Estimation of reef fish abundance and benthic habitat composition in the proposed Managaha Marine Conservation Area

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Technical Report 99-03

Federal Aid in Sportfish Restoration Act Project F-2-R

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ACKNOWLEDGEMENTS

This project was fully funded by the U. S. Fish and Wildlife Service (USFWS) through the Dingell-Johnson (DJ) Sportfish Restoration Act Grant Award F-2-R.

The Division of Fish and Wildlife would like to thank Representative Heinz Hofschneider for his unwavering support for the creation of the Managaha Marine Conservation Area (MMCA). The DFW would also like to acknowledge and thank former Natural Resource Chairman Manuel Tenorio for his support on the many natural resource conservation issues, including the MMCA, which he has promoted over the past four years.

John Jordan of the CNMI Coastal Resources Management Office (CRMO) provided the GIS map of the current boundaries of the proposed Managaha Marine Conservation Area, as well as area estimates of Managaha Island, the barrier reef, and reef slope.

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ABSTRACT

In the late spring of 1999 the Saipan office of the Division of Fish and Wildlife (DFW) was contacted by the Office of Representative Heinz Hofshneider of the CNMI legislature to provide assistance in the development of a marine conservation area around the island of Managaha. As part of the Dingell-Johnson Sportfish Restoration Act funded DFW Marine Sanctuaries project, the DFW, CNMI Department of Environmental Quality (DEQ), Coastal Resources Management Office (CRMO) and the CNMI legislature conducted underwater visual transects towards the goal of determining selected fish abundance, and sampled for benthic habitat composition in the proposed Managaha Marine Conservation Area (MMCA).

A stratified random sampling design was implemented to estimate fish abundance by family/group and by habitat type in the proposed conservation area. Results found that population size generally followed stratum size. The highest densities of fish were found in habitats 18 and 21, which were outer lagoon habitats dominated by sand/rubble and rubble/coralline algae, respectively.

Percent coral cover was highest in the reef slope habitat and in habitat 17. Cluster analysis of the dominant benthic features and dominant fish families/groups resulted in three clusters, which were distanced primarily by dominant benthic habitat types.

Collection of data in a timely manner would have provided a more comprehensive data analysis.

INTRODUCTION

Although little information exists pertaining to the island of Managaha prior to the settlement of the peoples from the Caroline Islands during the Spanish occupation in the 19th century, it was most likely an important base for both inshore and offshore fishing activities of the native Chamorro people. Historically, it is believed that the peoples of the Caroline Islands frequented the Mariana Islands to trade with the native Chamorros (Amesbury et al. 1989), and Managaha Island was probably a meeting place.

The island of Managaha has considerable cultural significance to the contemporary Carolinian community of Saipan. A burial shrine to the Carolinian Chief Agrub commemorates his guidance of the initial Carolinian settlers to Saipan in 1818 following the typhoon-generated destruction of their homes (Russell 1984).

Located near the main entrance into Saipan Lagoon, the island of Managaha today is the center of water-based tourism in Saipan lagoon and the Commonwealth of the Northern Mariana Islands (CNMI)(Figure 1). The majority of the approximately 200,000 tourists that visit Managaha each year are Japanese. Snorkeling, scuba diving, banana-boat rides, parasailing, and swimming are among many water activities based from Managaha. In addition, beach activities such as volleyball and sunbathing are also very popular.

A publication by Pacific Basin Environmental Consultants (PBEC 1985) first suggested that the island of Managaha become a conservation area managed under a now defunct Marine Parks Program established by the CNMI Coastal Resources Management Office (CRMO) (Figure 2). No apparent action was taken following the suggested designation for Managaha Island in the PBEC publication.

A 1994 survey conducted by the CNMI Division of Fish and Wildlife (DFW) found 79% of the interviewees to be in support of the creation of marine protected areas to effectively manage marine resources (DFW 1994b). The majority of answers to a follow-up question in that survey did not provide specific geographical areas, but of those that did the highest percentage was in reference to Saipan Lagoon (DFW 1994b).

In the late spring of 1999 the Saipan office of the DFW was contacted by the Office of Representative Heinz Hofshneider of the CNMI legislature to provide assistance in the development of a marine conservation area around the island of Managaha. As part of the Dingell-Johnson Sportfish Restoration Act funded DFW Marine Sanctuaries project, the DFW with assistance from the CNMI Department of Environmental Quality (DEQ), the Coastal Resources Management Office (CRMO) and the CNMI legislature conducted underwater visual transects towards the goal of determining selected fish abundance. From May 24-28, 1999 the CNMI Marine Monitoring Team sampled for benthic habitat composition in the proposed Managaha Marine Conservation Area (MMCA). Fish surveys were conducted from June though September 1999, as weather and logistics permitted.

This report provides estimates of fish abundance in the proposed Managaha Marine Conservation Area, and provides data on habitat characteristics.

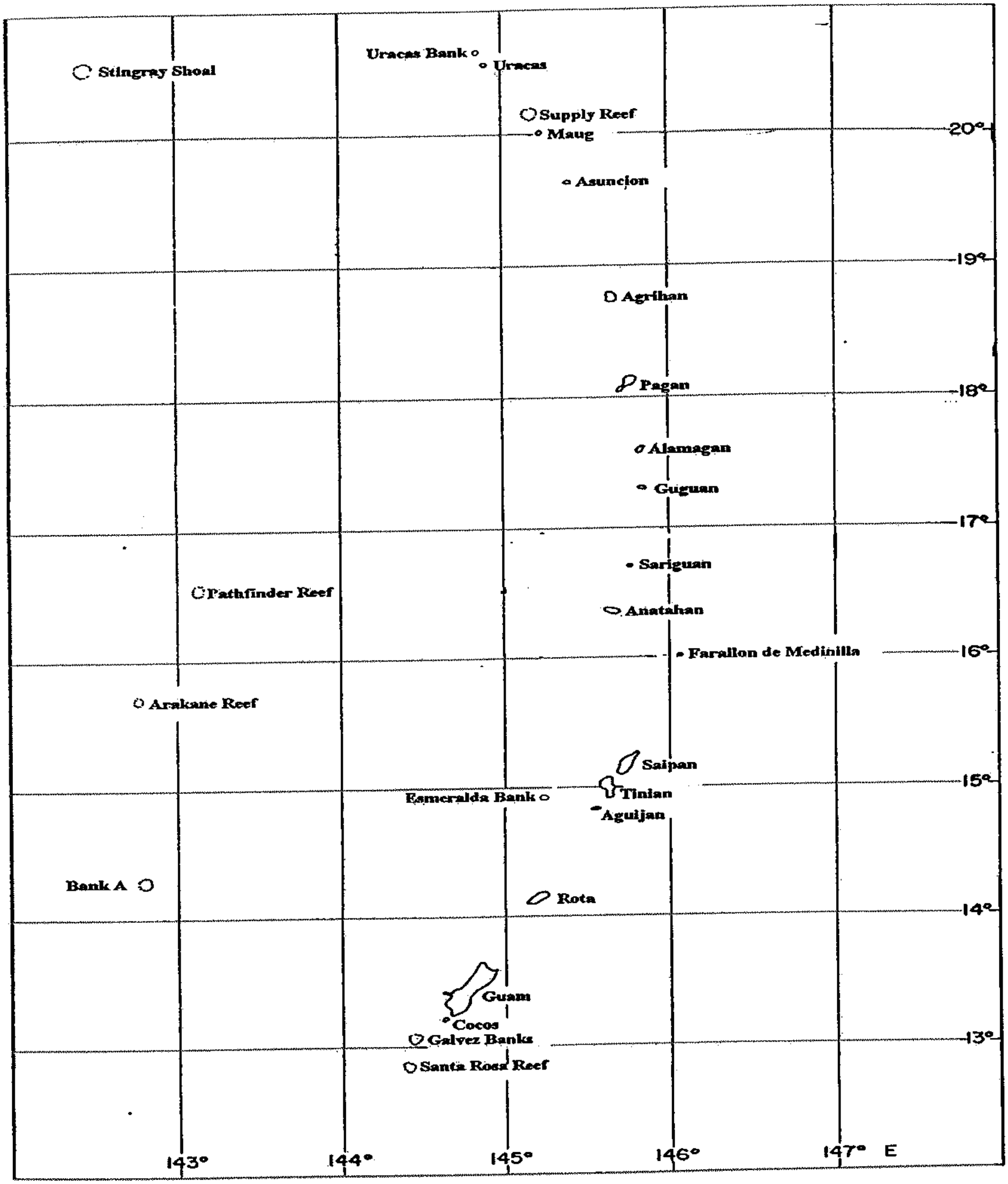


Figure 1. The Mariana Archipelago.

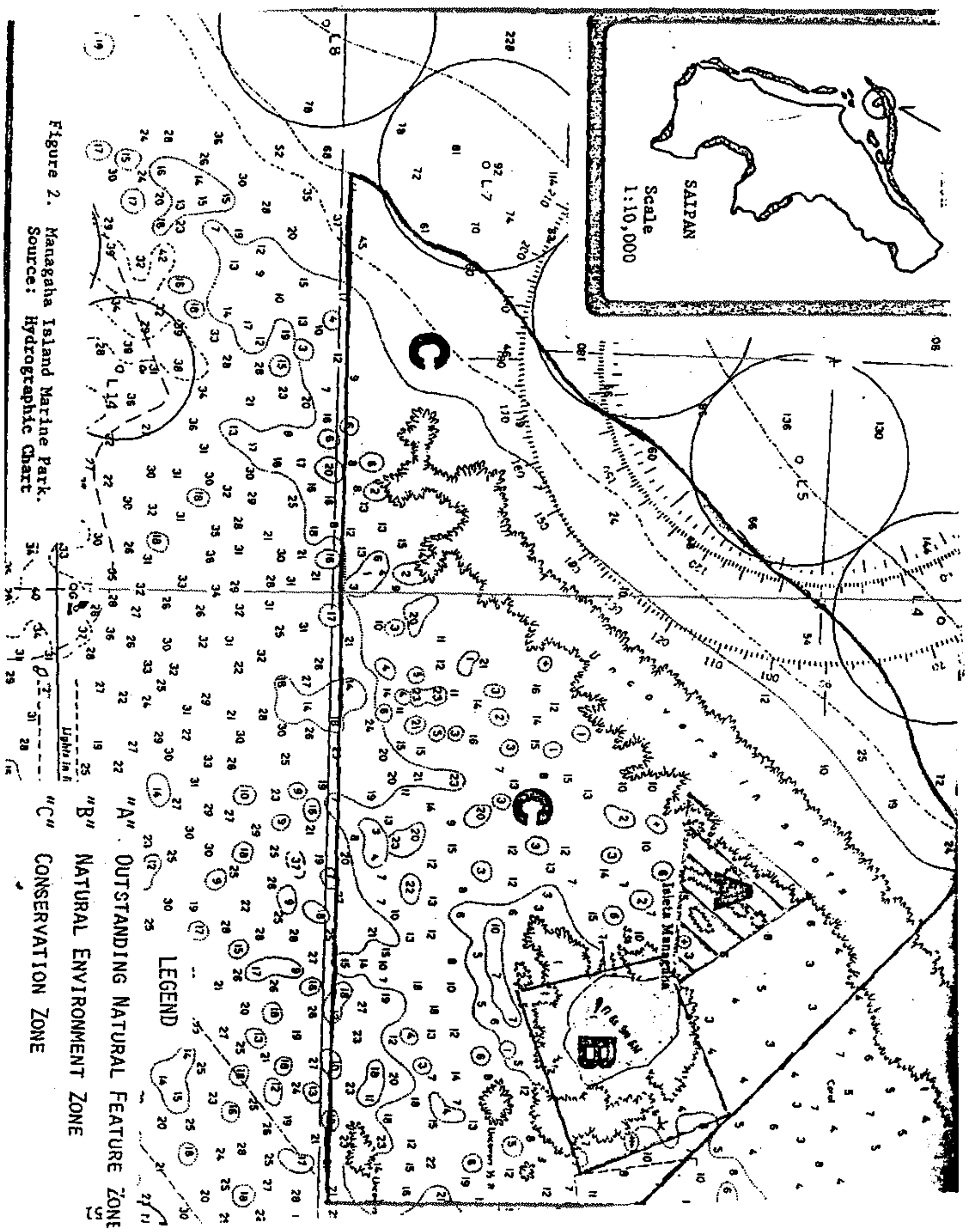


Figure 2. Managaha Marine Park boundary as recommended by Pacific Basin Environmental Consultants, Inc. (1985).

METHODS

Stratified random sampling was used to estimate fish abundance in the proposed sanctuary. DFW staff along with personnel from the CNMI Legislature and CRMO mapped out the proposed sanctuary boundaries in late spring of 1999. The different habitat-types within the proposed sanctuary were then determined from a study by Duenas and Associates (1997) on fish and sea cucumber abundance with Saipan Lagoon. These habitat types were then considered strata (Figure 3), and the small section of stratum 20 was included in stratum 18.

Underwater visual fish counts were conducted along randomly placed 25 meter long by 5 meter wide transects. Depth was found to be relatively uniform within the proposed MMCA strata, while outside the lagoon sampling was conducted at depth strata 15 (10-20), 25 (20-30), 35 (30-40) and 45 (40-50) feet along the reef slope, similar to the sampling protocol used in the proposed Tinian Marine Sanctuary (Trianni 1999). All fish observed were identified to the family level, with some families further divided into subfamilies (Acanthuridae), or by developmental stage (Scaridae).

Benthic habitat structure was determined by DEQ and CRMO Marine Monitoring Team (MMT) staff using randomly placed point-intercept-quadrats (PIQ), based on life-form categories and codes following AIMS (1994) (Table 1).

The number of samples taken within the sanctuary was determined by using estimates of the mean abundance and variance calculated from preliminary transects conducted in heavily fished and lightly exploited reef slope areas on Saipan. A formula developed by Elliot (1977) was used to determine the number of samples required to achieve a predetermined level of precision;

$$n_r = \frac{s^2}{mD^2}$$

Where n^r = number of samples, s^2 = estimate of variance, m= mean, and D^2= desired level of precision.

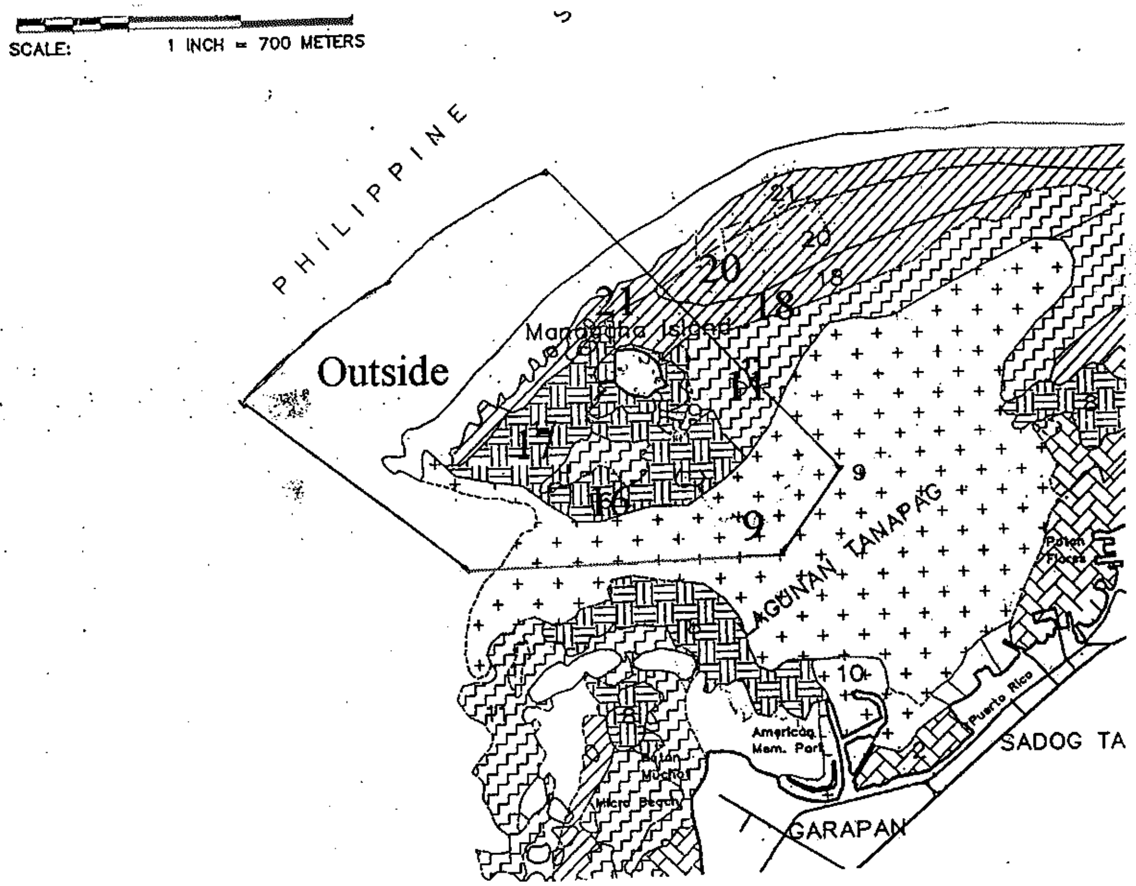
Simple proportional allocation was used to determine the number of transects per stratum (Cochran 1977). This technique weighs sample size by stratum size. The procedure for obtaining population estimates for each family/group follows.

Where N equaled the size of the h^{th} strata. Stratum weights were defined as:

$$W_h = N_h/N$$

The unbiased estimate of the population mean was determined by:

$$\bar{y}_{st} = \sum^{L}(W_h)\bar{y}_h$$



Outside = Reef Slope. Sampled to 50 feet.
9 = Harbor area. Sand with scattered algae and coral mounds.
11 = Sand and blue-green algae.
16 = Patch reef with crustose coralline alage.
17 = Live patch reef.
18 = Sand and rubble with blue-green algae (*Hormothamnion*).
21 = Dead staghorn coral with algae (*Hormothamnion* and *Dictyota/Halimeda*).

Habitat descriptions from Duenas and Assocaites (1997)

Figure 3. Habitat types used as strata in sampling the proposed Managaha Marine Conservation Area.

Table 1. Survey Codes for Tropical Marine Resources following Australian Institute of Marine Science (1994).

Fauna:	Codes:	Notes:
Soft Coral	SC	soft bodied coral
Sponges	SP	
Zoanthids	ZO	ex. *Platythoa, Protopalythoa*
Others	OT	Ascidians, anenomes, gorgonians, giant clams etc.
Algae:		
Algal Assemblage	AA	more than one species
Coralline Algae	CA	
Halimeda	HA	
Microalgae	MA	weedy/fleshy browns & reds
Turf Algae	TA	lush filamentous algae, often found inside damselfish territories.
Abiotic:		
Sand	S	
Rubble	R	unconsolidated coral fragments.
Silt	SI	
Water	WA	fissures deeper than 50cm
Rock	RCK	
Hard Corals:		
Dead Corals	DC	recently dead, white
Dead coral w/Algae	DCA	standing no longer white
Acropora:		
Branching	ACB	2^{o} branching, e.g. *Acropora palmata, A. formosa*
Encrusting	ACE	usually the base-plate for immature *Acropora* forms
Submassive	ACS	robust with knob or wedge like form
Digitate	ACD	no 2^{o} branching, typically includes *A. Humilis & A. digitifera*
Tabulate	ACT	horizontal flattened plate
Non-Acropora:		
Branching	CB	at least 2^{o} branching
Encrusting	CE	major portion attached to substratum as a laminar plate e.g. *Porites vaughani*
Foliose	CF	coral attached at one or more points, leaf-like appearance
Massive	CM	solid builder or mound
Submassive	CS	tends to form small columns, knobs, or wedges
Mushroom	CMR	solitary, free-living corals of the *Fungia*
Millepora	CME	fire coral
Heliopora	CHL	blue coral

Where y_i represents the estimated stratum means, and y_{st} the unbiased estimator of the population mean, u.

The unbiased estimate of total population size was then calculated as:

$$\hat{Y} = N(\bar{y}_{st})$$

RESULTS

The boundaries of the proposed Managaha Marine Sanctuary are shown in Figure 4. The current sanctuary boundaries include an area of 5.06 km^2, compared to the original boundary designation that covered 2.60 km^2 (Figures' 2 & 3; PBEC 1985). The estimation of fish abundance was based on an estimated area of 3.33 km^2, which does not include the island of Managaha or the continuous barrier reef. This estimate included the outer reef slope down to 10 fathoms, which appears to be beyond the outermost boundary of the MMCA as viewed in the most recent map of the MMCA (Figure 4).

Based on logistical constraints a precision of 30% was deemed acceptable, which resulted in the number of transects taken to be 72. An increase to 25% precision would have resulted in an additional 33 transects, which proved logistically impractical.

Summary statistics for fish abundance per stratum are given in Table 2. A total of 31 families and 33 groups were observed. Approximately 50% of the fish observed were classified as food fish. Population point estimates for the various families/groups sampled, as well as per strata sampled are given in Table 3. The most abundant food fish group was the subfamily Acanthurinae (surgeonfish) within the family Acanthuridae, accounting for over 28% of the total food fish observed. The second most abundant group was the Khyphosidae (rudderfish-26%), followed by the subfamily Nasinae (unicornfish-24%) and juvenile Scaridae (parrotfish initial phase-8%). The most abundant non-food fish were the Pomacentridae (damselfish), followed by the Cirrihitidae (hawkfish). The damselfish were found to be significantly dominant, accounting for over 68% of the total non-food fish observed, with the hawkfish accounting for 6%.

As shown in Table 3 the greatest abundance of fish were observed outside the barrier reef along the outer reef slope, which accounted for 48% of the total fish population estimate within the MMCA. This corresponded with the outside stratum comprising the largest segment of the MMCA (Table 4). The mean density of reef fish per 100 m^2 are also shown in Table 4, along with population estimates and bounds on error of estimation for each strata. The highest fish density was recorded in habitats' 18 and 21, which comprise the outer lagoon.

The highest percent coral cover was found in habitats' 17 and the reef slope ('outside'), which had the second lowest and fourth highest fish density, respectively (Table 5). Percent coral cover was found to be low in all other strata. The percentage of the dominant benthic structures per habitat are shown in Table 6. Sand was found to be the dominant feature in both

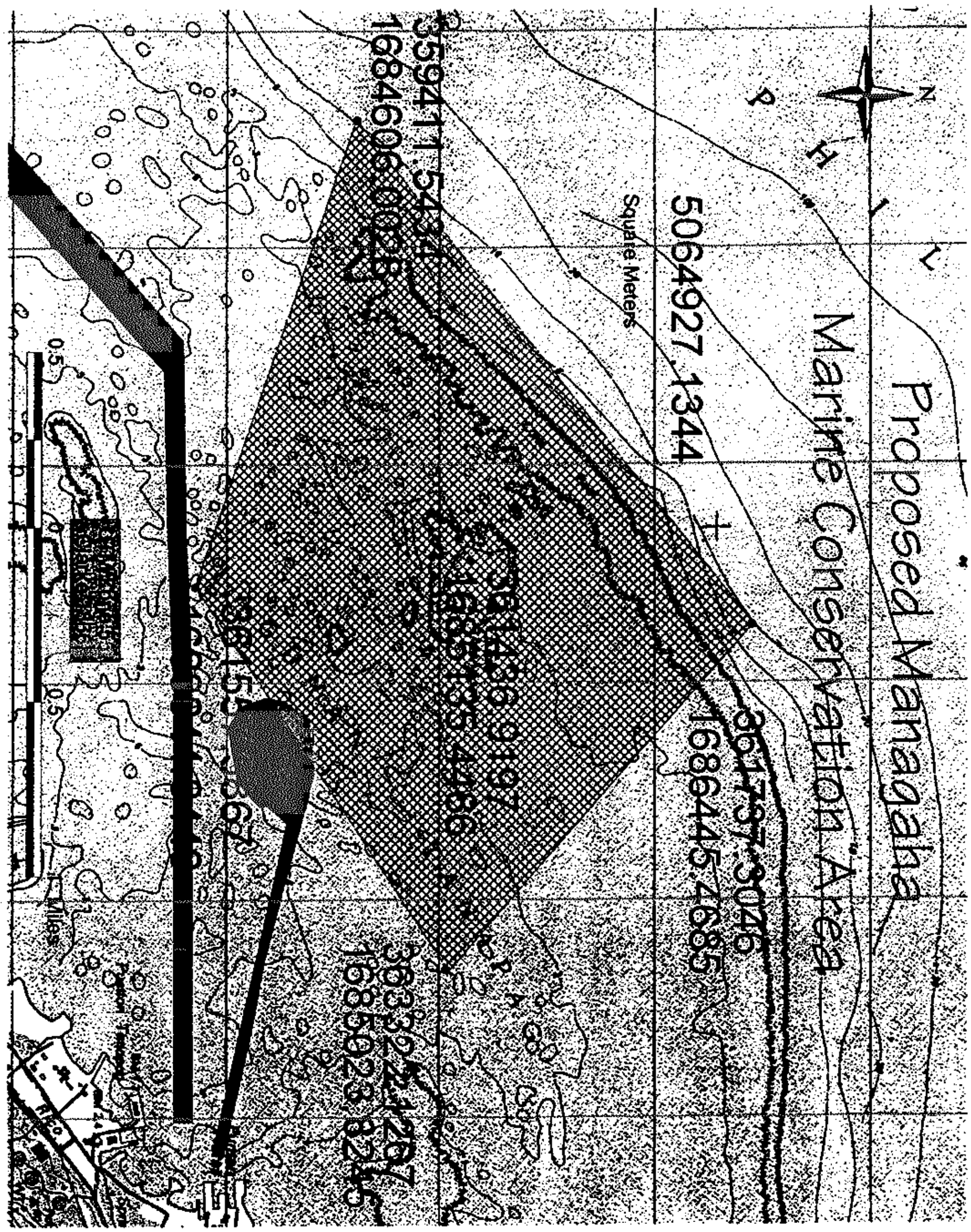


Figure 4. Boundaries of the proposed Manangaha Marine Conservation Area.

Table 2. Summary statisitcs of fish family/groups per habitat type from the proposed Managaha Marine Conservation Area.

Section	9			11			16			17			18			21			OutSide		
	Total	Mean	Var	Total	Mean	Var	Total	Mean	Var	Total	Mean	Var	Total	Mean	Var	Total	Mean	Var	Total	Mean	Var
Food Fish																					
Acanthuridae/S	95	10.6	180.03	90	12.9	240.81	45	3.2	12.03	133	19.0	22.67	114	19.0	261.60	238	29.8	722.79	360	17.1	81.33
Acanthuridae/U	25	2.8	26.69	187	26.7	871.90	46	3.3	51.14	71	10.1	35.81	116	19.3	99.87	260	32.5	1285.71	304	14.5	28.36
Balistidae	0	0.0	0.00	12	1.7	2.90	2	0.1	0.13	1	0.1	0.14	4	0.7	2.67	20	2.5	30.29	50	2.4	6.05
Carangidae	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	2	0.3	0.57	0	0.0	0.00	1	0.1	0.13	0	0.0	0.00
Gerridae	1	0.1	0.11	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
Haemulidae	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	2	0.1	0.09
Holocentridae	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	3	0.5	0.70	10	1.3	4.50	8	0.4	0.95
Kyphosidae	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	7	0.9	6.13	0	0.0	0.00
Labridae	39	4.3	13.00	56	8.0	18.33	102	7.3	47.45	31	4.4	11.29	97	16.2	24.57	48	6.0	13.71	457	21.8	187.69
Lethrinidae	1	0.1	0.11	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	1	0.2	0.17	2	0.3	0.50	0	0.0	0.00
Lutjanidae	0	0.0	0.00	0	0.0	0.00	6	0.4	1.34	0	0.0	0.00	0	0.0	0.00	5	0.6	1.98	32	1.5	42.66
Mullidae	32	3.6	71.28	2	0.3	0.24	10	0.7	2.99	2	0.3	0.57	33	5.5	8.30	26	3.3	12.50	14	0.7	1.33
Nemipteridae	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	1	0.1	0.14	1	0.2	0.17	18	2.3	19.93	3	0.1	0.43
Scaridae/I	119	13.2	588.69	7	1.0	1.67	16	1.1	2.75	10	1.4	2.95	49	8.2	140.17	59	7.4	43.13	56	2.7	14.83
Scaridae/T	3	0.3	1.00	0	0.0	0.00	4	0.3	0.53	4	0.6	0.62	0	0.0	0.00	2	0.3	0.50	10	0.5	1.36
Serranidae	1	0.1	0.11	0	0.0	0.00	1	0.1	0.07	0	0.0	0.00	0	0.0	0.00	1	0.1	0.13	24	1.1	3.13
Siganidae	125	13.9	646.36	109	15.6	398.95	11	0.8	8.64	0	0.0	0.00	51	8.5	185.50	2	0.3	0.50	10	0.5	4.76
Non-Food Fish																					
Apoganidae	64	7.1	178.11	1	0.1	0.14	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	8	1.0	0.86	1	0.0	0.05
Blennidae	17	1.9	6.61	25	3.6	22.95	3	0.2	0.34	3	0.4	0.62	1	0.2	0.17	44	5.5	12.86	13	0.6	1.15
Chaetodontidae	29	3.2	14.19	3	0.4	0.62	6	0.4	0.57	2	0.3	0.57	20	3.3	9.47	34	4.3	3.64	78	3.7	8.41
Cirrihitidae	1	0.1	0.11	3	0.4	0.62	3	0.2	0.18	2	0.3	0.24	0	0.0	0.00	18	2.3	2.21	140	6.7	9.33
Gobiidae	35	3.9	9.36	14	2.0	7.67	12	0.9	1.67	1	0.1	0.14	0	0.0	0.00	16	2.0	11.14	5	0.2	0.39
Microdesmidae	1	0.1	0.11	0	0.0	0.00	1	0.1	0.07	0	0.0	0.00	40	6.7	266.67	3	0.4	0.27	7	0.3	0.53
Monocanthidae	3	0.3	1.00	1	0.1	0.14	2	0.1	0.13	4	0.6	0.62	0	0.0	0.00	8	1.0	2.00	10	0.5	0.76
Ostracidae	4	0.4	0.53	7	1.0	3.00	2	0.1	0.29	0	0.0	0.00	7	1.2	2.57	4	0.5	0.57	1	0.0	0.05
Pempheridae	1	0.1	0.11	0	0.0	0.00	0	0.0	0.00	3	0.4	0.62	0	0.0	0.00	21	2.6	49.41	0	0.0	0.00
Pomacanthidae	0	0.0	0.00	4	0.6	1.29	0	0.0	0.00	9	1.3	11.57	2	0.3	0.27	104	13.0	555.14	47	2.2	7.99
Pomacentridae	461	51.2	1134.19	165	23.6	280.29	376	26.9	220.90	342	48.9	753.81	292	48.7	485.47	297	37.1	1612.70	785	37.4	407.05
Syngnathidae	4	0.4	1.78	3	0.4	1.29	0	0.0	0.00	1	0.1	0.14	1	0.2	0.17	17	2.1	19.84	0	0.0	0.00
Tetradontidae	9	1.0	2.50	8	1.1	2.14	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	14	1.8	5.64	16	0.8	9.29
Zanclidae	11	1.2	4.19	0	0.0	0.00	8	0.6	0.73	2	0.3	0.24	18	3.0	24.80	27	3.4	16.55	33	1.6	7.26
Penguipedidae	0	0.0	0.00	0	0.0	0.00	3	0.2	0.34	3	0.4	0.29	2	0.3	0.67	0	0.0	0.00	5	0.2	0.29
Unid.	0	0.0	0.00	0	0.0	0.00	2	0.1	0.13	1	0.1	0.14	0	0.0	0.00	1	0.1	0.13	0	0.0	0.00
Moranidae	0	0.0	0.00	1	0.1	0.14	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00

Acanthuridae/S = Surgeon Fish
Acanthuridae/U = Unicorn Fish
Scaridae/T = Terminal Phase
Scaridae/I = Initial Phase

Table 3. Population estimates of the various fish groups sampled from the proposed Managaha Marine Conservation Area.

Section	9	11	16	17	18	21	Outside	Totals
Food Fish								
Acanthuridae/Surgeonfish	54,097	28,929	10,848	68,875	26,125	44,641	257,143	490,658
Acanthuridae/Unicornfish	14,236	60,107	11,089	36,768	26,583	48,768	217,143	414,694
Balistidae	0	3,857	482	518	917	3,751	35,714	45,239
Carangidae	0	0	0	1,036	0	188	0	1,223
Gerridae	569	0	0	0	0	0	0	569
Haemulidae	0	0	0	0	0	0	1,429	1,429
Holocentridae	0	0	0	0	688	1,876	5,714	8,277
Kyphosidae	0	0	0	0	0	1,313	0	1,313
Labridae	22,208	18,000	24,589	16,054	22,229	9,003	326,428	438,512
Lethrinidae	569	0	0	0	229	375	0	1,174
Lutjanidae	0	0	1,446	0	0	938	22,857	25,241
Mullidae	18,222	643	2,411	1,036	7,563	4,877	10,000	44,751
Nemipteridae	0	0	0	518	229	3,376	2,143	6,266
Scaridae/Initial Phase	67,764	2,250	3,857	5,179	11,229	11,067	40,000	141,345
Scaridae/Terminal Phase	1,708	0	964	2,071	0	375	7,143	12,262
Serranidae	569	0	241	0	0	188	17,143	18,141
Siganidae	71,181	35,036	2,652	0	11,688	375	7,143	128,073
Non-Food Fish	0	0	0	0	0	0	0	0
Apoganidae	36,444	321	0	0	0	1,501	714	38,981
Blennidae	9,681	8,036	723	1,554	229	8,253	9,286	37,761
Chaetodontidae	16,514	964	1,446	1,036	4,583	6,377	55,714	86,635
Cirrihitidae	569	964	723	1,036	0	3,376	100,000	106,669
Gobiidae	19,931	4,500	2,893	518	0	3,001	3,571	34,414
Microdesmidae	569	0	241	0	9,167	563	5,000	15,540
Monocanthidae	1,708	321	482	2,071	0	1,501	7,143	13,227
Ostracidae	2,278	2,250	482	0	1,604	750	714	8,079
Pempheridae	569	0	0	1,554	0	3,939	0	6,062
Pomacanthidae	0	1,286	0	4,661	458	19,507	33,571	59,483
Pomacentridae	262,514	53,036	90,643	177,107	66,917	55,708	560,714	1,266,638
Syngnathidae	2,278	964	0	518	229	3,189	0	7,178
Tetradontidae	5,125	2,571	0	0	0	2,626	11,429	21,751
Zanclidae	6,264	0	1,929	1,036	4,125	5,064	23,571	41,989
Penguipedidae	0	0	723	1,554	458	0	3,571	6,307
Unid.	0	0	482	518	0	188	0	1,188
Moranidae	0	321	0	0	0	0	0	321
Totals	**615,569**	**224,357**	**159,348**	**325,214**	**195,250**	**246,653**	**1,765,000**	**3,531,390**

Table 4. Stratum size (km^2; represents area within 10 fathom contour), mean density of reef fish (100 m^2), and population estimate of reef fish in the proposed Managaha Marine Conservation Area.

Strata	Stratum Size	Mean Density	Population Estimate
9	0.509	121	614,401<**615,569**<616,737
11	0.223	101	223,638<**224,357**<225,076
16	0.340	47	159,209<**159,348**<159,487
17	0.364	89	324,897<**325,214**<325,531
18	0.142	138	194,870<**195,250**<195,630
21	0.154	160	246,018<**246,653**<247,306
Outside	1.505	117	1,764,381<**1,765,000**<1,765,619

habitats' 9 and 11, and to a lesser extent in habitat 18. Micro-algae and coralline algae dominated habitat 21, while turf algae and sand dominated habitat 16. Habitats' 17 and the reef slope were the most diverse in benthic structure, and were the only two habitats that were documented as having coral as a dominant feature (Table 6).

DISCUSSION

The habitats of the proposed MMCA were shown to be variable in nature. A cluster analysis was conducted on the different habitats, using dominant fish families (Acanthuridae, Labridae, Scaridae/Initial, Siganidae, Chaetodontidae, Cirrhitidae and Pomacentridae) (Tables' 2 & 3), and dominant benthic structures as variables (Table 6). The clustering method employed was unweighted-pair group averaging method (UPGMA), and the Euclidean distance measure was used to measure dissimilarity. The resulting dendrogram is shown below.

The habitat types of the proposed MMCA divided into three distinct groupings. The grouping of habitats 9, 11, and 18 was a result of each habitat having moderate to high representation of sand as a habitat structure, and rabbitfish (siganids) as a dominant fish family, the latter of which is consistent with the habitat requirements of that family. Both habitats 9 and 11 had the highest values for percent sand and density of rabbitfish.

The grouping of habitats' 17, 16, and the reef slope was somewhat more complicated. Habitat 17 and the reef slope had the highest percent coral cover and percent cover of coralline

Table 5. Percent coral cover per strata in the proposed Managaha Marine Conservation Area.

	Strata						
	9	**11**	**16**	**17**	**18**	**21**	**Outside**
Mean	2.5	2.0	4.5	25.5	10.3	4.4	24.0
Variance	65.42	67.93	123.91	650.1	383	47.8	427.65
Range	0.0-43.8	0.0-50.0	0.0-68.6	0.0-100	0.0-93.8	0.0-31.3	0.0-100

Table 6. Percentage of dominant benthic structures per strata in the proposed Managaha Marine Conservation Area.

	Strata						
Structure	**9**	**11**	**16**	**17**	**18**	**21**	**Outside**
Sand	**75.0**	**79.7**	**26.0**	**11.0**	**49.4**	**6.2**	0.9
Microalgae	2.2	**6.7**	**15.2**	**9.9**	2.5	0.7	2.8
Rubble	3.1	**6.3**	3.0	2.3	**23.3**	**48.5**	1.3
Rock	0.5	0.0	0.0	0.7	0.0	**10.0**	0.6
Coralline algae	5.5	4.1	**6.8**	**24.4**	**10.5**	**20.6**	**28.6**
Turf algae	**10.0**	0.0	**42.8**	**18.8**	1.2	**7.6**	**38.0**
Encrusting Coral	1.5	1.2	3.5	**9.7**	5.2	1.7	3.8
Massive coral	0.3	0.0	0.1	**5.7**	0.4	1.4	**9.5**
Sub-massive coral	0.3	0.2	0.9	2.3	0.3	0.4	**5.9**

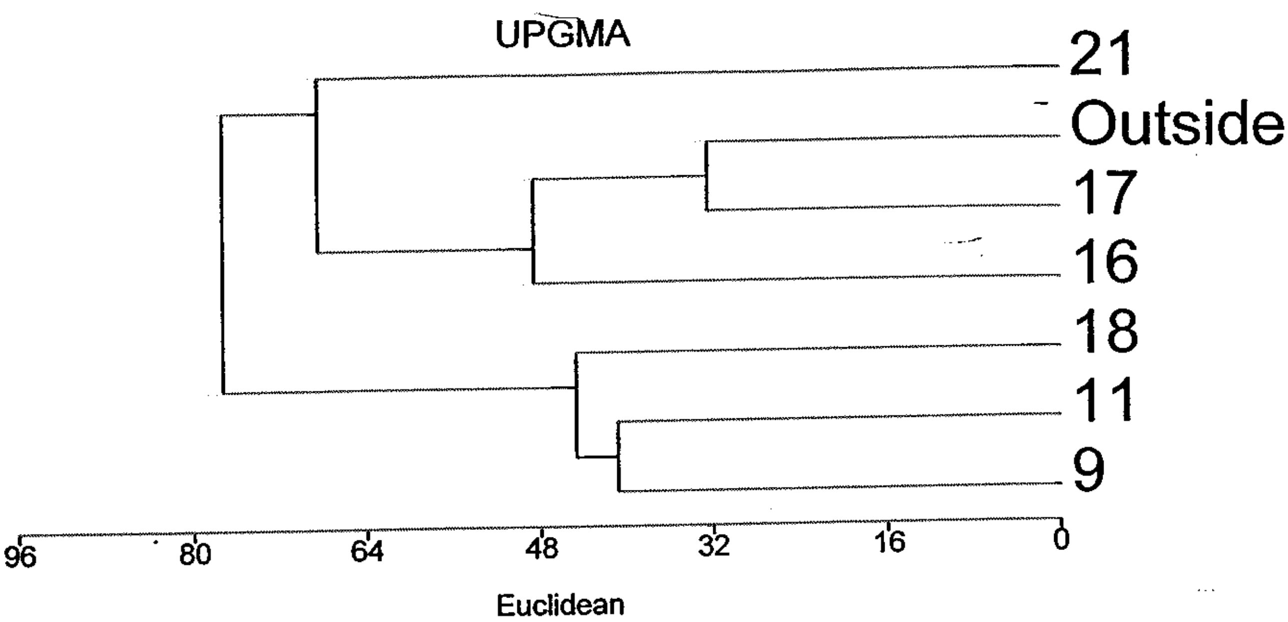


Figure 5. Cluster analysis dendrogram for fish families and habitat characteristics in the proposed MMCA.

algae, with moderate to high percent cover of turf algae. Habitat 16 had a moderate coverage of turf algae.

The last grouping of habitat 21 resulted from a high percent coverage of rubble, and the highest densities of both surgeonfish and unicorn fish (Acanthuridae) per strata.

Unfortunately, data pertaining to rugosity was not properly collected during this survey, and subsequently dropped from analysis. This may have provided further insight into the relationship between fish abundance and habitat structure.

While it was shown that the different habitat types found within the proposed MMCA support a variety of fish families/groups, it is also noted that surveys using line transects have a tendency to underestimate large, roving predators such as the snappers (Lutjanidae) and emperors (Lethrinidae) (Samoilys & Carlos 1992). In addition, benthic infaunal predators such as numerous skates and rays (Myers 1991), which cover relatively considerable distances in comparison to most reef associated species, are hardly ever documented. Predators such as these are highly dependent upon soft-sediment habitats such as sand, that harbor high densities of infaunal prey species such as mollusks.

CONCLUSION

These data will serve as a baseline of data from which future management measures can be formulated. It is recommend that in one to two years this survey be repeated using the same sampling design in order to determine any significant changes in abundance and habitat structure due to designation as a marine conservation area.

Stringent regulations have been implemented into the pending legislation for designation of the Managaha Marine Conservation Area, and these regulations should prove beneficial to both coral and fish resources. Any future surveys must be cognizant of any natural events, such as typhoons, that would influence benthic structure, as well as significant man-made disturbances such as lagoon channel dredging. Such occurrences should be documented between surveys, and stated in any subsequent reports. No typhoons had occurred for over a year and a half when this survey was undertaken.

Channel dredging had only recently halted, and this activity was believed to have had a negative impact on coral growth in Saipan lagoon, although no data were available prior to dredging, and consequently no hypothesis testing could be performed. As the main lagoon channel forms the southwestern boundary of the proposed MMCA, it is prudent to expect that sediment accretion rates resulting from the recent channel dredging activities would have increased within the boundaries of the proposed MMCA. Answering this type of question in the future will require monitoring of sediment rates prior to such an activity as channel dredging. The CNMI DEQ monitors sediment accretion rates in Saipan lagoon and should set up stations near and within the declared MMCA.

With estimates of mean fish abundance and associated variance per habitat type, an optimal allocation sampling design can be implemented in future surveys utilizing the same sampling protocol. An optimal allocation design will result in efficient use of survey time and resources. It is also advised that in addition conducting the same type of survey, habitat use by skates and rays be evaluated.

This project was extended nearly four months, which precluded a more extensive analysis of the data. With a larger number of DFW professional staff active in future surveys, and a more coherent inter-agency plan, it will be possible to collect these types of data in a more timely, and precise manner.

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