-	-	-	-	-	-	-
Pomacentridae	*Abudefduf abdominalis*	0.03	0.03	-	-	-	-	-	-	-	-	-	-
Pomacentridae	*Abudefduf sordidus*	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	*Abudefduf vaigiensis*	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	*Chromis agilis*	1.50	6.36	0.06	-	-	-	-	-	-	-	-	-
Pomacentridae	*Chromis hanui*	0.81	1.56	-	-	-	-	-	-	-	-	-	-
Pomacentridae	*Chromis ovalis*	1.89	0.19	0.36	-	-	-	-	-	-	-	-	-
Pomacentridae	*Chromis vanderbilti*	32.69	3.36	-	-	-	-	-	-	-	-	-	-
Pomacentridae	*Dascyllus albisella*	0.75	0.42	-	-	-	-	-	-	-	-	-	-
Pomacentridae	*Plectroglyphidodon imparipennis*	15.53	6.42	-	-	-	-	-	-	-	-	-	-
Pomacentridae	*Plectroglyphidodon johnstonianus*	0.94	4.42	0.06	-	-	-	-	-	-	-	-	-
Pomacentridae	*Stegastes marginatus*	1.97	13.22	0.47	-	-	-	-	-	-	-	-	-
Scaridae	*Calotomus carolinus*	-	0.14	0.25	0.08	-	-	-	-	-	-	-	-
Scaridae	*Chlorurus perspicillatus*	-	-	0.14	-	0.03	0.06	0.03	0.03	-	-	-	-
Scaridae	*Chlorurus spilurus*	1.25	2.44	5.28	3.58	1.86	0.58	1.14	0.39	0.06	0.03	-	-

Scaridae	*Scarus dubius*	0.39	0.56	0.67	0.75	0.42	-	-	-	-	-	-	-
Scaridae	*Scarus psittacus*	1.36	1.42	4.78	1.36	0.81	0.22	0.28	-	-	-	-	-
Scaridae	*Scarus rubroviolaceus*	0.28	0.92	1.25	0.75	0.28	0.08	0.19	0.17	0.08	-	-	0.06
Scaridae	*Scarus sp.*	0.89	0.53	1.42	0.14	-	-	-	-	-	-	-	-
Scorpaenidae	*Dendrochirus barberi*	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	*Sebastapistes coniorta*	0.39	0.06	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	*Taenianotus triacanthus*	-	0.03	-	-	-	-	-	-	-	-	-	-
Serranidae	*Cephalopholis argus*	-	-	-	0.08	0.44	0.19	0.42	0.81	0.36	0.11	-	-
Synodontidae	*Saurida flamma*	-	-	-	0.03	-	-	-	-	-	-	-	-
Synodontidae	*Saurida gracilis*	-	-	-	0.03	-	-	-	-	-	-	-	-
Synodontidae	*Synodus sp.*	-	-	-	-	-	-	-	-	-	-	-	-
Synodontidae	*Synodus variegatus*	0.03	0.03	0.06	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Arothron hispidus*	-	-	-	-	-	0.03	0.08	-	-	-	-	-
Tetraodontidae	*Arothron meleagris*	0.06	0.06	-	-	0.11	-	0.03	-	-	-	-	-
Tetraodontidae	*Canthigaster amboinensis*	0.17	0.72	0.14	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Canthigaster coronata*	-	0.11	0.03	-	-	-	-	-	-	-	-	-
Tetraodontidae	*Canthigaster jactator*	3.31	1.97	-	-	-	-	-	-	-	-	-	-
Zanclidae	*Zanclus cornutus*	-	-	0.11	0.36	-	-	-	-	-	-	-	-