THE IMPACTS OF BOTTOMFISHING ON RAITA AND WEST ST. ROGATIEN BANKS IN THE NORTHWESTERN HAWAIIAN ISLANDS

BY

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ABSTRACT

The authors assessed the impacts of bottomfishing in the Raita and West St. Rogatien Bank Reserve Preservation Areas (RPAs) in the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve (NWHICRER). The executive order creating NWHICRER stipulates that bottomfishing will be allowed in these RPAs only if it is determined not to be having an adverse impact on their resources. In order to address that provision, known fishing sites on both banks were surveyed in 2001 using a submersible and a remotely operated vehicle (ROV). One site from each bank subsequently was selected where three submersible dives were conducted in both 2002 and 2003. During the dives, a standardized protocol was used to obtain data on the abundance and size of bottomfish targeted by fishermen, amount of fishing debris present at the sites, and the types and abundance of benthic invertebrates and other fish species that could be impacted by fishing activities. In 2002, comparative data also were obtained from dives in one other RPA (Brooks Bank), two heavily fished sites in the Main Hawaiian Islands (MHI), and two sites within the Kahoolawe Island Reserve where bottomfishing has been prohibited for over 8 years. The impacts resulting from bycatch, lost fishing gear, and discarded trash are relatively low. The populations of one bottomfish species, onaga (*Etelis coruscans*), could be decreasing on Raita Bank, although previous estimates of maximum sustainable yield indicate the number being taken is sustainable.

INTRODUCTION

The NWHICRER was created in 2001 by President Clinton's Executive Order (EO) 13178. Within the reserve, nine islets/atolls and six banks were designated as RPAs, each having its own additional layer of regulations regarding usage and access. Two of these RPAs, Raita Bank and the first bank west of St. Rogatien Bank (WSR Bank) have the specific condition that after 5 years, bottomfishing will be allowed to continue only if it is determined that it has no adverse impact on the resources of these banks. Commercial bottomfishing targets seven species of snappers (family Lutjanidae), one grouper (family Serranidae), and one jack (family Carangidae). All but one of these species are typically

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caught with hook and line at depths of 100 m or more. The exception, uku (*Aprion virescens*), is caught by surface trolling over the tops of the banks well above that depth.

In 2001, a 3-year study was initiated to address the bottomfishing provisions in the EO for Raita and WSR Banks. A comprehensive report on the findings from this study, along with recommendations regarding the continuation of bottomfishing in these two RPAs, was submitted to federal and state management agencies in August 2004. In this paper, we summarize the content of that report for a wider audience.

MATERIALS AND METHODS

Potential bottomfishing impacts were classified into three categories: additions, removals, and alterations. "Addition" impacts included man-made materials found on the sites of which there were two types: a) lost fishing gear such as fishing lines, hooks, weights, and anchors; and b) trash such as beverage cans, bottles, plastics, metal objects, and cloth that may have been discarded by fishers or may have come from other sources. Removal impacts included reduced numbers of targeted bottomfish species as well as nontargeted or "bycatch" species that were caught, killed, and either kept or discarded. Alteration impacts were considered to be either direct or indirect. The former included damage caused by fishing gear to the substrate or benthic invertebrates, particularly attached cnidarians and sponges. Indirect alterations were considered to be changes in the community structure as a result of removals and or additions, (i.e., changes in predator, competitor, and prey abundances).

The locations of 15 potential study sites were obtained from commercial bottomfishers who were actively fishing these banks. Direction observations were made on each site with the use of the manned *Pisces IV* and *V* submersibles and unmanned *RCV-150 ROV* operated by the Hawaii Undersea Research Laboratory (HURL). Funding was provided for 6, 8-hour submersible dives per year and between 6 and 18, 2-hour ROV dives per year for a total of 3 years. The first set of dives in 2001 was for an initial survey of all 15 sites. One study site was subsequently selected on each bank where all 2002 and 2003 submersible dives were conducted.

During each submersible dive, counts of all fish, invertebrates, and fishing debris on the sites as well as size estimates for bottomfish species were obtained using two techniques: four 30-minute "contour" transects and two 30-minute bait stations. During transects, two observers made independent identifications and counts from each side of the submersible. The length of each transect varied as a result of current conditions and bottom topography, but on average covered a distance of 1 km. Bait stations were conducted in areas where targeted bottomfish species were seen during transects. At each station, approximately 4.5 kg of chopped squid and fish was released next to a 10-cm diameter spherical marker used as a size reference. After the bait and marker were deployed, the sub retreated to a distance of 5-10 meters and settled on the bottom with its lights out. Bottomfish and other predatory species attracted to the bait were recorded in ambient light on a ROS 20/20 Navigator wide-angle CCD camera. A 20-cm twin laser scale attached to the camera's pan and tilt provided additional size data during the stations. After the dives, transect and bait station counts were extracted from the videotapes, the latter being the maximum number of fish caught on a single video frame and/or recorded by an observer at any one point in time. Bait station size measurements were extracted from video still captures using Scion Image software.

In 2002, sets of three submersible dives using the same data-collecting protocol were conducted on one other bottomfishing site in the NWHICRER (Brooks Bank), two sites on Penguin Bank (PB1 and PB2), which is a well-known bottomfishing area in the MHI, and two sites in the Kahoolawe Island Reserve (KIR 1 and KIR 2), where bottomfishing has been prohibited since 1993. These sites provided comparative data for interpreting the findings from the Raita and WSR dives.

Statistical comparisons of the 2002 and 2003 transect and bait station counts among sites were conducted according to the hypotheses shown in Table 1. Rankings (1 being the highest expected mean counts/transect) were based on presumed fishing activity at the different sites. For example, the two KIR sites were presumed to have the lowest fishing activity and therefore were expected to have the higher bottomfish counts (rank = 1), while the opposite was expected for the two Penguin Bank sites (rank = 3). Bycatch analyses were carried out only on bait station counts of nonbottomfish species. The assumption was that species attracted to the bait and recorded at the stations were also the most likely to be caught during commercial bottomfishing activities. Cnidarians and nonprey invertebrate (i.e., sponges, urchins, and seastars) counts also were hypothesized to be highest on the KIR sites and lowest on the PB1 and PB2 sites, because of their potential susceptibility to damage from fishing activities. Counts of potential prey and competitor species were hypothesized to be inversely related to bottomfish counts. Adult bottomfish targeted by fishers would have relatively few potential predators besides medium to large sharks. Predators of this size are observed infrequently from the submersible at bottomfish habitat depths, and therefore it was assumed that their response to bottomfish removals could not be evaluated.

Table 1: Expected (i.e., hypothesized) count rankings for each data category used in comparing 2002 transect and bait station data obtained from each site. Numbers and shadings are the expected ranks of mean counts for each category with 1 (dark shading) being the highest and 3 (no shading) being the lowest. Bottomfish and bycatch counts were used in evaluating removal impacts; fishing gear and trash counts were used in evaluating addition impacts; and counts of cnidarians, other invertebrates, potential competitor species, and potential prey species were used in evaluating alteration impacts. The last row shows the presumed fishing activity at each site. The expected rankings are also shown in Tables 3-5 for reference.

Expected Count Rankings	**Raita**	**WSR**	**KIR1**	**KIR2**	**PB1**	**PB2**	**Brooks**
Bottomfish	2	2	1	1	3	3	2
Bycatch	2	2	1	1	3	3	2
Fishing Gear	2	2	3	3	1	1	2
Trash	2	2	3	3	1	1	2
Cnidarians	2	2	1	1	3	3	2
Other Inverts	2	2	1	1	3	3	2
Competitors	2	2	3	3	1	1	2
Prey	2	2	3	3	1	1	2
Presumed Fishing Activity	med	med	low	low	high	high	med

Counts from transects were first extrapolated to a standard 1,000-m length, yielding a 2-hectare sampling area (20 by 1,000 m). These hypotheses were tested statistically using software based on the analytical methods described in Krebs (1999). First, the data from each site were fitted to a negative binomial distribution to derive an estimated mean, variance, and negative binomial exponent, k. Then the values for each site were used in both U-tests and T-tests to determine their approximate goodness of fit to this type of distribution. Different sites were tested for equality following the method of White and Eberhardt (1980). The results of these tests are presented as one of four models:

Model 1: the data from the tested sites have different means and different k values
Model 2: the data from the tested sites have different means but the same k values
Model 3: the data from the tested sites have the same means but different k values
Model 4: the data from the tested sites have the same means and the same k values

The analyses of the means were considered to be most relevant to the hypotheses above. Therefore, for the purpose of this report, only models 1 and 2 were considered indicative of a significant difference among the sites at $P = 0.05$.

Bait station size data on bottomfish species were normally distributed and analyzed by one-way analysis of variance (ANOVA) using Minitab 12.1 software. Similar to counts, average sizes were expected to be inversely related to the amount of fishing activity on the sites. It was hypothesized that the largest fish would be found on the KIR sites while the smallest fish would be found on the Penguin Bank sites. No statistical analysis was attempted on ROV transect records.

Commercial bottomfish and bycatch data from the Raita and "Rogatien" (combined WSR and St. Rogatien Banks) reporting grids were obtained for 2001-2003 by Robert Moffitt from the National Oceanic and Atmospheric Administration (NOAA) fisheries database and were used as a second means of evaluating removal impacts in these RPAs. Due to limitations imposed on the length of this paper, only the most relevant fishing data along with the submersible data obtained on bottomfish, fishing debris/trash, and cnidarians are presented here. For those interested, a full-length version of the original unpublished report from this study is available from the authors on request.

RESULTS

In Table 2, we provide 2001-2003 bottomfish catch and bycatch data for the Raita and Rogatien grids. The values are the reported number of fish caught at each location by year. However, the listed locations may include a wider area than just the nominal bank, e.g., adjacent banks, pinnacles, and seamounts. On average, 2,017 bottomfish reportedly were removed from the Raita Bank area during each of the last 3 years. Onaga (*Etelis coruscans*) and uku accounted for 44% of the catch followed by hapuupuu (*Epinephelus quernus*), ehu (*Etelis carbunculus*), opakapaka (*Pristipomoides filamentosus*), gindai (*Pristipomoides zonatus*), butaguchi (*Pseudocaranx dentex*), and kalekale (*Pristipomoides sieboldii*). A reported 2,180 bottomfish were removed from the Rogatien area. Over half of the fish (51%) were opakapaka, followed by onaga, uku, ehu, butaguchi, kalekale, gindai, and hapuupuu. On average, 214 bycatch fish reportedly were caught in the Raita area each year during 2001-2003, and 138 bycatch fish were caught in the Rogatien area. Of the six bycatch taxa, kahala (*Seriola dumerili*) was by far the most abundant species in the catch (93% and 88% for the two areas, respectively).

Table 2: Raita and St. Rogatien bottomfish catch and bycatch (# of fish 2001-2003 data).

	Raita				St Rogatien			
Species	**2001**	**2002**	**2003**	**mean/yr**	**2001**	**2002**	**2003**	**mean/yr**
Pseudocaranx dentex	113	174	162	**150**	126	227	91	**148**
Etelis carbunculus	304	195	132	**210**	199	114	187	**167**
Pristipomoides zonatus	93	313	89	**165**	31	95	66	**64**
Epinephelus quernus	264	370	262	**299**	51	113	21	**62**
Pristipomoides sieboldii	82	203	119	**135**	85	156	133	**125**
Etelis coruscans	576	450	297	**441**	323	368	190	**294**
Pristipomoides filamentosus	173	259	99	**177**	1395	1089	839	**1108**
Aprion virescens	221	84	1016	**440**	214	61	362	**212**
Total Bottomfish	**1826**	**2048**	**2176**	**2017**	**2424**	**2223**	**1889**	**2180**
Shark	0	2	0	**0.7**	3	0	2	**1.7**
Galeocerdo cuvieri	0	1	0	**0.3**	0	0	0	**0.0**
Pontinus macrocephalus	8	3	2	**4.3**	0	6	4	**3.3**
Caranx ignobilis	9	17	0	**8.7**	36	0	0	**12.0**
Seriola dumerili	142	326	131	**199.7**	177	94	92	**121.0**
Priacanthid	1	0	0	**0.3**	0	0	0	**0.0**
Total Bycatch	**160**	**349**	**133**	**214**	**216**	**100**	**98**	**138**

In 2002 and 2003, all submersible dives were completed as planned which yielded 12 transects at each of the seven sites. With one exception (the KIR2 site, where five bait stations were conducted), all submersible bait stations were completed as planned which yielded six per site. A summary of the 2002 bottomfish, fishing/trash debris, and cnidarian transect count data is presented in Table 3. The first row of each section of the table shows the predicted ranking of the sites (different shadings) and whether they are expected to be significantly different (+ or -). The remaining rows provide the mean and standard error of counts, which were ranked and shaded for comparison to the predicted pattern, and indicate if the sites were significantly different at $P<0.05$. Data from sites where counts were either 0 or 1 for 12 transects, or where the variance was equal to or lower than the mean (failed the assumptions of a negative binomial distribution) could not be tested (nt).

Of the 10 bottomfish species observed during submersible dives, only onaga and ehu counts were significantly different among sites. PB1 had the highest mean onaga counts/hectare at 26.7, while Raita (0.6) and WSR (1.3) had the lowest. Raita had the second highest counts for hapuupuu. For bottomfish in general, the most number of counts were obtained from the Kahoolawe and Brooks sites while the least number of counts were obtained from Raita and PB2 sites. While a few counts were made on lehi (*Aphareus rutilans*), uku, yellowtail kale (*Pristipomoides auricilla*), and butaguchi, these species were not adequately sampled in this study, as a result of the transects being generally below their optimal depth. Between 2002 and 2003, there was a significant decrease in onaga, ehu, and kalekale counts at Raita Bank (Kelley and Moffitt, unpublished report). At WSR Bank however, unlike Raita, the difference was only significant for kalekale. In general, bottomfish counts at both banks decreased between 2002 and 2003.

Table 3: Comparison of bottomfish, fishing/trash debris, and cnidarian counts among all 2002 sites (counts/hectare, n = 12).

Description	Raita Mean +/- SE	WSR Mean +/- SE	KIR1 Mean +/- SE	KIR2 Mean +/- SE	PB1 Mean +/- SE	PB2 Mean +/- SE	Brooks Mean +/- SE	
Expected Count Rankings	2	2	1	1	3	3	2	P<0.05
Bottomfish Counts								
Etelis coruscans	0.6 +/- 0.25	1.3 +/- 0.71	11.7+/-7.90	2.4 +/- 0.90	26.7 +/- 25.40	2.3 +/- 1.41	2.8 +/- 1.62	+
Etelis carbunculus	5.2 +/- 1.84	3.8 +/- 1.28	8.4 +/- 3.91	4.9 +/- 1.65	2.6 +/- 0.89	7.5 +/- 2.52	1.0 +/- 0.31	+
Epinephelus quernus	1.0 +/- 0.36	0.7 +/- 0.33	0.1 +/- 0.13	0.3 +/- 0.21	0.0 +/- 0.00	0.0 +/- 0.00	1.3 +/- 0.86	-
Pristipomoides filamentosus	0.0 +/- 0.00	0.0 +/- 0.00	2.2 +/- 1.48	0.8 +/- 0.43	0.1 +/- 0.08	0.0 +/- 0.04	3.2 +/- 3.12	nt
Pristipomoides sieboldii	0.2 +/- 0.11	5.4 +/- 4.29	1.0 +/- 0.97	15.9 +/- 15.80	5.2 +/- 4.95	0.9 +/- 0.66	11.0 +/- 4.26	-
Pristipomoides zonatus	0.9 +/- 0.34	0.9 +/- 0.58	0.8 +/- 0.40	2.4 +/- 0.99	0.5 +/- 0.20	0.7 +/- 0.32	3.5 +/- 1.55	-
Pseudocaranx dentex	0.0 +/- 0.00	0.1 +/- 0.09	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	1.2 +/- 1.17	nt
Aphareus rutilans	0.0 +/- 0.00	0.0 +/- 0.00	0.1 +/- 0.10	0.4 +/- 0.30	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.04	nt
Pristipomoides auricilla	0.0 +/- 0.00	0.1 +/- 0.08	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.1 +/- 0.07	0.0 +/- 0.00	nt
Aprion virescens	0.0 +/- 0.00	0.1 +/- 0.06	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	nt
Fishing/Trash Debris Counts								
anchors	0.0 +/- 0.00	0.0 +/- 0.03	0.2 +/- 0.10	0.1 +/- 0.07	0.0 +/- 0.20	0.2 +/- 0.07	0.2 +/- 0.11	-
anchor chains	0.0 +/- 0.00	0.0 +/- 0.03	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.04	0.0 +/- 0.04	0.0 +/- 0.00	nt
anchor lines	0.0 +/- 0.04	0.2 +/- 0.07	0.3 +/- 0.13	0.2 +/- 0.12	0.2 +/- 0.12	0.4 +/- 0.10	0.0 +/- 0.00	-
fishing weights	0.0 +/- 0.00	0.0 +/- 0.00	0.1 +/- 0.06	0.0 +/- 0.00	0.0 +/- 0.04	0.0 +/- 0.00	0.0 +/- 0.00	nt
fishing lines	0.1 +/- 0.05	0.3 +/- 0.13	0.4 +/- 0.26	0.1 +/- 0.07	1.6 +/- 0.39	0.7 +/- 0.22	0.3 +/- 0.15	+
traps and lines	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	nt
netting	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	nt
Total Fishing Debris Counts	0.1 +/- 0.06	0.6 +/- 0.17	0.9 +/- 0.40	0.4 +/- 0.14	2.3 +/- 0.58	1.3 +/- 0.30	0.6 +/- 0.16	+
wood/paper debris	0.0 +/- 0.04	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	nt
metal debris	0.0 +/- 0.00	0.2 +/- 0.07	0.3 +/- 0.13	0.7 +/- 0.24	0.0 +/- 0.04	0.1 +/- 0.09	0.2 +/- 0.13	-
plastic/rubber debris	0.0 +/- 0.04	0.1 +/- 0.08	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.04	nt
cloth debris	0.0 +/- 0.00	0.0 +/- 0.04	0.1 +/- 0.00	0.7 +/- 0.22	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.04	nt
ceramic/stone/glass debris	0.0 +/- 0.00	0.0 +/- 0.00	0.1 +/- 0.10	0.0 +/- 0.04	0.0 +/- 0.04	0.1 +/- 0.12	0.1 +/- 0.05	nt
Total Trash Counts	0.1 +/- 0.06	0.3 +/- 0.17	0.5 +/- 0.16	1.4 +/- 0.37	0.1 +/- 0.05	0.2 +/- 0.14	0.3 +/- 0.17	+
Cnidarian Counts								
Actinarians	1.6 +/- 0.48	0.9 +/- 0.35	2.4 +/- 1.15	37.8 +/- 32.30	2.9 +/- 1.98	4 +/- 1.62	1.7 +/- 1.00	+
Alcyonaceans	3.8 +/- 3.39	5.7 +/- 4.75	14.1 +/- 6.25	0.6 +/- 0.24	7.3 +/- 4.63	0.8 +/- 0.40	0.5 +/- 0.52	+
Antipatharians	24.3 +/- 14.10	28.7 +/- 8.81	22.4 +/- 6.54	16.3 +/- 7.08	71.1 +/- 43.90	1.7 +/- 1.00	127.6 +/- 52.30	+
Gorgonians	7.4 +/- 2.68	0.2 +/- 0.10	1190.2 +/- 516.00	262.7 +/- 174.00	483.3 +/- 341.00	19.1 +/- 9.89	19.0 +/- 13.90	+
Pennatulaceans	2.4 +/- 1.24	0.2 +/- 0.13	4.6 +/- 2.52	165.4 +/- 81.60	0.1 +/- 0.07	0.2 +/- 0.12	1.9 +/- 1.18	+
Scleractinians	0.2 +/- 0.12	0.2 +/- 0.18	1116.1 +/- 630.00	242.1 +/- 185.00	32.3 +/- 27.40	3.2 +/- 1.43	0.2 +/- 0.17	+
Unidentified	1.2 +/- 1.11	0.0 +/- 0.04	0.0 +/- 0.00	23.3 +/- 22.80	0.0 +/- 0.05	0.0 +/- 0.04	2.6 +/- 2.45	+
Total Cnidarians	40.9 +/- 13.90	36.1 +/- 11.10	2349.7 +/- 665.00	748.3 +/- 232.00	597.1 +/- 381.00	28.9 +/- 9.71	153.5 +/- 50.10	+

As expected, the total amount of fishing debris was significantly higher on PB1 and PB2 in comparison to other sites. However, Raita had the lowest level of all seven sites including KIR1 and KIR2, while WSR and Brooks had intermediate levels as expected. Fishing lines, rather than anchors, anchor chains, or fishing weights, were the major type of lost gear. Overall, trash counts were low with KIR1 and KIR2 topping the list at 0.5 and 1.4 items/hectare, respectively. Metal and cloth debris resulting from past military activities off Kahoolawe accounted for the majority of items seen. Raita and PB1 had the lowest levels of trash counts, both of which had 0.1 items/hectare. Neither fishing debris nor trash appeared to be significant problems on any of the seven sites in 2002; also there was no change in the amount of fishing debris or trash on Raita between 2002 and 2003 (Kelley and Moffitt, unpublished report). Bottomfishing debris *per se* was rarely encountered and did not significantly increase on either bank.

With respect to alteration impacts, 64 different cnidarians were counted which were grouped into seven categories: Actinarian-like (anemones, corallimorpharians, and ceriantharians), Alcyonacean-like (soft corals and tubularid hydrozoans), Antipatharians (black corals and "bushy" hydrozoans), Gorgonians (gorgonians and zoantharians that grow on gorgonians), Pennatulaceans (sea pens), Scleractinians (hard corals), and unidentified cnidarians that could not be assigned to one of the other six groups. Significant differences among sites were present in all seven categories as well as the total numbers of cnidarians. Of particular interest were the low counts at Raita, WSR, and PB2 (28-41/hectare) in comparison to the other sites (153-2,350/hectare). KIR1 and KIR2 had the highest total cnidarian counts due to high numbers of gorgonians (263-1,190/hectare) and scleractinians (242-1,116/hectare). Antipatharians and alcyonaceans were the only two groups on Raita and WSR with moderate numbers in comparison to the other sites.

Tables 4a and 4b summarize the bottomfish and bycatch bait station counts from each site. Mirroring the results from transects, Raita and WSR generally had the lowest mean number of bottomfish per station. Raita hapuupuu and WSR kalekale were the two exceptions, although neither was significantly higher than other sites. Similar to transect data, the PB1 and KIR1 sites had the highest onaga counts, followed by Brooks. Between 2002 and 2003, mean onaga bait station counts decreased on both Raita and WSR, although the difference on the latter was not significant. Consistent with commercial catch data, kahala were the predominant "bycatch" species observed at bait stations. Two *Seriola* species were observed at a number of the stations (*S. dumerili* and *S. rivoliana*), which were not always easy to differentiate. Therefore, the data on these species were combined in Table 4b as *Seriola sp.*

Bait station size data are presented in Table 5. Size data from the Brooks site were not available for the preparation of this report. With the exception of one extremely large individual at PB2 (FL = 99 cm), Raita Bank had the largest sized onaga (mean = 65.3 cm FL, n = 30), ehu (mean = 44.5 cm FL, n = 16) and hapuupuu (77.7 cm FL, n = 19). In contrast, WSR had the smallest onaga (mean = 49.3 cm FL, n = 39) as well as the smallest ehu (34.3 cm FL, n = 8) of the six sites shown. Gindai were the only other species of which measurements were made at more than two sites. WSR had the second largest individuals (mean = 36.3 cm FL, n = 8) after PB1 (mean = 36.8 cm FL, n = 10). In general, size measurements did not follow the expected pattern among sites. Furthermore, 2003 Raita and WSR size data did not follow the expected pattern either.

Table 4a: Comparison of bottomfish bait station counts among all 2002 sites (counts/station, n = 6 except KIR2, n = 5)

DESCRIPTION	Raita Mean +/- SE	WSR Mean +/- SE	KIR1 Mean +/- SE	KIR2 Mean +/- SE	PB1 Mean +/- SE	PB2 Mean +/- SE	Brooks Mean +/- SE	
Expected Count Rankings	2	2	1	1	3	3	2	P<0.05
Bottomfish Counts								
Etelis coruscans	3.0 +/- 0.82	3.8 +/- 2.87	14.7 +/- 5.73	5.6 +/- 3.11	17.5 +/- 3.71	0.5 +/- 0.50	10.5 +/- 4.82	+
Etelis carbunculus	1.8 +/- 1.33	1.0 +/- 0.82	4.5 +/- 1.65	3.4 +/- 1.60	4.0 +/- 1.24	4.0 +/- 1.18	0.5 +/- 0.34	-
Epinephelus quernus	2.3 +/- 1.05	1.7 +/- 0.92	0.0 +/- 0.00	0.2 +/- 0.2	0.2 +/- 0.17	0.0 +/- 0.00	2.7 +/- 0.72	+
Pristipomoides filamentosus	0.0 +/- 0.00	0.3 +/- 0.21	0.2 +/- 0.17	7.6 +/- 5.75	0.0 +/- 0.00	0.5 +/- 0.34	2.8 +/- 1.49	+
Pristipomoides sieboldii	0.0 +/- 0.00	8.5 +/- 8.50	0.0 +/- 0.00	6.2 +/- 5.95	3.3 +/- 3.3	3.8 +/- 3.64	0.0 +/- 0.00	-
Pristipomoides zonatus	0.0 +/- 0.00	1.0 +/- 0.52	0.2 +/- 0.17	3.0 +/- 0.84	1.2 +/- 0.40	2.2 +/- 0.83	0.5 +/- 0.34	+
Pseudocaranx dentex	0.3 +/- 0.33	0.2 +/- 0.17	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	4.7 +/- 2.95	-
Aphareus rutilans	0.0 +/- 0.00	0.0 +/- 0.00	0.3 +/- 0.33	2.8 +/- 1.96	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	nt
Pristipomoides auricilla	0.0 +/- 0.00	1.2 +/- 1.17	0.0 +/- 0.00	0.6 +/- 0.6	2.8 +/- 2.83	1.7 +/- 1.17	0.0 +/- 0.00	-
Aprion virescens	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	nt

Table 4b: Comparison of bycatch bait station counts among all 2002 sites (counts/station, n = 6 except KIR2, n = 5)

DESCRIPTION	Raita Mean +/- SE	WSR Mean +/- SE	KIR1 Mean +/- SE	KIR2 Mean +/- SE	PB1 Mean +/- SE	PB2 Mean +/- SE	Brooks Mean +/- SE	
Expected Count Rankings	2	2	3	3	1	1	2	P<0.05
Bycatch Counts								
Bodianus vulpinus	0.5 +/- 0.50	0.8 +/- 0.54	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.2 +/- 0.17	-
Carcharhinus sp	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.5 +/- 0.34	nt
Gymnothorax sp	1.2 +/- 0.31	1.0 +/- 0.45	0.7 +/- 0.21	0.8 +/- 0.37	1.8 +/- 0.40	1.2 +/- 0.17	0.0 +/- 0.00	-
Randallichthys filamentosus	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	1.0 +/- 0.63	0.3 +/- 0.21	0.7 +/- 0.33	nt
Seriola sp	3.3 +/- 1.00	3.7 +/- 1.12	0.5 +/- 0.22	1.8 +/- 0.80	2.0 +/- 0.45	1.7 +/- 1.00	10.7 +/- 3.60	+
Dasyatis sp	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.8 +/- 0.31	0.0 +/- 0.00	0.0 +/- 0.00	nt
Polylepion russelli	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.3 +/- 0.33	0.0 +/- 0.00	0.0 +/- 0.00	nt
Taractichthys steindachneri	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.3 +/- 0.33	0.0 +/- 0.00	nt
Conger oligoporus	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.3 +/- 0.33	0.0 +/- 0.00	nt
Squalus mitsukurii	0.7 +/- 0.70	0.2 +/- 0.17	0.0 +/- 0.00	0.0 +/- 0.00	0.0 +/- 0.00	0.2 +/- 0.17	0.0 +/- 0.00	nt

Table 5: Comparison of bottomfish bait station size measurements (fork lengths in centimeters) among 2002 sites (Brooks not included)

	Raita		WSR		KIR1		KIR2		PB1		PB2		
Expected Rankings	2		2		1		1		3		3		
Bottomfish species	**N**	**Mean +/- SE**	**N**	**Mean +/- SE**	**N**	**Mean +/- SE**	**N**	**Mean +/- SE**	**N**	**Mean +/- SE**	**N**	**Mean +/- SE**	**P**
Etelis coruscans	30	65.3 +/- 3.51	39	49.3 +/- 1.42	49	59.7 +/- 1.60	51	52.3 +/- 1.17	69	53.6 +/- 1.40	1	99.1	0.00
Etelis carbunculus	16	44.5 +/- 2.69	8	34.3 +/- 4.80	31	36.3 +/- 1.50	28	37.8 +/- 1.83	26	38.9 +/- 1.37	40	35.3 +/- 0.84	0.01
Epinephelus quernus	19	77.7 +/- 4.70	9	62.5 +/- 5.11	-	-	2	37.8 +/- 2.16	3	58.9 +/- 1.42	-	-	0.02
Pristipomoides filamentosus	-	-	5	48.8 +/- 4.11	-	-	97	48.3 +/- 1.12	-	-	-	-	0.90
Pristipomoides sieboldii	-	-	28	33.8 +/- 0.56	-	-	28	37.6 +/- 1.68	-	-	11	30.2 +/- 1.07	0.00
Pristipomoides zonatus	-	-	8	36.3 +/- 2.54	-	-	35	35.1 +/- 0.91	10	36.8 +/- 1.63	12	32.0 +/- 1.42	0.17
Aphareus rutilans	-	-	-	-	2	63.2 +/- 27.4	8	56.4 +/- 2.16	-	-	-	-	-

DISCUSSION

All types of fishing methods lead to removal impacts. Methods are considered selective when they yield a high percentage of target versus bycatch species in the catch. Different methods also have varying potential for addition and alteration impacts. Bottom trawling is the subject of the largest number of reports on fishing impacts over the last 3 years (Rester, 2003). Bottom trawling generally causes substantial removal impacts with low selectivity (high levels of bycatch); can cause dramatic alterations to the benthic habitat and community (particularly cnidarians and other sessile benthic invertebrates); and when lost can contribute heavily to the addition of fishing debris. Trap fishing is more selective than trawling, but can produce moderate levels of addition and alteration impacts. In contrast, hook-and-line methods (including trolling, longline, and handline fishing) are considered to be "low impact" (Morgan and Chuenpagdee, 2003). Longline fishing has been shown to alter prey and competitor populations in pelagic ecosystems (Ward and Myers, in press); however, trolling and handline fishing are relatively selective and are not considered to have major impacts. Bottomfishing (a form of handline fishing) and trolling are the only types of fishing permitted on Raita and WSR Banks.

Commercial catch data from 2001-2003 indicated that on average, over 2,000 bottomfish are being removed from each of the Raita and St. Rogatien reporting grids per year. The estimated maximum sustainable yields (MSY) are reported as 16.9 and 11.7 mt, respectively (WPRFMC, 1986). If the mean fish weight is assumed to be 4.5 kg, the take on these banks is just below MSY. Unfortunately, due to poor spatial resolution of the reporting grids, it is not known exactly how many fish are removed annually from each of the two RPAs. This is a particular problem for the St. Rogatien grid data which includes both the WSR as well as the larger St. Rogatien Bank. Above the 100-fathom contour, the calculated areas of Raita, WSR and St. Rogatien are 570, 54, and 484 km^2, respectively. The combined area of the latter two is 538 km^2, or approximately the same as Raita, which may be why the catches from these two grids are similar. However, the extent of suitable bottomfish habitat on each of the banks has not been determined.

Fishing undoubtedly has a significant effect on the abundance and mean fish size of targeted species from these and other areas throughout the Hawaiian Archipelago. Perhaps the more important question is whether the sustainability of the populations on these banks is being impacted by this activity. As Table 2 shows, landings of onaga and opakapaka generally decreased while landings of uku generally increased during the 3-year study period. Both changes were most likely due to a shift in fishing effort. Either an increase in uku catchability (previously reported several times for the NWHI fishery) or a decrease in onaga and opakapaka catchability could have been the cause of this pattern. These data are difficult, if not impossible, to interpret without knowing the effort expended targeting each species during that period.

In 2002, the number of onaga counted from the submersible at both Raita and WSR were significantly lower than at the other five study sites (Kelley and Moffitt, unpublished report). Comparison between the 2002 and 2003 data also supports the possibility that onaga abundance is decreasing at the two sites as well. Opakapaka observations were too low to be statistically tested, but it should be noted that they followed the same pattern. Comparison of bait station size measurements in our study shows that the onaga mean size at the WSR site is similar to or lower than most of the MHI sites. It is, however, presumptuous to assume that abundance and size estimates obtained at one site on each bank are reflective of what is occurring on each bank as a whole. The data cannot be considered conclusive but rather only indicate the possibility of a problem with onaga populations in these two RFAs. Furthermore, the problem does not appear to extend to populations of other bottomfish species. Hapuupuu counts at Raita were second highest only to Brooks, with the other species falling between the heavily and no-fished sites as expected. Raita onaga were larger, not smaller than MHI onaga in contrast to what was observed on WSR. The WSR pattern was not true for all species nor was it true for the period from 2002 to 2003, when sizes actually increased at both banks (Kelley and Moffitt, unpublished report).

Bycatch from bottomfishing potentially is being understated on commercial catch reports, as has been suggested for other types of fisheries (Morgan and Chuenpagdee, 2003). The data from bait stations combined with fishing surveys (Kelley, unpub.; Moffitt, unpub.) identify 41 potential bycatch species, most of which are rarely caught. Of these, kahala are by far the most common and usually are thrown back alive, as are dogfish, *Squalus mitsukurii*. Hogos (*Pontinus macrocephalus*) are occasionally caught on deeper drops and are kept to be sold or eaten. Bycatch impacts are probably not significant on either Raita or WSR Banks.

Counts of debris from bottomfishing on Raita and WSR were the lowest of all seven sites. This is probably because the number of boats permitted to fish the banks is low, with only four or five operating during the study period. Second, these are more experienced commercial fishers, who are much less likely to lose gear than recreational or part-time fishers. For probably the same reasons, significant amounts of trash also were not observed on either bank. This type of impact was not found to be significant on either bank.

Cnidarians, particularly fan-like gorgonians, are considered to be the highest risk organisms for alteration impacts, since they are attached to the bottom and present a relatively large surface area that could be entangled with fishing line. In contrast to what was expected, Raita and WSR cnidarian densities were significantly lower than those observed on other study sites as well as at other sites surveyed by submersible and ROV on the banks. With averages of less than 50 cnidarians per hectare, bottomfishing gear contacting these animals must be occurring at a very low frequency. Although not presented here, three other groups of benthic invertebrates, sponges, urchins, and seastars, were examined that could also be at moderate to low risk. However, Raita and WSR urchin and sponge counts were significantly lower, while seastar counts were approximately the same as those on other sites (Kelley and Moffitt, unpub. report).

In conclusion, bottomfishing in the WSR and Raita RPAs may be reducing the populations of onaga, particularly on Raita; however, the data are not conclusive. Bottomfishing is a form of handline fishing, which is considered to have low collateral impact in comparison to other types of fishing. The data obtained in this study are consistent with that position. The number of fishers working in the WSR and Raita RPAs is low, as is the amount of gear and trash they appear to be leaving. The substrate on each of the banks has been described by submersible pilots as a "barren, lifeless wasteland" (Kerby, pers. comm.) in comparison to the many other dives they have made during their careers. The tops are primarily covered with rhodoliths while the slopes are relatively featureless carbonate rock and sediment. Reef-building corals are not found at bottomfishing depths, only other types of cnidarians whose abundance is also low. Sponge, urchin, and seastar abundances are relatively low. In general, there appears to be very little damage that bottomfishing could do on either Raita or W. St. Rogatien. However, these findings do not apply to all of the banks in NWHICRER where fishing activity has been and is taking place. For example, Brooks was found to have a relatively extensive bed of black coral, *Antipathes ulex*, within bottomfishing depths (Kelley and Moffitt, unpub.). Whether other banks in NWHICRER also have extensive coral beds or other resources vulnerable to bottomfishing impacts is presently unknown.

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