Fisheries Resource Assessment of the Mariana Archipelago, 1982-85

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Introduction

The Resource Assessment Investigation of the Mariana Archipelago (RAIOMA) was a 5-year program initiated by the Honolulu Laboratory of the National Marine Fisheries Service's Southwest Fisheries Center in 1980 to quantify the distribution and sustainable yield of insular fishery resources with commercial potential in the Mariana Archipelago (Fig. 1).

To identify fishery resources with commercial value or potential, data from the commercial landings collected by the Governments of Guam and the Commonwealth of the Northern Marianas together with data from earlier research cruises were used to rank species of fish by their economic potential and importance to the subsistence fishery. Four species groups were thus identified as important fishery resources in the Marianas: 1) Tunas, 2) deepwater snappers and groupers, 3) deepwater shrimp *Heterocarpus* spp., and 4) akule or bigeye scad, *Selar crumenophthalmus* (Polovina[1]).

The tuna resource has the greatest economic potential, but an assessment of the tunas in the Marianas would require an assessment of the tuna stocks in the western Pacific which was beyond the scope of the program. Thus, information on the tuna resource in the Marianas was obtained from historical catch and effort statistics provided by Japanese longliners and baitboats operating in

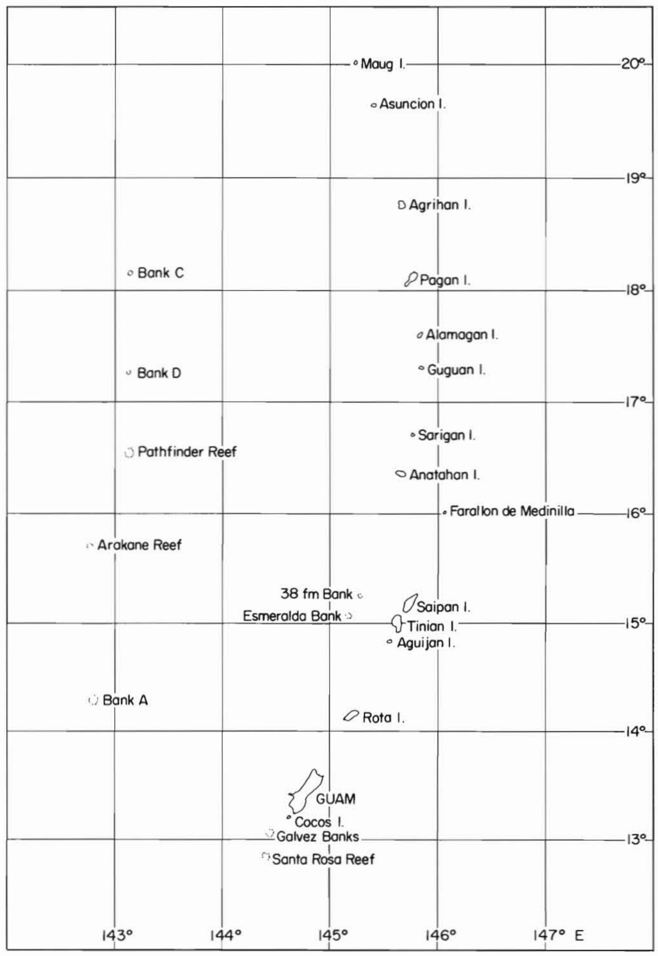

Figure 1.—The Mariana Archipelago with the 22 islands and banks sampled during the RAIOMA Program.

[1]Polovina, J. J. 1981. Planning document for the assessment of marine resources around Guam and the Commonwealth of the Northern Mariana Islands. Honolulu Lab., Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812. Admin. Rep. H-81-10, 13 p.

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Table 1.—Bottom fish catch per unit effort (CPUE) and standard error (SE), by island and bank for the six cruises.

Area	No. of drifts	Mean drift CPUE (numbers)	SE	Latitude N
Northern Islands and Banks				
Maug	7	5.03	1.02	20°02′
Asuncion	17	2.16	0.49	19°40′
Agrihan	45	4.20	0.31	18°46′
Pagan	100	4.57	0.40	18°06′
Alamagan	118	2.37	0.19	17°36′
Guguan	32	3.01	0.30	17°19′
Sarigan	28	2.82	0.37	16°43′
Anatahan	38	2.31	0.23	16°21′
38-Fathom	61	3.12	0.26	16°20′
Esmeralda	114	2.29	0.15	14°58′
Average drift CPUE		3.19		
Southern Islands and Banks				
Farallon de Medinilla	32	3.29	0.65	16°01′
Saipan	17	1.72	0.34	15°10′
Tinian	20	1.96	0.29	15°00′
Aguijan	13	3.84	0.98	14°52′
Rota	19	1.91	0.40	14°10′
Guam	20	1.53	0.35	13°25′
Galvez and Santa Rosa	41	2.95	0.31	13°00′
Average drift CPUE		2.46		
Seamounts				
Bank C	8	5.91	1.57	18°08′
Bank D	20	5.85	0.51	17°09′
Pathfinder	136	4.58	0.23	16°30′
Arakane	84	3.36	0.24	15°38′
Bank A	24	3.71	0.57	14°12′
Average drift CPUE		4.68		

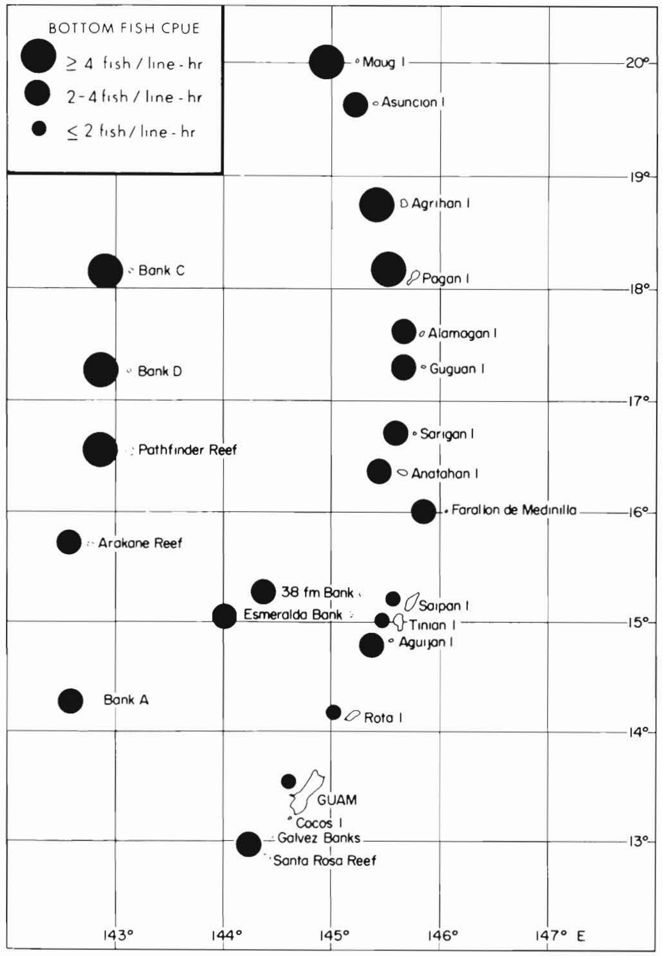

Figure 2.—The bottom fish CPUE grouped into three catch levels.

the fishery conservation zone (FCZ) around the Marianas (Polovina and Shippen[2]).

The insular resources were assessed by a field program which consisted of six cruises, each of 40 days, using the NOAA ship *Townsend Cromwell*, from May 1982 through June 1984. On these cruises a systematic survey was conducted to measure geographic and seasonal variation of deepwater bottom fishes and shrimps at 22 islands and banks (Fig. 1). Also, intensive fishing experiments were conducted to estimate catchability of the bottom fishes and shrimps. A collection of all specimens which appeared to represent new records was developed. Two aerial surveys were made in an attempt to estimate the abundance of akule in the Marianas. Finally bathymetric surveys were conducted and chartlets produced for 11 islands and banks where existing bathymetric data were insufficient for fishing and fishery assessment work (Polovina and Roush[3]). This report summarizes the main findings of the RAIOMA Program.

Deepwater Snappers and Groupers

At each island and bank, an attempt was made to conduct a systematic fishing survey of the bottom fish community in the 125-275 m depth range. A total of 7,621 bottom fishes of over 30 species were caught with handline gear during the six cruises. Gindai, *Pristipomoides zonatus*, accounted for 51.2 percent of the catch, and three species (gindai, yellowtail kalekale, *P. auricilla*; and ehu, *Etelis carbunculus*) accounted for 79.1 percent of the total catch (Polovina, In press).

Catch per unit effort (CPUE) was measured by the number of fish caught per line-hour. For each bank, bank CPUE was computed as the mean of all the drift CPUE values, where a drift CPUE is the number of fish caught during an uninterrupted drift of the vessel while it is fishing in the 125-275 m depth range divided by the drift line-hours. The mean drift CPUE is presented for all 22 banks and islands in Table 1 and Figure 2.

[2]Polovina, J. J., and N. T. Shippen. 1983. Estimates of the catch and effort by Japanese longliners and baitboats in the fishery conservation zone around the Mariana Archipelago. Honolulu Lab., Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812. Admin. Rep. H-83-1, 42 p.

[3]Polovina, J. J., and R. C. Roush. 1982. Chartlets of selected fishing banks and pinnacles in the Mariana Archipelago. Honolulu Lab., Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812. Admin. Rep. H-82-19, 15 p.

Taken by bank type, the seamounts have the greatest mean drift CPUE (4.68 fish/line-hour), followed by the northern islands (3.19 fish/line-hour), and then the southern islands (2.46 fish/line-hour). The main inhabited islands of the Marianas are Guam, Saipan, Rota, and Tinian—all in the southern group. Fishermen at these islands exploit the local stocks of bottom fishes which most likely account for the relatively low CPUE values for the islands. The mean of the bank CPUE for the uninhabited islands and banks in the southern group is 3.36 fish/line-hour which suggests that when islands with heavy fishing mortality are excluded, there is no difference in bottom fish standing stock between the northern and unfished southern islands. The seamounts, however, appear to support a higher standing stock than the northern or southern islands and banks.

Bottom fish species were stratified by depth. The results, summarized in Table 2, show that the centers of distribution for black ulua or black jack, *Caranx lugubris*; lehi, *Apharens rutilans*; and the yelloweye opakapaka, *P. flavipinnis*; and pink opakapaka, *P. filamentosus*, were between 164 and 183 m (90 and 100 fathoms). Similarly, yellowtail kalekale, kahala or greater amberjack, *Seriola dumerili*; and gindai were most abundant between 183 and 201 m (100 and 110 fathoms). Species with deeper depth distributions, i.e., mean depth of capture >201 m (110 fathoms), were the pink kalekale, *P. sieboldii*; black grouper, *Epinephelus* sp.; ehu, and onaga, *Etelis coruscans*. Studying each fishing bank individually showed that, overall, depth distributions were similar over the archipelago.

The approach to yield estimation for the deepwater bottom fishes is described in detail by Polovina and Ralston (In press). Using an estimate of catchability obtained from an intensive fishing experiment and a measure of bottom fish habitat together with the estimated relative abundance from the systematic survey, the total bottom fish biomass which can be exploited with handline gear was computed. The Beverton and Holt (1956) yield equation, together with estimates of growth and mortality parameters obtained from otolith and size-frequency data, was used to first determine the age of entry for each of the major species which will maximize the yield per recruit. Then with the estimate of unexploited biomass the equilibrium yield was estimated as a function of fishing mortality. Also the change in the spawning stock biomass relative to its level in the absence of exploitation can be computed with the Beverton and Holt yield equation as a function of fishing mortality.

The equilibrium yield for the multispecies bottom fish complex fished with handline gear in the 125-275 m depth range for the 22 islands and banks of the Mariana Archipelago increases rapidly as a function of fishing mortality to a level of about 100 metric tons (t) and beyond that exhibits a gradual increase with increasing fishing mortality (Table 3). In view of the flat-topped, yield curve which assumes constant recruitment and does not incorporate any economic considerations, an approach to determining the optimum equilibrium yield has been suggested (and adopted for several North Atlantic fisheries) as the yield corresponding to that level of effort where an increase of one unit of effort will increase the catch by 0.1 of the amount caught by the very first unit of effort (Gulland, 1983; 1984).

The value of $F_{0.1}$ for the bottom fish resource in the Marianas is estimated to be $F = 1.0$, and the corresponding annual equilibrium yield is 109 t (Table 3). An approximate 95 percent confidence interval (CI) for this yield is 81-137 t (Polovina and Ralston, In press). About 70 percent of this yield would come from the southern islands and banks, 27 percent would come from the northern chain, and only 3 percent from the seamounts (Table 4; Fig. 3). At a fishing mortality of 1.0, the spawning stock biomasses for the seven major species are reduced 20-42 percent of their unexploited levels. Although the spawner recruit curve for these species is unknown, as a generic lower bound, the spawning stock biomass should not be

Table 2.—Mean depth of capture for the principal bottomfish species captured during the RAIOMA cruises (N = sample size).

Scientific name	Mean depth: Meters	Mean depth: Fathoms	N
Caranx lugubris	166	91	270
Pristipomoides flavipinnis	170	93	499
P. filamentosus	170	93	191
Aphareus rutilans	174	95	81
P. auricilla	188	102	1,166
Seriola dumerili	196	107	47
P. zonatus	199	109	3,890
Epinephelus sp.	214	117	38
P. sieboldii	214	117	57
Etelis coruscans	218	119	200
E. carbunculus	225	123	950

Table 3.—Annual equilibrium bottom fish yield in metric tons (t) for the age at entry which maximizes the yield per recruit for each species.

Fishing mortality (F)	Total yield (t)
0.1	35
0.5	91
[1]1.0	109
1.5	114
2.0	116
2.5	116

[1]$F_{0.1}$ and $Y_{0.1}$ as defined by Gulland (1983).

Table 4.—Annual equilibrium bottom fish yield and yield per nautical mile of 200 m contour for the age at entry which maximizes the yield per recruit at a level of fishing mortality of F = 1.0.

Area	Total yield (t/year)		Yield[1]/n.mi. of 200 m contour
Northern Islands and Banks			
Maug	2.7		262.2
Asuncion	2.1		188.4
Agrihan	5.6		303.6
Pagan	7.7		255.1
Alamagan	2.0		177.6
Guguan	1.7		179.0
Sarigan	1.6		193.8
Anatahan	2.5		144.2
38-Fathom	0.5		187.3
Esmeralda	2.9		237.4
Subtotal	29.3	Mean	212.9
Southern Islands and Banks			
Farallon de Medinilla	16.7		216.6
Saipan	13.4		254.1
Tinian	8.8		303.9
Aguijan	4.2		266.7
Rota	6.1		192.2
Guam	17.2		201.6
Galvez and Santa Rosa	8.6		164.2
Subtotal	76.0	Mean	228.5
Seamounts			
Bank C	0.9		288.2
Bank D	1.1		351.2
Pathfinder	0.9		303.5
Arakane	0.6		199.6
Bank A	0.6		179.7
Subtotal	4.1	Mean	264.4

Total yield from all banks = 109 t per year.

[1]Yield in kg/year

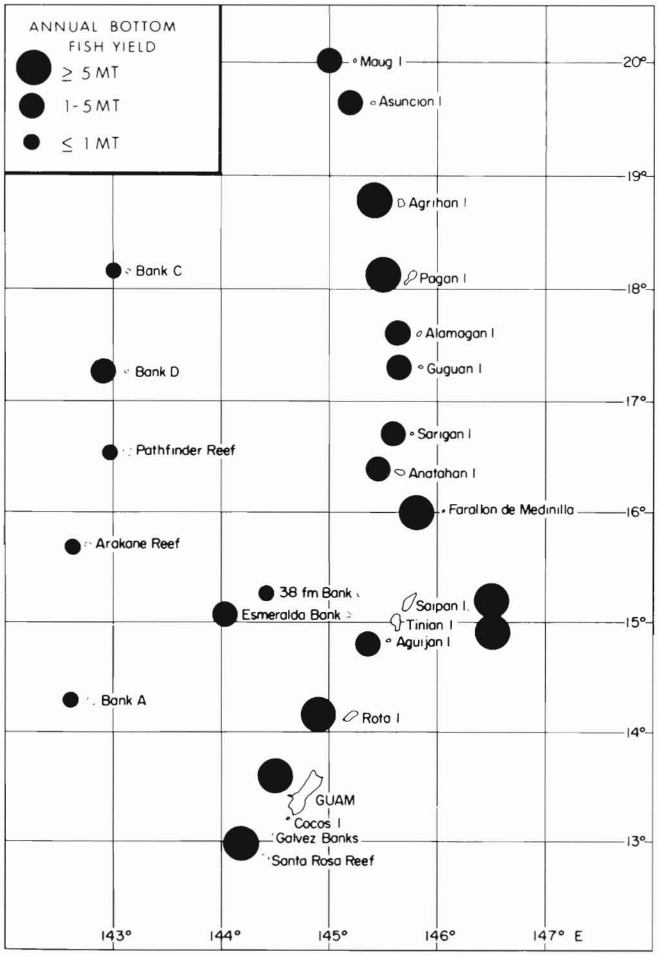

Figure 3.—Annual bottom fish yield grouped into three yield levels.

Table 5.—The percentage of annual sustainable yield by species group for fishing mortality of 1.0/year at age of entry which maximizes yield per recruit.

Species	Annual sustainable yield (percent)
Caranx lugubris	8.3
Pristipomoides filamentosus	8.2
P. auricilla	7.3
P. flavipinnis	28.7
P. zonatus	23.1
Etelis coruscans	5.0
E. carbunculus	5.9
Others	13.5

Table 6.—Estimates of Guam fish landings, 1980-84[1].

	Landings (t)	
Year	Pelagic species	Deep bottom fish
1980	198	6
1981	223	12
1982	240	9
1983	189	11
1984[2]	265	20

[1]Based on data from the Honolulu Laboratory's Western Pacific Fishery Information Network file on the Guam Division of Aquatic and Wildlife Resources offshore creel survey. Confidence interval ±30 percent of catch for pelagics and ±50 percent of catch for bottom fish.
[2]Estimate expanded from data from period June-September 1984.

reduced below 20 percent of its unexploited level if a serious reduction of recruitment is to be avoided (Beddington and Cooke, 1983).

The means of the annual equilibrium yield per nautical mile of 200 m contour for the northern banks, southern banks, and western seamounts are 212.9, 228.5, and 264.4 kg/n.mi., respectively. The ratio of total yield for the archipelago to the total length of the 200 m contour is 222.4 kg/n.mi. (95 percent CI of 165.3-279.6 kg/n.mi.) (Table 4). These values suggest that the stocks in the Marianas are slightly less productive than those in Hawaii where a lower-bound estimate of maximum sustainable yield of 272 kg/n.mi. of 200-m contour was obtained from a stock production model applied to commercial catch and effort data (not including the recreational fishing component) of snappers and groupers from Penguin Bank (Ralston and Polovina, 1982).

If the entire archipelago is fished, *P. flavipinnis* and *P. zonatus* together will comprise about 50 percent of the catch (Table 5).

Over the period 1980-84 it is estimated that annual bottom fish landings have increased from 6 t in 1980 to 20 t in 1984 (Table 6). Although the location data were not always obtained for these data, it appears that 65-95 percent of this catch comes from around Guam and the remainder comes from Galvez Banks and Santa Rosa Reef south of Guam or areas in the Commonwealth of the Northern Marianas. Given the estimated equilibrium yield of 17.2 t for Guam and that the CPUE around Guam is about half of the archipelago average, it appears that Guam is already fished at its maximum sustainable yield and most probably overfished on the leeward coast. There may be an opportunity to increase the yield with more fishing effort directed toward Galvez Banks and Santa Rosa Reef, but most of the additional yield potential lies in the islands and banks to the north of Guam (Table 4).

The commercial landings at Saipan have ranged from 4 to 10 t, compared with the estimate of equilibrium yield of 29 t from Saipan, Tinian, Aguijan, and Esmeralda Bank (Tables 4 and 7). These sites are all within 30 miles of Saipan suggesting that there is an opportunity to increase bottom fish landings from Saipan, Tinian, Aguijan, and Esmeralda Bank with a bottom fishing fleet operating out of Saipan and Tinian.

Based on the catchability estimated from the intensive fishing experiment,

Table 7.—Estimates of the Commonwealth of the Northern Mariana Islands commercial landings, 1981-83[1].

	Landings (t)	
Year	Pelagic species	Deep bottom fishes
1981	40.8	5.3
1982	47.2	3.7
1983	89.2	6.4
1984	123.8	9.9

[1]Data from the Honolulu Laboratory's Western Pacific Fishery Information Network.

Table 8.—Depth stratification for *Heterocarpus* spp.

Depth			Depth		
Meters	Fathoms	CPUE[1]	Meters	Fathoms	CPUE[1]
Heterocarpus ensifer			*H. laevigatus* (continued)		
320	175	0			
366	200	0.18	686	375	1.93
412	225	0.15	732	400	1.64
458	250	0.10	778	425	2.33
503	275	0.09	824	450	1.10
549	300	0.02	869	475	0.87
595	325	0.02	915	500	0.36
640	350	0.03	961	525	0.05
686	375	0	1,006	550	0.02
732	400	0	1,052	575	0.02
H. laevigatus			*H. longirostris*		
366	200	0	824	450	0
412	225	0.08	869	475	0.11
458	250	0.01	915	500	0.29
503	275	0.62	961	525	0.38
548	300	2.10	1,006	550	0.46
595	325	1.95	1,052	575	0.75
640	350	1.75	1,098	600	0.63

[1]CPUE in kg/trap.

the fishing mortality of 1.0 per year is equivalent to an annual fishing effort of 74,153 line-hours. Thus, for example, 15 small vessels each with two electric or hydraulic gurdies which fish 12 hours a day for 200 days a year can achieve this level of fishing effort and would have a fleet catch rate of 1.5 kg/line-hour with an annual average catch of 7.3 t per vessel.

Deepwater Shrimp

Deepwater shrimp, *Heterocarpus* spp., was sampled at depths from 360 to 900 m (about 200-500 fathoms). The sampling gear consisted of Quonset[4] shaped traps about 90 by 66 cm at the base and a height of 46 cm. The frame is made of rebar and is covered with a wire mesh which is then covered on the top and two sides with a canvas cover. The entrances to the trap are two cones on opposite sides of the trap. Five traps were used on a string with a separation of about 40 m between traps. The traps were baited with mackerel.

The shrimp catches were primarily *H. ensifer*, *H. laevigatus*, and *H. longirostrus* which are stratified by depth (Table 8). The catch rates of *H. laevigatus* were the highest of the three species and were greatest in the depth range 500-825 m.

The systematic survey of the relative abundance of *Heterocarpus* spp. in the 500-825 m depth range found little seasonal variation but considerable variation in CPUE between banks. As with the bottom fishes, the seamounts had the highest catch rates (2.37 kg/trap-night), followed by the northern islands and banks (2.01 kg/trap-night), and then the southern islands and banks (1.39 kg/trap-night) (Table 9; Fig. 4).

A growth equation for *H. laevigatus* was estimated from a time-series of length-frequency data and estimates that the shrimp become susceptible to trap fishing at age 2 and that the females become sexually mature at age 4.5 (Moffitt and Polovina[5]). Yield-per-recruit analysis indicates that an age-of entry of 2 maximizes the yield per recruit. The Beverton and Holt yield equation estimates equilibrium yield as a function of fishing mortality and the ratio of spawning stock biomass under exploitation to the unexploited spawning stock biomass (Table 10). At a fishing mortality of $F = 0.5$, the spawning stock is reduced to 20 percent of its original level in the absence of exploitation which has been suggested as a generic lower bound before a substantial decrease in recruitment may occur (Beddington and Cooke, 1983). At $F = 0.5$ the equilibrium yield from the entire archipelago in the 500-825 m depth range is estimated at 162 t, with a 95 percent CI of 102-218 t, which would almost exclusively consist of *H. laevigatus*. About 85 percent of this yield would come from the southern islands and banks, 13 percent from the northern islands and banks, and about 2 percent from the seamounts (Table 11; Fig. 5).

Although there have been several short-lived attempts to harvest deepwater shrimp around Guam, there is currently no shrimp fishing around Guam or anywhere else in the Marianas. Given that the catch rates around Guam are <50 percent of the catch rates at most other banks, any shrimp fishing should target areas other than Guam. In the southern islands the best shrimp fishing areas are Saipan, Tinian, and Aguijan (Table 9). Although Galvez Banks and Santa Rosa Reef south of

Table 9.—Catch rates and habitat for *Heterocarpus* spp. in the 500-825 m depth range.

Area	CPUE (kg/trap)	Area (n.mi.^{2}) (500-825 m)
Northern Islands and Banks		
Maug	1.88	3.83
Asuncion	2.11	5.93
Aguijan	1.96	12.39
Pagan	2.17	16.19
Alamagan	2.18	11.43
Guguan	2.52	5.60
Sarigan	1.45	4.55
Anatahan	2.36	10.89
38-Fathom	2.12	6.37
Esmeralda	1.35	2.03
Mean = 2.01		
Southern Islands and Banks		
Farallon de Medinilla	0.97	88.55
Saipan	2.06	213.99
Tinian	1.81	73.80
Aguijan	1.61	39.36
Rota	1.02	197.31
Guam	0.72	44.24
Galvez and Santa Rosa	1.78	50.77
Mean = 1.39		
Seamounts		
Bank C	2.07	2.71
Bank D	2.72	2.71
Pathfinder	2.79	2.71
Arakane	1.91	2.10
Bank A	1.43	3.33
Mean = 2.37		

Table 10.—Equilibrium yield (t) for *Heterocarpus laevigatus* in the 500-825 m depth range and relative spawning stock biomass as a function of fishing mortality (*F*).

F	Total yield (t) in 500-825 m depth	Spawning stock biomass under *F*/unexploited spawning biomass
0.1	56.3	0.70
0.2	95.6	0.51
0.3	124.2	0.37
0.4	145.1	0.27
0.5	161.5	0.20
0.6	174.1	0.15
0.7	181.1	0.11

[4]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[5]Moffitt, R. B., and J. J. Polovina. The distribution and yield assessment of the deepwater shrimp resource in the Marianas. Manuscr. in prep.

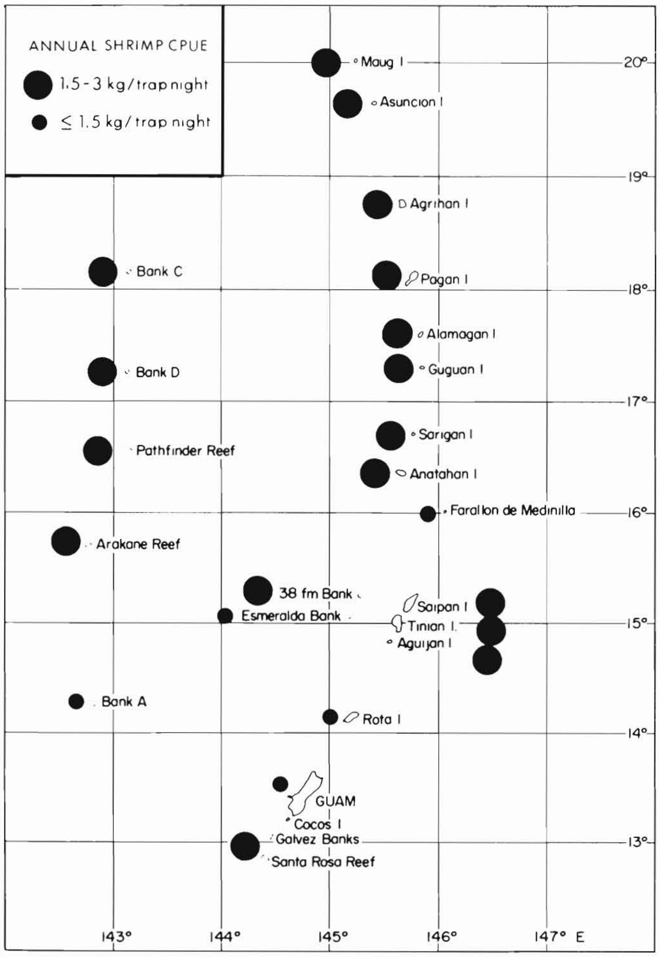

Figure 4.—Deepwater shrimp CPUE grouped into two catch levels.

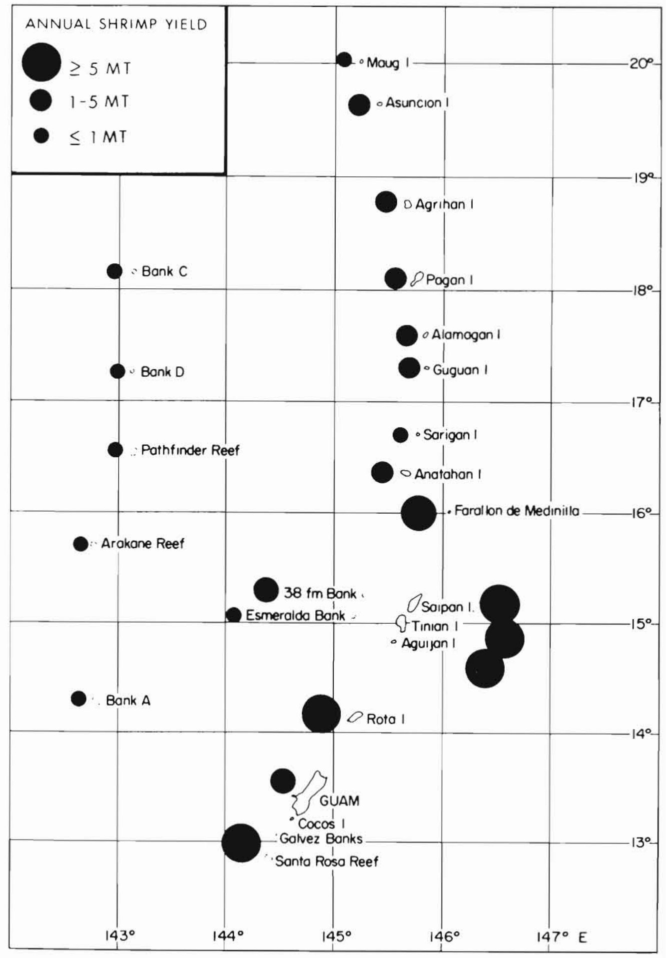

Figure 5.—Annual deepwater shrimp yield grouped into three yield levels.

Guam have good catch rates, the strong currents encountered there during the assessment work resulted in considerable trap loss.

The estimated catchability from the intensive trapping and the F of 0.5 correspond to an effort of 280 trap-nights/n.mi.^{2}. Given a total habitat of 800 n.mi.^{2} from 500 to 825 m, an annual effort of 224,000 trap-nights would produce the fishing mortality of 0.5 for the entire archipelago. Thus, for example, 28 small vessels which each set 40 traps/night for 200 nights/year would produce this effort and have an average fleet catch rate of 0.7 kg/trap-night and an average annual landing of 5.8 t/vessel.

Other Resources

There is a substantial resource of tunas and other pelagic species around the Marianas. The Japanese longline catch and effort data for the period 1965-79 and Japanese baitboat data for the period 1970-79 within 50 n.mi. and within the FCZ around Guam and the Commonwealth of the Northern Marianas have been analyzed by Polovina and Shippen[2]. The total annual tuna catches from Japanese longliners within the FCZ around Guam ranged from 9

Table 11.—Equilibrium yield for *Heterocarpus* spp. in the 500-825 m depth range.

Area	Yield[1]	Area	Yield[1]
Northern Islands		Saipan	54.1
and Banks		Tinian	16.3
Maug	0.9	Aguijan	7.8
Asuncion	1.5	Rota	24.7
Aguijan	3.0	Guam	3.9
Pagan	4.3	Galvez and	
Alamagan	3.0	Santa Rosa	20.2
Guguan	1.7	Subtotal	137.6
Sarigan	0.8		
Anatahan	3.1	Seamounts	
38-Fathom	1.7	Bank C	0.7
Esmeralda	0.3	Bank D	0.9
Subtotal	20.3	Pathfinder	0.9
		Arakane	0.5
Southern Islands		Bank A	0.6
and Banks		Subtotal	3.6
Farallon de			
Medinilla	10.6	Archipelago total =	161.5

[1]Metric tons/year based on a fishery mortality of 0.50.

to 1,334 t, and the annual catches within the FCZ around the Commonwealth of the Northern Mariana Islands ranged from 71 to 576 t. Billfish catches typically were about 10-30 percent of the total tuna catch. The total annual tuna catches from Japanese baitboats within the FCZ around Guam ranged from 83 to 2,059 t, and the catches within the FCZ around the Commonwealth of the Mariana Islands ranged from 2,554 to 12,564 t.

Annual catches of pelagic species typically from nearshore trolling, which include tunas, mahimahi, wahoo, and billfishes, are estimated at about 200 t for Guam and varied from 40 to 124 t for Saipan (Tables 6 and 7).

Although the Japanese catches indicate that the magnitude of the pelagic resource is large it is also widely dispersed. Fish aggregating devices are widely used throughout the Pacific and appear to be useful as a means of aggregating pelagic species and hence increasing catches, but the frequency of typhoons in the Marianas is an impediment to their application. The expansion of the charter fishing industry may have potential as a means of further exploiting the tuna and billfish resources, given the strong tourist industry in both Guam and Saipan.

Akule, often called atulai or bigeye scad, is a popular resource which is usually netted or hooked in nearshore areas. Reported annual landings in Guam and the Commonwealth of the Mariana Islands are only about 5 and 1 t, respectively, but much of the resource does not go through the usual market channels and is not reported. The RAIOMA Program found akule present at most of the islands and banks but, given the seasonal nature of the resource and effect of moon phase on the catch rates, a systematic survey was not possible. Two aerial surveys were not effective in estimating the nearshore akule biomass. The estimated catch rate of akule in the Hawaiian Islands from 1948 to 1982 varies from 0.4 to 0.9 t/n.mi. of 200 m contour. If it is assumed that abundance of akule in the Marianas is equivalent to that in Hawaii, then the Marianas, where the length of the 200 m contour is 490 n.mi., would offer a range of harvest from 200 to 440 t per year. However, most of the catches in Hawaii are by small purse seiners using aerial spotters, and these catches extrapolated to the Marianas may represent upper bounds for the more traditional gear.

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