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THE FISH RESOURCES OF THE WESTERN CENTRAL PACIFIC ISLANDS

by

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1. TOPOGRAPHY

As defined here, the western central Pacific islands include American Samoa, Cook Islands, Fiji Islands, French Polynesia composed of the Austral, Gambier, Marquesas, Rapa, Society, and Tuamotu Islands, Gilbert Islands, Guam, Hawaiian Islands, Line Islands, Nauru, New Caledonia, New Hebrides, Niue, Papua New Guinea, Solomon Islands, Tokelau Islands, Tonga Islands, Trust Territory of the Pacific Islands, Tuvalu, Wallis and Futuna Islands, and Western Samoa.

Around these islands, there is little or no shelf area, which along the continents supports large-scale trawl fisheries for various demersal species. Usually, the bottom contour near the coast is highly irregular and drops off precipitously to deep water several kilometers beyond the outer reef.

Data on bottom topography are rather sparse for the islands of the western central Pacific. For Fiji Islands, the shelf area to 200 m is estimated to be 15,000 km^2 (FAO 1972), whereas off Western Samoa, the shelf area is 4,500 km^2 (FAO 1975b). Off the Solomons, which has a coastline totaling 4,023 km, the shelf area is about 100,000 km^2 (Moiseev 1969). The shelf area to a depth of 914 m around the major Hawaiian group (Hawaii to Kauai) is estimated to be about 44,076 km^2 (Yoshida 1972).

2. HYDROGRAPHY

2.1 Surface currents

Two regions of trade wind induced currents, one in each hemisphere, exist in the Pacific Ocean. These currents have a persistent westward drift during the entire year. The tangential stress of the persistent trade winds, which embrace the major part of the world's ocean, is responsible for the trade wind regions being the center of action for surface circulation (Dietrich 1963).

In the western central Pacific, the dominating influence is the North and South Equatorial Current. The major oceanic circulation in the Pacific is shown in Figure 1.

Because the thermal Equator remains in the Northern Hemisphere throughout the year, the North and South Equatorial Currents are not symmetrical about the geographical Equator (Defant 1961). The southern boundary of the North Equatorial Current is between lat. 6° and 7°N in winter and between lat. 9° and 11°N in summer. The current, which is much stronger in winter, increases its velocity steadily toward the western Pacific. Wyrtki (1967) estimated that the North Equatorial Current has surface velocities of about 25 cm/sec near the northernmost part, up to 32 cm/sec near lat. 15°N, and in excess of 42 cm/sec near the southern boundary. The net transport in the North Equatorial Current is about 22 million m^3/sec. Off the Philippines, the North Equatorial Current divides into two branches; one flowing northward to become the Kuroshio and the other turning southward into the Equatorial Countercurrent (Defant 1961).

The South Equatorial Current, which extends the width of the southeast trade wind belt between lat. 5°N and 40°S, has its highest velocity and constancy along the northern boundary between lat. 5°N and 5°S (Defant 1961). West of Papua New Guinea and the Solomons, the South Equatorial Current is strongly developed during the northern summer and extends as far as Halmahera. It flows along the north coast of Papua New Guinea, into the Southeast Asian region south of Mindanao and Halmahera, then recurves northward and eastward to become the principal water mass of the countercurrent. Off east Australia, the South Equatorial Current bends southward to become the East Australian Current. The South Equatorial Current is broken near lat. 10°S by the eastward flowing South Equatorial Countercurrent (Reid 1959).

The flow representing the northern part of the South Equatorial Current has geostrophic speeds exceeding 110 cm/sec. The net transport between lat. 6°N and the Equator

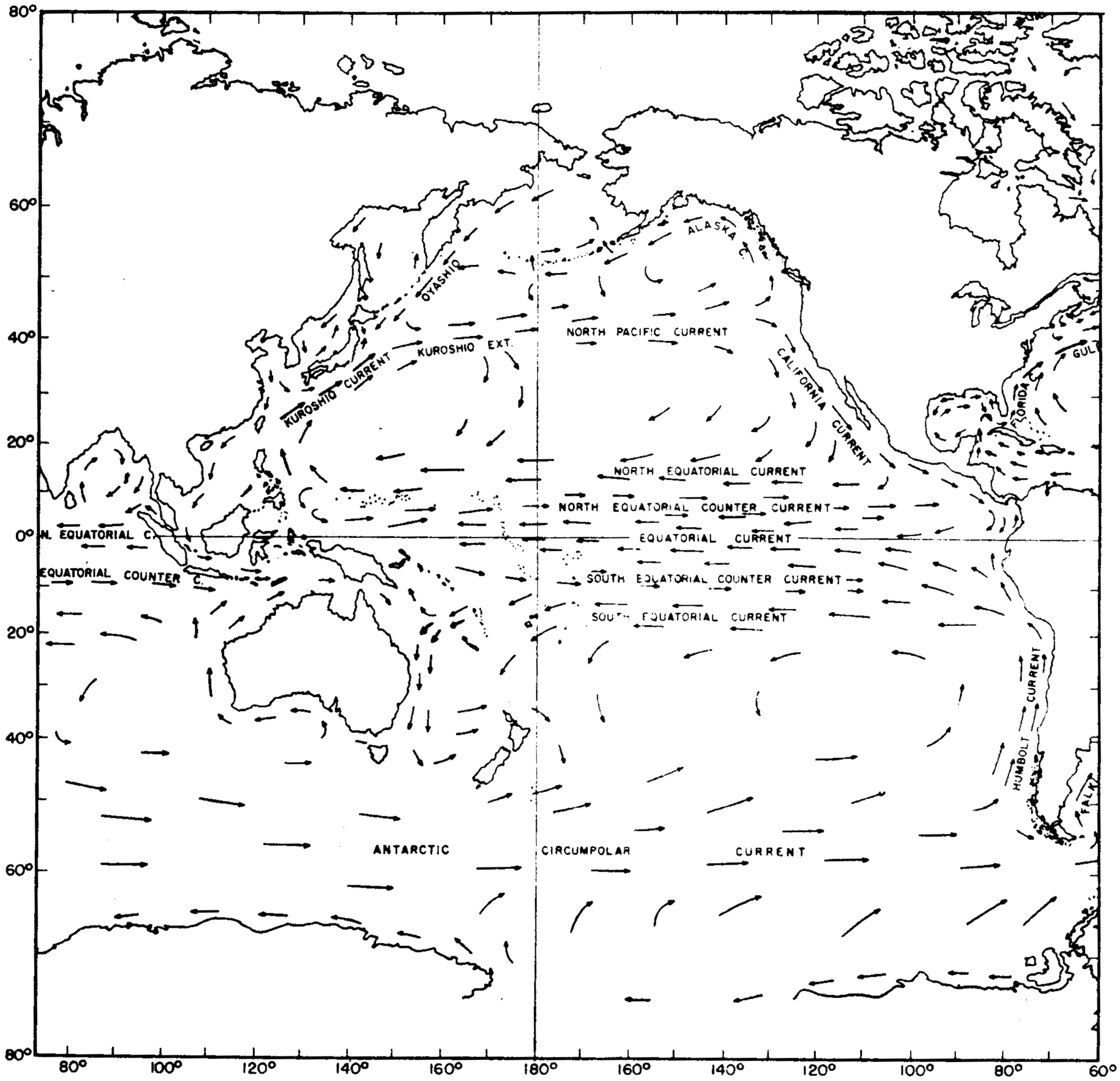

Figure 1.--Major features of the surface circulation of the Pacific Ocean (McLellan 1965).

is 32 million m^3/sec to the west, indicating that the South Equatorial Current is well developed (Montgomery and Stroup 1962).

Between the North and South Equatorial Currents, the countercurrent exists all year long (Defant 1961). During the northern winter, the countercurrent is weak and narrow except near its origin in the west; however, during the northern summer, particularly in August-September, the countercurrent flows persistently from Mindanao-Palau-Halmahera to Panama, a distance of nearly 15,000 km. The countercurrent, which extends about 550 km in width between lat. 5° and 10°N, is separated from the two Equatorial Currents on both sides by well-defined boundaries, particularly on the northern side.

In the countercurrent, the velocity distribution shows a subsurface velocity maximum, which coincides approximately with the lower boundary of the thermocline and has speeds in excess of 60 cm/sec to the east. Below 200 m, the flow is westward, thus showing that the countercurrent is limited to a shallow surface layer. The net transport is estimated to be 26 million m^3/sec in the 0-500 m depth range.

2.2 Surface temperature

Monthly mean, minimum, and maximum sea-surface temperatures may be found in LaViolette (1970). Table 1, which shows the mean annual sea-surface temperatures for the Pacific for 10° zones of latitude, indicates that the thermal Equator is displaced northward; the temperature maximum lies at about lat. 7°N. Particularly noticeable is the large contrast between the North and South Pacific in sea-surface temperature; in the Northern Hemisphere, the temperature usually is about 1°-2°C warmer in all latitudes.

Table 1.--Mean annual sea-surface temperature for 10° latitudinal zones (°C) (Defant 1961).

Latitude	North Pacific Ocean	South Pacific Ocean
0°-10°	27.2	26.0
10°-20°	26.4	25.1
20°-30°	23.4	21.5
30°-40°	18.6	17.0
40°-50°	10.0	11.2
50°-60°	5.7	5.0
60°-70°	--	-1.3
70°-80°	--	-1.7

In November-April in the North Pacific, north of the Hawaiian chain, a latitudinally parallel isothermal structure exists which has a temperature gradient of about 0.6° to 0.8°C per degree of latitude (Seckel 1962). A change in this temperature structure first becomes apparent in May followed by a breakdown of the parallel isothermal structure in June. An irregular temperature regime persists in the northern section of the Hawaiian chain in July-September, but in October, the isotherms again become parallel.

Minimum and maximum temperatures generally occur in March and September, respectively (Seckel 1962). Although the minimum sometimes occurs in February and the maximum in August or October, they show no significant differences from those in March and September.

West of the Hawaiian Islands, in the region of Micronesia, surface temperatures show small variations throughout the year (LaViolette and Seim 1969). In the Marshalls, surface temperatures vary between 23° and 33°C; the lows usually occur in March-April and the highs in September-October. Around the Western Carolines and Marianas, the minimum temperature is about 24°C and the maximum slightly above 29°C. Temperatures are usually lowest in February and highest in August-September. One of the notable features of the surface temperatures around the Marshalls is that it usually decreases slowly with increasing latitude (Mao and Yoshida 1955). In summer, low-surface temperatures occur at or near the Equator indicating intense upwelling associated with equatorial divergence. In the winter, however, the feature is not evident.

2.3 Thermocline

The main or permanent thermocline is always present in the Hawaiian region (Seckel 1962). Below the mixed layer, the average temperature gradient is about 15°, 6°, and 5°C per 100 m at lat. 10°, 20°, and 30°N, respectively. Superimposed on the permanent thermocline may be a seasonal thermocline and, in addition, there may also be a diurnal thermocline, which is defined as a small rise in surface temperature of the order of 1°C extending to a depth of about 10 m.

In the central Pacific, the mixed surface layer is uniformly warm; a few patches of water above 26°C appear in the countercurrent and South Equatorial Current (Wyrtki 1967). The thermocline in the North Equatorial Current between lat. 19° and 9°N varies from 100 to 200 m but deepens to the south. Between lat. 9° and 5°N, where the countercurrent flows, the thermocline is very steep and isotherms between 12° and 24°C are closely spaced. The Equatorial Undercurrent is very pronounced and is characterized by a spreading of the isotherms within the thermocline.

At long. 137°E, the depth of the main thermocline slopes sharply downward from the northern edge of the Kuroshio to the southern edge, where the mixed layer is nearly isothermal and thickest over the section. Southward from lat. 30° to 15°N, the thermocline shallows gradually. The thermocline is shallowest and the vertical temperature gradient largest at the boundary between the North Equatorial Current and the countercurrent (Masuzawa 1967).

2.4 Surface salinity

Equivalent to temperature in importance as a climatic indicator in oceanography is salinity. In the vicinity of the Hawaiian Islands, the maximum surface salinity occurs in November-February and the minimum in July (Seckel 1962). The 35°/₀₀ salinity isopleth moves northward in April, reaches an extreme position in July, then moves southward and eventually positions itself at lat. 17°-19°N, the extreme winter location, in November-February. The maximum surface salinity of 35.35°/₀₀ is reached at lat. 28°N. The high salinity gradient found within and slightly north of the Hawaiian chain indicates the presence of a transition zone or boundary between different types of water.

To the north and south of the Hawaiian Islands, low and high salinities occur about the same time as low and high temperatures (Seckel 1962). In the vicinity of the Hawaiian Islands, however, low and high salinities occur about 3 mo after the time that the mixed layer reaches its minimum and maximum depths, respectively. Near Midway, where the salinity maximum is located, a sharp decline of about 0.35°/₀₀ is evident, resulting from either a southward or a northward displacement of the high salinity cell.

From the Hawaiian Islands southward, surface salinity decreases and the lowest values (less than 34.1°/₀₀) are observed in the North Equatorial Current between lat. 14° and 9°N (Charnell, Au, and Seckel 1967a, 1967b, 1967c, 1967d, 1967e, 1967f; Wyrtki 1967). Between the North Equatorial Current and the countercurrent at about lat. 9°N, a salinity front marks the boundary between low-salinity tropical surface water and high-salinity equatorial water. In the southern portion of the countercurrent and the northern part of the South Equatorial Current, in which the equatorial surface water lies, salinities are about 34.8°/₀₀. Just north of the Equator at lat. 0°31'N, another front in surface salinity is apparent. Here, equatorial surface water of about 34.8°/₀₀ is separated from subtropical surface water of the South Pacific. Both salinity fronts, however, do not coincide with current boundaries.

From north to south, across the countercurrent and into the South Equatorial Current, the salinity ranges between 34.0°/₀₀ at lat. 10°N and 35.2°/₀₀ near the Equator (Austin 1960). Somewhat farther south and east of the Line Islands is the southeastern Pacific surface salinity maximum of 36.0°/₀₀ or greater.

In the western equatorial Pacific, a notable feature of the horizontal distribution of salinity is the separation of the northern and southern high-salinity regions by one of low salinity, usually located between the Equator and lat. 10°N. The low-salinity water which intervenes between the northern and southern tropical waters is also tropical water which may have been transported westward from the eastern Pacific. The east Indian Ocean is another source of low-salinity tropical water which apparently flows through the Molucca Passage (Cannon 1966).

In the Western Carolines along long. 137°E, the North Pacific tropical water with salinity exceeding 35°/₀₀ lies in the upper part of the thermocline between lat. 10° and 20°N and is in contact with the sea surface near lat. 19°N. Saline water originating in the South Pacific is also detected in the Western Carolines and extends as far north as lat. 6°N near the northern boundary of the countercurrent. The North Pacific major salinity minimum can be traced from the coast of Japan as far south as lat. 15°N (Masuzawa 1967).

The most outstanding feature of the horizontal distribution of salinity in the Marshalls is the presence of a low-salinity band in the region between lat. 5° and 10°N where large eddies exist (Mao and Yoshida 1955). Waters of high salinity push toward this band of low salinity from both sides. The gradient on the southern side suggests that the strongest influx of high-salinity water comes from the Southern Hemisphere.

The band of low-salinity water results from high precipitation, absence of saline tropical water from the north and south at these latitudes, ascent of the northern intermediate water mass with decreasing latitude, and upwelling associated with currents and eddies. Upwelling, which originates at some intermediate depth, brings cool, low-salinity water into the upper level. The ascending northern and southern intermediate water masses may further strengthen this upwelling.

2.5 Upwelling

In the central Pacific, there is a zone of horizontal divergence and an adjacent zone of convergence near the Equator. The boundary between north-south convergence and divergence, shifts latitudinally depending on wind direction. The divergence feature of Cromwell's (1951, 1953; Sette 1955) model explained the equatorial upwelling whereas convergence produced significant sinking.

Briefly, the model proposed that under the stress of easterly winds, surface water moves in a westerly direction at the Equator, but Coriolis force north and south of the Equator tends to deflect the surface water poleward. As the water moves away from the Equator, deeper water rises toward the surface. When there are northerly or southerly components in the easterlies, asymmetry is introduced and the center of upwelling is displaced. For example, southeast trades would displace the center of upwelling to the south of the Equator.

North of the Equator, convergence occurs as the denser upwelled water sinks between the center of upwelling at the Equator and the southern edge of the low-density water of the countercurrent which flows from west to east. At deeper levels, sinking water may turn southward thus completing a cell, or it may move northward and dive under the countercurrent.

2.6 Undercurrent

The first clue to the existence of a submerged current near the Equator was provided through observations on the drift of longline fishing gear in the central equatorial

Pacific. The longline gear, suspended from buoys and floating freely in the water, has the main mass of fishing lines about 150-180 m below the surface (Cromwell, Montgomery, and Stroup 1954). Set near the Equator a number of times during exploratory fishing cruises, the gear moved eastward in spite of opposing trade winds, currents, and seas at the surface. This suggested that a submerged current was prevalent near the Equator. The existence of this eastward moving current in the lower part of the surface layer and upper thermocline was proved by using surface and deep drags.

3. PRIMARY PRODUCTION

3.1 Oceanic regions

Primary production of 5-10 mg C/m^3/day (average 6.7 mg C/m^3/day) is characteristic of the oceanic zone of not only the boreal and Antarctic regions but also of areas with less intense ascent of deep waters near the equatorial region (Koblentz-Mishke 1965). A narrow band of water in temperate latitudes and a broader one around the Equator have productivity at the surface varying between 2 and 5 mg C/m^3/day (3.8 on the average) and which may provisionally be referred to as transition zones. Low productivity, averaging 1 mg C/m^3/day, is restricted to extensive areas of tropical waters mainly occupied by the northern and southern central water masses.

In the central Pacific, the area of highest primary production is in waters of the countercurrent (Bogorov 1960a, 1960b). Bogorov characterized the different types of water in the central Pacific as shown in Table 2.

Table 2.--Physical, chemical, and biological characteristics of the geographical water zones established for the central Pacific Ocean (Bogorov 1960a).

Zone	Temperature °C			Transparency, m	O_2 (ml/liter, at 0 m)	$P-PO_4$ (mg/m^3 at 0 m)	$P-PO_4$ (mg/m^3 at 100 m layer)	Number of bacteria per 50 ml	Number of phyto-plankton cells (m^3)	Biomass of zooplank-ton (mg/m^3)	Biomass of fish (mg/m^3) (1,000-0 m)	Benthos (mg/m^2)	Benthic sediments (g/cc)
	Air	Water											
		0 m	300 m										
Northern[1] subtropical	17.0	21.0	13.0	32	5.0	3.2	12.5	18	3,600	97	2.0	500-100	1.46
Northern equatorial	25.5	27.6	14.0	36	4.6	2.3	3.0	72	3,100	26	0.7	50	1.40
Equatorial counter-current	27.5	29.1	10.9	26	4.1	9.0	14.0	150	19,900	46	1.4	50	0.90
Southern equatorial	27.0	28.4	14.5	38	4.4	8.0	10.0	95	4,300	12	0.7	50	1.00
Southern subtropical	22.0	21.7	15.0	39	5.5	4.9	7.1	38	3,600	36	1.2	160-400	1.20

[1]The characteristics of the subtropical zones are presented as a mean of the values of the northern and southern portions of these zones.

Dividing the northern subtropical zone water into a northern section along lat. 40°N and a southern section along lat. 30°N, Bogorov found that in the northern section, phosphate is low at the surface but relatively high at deeper levels. The bacterial count per 50 ml and cell count of phytoplankton per cubic meter are relatively low. Here, diatoms predominate over peridinians in the phytoplankton samples. Along the southern section of this zone, phosphates and bacterial counts do not differ markedly from those values found for the northern section. The phytoplankton count, in which peridinians predominate, rises significantly to about four times the level encountered in the northern sector. Venrick (1974) observed that localized blooms of phytoplankton in this zone are dominated by an increase in the abundance of Rhizosolenia.

The water of the north equatorial zone at lat. 10°-12°N is relatively low in phosphate but moderately high in bacteria. The phytoplankton, composed primarily of peridinians, is somewhat lower than in the northern subtropical zone.

In the countercurrent zone, phosphates reach their highest levels in the surface layer. Also, more bacteria and phytoplankton occur here than in any other zone. The phytoplankton count shows an almost equal number of diatoms as peridinians.

At lat. 10°S where the southern equatorial zone is located, the water is relatively high in phosphate, moderate in bacteria, and sparse in phytoplankton. Bogorov observed that whereas peridinians predominate over diatoms at long. 174°W, their roles are reversed at long. 172°E.

The southern subtropical zone is also subdivided into a northern and southern section. The northern section at about lat. 20°S is characterized by water which is low in phosphate, bacteria, and phytoplankton and where peridinians predominate. At lat. 30°S, the southern sector of the southern subtropical zone has water moderately high in phosphate. The bacterial and phytoplankton counts, however, are considerably lower than in the northern sector of this zone.

In general, heterotrophic bacterial counts are low in the northern parts of the area surveyed, but increase sharply in the equatorial countercurrent zone where primary production is maximal (Bogorov 1960b). The usual picture is a predominance of diatoms over peridinians in high latitudes and vice-versa in the lower ones. This is supplemented by the result in the equatorial countercurrent zone where Bogorov found that the increase in phosphates was accompanied by a similar increase in algae. In the southern subtropical zone, the blue-green algae occupy a significant position in the composition of the phytoplankton.

Primary productivity in the western Pacific has been investigated by Sorokin (1973a, 1973b) and Sorokin and Tsvetkova (1972). Briefly, the studies revealed that bacterioplankton can serve as a large supplementary source of food for filter-feeding zooplankton, particularly in waters of maximum zooplankton concentration. This situation is typical in tropical regions where bacterial production may be twice the primary productivity through photosynthetic processes (Sorokin 1973a).

In the tropical western Pacific near the Solomon Islands, primary production on the surface measured by Koblentz-Mishke et al. (1977) was 0.4 and 1.0 mg C/m^3/day at two locations in waters of the South Equatorial Current, which is relatively poor in plankton, 3.0 mg C/m^3/day in the divergence zone of the Coral Sea, which is relatively rich in plankton, and 6.9 mg C/m^3/day in Kieta Bay of Bougainville Island. Sorokin and Tsvetkova (1972) determined also that primary production was higher near the equatorial divergence and lower along the convergence near lat. 12°N. Peak concentration of live phytoplankton is usually found at the upper boundary of the thermocline where the amount of nutrient salts is close to the level which limits phytoplankton development. The peak layer, according to Sorokin and Tsvetkova, is stable throughout the day.

For Ninigo and Admiralty Islands and Papua New Guinea, the thickness of the euphotic zone in the neritic area is 1.3 to 2 times that in the open ocean. In the lagoons, photosynthetic production is 12-14 mg C/m^3/day, but in one bay, which had a production of 39 mg C/m^3/day, photosynthesis takes place even at depths of 75 m with 10% of the light intensity at the surface (Sorokin 1973b).

3.2 Coral reef

Coral reefs, whether they are fringing shore reefs, barrier reefs that encircle the islands, or coral atolls, are one of the outstanding features within the western central Pacific. Coral reef communities are tremendously varied associations of plants and animals and are most noteworthy for their immense concentration of life and its complexity. That gross primary productivity or the rate of formation of organic matter can be very high in a coral reef environment is attributable to the recycling of nutrients within the system. The output of harvestable protein, however, is not particularly high (Clutter 1972).

Odum and Odum (1955), who determined the relationship between standing crop (dry biomass of existing organisms per area) and productivity (rate of manufacture of dry biomass per area), observed that in a windward coral reef community on Enewetak atoll, the average living coral colony contains three times as much plant as animal tissue or 0.063 g/cm^2 dry weight of algae as compared with 0.021 g/cm^2 of animal polyp. Zooxanthellae (in the coelènterate polyp) comprises roughly 6% of the total plant portion, whereas filamentous green algae embedded in the skeleton make up the bulk of the plant material. The study demonstrated that the algal-coelenterate complex comprises a highly integrated ecological unit, which permits recycling of food and nutrients necessary for vigorous coral growth in tropical "desert" waters of a low plankton content. The coral reef, therefore, is thought of as almost a whole ecological unit in itself including producers, herbivores (utilizing food from symbiotic algae), and carnivores (plankton feeding at night).

The study also revealed that in all zones of the reef, a trophic structure with a pyramid of biomass exists. For example, the mean standing crop for the reef as a whole is 703 g/m^2 for producers, 132 g/m^2 for herbivores, and 11 g/m^2 for carnivores. The ratio between standing crop trophic level for producer/herbivore is 5.3:1 and for herbivore/carnivore is 12:1. Based on these results, Odum and Odum (1955) estimated a very high total production rate of about 83 MT (metric tons)/ha, which represents a turnover (ratio of annual primary production to average standing crop) of about 12.5 times per year.

Reefs are also important to ocean production because the coastal fauna, which develops as an indirect result of the infusion of mineral salts from land and upwelling of nutrient-rich waters along the coast, enriches the pelagic sphere (Grandperrin 1977). This permanent infusion of coastal fauna from reef ecosystems in many Pacific islands represents a substantial biomass, which includes the larvae of drifting benthic species and meroplanktonic organisms (larvae of benthic organisms which have a free-swimming pelagic phase). In examining the stomach contents of pelagic, deep-swimming species caught far from the coast, Grandperrin found that of the total number of fish consumed by albacore, *Thunnus alalunga*, and yellowfin tuna, *T. albacares*, 58% and 73%, respectively, are regarded as coastal species. In bigeye tuna, *T. obesus*, however, coastal fishes are entirely absent.

4. ZOOPLANKTON

In the Pacific, zooplankton volume is distributed in a similar fashion as PO_4-P (Reid 1962). Volumes are usually high in the eastern boundary current, low in central water, and relatively high along the Equator and in two zones associated with equatorial divergence north and south of the Equator.

The biomass of zooplankton in the various geographical zones established by Bogorov (1960a, 1960b), for the central Pacific is given in Table 2. From north to south, Bogorov observed that the zooplankton biomass reaches 161 mg/m^3 in the northern sector of the northern subtropical zone but is only 34 mg/m^3 in the southern sector. In the equatorial zone, zooplankton is even more sparse, reaching only 26 mg/m^3. This sparseness is attributed to the depletion of nutrients as the water flows under the influence of the trade winds from the eastern to the central Pacific.

In the countercurrent zone, upwelling of deep water to the surface occurs over an enormous area enriching the photosynthetic zone (0-200 m) in phosphates and nitrates. As a result, zooplankton volumes reach 46 mg/m^3 in this zone.

In the Southern Hemisphere, Bogorov observed that the equatorial zone, unlike its counterpart in the Northern Hemisphere, is even more sparse in zooplankton, with volumes reaching only 12 mg/m^3. The zooplankton biomass then rises to 28 mg/m^3 in the northern sector of the subtropical zone and finally reaches 45 mg/m^3 in the southern sector.

Near the Line Islands, King and Demond (1953) observed that in the northern summer, the standing crop of zooplankton reaches a maximum of more than 50 cc/1,000 m^3 of water strained at lat. 2°C and long. 150°W near Palmyra. In the northern winter, the location of maximum abundance remains the same, but the standing crop is only between 25 and 55 cc/1,000 m^3.

High zooplankton volumes also occur in the area between lat. 2°S and 8°N at long. 150°W with peak abundance at lat. 1°S. Latitudinally, the average zooplankton volume is greater in the zone of convergence and the countercurrent than in waters of the South Equatorial Current (King and Hida 1957). This asymmetrical distribution is attributed to formation of oceanographic fronts in the transition zone between the Equator and the southern boundary of the countercurrent. Longitudinally, within the equatorial region, there is a gradient of increasing zooplankton abundance from long. 180° to 150°W.

In the western North Pacific near Marcus Island, plankton biomass at 0-500 m is 18 mg/m^3 but only 9 mg/m^3 to the southeast near Wake Island (Vinogradov 1968). At the northern periphery of the North Equatorial Current near the Marianas Trench, plankton biomass is also low varying from 8 to 11 mg/m^3 at 0-500 m. Vinogradov noted that the biomass also decreases sharply with depth; for example, at 2,000-4,000 m, the biomass is 0.13 mg/m^3 but at 4,000-8,000 m, it is only 0.012 mg/m^3, which is 140 times less than that found at corresponding depths of the Kurile-Kamchatka Trench.

In the Southern Hemisphere near the Phoenix Islands, the influence of the productive equatorial region is evident in greater plankton biomass. Here, it is relatively high, reaching 16 mg/m^3 at 0-500 m. Below 200 m, however, the biomass starts to decrease sharply, its distribution and magnitude at various depths being comparable to concentrations in the tropical waters of the Northern Hemisphere. Along the southern periphery of the South Equatorial Current, the plankton biomass is extremely low reaching only 5.5 mg/m^3 at 0-500 m. In deeper layers, it is slightly lower than concentrations in plankton-poor waters of the Northern Hemisphere.

Water to the south of the Tonga Trench is relatively poor in plankton. Here, the biomass reaches 13 mg/m^3 at 0-500 m but below that the concentration decreases sharply and the distribution is sparse, conditions which are typical of tropical waters of the Southern Hemisphere. In fact, the planktonic biomass at the 1,000-2,000 m layer is lower than that found at corresponding depths in such plankton-poor waters as the North Equatorial Current.

In the Solomon Sea, the water is very rich in plankton in the upper 500 m. Here, the plankton biomass reaches 38.0 mg/m^3 or nearly four times that found in waters of the North Equatorial Current. This difference in biomass persists to about 1,000 m, but at 1,000-2,000 m, the concentrations decrease somewhat so that the biomass is only 2.4 times greater than that of the North Equatorial Current at comparable depths.

Larvae of epipelagic and mesopelagic species are also encountered in the upper 300 m of the oceanic regions. Gorbunova (1971) observed that in the western tropical Pacific, there are, in addition to representatives of typical oceanic icthyofauna, large numbers of larval anchovy, Stolephorus zollingeri, and lancelet, Amphioxides pelagicus, which occur more commonly in coastal waters. Among mesopelagic species, larvae of Gonostoma elongatum, Cyclothone alba, Symbolophorus evermanni, and Diaphus sp. are most common.

In terms of biomass, myctophids constitute 86%-95% of the entire ichthyoplankton. Their absolute biomass, measured from collections made in the western Pacific, ranges from 2.15 to 31.22 mg/m^3 and averages 12.38 mg/m^3 (Parin, Gorbunova, and Chuvasov 1972). The concentration of myctophids in the surface layer at night is significantly greater than their average density in the 0-500 m layer.

5. BENTHOS

5.1 Coral reefs

The benthic fauna in waters around the Hawaiian Islands has been discussed by Doty et al. (1968). At Kealakekua Bay, on the island of Hawaii, the noteworthy features of the benthic fauna are the diversity of organisms, the densities of some species, and the occurrence of some of the more spectacular molluscs in relatively shallow water. There are 184 marine molluscs in Kealakekua Bay compared to 110 species in Kaneohe Bay on Oahu, which is much larger. A striking aspect of the urchin population is the rich abundance of slate pencil urchin, Heterocentrotus, which is also highly important along many areas of the Kona coast of Hawaii, but is generally uncommon in other areas of the Hawaiian Islands. Other urchins present in large numbers are Echinothrix, Echinometra, and Tripneustes.

Studies on bottom biocoenoses in the upper parts of island shelves in the western Pacific have shown that species diversity and biomass magnitude depend largely on the number of larvae of different species arriving there from regions with a diverse population (Golikov et al. 1973). The largest biomass, which averages 10 kg/m^2 and consists predominantly of lush growth of reef-forming corals, occurs along the coast of Papua New Guinea. Off New Caledonia, American Samoa, Western Samoa, and New Hebrides, the biomass of corals reaches 6-7 kg/m^2 whereas other animals account for 5%-10% and underwater plants account for 1%-7% of the total mean biomass of benthos. At Fiji and Nauru Islands, corals form a somewhat smaller biomass, reaching 2.7-3.0 kg/m^2, but other animals, which account for 10%-24%, and plants, which contribute 8%-14%, play more significant roles in the total benthic biomass. In the Ellice Islands (Funafuti Atoll), the average biomass of coral reaches 4.7 kg/m^2 whereas other animals and plants account for 3% and 30%, respectively, of the total benthic biomass. Golikov et al. (1973) found the lowest biomass of corals, averaging 1.2 kg/m^2, and the most significant role of plants in the biocoenoses, accounting for 38% of the total biomass, at Marakei and Butaritari Atolls in the Gilberts. A similar relationship between the biomass of corals and plants occurs at Lord Howe Island.

In most of the islands studied, life is less abundant at the 0-1.5 m depth. The biomass, population density, and related metabolic activity in the biocoenoses reach a maximum at depths of 2 to 8 m, where reef-forming corals are extensive. Depending heavily on the size and weight of dominant species, the biomass varies significantly with depth and by islands whereas population density depends primarily on fecundity, spawning, recruitment, and elimination. Maximum indexes of abundance and diversity of life are observed in areas where reef-forming corals are strongly developed. Golikov et al. (1973) concluded that a characteristic feature of the vast majority of tropical biocoenoses is the high biomass (more than 100 kg/m^2 in some areas) and a relatively low abundance of species population.

A survey of the macrofauna inhabiting lagoon deposits on Aitutaki in the Cook Islands yielded about 100 species. Among the groups were Polychaeta (27 species), Decapoda (20+ species), Gastropoda (31 species), and Pelecypoda (13 species). Of three main deposit zones--intertidal sand flat of the mainland, reef rim, and lagoon floor--the intertidal flat had fewer species than either of the other two zones (Gibbs 1975). Many of the sand-dwelling molluscs in the intertidal flat are highly regarded as food by the islanders (Banner 1952).

5.2 Other shallow-water areas (less than 200 m)

In waters just outside the coral reefs off Oahu, Strasburg, Jones, and Iversen (1968), who made 28 descents in a small research submarine to survey bottom fauna, reported that invertebrates occurring near rocky patches and ledges between 24 and 107 m include the starfishes, Culcita and Linckia, sea urchin, Chondreocidaris, beds of a hydrozoan or anthozoan which resembled Pennaria but with larger and heavier individuals, and spiny lobsters, Panulirus. On the sandy plains, they observed sponges and the protruding tubes of annelid, occasional cone shells near rocks, and brittlestars which appeared to be relatively abundant. Strasburg et al. estimated that at depths between 60 and 70 m, as much as two-thirds of the sea floor is covered by beds of pen shell, Atrina, packed together at a density of about $540/m^2$. Beds of spatangid heart urchins, consisting of several thousand individuals spaced about 30 cm apart, occur at about 107 m.

At greater depths--between 107 and 116 m--the sloping plain drops off to steep cliffs, which plunge 60°-80° from the horizontal. Here, the coils of an antipatharian coelenterate, probably a species of Cirripathes, are rather common as are various starfish, sponges, and sea urchins down to about 192 m. At 137-183 m, beds of red coral, Stylaster and Corallium, are common.

5.3 Deep to very deepwater areas

Samples from an oligotrophic bottom under the North Pacific Central Water at a depth of 5,500 to 5,800 m showed a macrofaunal density averaging 115 $individuals/m^2$ (range 84 to $160/m^2$), much the same as in northwest Atlantic gyre waters (Hessler and Jumars 1974). The bottom fauna, composed in the overwhelming majority of deposit feeders, was extremely diverse. Most species, however, appeared to be rare, occurring only once in the samples. Only three species showed any significant deviation from randomness in their distribution--one polychaete worm and tanaid crustaceans.

Among the macrofaunal taxa, polychaetes were by far the most abundant numerically constituting 55% of the total, followed by tanaid crustaceans at 18%. Bivalves and isopods were the next two most important groups, comprising 7% and 6%, respectively, of the macrofauna. All the other taxa represented less than 15%; individually, each taxon contributed not more than 2% to the fauna. Most of the major taxa are sparsely distributed and are either missing from most of the samples or represented by only one or two individuals. Only the polychaetes, tanaids, and bivalves are present in all samples. Isopods and scaphopods are present in more than half of the samples.

Some major taxa usually found in benthic samples are noticeably absent (Hessler and Jumars 1974). Among them are amphipods, cumaceans, and echinoids.

Meiofaunal taxa, which are only partially retained by the screen used in washing, are also present in reasonable abundance in the box-core samples. Despite the shortcomings of the samples, the meiofauna are numerically 1.5 to 3.9 times as abundant as the macrofauna. Always present are nematodes, by far the most abundant, copepods, and ostracods. Nematodes comprise 53% and copepods 13% of the total metazoan fauna. The combined meiofaunal taxa average 2.2 times (range 1.5-3.9) more numerically abundant than the macrofauna. Foraminifera appears to be an important portion of the community, but their abundance cannot be assessed accurately because of the inability to distinguish living and dead tests. Remains of probably xenophyophoridans also appear to be an important segment of the community.

The tests of living and dead foraminifera combined are extremely abundant, involving 135-1,808 individuals or chamber-fragments/core sample (average 759.8). One species is present in abundance of up to $160/m^2$ (average 60). This quantity far exceeds the abundance of any metazoan species.

In the western Pacific, Moiseev (1969) showed that the benthic biomass in the oceanic regions is less than 0.05 g/m^2 and varies between 0.05 and 0.1 g/m^2 along a belt running from south of Japan to offshore Papua New Guinea. Along the eastern coasts of the Philippine and Papua New Guinea, the benthic biomass rises to about 10 g/m^2. The South China Sea region, according to Moiseev's figure, has a benthic biomass on the order of 0.05 to 0.1 g/m^2. By constrast, Moiseev pointed out that the benthic biomass in South Polar waters of the coastal regions of Antarctica is extremely high, varying between 450 and 500 g/m^2; however, the biomass composition is primarily sponge.

6. FISH STOCKS AND FISHERIES

6.1 The fisheries

Essentially, the fish fauna of the western central Pacific islands is similar to that found off Southeast Asia. There is, however, a considerable amount of difference in shelf and slope areas between these two regions. Whereas the western central Pacific islands have very little shelf and slope areas, Southeast Asian region includes nearly one-half of the shelf and continental slope areas to 2,000 m in the Pacific. The result is that there is little opportunity for trawl fishing off the western central Pacific islands. There are, however, high-seas fisheries resources such as those of tunas and billfishes (not discussed in this report). Furthermore, when the fishery resources of the myriad of islands are critically examined, the importance of subsistence fisheries is rather striking. For it is in this region that some of the most exotic small-scale fisheries in the world are found (Manar 1969).

A prominent feature, then, of the fisheries scene in the western central Pacific, is the existence of numerous islands whose inhabitants depend largely on artisanal fishing directed to fish and shellfish in coastal waters. Cole (1973) observed that there is no general agreement as to what constitutes artisanal fishery because conditions differ among countries. However defined, artisanal fishery is of a flexible and pragmatic nature. Artisanal fishermen may be found in coastal, estuary, lagoon, river, or lake fisheries, including aquaculture. With light capital investment, a low level of organization, and little specialized skill, artisanal fishermen fish mostly hand-operated gear from small boats. Productivity and incomes are usually low and catches are commonly sold fresh, salted, dried, or smoked for local consumption.

In the sections that follow, the fisheries of the western central Pacific islands are described.[1]

6.1.1 American Samoa

Much of the fishing being carried on in American Samoa is still of a subsistence type and confined to coastal waters, although in recent years a small commercial fishery has been developed. In many places, traditional fishing gears--spear, scoop net, cast net, gill net, trap, handline, and trolling line--are still employed. A small-scale fishery for "palolo," the wormlike sacs of eggs and sperm of a sea annelid, Eunice viridis, which are released by the adults, occurs in October-November (Van Pel 1961; Manar 1969; Otsu and Yoshida 1971).

Subsistence fishing, however, cannot meet the demand for fresh fish in the more populous areas. In fiscal year 1970, for example, American Samoa imported 900 MT of seafood including canned salmon, salted mackerel, and frozen bottom fish despite the availability of yellowfin tuna, Thunnus albacares, skipjack tuna, Katsuwonus pelamis, snappers, Lutjanidae, rockfishes, Serranidae, and other species in waters around the islands (Fishing News International 1972; Swerdloff 1972). Swerdloff has estimated that a domestic fleet could readily market fresh fish in excess of 450 MT annually.

In 1972, the first of the 7.3-m plywood Samoan dory, a modified version of the Pacific City (Oregon) dory, was launched (Fishing News International 1972; Office of Samoan

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[1]Throughout the remainder of this report, scientific names of fishes, crustaceans, molluscs, and echinoderms are used after the common name first appears and are repeated in some cases to avoid confusion. Where no scientific names are given, the author was unable to find them in the original report.

Information 1974). From December through March, about 75% of the fishing effort among the dories are expended in trolling for tuna whereas in the off-season for tuna, the dories spend about 75% of their time handlining for bottom fish at night (Naughton 1975[2]).

Major species caught by trolling are skipjack tuna, yellowfin tuna, mahimahi, Coryphaena hippurus, and kawakawa, Euthynnus affinis. Species of lesser importance include black marlin, Makaira indica, blue marlin, M. nigricans, dogtooth tuna, Gymnosarda unicolor, wahoo, Acanthocybium solandri, barracuda, Sphyraena forsteri, and rainbow runner, Elagatis bipinnulatus. Important species in the handline fishery are the green snapper, Lethrinus miniatus, red snapper, Lutjanus gibbus, jack crevally, Carangidae, dogtooth tuna, blue-line snapper, Lutjanus kasmira, groupers, Cephalopholis, Epinephelus, and Variola, barracuda, and bigeye scad, Trachurops crumenophthalmus.

6.1.2 Cook Islands

In the Cook Islands, a large proportion of the population is involved in fishing, which in most cases, is a semisubsistence activity in both inshore and offshore reef areas, lagoons, brackish-water ponds, creeks, and swamps (Van Pel 1961; FAO 1976a). There is no organized marketing system for fish; therefore, the fishermen sell their catches directly to the consumers.

Van Pel (1955) observed that in the reef area, which is overfished, islanders traditionally carry on some type of fishing--gathering shellfish or fishing for juveniles of giant clam, rock cod, Serranidae, and parrotfish using spear, scoop net, surround net, rock trap, and pole and line. In deeper waters, trolling line is used for surface schooling tunas, Spanish mackerel, Scomberomorus commerson, and particularly wahoo, and dip net and light (as an attractant) is used for flyingfish. Castor-oil fish, Ruvettus pretiosus, carangids, and barracuda are usually caught by handlines. At Aitutaki, northern Cook Islands, the main local fishing effort concentrates on netting in the lagoon for bonefish, Albula vulpes, goatfish, mullet, and bigeye scad, but there is also a seasonal fishery for yellowfin tuna from February to May (Hume 1976).

Although fishery development projects in the 1960's introduced powered outboard skiffs and modern fishing gears to the Cook Islanders (Powell 1962), there has been little progress since then in developing a commercial fishery (FAO 1976a). The growth and development of the industry is being impeded by shortage of suitable fishing boats and the lack of maintenance of those already in operation. Furthermore, use of illegal fishing methods such as dynamiting, poisoning, and netting with small-mesh nets have seriously depleted the stocks of fish in the lagoon.

6.1.3 Fiji Islands

Most fishing operations in Fiji are still little more than the traditional subsistence type and are carried on by about 2,000 fishermen. None of the 600 or more licensed, flat-bottomed fishing punts, about 5-8 m in length, is capable of sustained fishing in distant waters; therefore, the majority is unsuitable even for offshore fishing outside the reef (FAO 1972; Cole 1973; Aubray 1976). Using mainly handline and gill net within the lagoon, Fijian fishermen catch a wide variety of fish including mullet, mackerel scad, Decapterus pinnulatus, halfbeak, ponyfish, snappers, breams, Sparidae, bigeye scad, rabbitfish, Siganus sp., and milkfish, Chanos chanos. A number of important crustaceans including mud crabs, Thalamita sp., mangrove crab, Scylla sp., and mangrove lobster, Thallasina anomala, and several species of molluscs such as ark shell, Arca scapha, trochus shell, and mother-of-pearl are also harvested (Ministry of Agriculture, Fisheries and Forests 1976).

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[2]Naughton, J. J. 1975. Trip report, American Samoa, 18 July 1975. Western Pacific Program Office, National Marine Fisheries Service, NOAA, Honolulu, Hawaii 96812, 12 p., unpublished.

6.1.4 French Polynesia

Both subsistence and commercial fishing are fairly active in French Polynesia, although frequently these two segments of the fisheries cannot be readily distinguished. Tahitian fishermen use dugout canoes, propelled by paddles, sails, and outboard motors in many types of fishing. Fishing usually takes place in the open coastal waters, lagoons, and over the reef.

In open-water fishing, Tahitian fishermen use small, fast boats called "bonitier" to fish for skipjack and yellowfin tunas (Brun and Klawe 1968). These "bonitiers," which can accommodate up to three men, frequently cruise over 185 km in a day's fishing (Hinds 1971; Doumenge 1973). No refrigeration is used; therefore, each vessel's crew guts the fish before returning to unload its catch. On a good day's fishing, one boat may land 200-300 fish.

In the lagoon, the fishing gears are the traditional types--trap, pot, handline, pole and line, cast net, beach seine, crab net, gill net, harpoon, and spear--and generally used only for small-scale fishing (Clutter 1972). Lagoon fishing with small nets accounts for about 4% of the fish sold. Fixed trap, which accounts for about 31% of the fish marketed in Papeete, is widely used in the Leeward, Tuamotus, and Gambier Islands. Large-net fishing, accounting for 7%-11% of the market catch, is confined to reef passages and along the coast for bigeye scad and mackerel scad. Other species that often reach the market in Papeete are skipjack and yellowfin tunas, which account for about 38% of the sales, spiny lobster, and mother-of-pearl shell. Bigeye scad and mackerel scad not immediately destined for sale are kept alive in impoundments constructed of either old fish nets or galvanized chicken wire fences and stakes.

6.1.5 Gilbert Islands

In the Gilbert Islands, fishing is a subsistence activity carried on by individual families (Hinds 1969). Nearly every family has its own canoe and most residents spend much of their time in their fishing crafts and are expert outrigger canoe handlers and fishermen. Also popular are outboard-powered 3.6-m fiber glass boats which in recent years have contributed to an increase in catch.

Trolling in canoes and small motorized boats mainly in coastal waters is the principal method for catching tuna and other pelagic species. Also used are the traditional pole-and-line method with mother-of-pearl lures, deep handline, and dip net. Troll catches include tuna, skipjack, billfish, jack crevally, and barracuda; deep handline fishing produces not only small amounts of tuna and billfish but also castor-oil fish and shark. Dip-net fishing by torchlight is used at night for flyingfish.

On the reef flats, the method of fishing varies widely from hand gathering of shellfish, octopus, spiny lobsters, crabs, and small fish, either day or night, to trapping with large stone traps (Hinds 1969). Other gear frequently used for reef fishing are pole and line, dip net, and spear.

In the lagoon area, underwater spearfishing, handlining, and net fishing are popular. Lagoon catches include parrotfish, mullet, grouper, and snapper. Sardines are occasionally caught with a cast net.

Fish catches are usually divided first among relatives and friends of the fishermen and the surplus is sold directly to other consumers. The few fishermen who engage in commercial fishing usually keep the retail markets supplied with fresh fish.

6.1.6 Guam

In Guam, as in American Samoa, there is a critical shortage of fresh fish. Ikehara, Kami, and Sakamoto (1972) estimated that the potential demand for fresh or frozen fish on

Guam is more than 900 MT, yet no commercial fishery exists in the island. The supply of fresh fish is usually provided by weekend recreational fishermen who sell part of their catches, which annually amount to less than 140 MT.

A narrow reef, which fringes the island except in the northern half of the east coast, is uncovered at low tide. Recreational fishing on the reef produces goatfish, parrotfish, snapper, mullet, surgeonfish, leatherjacket, wrasse, jack crevally, rockfish, garfish, tarpon, anchovy, and scad (Van Pel 1961). Squids and turtles are also present as are edible shellfish.

Gear most commonly in use on the reef include fixed fish trap or weir, cast net, set net, surround net, handline, and spear. Just off the fringing reef where only limited fishing takes place, handlining and netting, sometimes with light attraction, produce the bulk of the catch, mainly pelagic species.

6.1.7 Hawaiian Islands

In the Hawaiian Islands, where the marine fauna forms an offshoot of that great marine zoogeographic region centered on the East Indies, the species complex is not as diverse as in the western Pacific. Here, the shelf zone that characterizes most of the world's great fishing areas is narrow and poorly developed. The result is that only about 60 of the 682 species of fish, mostly found on the reefs and inshore area, are commercially exploited. Most are captured by a variety of gear including pole and line, longline, haul seine, bag net, pot, trap, gill net, anchor net, handline, and cast net. But the major thrust of the commercial fishery is in the open ocean beyond 200 m in depth, where pole-and-line sampans catch almost all the Hawaiian landings of skipjack tuna and longline boats harvest deep-swimming yellowfin tuna, bigeye tuna, Thunnus obesus, albacore, T. alalunga, striped marlin, Tetrapturus audax, blue marlin, black marlin, swordfish, Xiphias gladius, shortbill spearfish, Tetrapturus angustirostris, sailfish, Istiophorus platypterus, wahoo, and mahimahi.

The nearshore fisheries in Hawaiian waters are for a variety of demersal and bathypelagic species. In the handline fishery, for example, the major species include pink snapper, Pristipomoides microlepis, gray snapper, Aprion virescens, red snapper, Etelis carbunculus and E. marshi, amberjack, Seriola dumerilii, jack crevally, and other carangids, goatfish, Mulloidichthys samoensis, and sea bass, Epinephelus quernus. Bigeye scad, second only to tuna and billfish in total landings, is caught by three types of gear--bag net, which accounts for nearly two-thirds of the annual landings, handline, which lands about 20%, and gill net, which contributes about 13% (Kazama 1977). Also of importance in the Hawaiian fishery is the mackerel scad, which is widely distributed in the tropics and is found in small schools just outside the breakers and off coral reefs. The gears for capturing mackerel scad are the hoop net, which accounts for slightly more than half of the mackerel scad landings, and handline, which produces roughly 45% of the catch.

An important fishery that is often overlooked in the published statistics of the Hawaii Division of Fish and Game is that for anchovy, Stolephorus purpureus. Caught in shallow bays and harbors throughout the major Hawaiian group, the anchovy is used primarily as live bait in the pole-and-line fishery for skipjack tuna, although some are caught and processed for consumption.

Blessed with year-round ideal weather, Hawaii is also ideal for marine-oriented, recreational fishing. The Hawaii Division of Fish and Game estimated that about 169,000 residents or 20% of the population engage in marine recreational fishing, for a total of 6 million fishermen-days per year. Recreational fishermen pursue a wide variety of fish using a wide assortment of gear. But in terms of tonnage landed, trolling gear appears to be the most important. Major species landed by trolling are yellowfin tuna, mahimahi, wahoo, blue marlin, and striped marlin.

A few long-range commercial fishing vessels in the Hawaiian fleet operate in waters of the Northwestern Hawaiian Islands, which extends from Nihoa northwestward to Kure Island. Fishing primarily with handline, fish trap, and lobster pot not only around Nihoa and Necker but also as far north as French Frigate Shoals on occasion, these vessels catch mainly spiny lobster, sea bass, jack crevally, amberjack, pink snapper, gray snapper, and red snapper (Uchida 1977[3]).

Beyond the northernmost tip of the Hawaiian chain, a relatively new trawl fishery has developed for seamount resources. Until 1967, groundfish on the seamounts in the central North Pacific aroused very little interest primarily because most fishery scientists doubted the possibility that they could be exploited commercially. The discovery of commercial concentrations of pelagic armorhead, Pentaceros richardsoni, and alfonsin, Beryx splendens, on the Emperor Seamount Chain northwest of Midway Islands was made by a commercial trawler of the Soviet Union in November 1967 (Sakiura 1972). Almost immediately after the discovery, Soviet trawlers worked the banks and seamounts of this chain. Subsequent surveys by Soviet research vessels were concentrated on Kinmei Bank, Milwaukee Bank, and Hancock Seamount.

Fishing over seamount tops ranging from 100 to 400 m below the sea surface, the Soviet trawlers found schools of armorhead averaging 30 m thick and produced catches varying from 3 to 50 MT on 10- to 20-min hauls. Often, the catches reached 30 MT in a 10-min haul. Sakiura reported that the Soviet trawlers produced 133,400 MT (unconfirmed) of armorhead from these seamounts between December 1969 and July 1970.

In 1969, the Japanese started deepwater trawling over seamounts and banks in the central North Pacific, north of Midway. Working the grounds mainly for pelagic armorhead and alfonsin, the Japanese trawlers made fairly good catches. On one particular trip from mid-June to early August 1975, one Japanese trawler caught 280 MT of fish over the seamounts (U.S. NMFS 1975).

After the developmental years 1969-71, Japanese catches of armorhead began to stabilize at about 20,000-30,000 MT, but effort increased from about 500 h in 1972 to 2,700 h in 1976. The result was that catch per effort declined progressively from about 60 MT/h in 1972 to 10 MT/h in 1976 (Takahashi and Sasaki 1977). Up to 7% of the Japanese catches in 1969-76 was composed of alfonsin.

6.1.8 Nauru

The fishing industry in the Republic of Nauru has been described as quasi-commercial but on a relatively small scale (Clutter 1972). Power boats and locally built canoes are used in fishing, but because there is no direct distribution system, the fishermen sell their catches directly to the consumer. Under present conditions, this distribution system appears to be adequate to meet the demand.

The government is anxious to diversify sources of revenue and fisheries development appears to show good potentials. A feasibility study conducted recently evaluated the fishery development and processing of marine products in the Republic.

6.1.9 New Caledonia and dependencies

Fishing in New Caledonia is an important economic activity. Full- and part-time commercial and sport fishermen of several nationality including European, Indo-Chinese, Indonesian, Polynesian, and Melanesian engage in all forms of fishing activity (Van Pel 1961).

Commercial fishing crafts in New Caledonia include 9-12 m cutters with inboard engine,

[3]Uchida, R. N. 1977. A summary of environmental and fishing information of the Northwestern Hawaiian Islands. SWFC Admin. Rep. 4H, 60 p. Southwest Fisheries Center, National Marine Fisheries Service, NOAA, Honolulu, Hawaii 96812, unpublished.

auxiliary sail and either a live well or refrigerated holds, small sailing boats for trochus gathering, and large numbers of miscellaneous fishing boats such as canoes, flat-bottomed punts, and cabin cruisers powered with outboard motors. In 1974, Sauvée (1974) reported that artisanal fishing was carried out in the lagoon by about 130 boats, 40 of which were considered operating on a truly commercial scale. Fishing is usually confined within the lagoon and on the reefs, although some deep-sea fishing takes place around the neighboring Loyalty Islands. A large proportion of the catch includes snapper, sweetlip, rockfish, mullet, Spanish mackerel, and surgeonfish. The gears most frequently used are handline, trolling line (some boats are equipped with outriggers for multiple trolling), surround net, gill net, seine, barrage net, cast net, spear, and bottom trap.

Studies have shown that New Caledonian waters are rich in tuna. Angot (1959) has shown that trolling gear was the most suitable for taking skipjack and yellowfin tunas. A commercial trolling fishery has been established in New Caledonia and the catch is sufficient to supply the demands of the Noumea market.

6.1.10 New Hebrides

New Hebrides has no large-scale commercial fishery. There is, however, a tuna-fishing industry established by American, British, French, and Japanese capital based at Palekula, which obtains tuna from Japanese longliners and exports them to various canneries.

Subsistence fishing accounts for most of the fresh fish and shellfish caught in waters around New Hebrides and any excess, usually only a small quantity, is sold in Port Vila and Luganville, two main centers of population. Canoes are in general use, but sailing and motor boats also contribute to the fish landings. The main types of gear are spear, handline, trolling line, cast net, small seine, bottom trap, and fixed trap (Van Pel 1961).

6.1.11 Niue

In Niue, which has no commercial fishery, fishing is essentially for subsistence and subsidiary to small-scale agricultural production (Clutter 1972). By custom, a Niue resident must be equally adept in agricultural practices and fishing.

Some 500 residents, mostly part-time fishermen, use single (about 320) and three-men (about 30) canoes, which are locally made, and primitive fishing methods to land about 10 MT of fish annually, supplying about one-sixth of the island's fish requirement. Among the gear in common use are handline, trolling line, and scoop net for flyingfish, which are usually captured at night. Fishing grounds for handlining are limited to areas on the eastward slope of the narrow, shelflike fringing reef.

6.1.12 Papua New Guinea and West Irian

Although the waters off the Papua New Guinea mainland and its 600 small islands support a rich and varied marine fauna, it was only in recent years that fishing became an important economic activity. From Papua New Guinea's waters, some 1,600 fish species, 5,000 molluscs, and about the same number of crustaceans have been identified but only a few--perhaps no more than 100--are utilized by the 100 or so licensed commercial fishermen and several thousand subsistence fishermen. Pownall (1972) estimated that the annual subsistence catch, about 20,000 MT, is insufficient to meet all needs, particularly in inland districts which depend heavily on frozen imports and processed fish. But efforts are underway to increase production through boat-building programs, introduction of motorized boats, and construction and demonstration of new nets, fishing techniques, and fish handling procedures.

Joint venture companies have had a tremendous impact in the rapid development of commercial fisheries, particularly for tuna and shrimp, in Papua New Guinea. Surveys conducted by commercial fishing boats and by the government's Research and Survey Branch revealed commercial concentrations of banana shrimp, Penaeus merguiensis, and skipjack tuna in waters of Papua New Guinea. Trawlers, licensed to operate under joint venture agreements, produced 349 MT of shrimp in 1970-71 (Pownall 1972). In the tuna pole-and-line fishery, one joint venture company operated in 1970 and produced 2,430 MT. By 1971, however, three ventures were operating and the catches in 1971-75 fluctuated between 13,100 and 42,050 MT.

Traditional fishing methods are still widespread in Papua New Guinea despite rapid development of fisheries for tuna, shrimp, spiny lobster, Panulirus ornatus, and barramundi, Lates calcarifer. Most of the inshore fishing is done from canoes but motor boats have increased in popularity (Hinds 1969). More than 3,000 outboard-powered canoes, dinghies, and other small crafts are actively engaged in fishing. The main types of gear include a variety of spears used in inshore waters, rivers, and lakes, an assortment of traps from the large Rabaul type to the single-handed cones for river and lake fishing, gill net which is popular for catching barramundi and reef fishes, surround net, scoop net, skimming net, pole and line, handline, and trolling line (Van Pel 1961; Pownall 1972).

Among the major species caught by subsistence fishing in the delta area are catfish, Tachysuridae, barramundi, jewfish, Sciaenidae, beach salmon, Leptobrama mulleri, threadfin salmon, Polydactylus sheridani and Eleutheronema tetradactylum, and mullet (about 10 species with Liza dussumieri commonest). Also caught are small numbers of bream, Acanthopagrus berda, mangrove jack, Lutjanus argentimaculatus, tripletail, Datmoides quadrifasciatus and Lobotes surinamensis, javelinfish, Pomadasys hasta, and leatherskin, Chorinemus lysan. Commercial exploitation of these species, with the exception of barramundi, is very limited (Fisheries Division and the National Investment and Development Authority (FDNIDA) 1976).

The development of the commercial fisheries revolved around four major resources--tuna and shrimp which are by far the most important followed by barramundi and spiny lobsters. The skipjack tuna fishery has been described by Kearney (1973, 1974) and Kanudi Fisheries Research Station (1977). For shrimps, surveys by Japanese research and commercial vessels have shown that the potential for a fishery, based on the availability and abundance of banana shrimps, is excellent. The shrimp fishery, which is the major fishery in the Gulf of Papua, had a modest beginning in 1955 but it evolved into a large commercial operation which in terms of effort and value of catch far outweighs other fishery development in the Gulf (FDNIDA 1976).

The spiny lobster, Panulirus ornatus, fishery is concentrated in three locations--around Daru in the western province, in the Gulf of Papua, and at Yule Island. Lobsters are fished year-round at Daru, from August to November at Kerema, and from January to April at Yule Island. At Yule, lobsters are captured alive, in Daru they are speared, and in the gulf, where the major fishery for lobster operates, they are caught by trawler (Wilson 1976). Barramundi, the fish in greatest demand in Papua New Guinea, constitute one of the most important resources of Daru and the western province. Their distribution is most dense in the Fly River basin area. The fish is caught in a seasonal coastal fishery which depends on migrating fish from the inland areas and also in an inland fishery.

Fishing in West Irian is mainly for subsistence and is quite active along the coast and neighboring island (Van Pel 1961). There is no commercial fishery in the island although some fishermen sell their catches around the main centers of population. Very little locally caught fish reach the interior.

Fishing is usually conducted from canoes propelled by paddle, sail or outboard motor, and from a few motorized boats. Spear, pole and line, handline, trolling line, bottom trap, reef trap, beach trap, reef net seine, gill net, dip net, and cast net are the main gears in use.

6.1.13 Solomon Islands

Fishing in the Solomon Islands is mainly a subsistence activity although fish in excess to a fisherman's immediate need are sold or bartered for other goods (Van Pel 1961).

Coastal villages fare better than those farther inland as they generally have sufficient fish to meet their nutritional needs. In other areas, for example, in the capital city of Honiara, the residents depend heavily on imported fish.

Most of the fishing crafts used are canoes propelled by paddles or sails. The Solomon islanders fish over the reefs and near-coastal waters using a wide variety of traditional gear including spear, harpoon, pole and line, handline, trolling line, lift net, scareline equipped with a bag net, surround net, gill net, turtle net, and dip net. Among the principle species caught are flyingfish, yellowfin tuna, kawakawa, Spanish mackerel, barracuda, jack crevally, skipjack tuna, and mahimahi.

Enactment of the 200-mile conservation and management zone vastly increases the developmental potential of the fishery resources of the Solomon Islands (James 1977b). The pole-and-line skipjack tuna fishery established in 1973 under a joint venture agreement between the Solomon Islands Government and Taiyo Fishing Company of Japan, has flourished and in 1976 was the single largest producer in the islands with exports values at $A7.5 million. Other species have also been targeted for further development. In fact, fisheries have developed in advance of the marketing infrastructure but with additional injection of capital, a more organized marketing structure should emerge. Among the species that are being exploited commercially are the spiny lobster, oyster, crab, and shrimp.

6.1.14 Tokelau Islands

In the Tokelau Islands, fishing and related activities are of the utmost importance (Van Pel 1961). Fishing is confined primarily on the reef and inside the lagoon the year-round and outside the lagoon in favorable weather and is conducted mainly from outrigger canoes which are built of planks and propelled by paddle or sail. While the catch usually includes a wide assortment of reef species, ocean fishing provides species such as tuna, Spanish mackerel, bonito, jack crevally, shark, and barracuda. Flyingfish is captured at night with torchlight and dip nets. The outer reef is also fished for bigeye scad practically all year.

6.1.15 Tonga Islands

Tonga has no organized fishing industry in a strictly commercial sense. The industry lacks professional fishermen and is at a very early stage of development, based mainly on the inshore and nearshore fish resources (Wilkinson 1974). There are between 1,300 and 1,400 residents engaged in fisheries in the southern and central islands and an additional 300 in the northern islands (FAO 1975a). Among the 500 small crafts in use are outrigger canoes, skiffs with outboard motors, launches with inboard engines, and sailing boats.

The fishing gear used are the traditional types including spear, gill net, trammel net, beach seine, cast net, coconut frond net, turtle net, handline, and pole and line (Williams 1969). The main fisheries are based on reef and inshore handlining, commonly conducted at night with light attraction, surface trolling, and trapping (Lorimer and Maclean 1974; FAO 1975a).

Longline fishing within Tongan waters began in 1970 and continues to show relatively good progress. In 1976, the longliner "Ekiaki" fished 107 days by the end of October and produced 117 MT of deep-swimming tunas and billfishes (Wilkinson 1977a). A second longliner, donated to Tonga by the Japanese Government, is slated for service with an all-Tongan crew.

The inshore lagoon and near reef catches consist of a wide assortment of tropical species including jack crevally, flyingfish, Spanish mackerel, barracuda, parrotfish, snapper, goatfish, and milkfish. Most fish marketed are small or juveniles of large species, usually 15 to 25 cm in length. Among the main species marketed throughout the year are juvenile emperor, Lethrinus variegatus, rabbitfish, Siganus oramin, and bigeye scad. Unicornfish, Naso unicornis, blue-line snapper, triggerfish, tuskfish and other labrids, and longtom, are also common (Lorimer and Maclean 1974). Porcupinefish and stonefish are frequently sold for consumption. Mullet, Mugil cephalus, occur in abundance in August-November and dominate landings at this time.

Among various other marine animals harvested for consumption are holothurians (bêche-de-mer) of which only the intestines are marketed, large, short-spined sea urchins, which are very popular, and octopus, which are either sold fresh or dried and smoked.

6.1.16 Trust Territory of the Pacific Islands

In the Trust Territory, as in most other Pacific islands, subsistence fishing is an important daily activity. Most fishing takes place on the reefs and in the lagoons. Canoes with and without outriggers and propelled with paddles, sails or outboard motors, are still quite commonly used. There is also an increasing number of modern motorized vessels in use. The main fishing gears include handline, trolling line, pole and line, beach seine, surround net, gill net, dip net, cast net, scareline, spear, fixed traps of rocks or wire, and bottom trap. Fish caught and landed in excess of an island's need, for example at Palau and Ponape, are exported to other islands of the Trust Territory and Guam (Van Pel 1961).

The inshore waters in Micronesia are presently not suitable for major commercial exploitation because of the limited productivity of the coral reefs and the "territorial" characteristics of many of its inhabitants. Furthermore, past practices of intensive fishing with gill nets and seines and the use of mechanized crafts have partly contributed to severe depletion of the inshore resources (Rechebei 1977).

6.1.17 Tuvalu

Tuvalu, formerly known as the Ellice Islands and which were separated from the British colony of Gilbert and Ellice Islands and formed into a new colony on 1 October 1975, has a vital stake in developing its fish resources, because there is very limited alternate resources that could be developed to boost the country's economy. In a pre-European economy, Ellice islanders were subsistence fishermen, catching indigenous marine fishes and shellfishes with traditional fishing gears in outrigger canoes (South Pacific Commission 1977c). Today, fishing is still domestic in character and very little commercial exploitation occurs despite a continuing strong demand for fresh fish (see 6.1.5 Gilbert Islands for information on fishing in Tuvalu).

6.1.18 Wallis and Futuna Islands

From reports of the South Pacific Commission (1977b), it is evident that a serious decline in primitive subsistence fishing has occurred in the Wallis and Futuna Islands. By 1970, only a few traditional canoes remained on the islands. Clutter (1972) reported that these canoes are heavy and difficult to maneuver; therefore, the fishermen never venture into the open ocean beyond the encircling reef, where scombrids such as dogtooth tuna, Gymnosarda nuda, Spanish mackerel, Scomberomorus commerson, and wahoo, Acanthocybium solandri, are present. Instead, the residents concentrate continuous and undesirable fishing pressure on the lagoon stock using handlines and nets. The result is that there has been a serious decline in the lagoon stock and supplies of fresh fish are insufficient to meet the local demand, which is satisfied by imported canned fish and beef.

6.1.19 Western Samoa

In Western Samoa, fishing is basically a subsistence activity, although some commercial fishing occurs; there is no organized fish market through which the fish are sold. Fishing is concentrated primarily on the fringing reefs and lagoons. The Western Samoan fishermen catch any edible organisms, irrespective of size, including fish, shells, crustaceans, turtles, bêche-de-mer, squids, octopus, and sea urchins as well as large quantities of "palolo" when in season. In use are 1,500 canoes and 50 catamarans, all powered with outboard motors (Van Pel 1961; FAO 1975b).

To capture their prey, the fishermen use fixed fish traps, gill net, beach seine, stake net, eel trap, spear, pole and line, trolling line, handline, and cast net. There are about 7,000 part-time fishermen using mainly spear and net to harvest organisms from the reef area. The result is that there is considerable fishing pressure exerted and the reef and lagoon fauna are undoubtedly overfished. Fortunately, schools of bigeye scad enter the lagoons occasionally, thus relieving some of the pressure on the reef stock.

Trolling for tuna is another of the principal methods of fishing (Gulbrandsen 1977). Using motorized double-hulled canoes and fishing outside the reef, about 400 Western Samoan fishermen find trolling one of the most economical ways to fish because of the low initial investment in gear, simplicity of the technique, and the recreational value involved. Despite the seasonally good catches made by these trollers, there are periods when the availability of tuna is either very low or tuna are entirely absent from Western Samoan waters. Therefore, to insure profitability of these trollers, bottom handline fishing along the outer reef was begun in 1975.

Good bottom fishing grounds are usually located at the drop-off of the outer reef at depths between 100 and 150 m. Because currents around the islands are generally swift, the boats anchor on the grounds. The major species caught by handlining in Western Samoan waters include shark, sharptooth snapper, Pristipomoides typus, rosy job fish, Aprion microlepus, Malabar red snapper, Lutjanus malabaricus, longface emperor, Lethrinidae, castor-oil fish, red snapper, L. bohar, grouper, Serranidae, green job fish, A. virescens, snake mackerel, Promethichthys prometheus, and small-toothed job fish, Aphareus furcatus.

6.2 Statistics

Catch statistics from western central Pacific islands are summarized for 1965-75 in Tables 3 and 4, by islands and species groups, respectively. Although several island governments have implemented fish catch data collection systems in recent years, none of the statistics are entirely satisfactory.

The data collection system in American Samoa was started in 1971 and has shown steady improvement. Three systems were set up initially--one for the Samoa-based longline fishery for albacore, another for the Samoan-dory commercial operation, and a third for the subsistence fishery among the many outlying villages. Of a potential sample size of 1,550 vessel trips among the longliners in 1971-73, data on albacore lengths were obtained from 82% and on catch and effort from 76% of them. For the Samoan-dory fleet, standardized catch and effort reports were collected from about half of the trips recorded. Attempts to collect subsistence fishing data, however, proved to be fruitless, because the catches reported by many of the villages were considered unreliable (Sesepasara 1973; Office of Marine Resources 1976).

In French Polynesia, Tahitian yellowfin and skipjack tuna catches actually represent only about a third to a half of the true tuna production. There are two important sources of error: First, because all the yellowfin and skipjack tunas are gutted at sea, the landings at Papeete Municipal Market represent weights of eviscerated fish (Brun and Klawe 1968) and second, many fishermen bypass the Papeete Market and dispose of their catches directly to local fish dealers or through roadside and door-to-door sales (Doumenge 1973).

The most extensive statistics are for the commercial fisheries of the Hawaiian Islands, but these too are deficient in certain categories. For example, they exclude (1) catches made by many of the recreational fishermen who do not obtain commercial fishing licenses and, therefore, are not subject to reporting their catches, and (2) detailed data on the amount of fishing effort expended except in the well-developed skipjack tuna pole-and-line fishery.

Table 5 lists several fish groups and the annual catches of the important species within them for 1961-75 for the Hawaiian Islands. Landings by types of gear used and number of licensed fishermen and boats, by islands, are given in Table 6. Table 7 gives the catch, effort, and catch per effort in the Japanese trawl fishery for armorhead and alfonsin on the central North Pacific seamounts.

At present, it is difficult to estimate the production of fish in Papua New Guinea. In the case of subsistence fishing, the trade and sale of fish is very widespread. The result is that statistics are difficult to obtain, although some data from fisheries market surveys, fishing groups, fishing surveys, and cooperatives are available; however, the extent to which data from these sources reflect the total local trade in fish, and relationship of commercial production to subsistence fishing remains to be evaluated. Licensed fishermen are required to furnish the best data available on effort and catch; the data collected, however, are unsatisfactory and incomplete (Conroy 1972).

Catch data from the Trust Territory of the Pacific Islands have been judged to be gross underestimates because they represent only fish sold through the major fishing cooperatives. Catches sold directly to consumers are not recorded (Rechebei 1977).

6.3 Stock assessment

With the exception of the tuna resources, very little work on stock assessment, by species, has been carried out in this area, primarily because the commercial fishery in many of the island groups are still in its infancy. The one exception is in the Hawaiian Islands where limited assessment studies on some species have been completed and others are in progress.

Table 3.--Nominal catches of fish, crustaceans, and molluscs in the western central Pacific islands (in metric tons) (FAO 1970, 1975c, 1976b).

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
American Samoa	--	--	--	--	--	00	--	--	100	82	--
Christmas Island	--	--	--	--	--	--	00	00	00	0	0
Cook Islands	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Fiji Islands	--	--	--	--	--	4,100	4,200	4,800	5,100	4,261	4,868
French Polynesia	1,900	2,100	2,000	2,100	2,300	2,300	2,200	2,400	2,600	2,386	2,169
Gilbert Islands	--	--	--	--	--	200	500	500	500	750	750
Guam	100	100	200	100	200	200	100	100	100	92	122
Hawaiian Islands[1]	9,089	6,086	5,552	6,096	4,577	5,310	8,020	6,911	6,759	5,372	4,624
New Caledonia	900	800	500	500	500	500	500	500	800	868	900
New Hebrides	3,400	6,200	5,400	7,900	8,000	8,000	8,000	8,000	8,000	8,000	8,000
Papua New Guinea	11,000	11,000	14,000	14,000	14,000	18,700	33,300	29,900	48,500	52,708	42,748
Solomon Islands	--	--	--	--	--	1,000	5,700	8,800	7,300	11,585	8,711
Tonga Islands	--	--	--	--	--	--	500	500	600	726	901
Trust Territory of the Pacific Islands	700	800	1,000	1,000	1,000	1,000	1,000	400	6,300	3,360	3,360
Tuvalu	--	--	--	--	--	--	00	00	00	0	0
Western Samoa	900	900	900	900	900	900	900	900	900	900	1,000

00 = More than zero but less than 50 MT.

0 = More than zero but less than 0.5 MT.

[1]Data are from Hawaii Division of Fish and Game, commercial fish catch, by species, 1965-75, mimeo.

Table 4.--Nominal catches of marine fishes in the western central Pacific islands (in metric tons) (FAO 1970, 1975c, 1976b).

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Herrings, sardines, anchovies, etc.											
Gilbert Islands	--	--	--	--	--	--	--	--	--	105	105
Hawaiian Islands	211	185	187	209	177	196	236	229	245	242	214
Papua New Guinea	--	--	--	--	--	--	--	--	--	1,000	750
Jacks, mullets, etc.											
Gilbert Islands	--	--	--	--	--	--	--	--	--	95	95
Hawaiian Islands[1]	422	520	605	672	584	639	609	612	537	493	505
Mackerels, snoeks, cutlassfishes, etc.											
French Polynesia	200	200	200	200	200	200	--	--	--	--	--
New Hebrides	00	300	400	900	100	100	1,000	1,000	1,000	1,000	1,000
Milkfish											
Gilbert Islands	--	--	--	--	--	--	--	--	--	50	50
Hawaiian Islands[1]	9	11	6	15	14	12	8	4	5	7	4
Redfishes, basses, congers, etc.											
Gilbert Islands	--	--	--	--	--	--	--	--	--	245	245
Hawaiian Islands[1]	207	224	220	188	209	179	196	211	241	221	269
Marine fishes (N.E.I.)											
American Samoa	--	--	--	--	--	00	--	--	100	33	--
Christmas Island	--	--	--	--	--	--	00	00	00	0	0
Cook Islands	400	400	400	400	400	400	400	400	400	400	400
Fiji Islands	--	--	--	--	--	4,100	4,200	4,300	4,300	3,700	4,240
French Polynesia	2,900	3,200	3,200	3,200	3,200	1,400	1,500	1,600	1,900	1,673	1,566
Gilbert Islands	--	--	--	--	--	200	200	200	300	300	--
Guam	100	100	200	100	200	100	100	100	100	92	122
Hawaiian Islands[1]	8,199	5,094	4,485	4,958	3,487	4,172	6,837	5,709	5,577	4,291	3,520
New Caledonia	500	400	400	400	400	400	400	400	600	600	650
New Hebrides	00	200	200	200	200	200	200	200	200	200	200
Papua New Guinea	9,800	9,800	11,700	11,700	11,700	16,000	16,000	16,000	19,000	5,000	15,000
Solomon Islands	--	--	--	--	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Tonga Islands	--	--	--	--	--	--	500	500	600	726	901
Trust Territory of the Pacific Islands	700	800	1,000	1,000	1,000	00	00	00	100	145	145
Tuvalu	--	--	--	--	--	--	00	00	00	0	0
Western Samoa	900	900	900	900	900	900	900	900	900	900	1,000

00 = More than zero but less than 50 MT.

0 = More than zero but less than 0.5 MT.

N.E.I. = Not elsewhere included.

[1]Data are from Hawaii Division of Fish and Game, commercial fish catch, by species, 1965-75, mimeo.

Table 5.--Nominal catches of fishes, crustaceans, and molluscs in Hawaii.[1]

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Tunas, bonitos, billfishes															
Skipjack tuna, *Katsuwonus pelamis*	4,942	4,271	3,674	4,093	7,329	4,257	3,647	4,227	2,705	3,334	6,051	4,952	4,875	3,373	2,293
Yellowfin tuna, *Thunnus albacares*	208	180	175	227	226	228	226	188	192	320	389	375	349	523	781
Bigeye tuna, *T. obesus*	471	554	430	380	351	346	294	256	322	216	214	229	185	187	157
Striped marlin, *Tetrapturus audax*	103	125	152	228	175	144	181	188	144	156	87	78	64	89	106
Pacific blue marlin, *Makaira nigricans*	7	83	86	79	78	67	66	48	68	101	50	25	38	56	48
Wahoo, *Acanthocybium solandri*	12	11	14	15	14	10	18	13	16	20	18	24	34	33	53
Other tunas	7	14	34	20	10	21	34	24	30	17	24	25	29	25	73
Other billfishes	136	24	13	19	15	21	17	13	10	7	4	1	2	1	7
Redfishes, basses, congers															
Snappers, Lutjanidae	96	125	134	133	107	118	115	109	101	74	95	119	127	123	164
Goatfishes, Mullidae	61	48	58	57	49	45	36	30	37	36	34	36	41	33	33
Sea bass, Serranidae	9	10	15	11	10	15	11	10	10	18	22	17	23	18	27
Various reef species	45	40	49	50	41	46	58	39	61	51	45	39	50	47	45
Jacks, mullets, sauries															
Mahimahi, *Coryphaena hippurus*	53	49	58	39	41	39	33	33	26	34	52	79	52	50	53
Amberjack, *Seriola dumerilii*	35	39	48	43	34	45	31	39	33	32	38	26	30	15	14
Bigeye scad, *Trachurops crumenophthalmus*	130	99	68	73	204	283	387	429	362	445	371	394	325	284	232
Mackerel scad, *Decapterus pinnulatus*	95	174	182	133	86	100	96	111	98	79	104	78	94	98	146
Other jacks, mullets, barracuda	76	66	73	79	57	53	58	60	65	49	44	35	36	46	60
Herrings, sardines, anchovy															
Bonefishes, ladyfishes, Albulidae, Elopidae	14	8	14	14	13	13	13	16	13	13	7	17	18	18	11
Anchovy, *Stolephorus purpureus*	202	186	178	167	198	172	173	193	164	183	229	212	227	223	203
Marine crabs															
Frog crab, *Ranina serrata*	8	14	8	4	6	4	9	17	16	18	23	33	21	17	8
White crab, *Portunus sanguinolentus*	1	1	1	3	4	3	2	1	10	18	19	17	13	26	16
Other crabs	4	3	2	4	3	5	3	3	2	3	3	2	2	1	1
Lobsters															
Spiny lobsters, *Panulirus penicillatus* and *P. marginatus*	6	4	5	4	4	2	2	2	4	2	3	2	2	2	-
Molluscs															
Octopus, *Polypus marmoratus*	2	2	3	3	3	3	4	3	2	3	4	5	6	5	4
Squid, *Sepioteuthis arctipinnis*	4	5	2	4	1	3	1	2	1	3	6	1	5	2	2
Limpet, *Cellana* sp.	5	5	9	9	6	12	11	12	10	10	6	8	9	8	8

[1] Data are from Hawaii Division of Fish and Game, commercial fish catch, by species, 1961-75, mimeo.

Table 6.--Fish and shellfish catches, by type of gear, number of licensed commercial fishermen, and number of commercial fishing boats, Hawaiian Islands (Power 1963; Power and Lyles 1964; Lyles 1965, 1966, 1967, 1968, 1969; U.S. National Marine Fisheries Service, 1971, 1975, 1976; Wheeland 1972a, 1972b, 1975; Thompson 1974; Pileggi 1976; and files of the Western Pacific Program Office, National Marine Fisheries Service, NOAA, Honolulu, Hawaii 96812).

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Catch by gear:															
Lines - Hand and pole and line	5,133	4,490	3,912	4,576	7,740	4,698	4,097	4,682	3,127	3,674	6,573	5,481	5,401	3,962	3,069
Longline	1,100	1,157	1,096	854	774	751	709	612	642	698	522	478	353	377	339
Troll	20	25	32	37	40	44	55	31	60	79	54	61	110	224	424
Nets - Haul seines	238	203	194	191	218	185	213	213	207	202	233	215	246	228	208
Bag nets	100	66	46	57	155	219	314	336	260	326	244	268	201	119	84
Gill nets, anchored	28	15	26	27	29	40	44	48	48	66	62	82	96	139	115
Lift nets	46	104	94	70	45	54	52	66	55	53	72	64	68	64	54
Cast nets	--	--	1	2	1	2	3	2	4	3	3	2	3	3	2
Unclassified	7	14	22	18	23	26	15	7	6	4	5	5	15	3	5
Pots and traps	57	50	50	54	41	37	31	31	35	51	52	46	37	50	34
Spears	--	--	2	2	2	3	3	2	2	2	3	3	4	4	3
Hand	--	--	4	7	1	2	2	2	2	2	1	2	4	4	2
Other marine gear	4	4	<1	1	3	3	3	1	35	27	50	52	48	22	32
Pond gear	32	24	20	23	10	10	5	5	9	9	7	6	7	11	8
Licensed commercial fishermen															
Oahu	345	371	396	360	372	412	391	596	763	781	812	912	1,083	1,044	1,115
Hawaii	114	194	174	162	156	128	119	172	220	317	380	415	565	556	671
Maui	80	123	129	105	109	109	90	149	233	207	197	204	241	192	228
Kauai	27	52	52	56	52	42	55	72	81	84	96	101	139	138	145
Molokai	16	53	47	42	43	39	33	27	26	37	36	55	47	47	23
Lanai	7	24	22	18	12	14	11	16	15	10	18	10	16	15	15
Commercial fishing boats															
Oahu	149	203	212	203	188	196	201	286	350	360	395	410	507	410	515
Hawaii	53	79	101	99	89	62	57	97	155	204	290	317	425	397	475
Maui	36	50	56	61	59	71	64	78	108	112	116	97	127	116	141
Kauai	22	47	46	48	43	36	39	57	57	69	79	73	101	108	119
Molokai	13	21	17	12	18	16	15	13	10	17	14	25	29	25	19
Lanai	7	14	7	8	7	7	7	12	12	6	9	6	9	10	9

Table 7.--Catch, effort, and catch per effort of armorhead and alfonsin caught by Japanese trawlers over the central North Pacific seamounts in 1969-76 (Takahashi and Sasaki 1977).

Year	Catch		Effort (h)	Catch per effort	
	Armorhead (MT)	Alfonsin (MT)		Armorhead (MT)	Alfonsin (MT)
1969	8,280	27	157	20.892	0.172
1970	30,047	618	2,807	10.704	0.220
1971	5,891	68	1,304	4.525	0.052
1972	29,880	59	496	60.242	0.120
1973	25,047	34	740	33.847	0.046
1974	34,538	0	1,583	21.818	0.000
1975	18,952	0	1,377	13.763	0.000
1976	25,795	1,726	2,667	9.672	0.647

6.3.1 Anchovy, Stolephorus purpureus and S. heterolobus

The anchovy, S. purpureus, is a small (40-60 mm), fragile fish that school over sand and mud bottoms in scattered harbors and bays throughout the Hawaiian Islands. It possesses most of the qualities of good baitfish; therefore, it is the preferred bait in the Hawaiian skipjack tuna fishery (Uchida in press).

Regarded as one of the more important fish resources in the Hawaiian Islands because of its direct association with the skipjack tuna fishing industry, this anchovy, known locally as nehu, has been widely studied by several investigators (Hiatt and Tester 1950; Welsh 1950; Hiatt 1951; Tester 1951, 1955; Yamashita 1951; Tester and Hiatt 1952; Bachman 1963, Uchida in press; Wetherall in press). In determining the relationship between average catch per day of baiting and the number of days of baiting for three different baiting grounds in Hawaiian waters, Bachman (1963) determined that in 1948-60, there was no evidence that fishing had diminished the stock in Kaneohe Bay, Pearl Harbor, and Maalaea Bay. The Schaefer (1954) method for maximum sustained yield and catchability produced results for the stock fished at Pearl Harbor only. In the day-bait fishery here, the maximum sustained yield was calculated to be 18,620 buckets (100 MT), obtained at a fishing intensity of 691.5 boat days; catchability coefficient was -0.0022, a negative, meaningless value.

More recently, Wetherall (in press) examined nehu catch and nominal effort statistics from the Kaneohe Bay day-bait fishery to explore two sources of variation in baiting success: (1) nehu stock abundance and (2) abiotic environmental variables. The results showed that availability, catchability, or both, are reduced in January-April when rainfall is high and streamflow heavy, and enhanced in June-October when streamflows drop. Baiting success, however, was unrelated to nominal baiting effort.

For the skipjack tuna fishery in Palau, Muller (in press) determined a von Bertalanffy growth equation for S. heterolobus from length frequencies of fish collected from the commercial fishing fleet from December 1971 to July 1973:

$$L_t = 91\ (1-\exp(-0.0058(t + 3.4)))$$

where L_t = standard length in millimeters and

t = days

Total mortality for the 19-mo period was 6.0 yr^{-1} and average fishing mortality reached 3.0 yr^{-1}. Using the logistic models of Schaefer (1954) and Fox (1970), Muller obtained a maximum sustainable yield of about 80,000 buckets (160 MT) with an effort of under 2,000 boat nights. The dynamic pool model of Beverton and Holt (1957) gave the maximum yield per recruit at a fishing mortality of 5.0 yr^{-1}; however, at 3.6 yr^{-1}, or 2,000 boat nights, the yield per recruit was within 1.8% of the maximum. Muller concluded that the bait fishery in Palau is operating at the optimum level.

6.3.2 Bigeye scad, Trachurops crumenophthalmus

Excluding tunas and billfishes, the most heavily exploited major fish stocks are those of bigeye scad. Most of the fishing occurs in the Hawaiian Islands and French Polynesia. In Hawaii, the catches show wide annual fluctuations varying from around 70 to 444 MT in 1948-75. Kawamoto (1973) observed that present management regulations--the restriction of mesh size to not less than 3.8 cm and prohibition on netting fish of less than 21.6 cm in July-October--are presently effective because catches appear to be stabilized at a relatively high level of 360 MT annually.

6.3.3 Pelagic armorhead, Pentaceros richardsoni

There appears to be some indication that the pelagic armorhead stock has started to decline. Three Japanese trawlers fishing for this species off Midway atoll reported an average catch of 30 MT/day, considerably less than the break-even level of 40 MT/day (U.S. National Marine Fisheries Service 1976). These Japanese trawlers reported that armorhead landings in this area have declined sharply after a Soviet trawling fleet worked the same grounds for armorhead.

6.4 Other estimates of potential: Fishing surveys and exploratory fishing

6.4.1 American Samoa

Surveys in American Samoa in recent years have been concentrated on evaluating the potentials of bottom fishing, trolling, and pole-and-line fishing with live bait. On 19 research cruises of the research vessel "Alofaga," bottom fishing and trolling were combined and the total catch during that trial period amounted to 1,608 kg or about 85 kg/trip (South Pacific Commission 1977a). Fifty pole-and-line fishing trips with live bait yielded 14.2 MT or an average of 284 kg/trip.

Another of the important projects designed to boost American Samoa's economy is the evaluation of sport fishing development. During a 5-yr period in which 135 sport fishing surveys were conducted, 1,098 fish, weighing 5,800 kg or an average of 43 kg/trip, were caught. On an average trip of 5.8 h, therefore, the potential sport fishing catch reached 8.1 fish/trip. Among the species taken by the trolling gear were Pacific blue marlin, mahimahi, and skipjack tuna.

6.4.2 Cook Islands

In 1975, an outer-reef fishery project, which was started to survey the demersal and pelagic resources at Aitutaki, demonstrated that trolling for pelagic fishes, except wahoo, and bottom fishing during daylight would be economically unfeasible (Hume 1976). At night, however, handline catches were relatively good so that a reasonable return could be expected. The average catches from bottom fishing reached 71.4 kg/night-trip and 29.0 kg/day-trip, whereas the catch rates by trolling was only 25.9 kg/trip.

6.4.3 Fiji Islands

The potential for increasing fish yield in Fiji lies in harvesting the resources over the continental shelf. Aubray (1976) has estimated that perhaps 70% of the average potential yield of 15,000 MT, based on a minimum production of 15 kg/ha, would consist of demersal fish whereas the remaining 30% would constitute tuna and other pelagic species.

One of the pelagic species that has a tremendous potential for development is Spanish mackerel, *Scomberomorus commerson*. In 1975 and 1976, an estimated 20 and 26 MT, respectively, of this species were marketed in Fiji. Results of exploratory surveys in nearshore pelagic waters have shown that whereas the bulk of the Spanish mackerel taken prior to 1976 was by handlining, surface trolling is less labor-intensive and, therefore, more appropriate for catching this species (Brown 1977).

6.4.4 Hawaiian Islands

The Hawaii Division of Fish and Game, actively pursuing programs designed to develop new commercial fisheries, introduced marine species which have potentials for development as commercially exploitable resources in Hawaiian waters between 1955 and 1961. Of six species of groupers and five species of snappers introduced (Table 8), at least three species--*Cephalopholis argus*, *Lutjanus vaigiensis*, and *L. kasmira*--became fairly well established in Hawaiian waters (Hawaii DLNR (Department of Land and Natural Resources) 1969). Fishing for these species was opened to the public in October 1966 and at present *L. vaigiensis* and *L. kasmira* are caught by both sport and commercial fishermen.

Table 8.--Summary of the status of groupers and snappers introduced to Hawaiian waters (Hawaii DLNR 1967).

	Total number released	Year: 1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967[1]
Groupers														
Roi, *Cephalopholis argus*	2,385		R	X	X		X	R-X	X	X	X	X	X	X
Tarao,[2] *Epinephelus merra* and *E. hexagonatus*	2,612		R					R-X	X	X	X	X	X	X
Rero, *C. urodelus*	1,811				R-X	X	X	R-X		X	X	X	X	X
Matapuu, *E. fasciatus*	51				R-X	X	X	X						
Pukokoo, *E. spiniger*	22				R-X				?					
Snappers														
Toau, *Lutjanus vaigiensis*	2,232	R	R		R-X		X	R-X	X	X	X	X	X	X
Taape, *L. kasmira*	3,168	R			R-X	X	X	R-X	X	X	X	X	X	
Tuhara, *L. gibbus*	177				R			R-X	X				?	?
Aaravi, *Lethrinus* sp.	32		R		R			R						
Mexican snapper, *Lutjanus guttatus*	3,439						R-X	X		X				

[1]To 30 June 1967.

[2]*Epinephelus merra* and *E. hexagonatus* grouped together as "Tarao" due to similarity in appearance.

R - Year of release.

X - Species caught or sighted during the year.

? - Unconfirmed report of sighting.

Another project designed to increase fish populations is the creation of artificial reefs and the results appear to be extremely encouraging (Hawaii DLNR 1966). Creation of these artificial shoals with old auto bodies and damaged concrete pipes has significantly increased fish populations. The fish counts, however, show wide variations. At Waianae, Oahu, for example, estimates of the standing crop varied from 550 kg/ha to 1,444 kg/ha. Kanayama and Onizuka (1973) attributed the wide variation in fish densities to schools of surgeonfish, Naso unicornis and N. hexacanthus, gray snapper, amberjack, and mackerel scad, which wander freely in and out of the shoal area. Furthermore, artificial shoals have attracted commercially valuable species such as squirrelfish, Myripristis berndti, goatfish, Mulloidichthys auriflamma and M. samoensis, jack crevally, Carangoides ferdau, Japanese barracuda, Sphyraena helleri, and surgeonfish, Acanthurus olivaceus and A. dussumieri (Hawaii DLNR 1967).

In general, for three areas in which artificial shoals were created, fish densities have increased tremendously. At the Waianae, Oahu auto-body reef, the pre-reef density in 1962 reached 115 kg/ha; the post-reef values averaged 1,424 kg/ha or more than 12 times the pre-reef density (Kanayama and Onizuka 1973). The post-reef average reached 556 kg/ha where concrete pipes were used. At Maunalua Bay, Oahu, where the pre-reef density was only 41 kg/ha in 1960, the post-reef density averaged 938 kg/ha. The densities at Keawakapu, Maui were equivalent to 3 kg/ha for the pre-reef count in 1962 and 249 kg/ha for the post-reef count (Hawaii DLNR 1967, 1973).

By comparison, fish densities estimated from fish-counting transects in areas without artificial reefs were much lower. For example, in Kealakekua Bay, Hawaii, which has a relatively pristine environment, the densities ranged from 65 kg/ha to 750 kg/ha and averaged 245 kg/ha. This average is probably low as it reflects a bias due to positioning transects over sandy areas where fish are scarce. At Honaunau Bay, Hawaii, the count was equivalent to a density of 254 kg/ha and off Waikiki, Oahu, the density was 166 kg/ha. The highest fish density recorded in the Hawaiian Islands was off the island of Niihau, where pristine conditions exist. Here, the mean count was 308 kg/ha over a transect located on a substrate particularly favorable for fish (Doty et al. 1968).

In Northwestern Hawaiian Islands waters, carangids, snappers, and groupers offer good potentials. Fourteen exploratory fishing stations with handline yielded good catches of white crevally, Carangoides ajax, thick-lip crevally, Caranx cheilio, pink snapper, Pristipomoides microlepis, amberjack, Seriola dumerilii, and sea bass, Epinephelus quernus (cruise report, "Townsend Cromwell," cruise 67, 20 October-26 November 1975). Good catches were obtained near Gardner Pinnacles where 11 C. ajax totaling 181 kg were taken and at Laysan Island where 33 C. ajax weighing 293 kg were captured in 3 h of fishing with five handlines.

Among other fishing methods used to assess the fish resources in Northwestern Hawaiian Islands waters, trawling is potentially one of the most important, particularly over the numerous banks and seamounts. The Soviet and Japanese seamount trawl fisheries appear to be relatively well established, although, as mentioned earlier, there is some evidence of a decline in armorhead catches. Exploratory trawling, conducted by the "Townsend Cromwell" (cruise report, "Townsend Cromwell," cruise 67, 20 October-26 November 1975), demonstrated that at Middle Bank, which is 62 m below surface, there were sizable concentrations of three species of acanthurids, Naso brevirostris, N. hexacanthus, and N. lopezi, a small serranid, Caesioperca thompsoni, and an introduced lutjanid, Lutjanus kasmira. Catch rates ranged up to 110 kg/h for Naso spp., 129 kg/h for C. thompsoni, and 41 kg/h for L. kasmira. Four daylight hauls at Middle Bank yielded from 33 to 230 kg, which when extrapolated indicate catch rates of 44-414 kg/h or an average of 242 kg/h. Assuming an effective trawl sampling width of 11.5 m using a "Norwegian" trawl with a 19.2-m headrope and an 25.3-m footrope, the standing biomass at Middle Bank was calculated to be 855-8,137 kg/km^2 or an average of 4,680 kg/km^2. These values compare favorably with estimated densities of demersal stocks in the region of the South China Sea, which range from 1,250 to 5,000 kg/km^2.

Five trawl stations occupied by the "Cromwell" north of Nihoa also yielded good catches. The catches, which varied from 83 to 158 kg/h and averaged 117 kg/h, indicated a standing biomass of 1,011-2,074 kg/km^2. Catches at Nihoa Bank, which is relatively shallow at 48-55 m, were dominated by N. brevirostris, N. hexacanthus, and Acanthurus olivaceus.

At a depth of 29-48 m near Necker, two daylight hauls by the "Cromwell" yielded relatively poor catches. A single night tow, however, produced a catch equivalent to a rate of 512 kg/h and to a standing biomass of about 8,028 kg/km^2. Although a variety of species was caught at this location, N. hexacanthus was again the dominant species. Trawl catches from deeper areas around Necker were very poor as were those made at St. Rogatien Bank.

Fish and shrimp traps also have been fished experimentally in waters of the Northwestern Islands. Snapper, locally called "opakapaka," were caught in fair numbers on four occasions in traps fished at the shelf edge north of Necker in 44-57 m of water. Catches ranged from 4.5 to 7.7 kg/set and averaged 5.4 kg. Near Kure, one trap, fished at 48 m produced 18.4 kg of Caranx cheilio. Two of 12 traps fished at Lisianski produced 16 and 48 kg of Carangoides ajax.

Surveys of the nearshore fishery resources also have been conducted in waters of the Northwestern Hawaiian Islands by the Hawaii Division of Fish and Game (narrative report, "Townsend Cromwell," cruise 76-04, 3 May-9 June 1976). Surveys around Nihoa, French Frigate Shoals, Laysan, and Necker showed that the carangids and sharks were relatively large compared to those found in waters of the major Hawaiian group and also more numerous. Members of the families Chaetodontidae, Apogonidae, Pomacentridae, Muraenidae, Holocentridae, and Acanthuridae, commonly associated with similar habitats in waters of the major Hawaiian group, were noticeably absent near the islands surveyed.

Fish counting transects demonstrated that densities were highest at Whale-Skate Island in the French Frigate group. Here, the estimated density averaged 4,744 kg/ha with goatfish, Mulloidichthys samoensis, C. ajax, and parrotfish, Scarus perspicillatus of major importance (Table 9). The lowest density occurred at Nihoa where the average was only 165 kg/ha with the pomacentrid, Chromis ovalis, and surgeonfishes, Ctenochaetus strigosus and Naso lituratus, the most predominant species.

Table 9.--Results of fish counting transects.

Location	Number of fish species	Estimated densities (kg/ha)	Major fish species ranked in terms of greatest densities
Nihoa Island	26	165	1. Chromis ovalis 2. Ctenochaetus strigosus 3. Naso lituratus
French Frigate Shoals			
East Island	29	2,219	1. Scarus perspicillatus 2. Kyphosus cinerascens 3. Mulloidichthys samoensis
Whale-Skate Island	32	4,744	1. Mulloidichthys samoensis 2. Carangoides ajax 3. Scarus perspicillatus
Laysan Island	34	848	1. Scarus perspicillatus 2. Acanthurus triostegus (= A. sandvicensis) 3. Thalassoma purpureum (= T. umbrostigma and T. fuscum)

In terms of species density, M. samoensis reached 2,206 kg/ha but S. perspicillatus was only slightly lower at a density of 2,183 kg/ha. When numbers of individuals were examined, however, the small round herring, Spratelloides delicatulus, was most numerous, occurring at a rate of 123,500 individuals/ha (Table 10).

Table 10.--Ten species of fish observed during underwater fish counting transects, ranked by estimated densities and number of individuals counted (narrative report, "Townsend Cromwell," cruise 76-04, 3 May-9 June 1976).

Rank	Common name	Scientific name	Density (kilograms per hectare)	Occurrence (number of stations)
		Estimated densities		
1	Weke-'a'a	Mulloidichthys samoensis	2,207	3
2	Uhu uliuli	Scarus perspicillatus	2,183	3
3	White ulua	Carangoides ajax	1,145	1
4	Nenue	Kyphosus cinerascens	626	4
5	Kala	Naso unicornis	430	4
6	Manini	Acanthurus triostegus (= A. sandvicensis)	420	4
7	Hinalea	Thalassoma purpureum (= T. fuscum and T. umbrostigma)	170	3
8	'Omilu	Caranx melampygus	143	3
9	Hinalea luahine	Thalassoma ballieui	95	4
10	White banded maiko	Acanthurus leucopareius	91	4
		Number of individuals		
1	Piha	Spratelloides delicatulus	123,500	2
2	Weke-'a'a	Mulloidichthys samoensis	2,485	3
3	Manini	Acanthurus triostegus (= A. sandvicensis)	590	4
4	Nenue	Kyphosus cinerascens	548	4
5	Uhu uliuli	Scarus perspicillatus	445	3
6	Kole	Ctenochaetus strigosus	267	4
7	Hinalea lau-wili	Thalassoma duperreyi	259	3
8	Blue damselfish	Chromis ovalis	247	1
9	Kala	Naso unicornis	242	4
10	'Omaka	Stethojulis balteata (= S. axillaris and S. albovittata)	185	2

6.4.5 Line Islands

Christmas Island, in the central equatorial Pacific, has been suggested as a possible site for a sport fishing resort. Helfrich (1973), who studied the feasibility of brine shrimp, Artemia salina, production on the island, recognized the potential for sport fishing resort development. Christmas Island, according to Helfrich, offers not only superb light-tackle fishing for bonefish and jack crevally but also ocean trolling for other game fish including yellowfin and skipjack tunas, wahoo, mahimahi, billfish, barracuda, and shark. Twenty-five and a half line hours of trolling yielded 42 fish totaling 361 kg or an average of 1.65 fish/line hour. In bottom fishing off the outer reef, catches varied from only a few red snappers, Lutjanus bohar and L. gibbus, per night to about 120 fish/h.

6.4.6 New Caledonia

Experimental deepwater handline fishing in New Caledonia, concentrated primarily on snappers and groupers at depths between 120 and 400 m, demonstrated that Pristipomoides flavescens were widespread at depths of 150-300 m and P. filamentosus occurred in large schools at depths as shallow as 30 m but usually down to 280 m (Fourmanoir 1973). Also found were P. sieboldi, usually caught at depths beyond 180 m and P. typus, a rather large snapper which were plentiful at depths of 190 and 210 m. Snappers of the genus Etelis were also caught but usually at greater depths. Etelis carbunculus usually occurred at 230-350 m whereas E. oculatus were found deeper at 400 m. Groupers, Epinephelus compressus, E. morrhua, and E. chlorostigma, were also prominent in the catches with E. compressus occurring in some abundance at 290 m.

6.4.7 Papua New Guinea

Based on current production, Wilson (1976) projected catches of several species groups from Papua New Guinea's waters in 1982 as follows: tuna - 68,000 MT; shrimps - 1,630 MT, lobsters - 360 MT; barramundi - 450 MT; baitfish - 1,360 MT; crabs - 180 MT; coastal species - 27,220 MT; and miscellaneous - 20 MT.

Studies conducted in Papua New Guinea indicate that, at present, there is no danger to any of the stocks fished, but barramundi catches may be close to the maximum sustainable yield and a major increase in fishing effort for this species will be discouraged (FDNIDA 1976). The lobster catch in the Daru reef area could be significantly increased without damage to the stock. Other studies have shown that marketable sharks and threadfins, Polydactylus sheridani and Eleutheronema tetradactylum, are abundant and could withstand increased harvesting. Lack of accurate statistics in the shrimp fishery prevents the formulation of suitable guidelines, but some control measures, particularly in the amount of fishing effort, will probably be adopted and modified as more accurate statistics become available.

Mixed reef-fish catches are not recorded accurately, but because coral reefs extend around most of the coast, the total production could be substantial. Offshore, in addition to skipjack tuna, small stocks of longtail tuna, Thunnus tonggol, are available but perhaps 1,000 MT would be its limit.

6.4.8 Solomon Islands

Among the options being considered for development in the Solomon Islands are fisheries for gem coral and deepwater demersal fishes. Initial results of a gem coral survey were inconclusive but further explorations are being planned (James 1977b). Offshore deepwater handline fishing surveys have indicated excellent catches of several tons per day of demersal fishes and, according to James, could possibly become an alternate fishery to the skipjack tuna pole-and-line fishery and gem coral harvesting. New fishing techniques are also being tried--bottom longlining and tangle netting have aroused keen interest among the local fishermen.

6.4.9 Tonga Islands

The prospects for developing fishery resources in the Tonga Islands appear to be extremely good because of the extensive shallow-water areas available to the fishermen (Wilkinson 1977b). The fishing grounds are all within cruising range of 30-40 fishing boats ranging in size from 9 to 12 m. In these shallow waters, the demersal stock, composed mainly of lethrinids and lutjanids, undergoes distinct seasonal migrations involving distances of up to 150 km between coral reef systems. Exploratory handline fishing has yielded catches dominated by Lethrinus lentjan, L. miniatus, L. variegatus, Pristipomoides typus, P. argyrogrammicus, and Cephalopholis sp. (Lorimer and Maclean 1974).

Initial trials with the Japanese fixed trap net (teichi-ami) have also been highly successful in Tongan waters (Wilkinson 1977a). One trap, fishing continuously at Pangaimotu near Tongatapu, produced 6.5 MT of several species of fish including T. crumenophthalmus, Harengula ovalis, Dussumiera sp., and Decapterus sp. Of these, Wilkinson considered 53.2% were of suitable size as live bait for skipjack tuna fishing, whereas the larger fish had a ready market among the local residents.

Fishery development projects also include establishment of a market infrastructure--cold storage facilities, transport, and introduction of modern, dory-type dual purpose fishing boats, which would be used to exploit pelagic species such as tunas when seasonally abundant and demersal species in the off-season for tuna (Wilkinson 1974).

6.4.10 Trust Territory of the Pacific Islands

The success of the dory project in American Samoa prompted other island governments in the Pacific to investigate the possibility of initiating similar projects. Among them was Ponape's Community Action Agency which launched a dory-building project by constructing a dory boat works in 1971. By 1973, the agency had constructed and launched eight dories which were designed for trolling and handline fishing nearshore (Perez and Sablan 1974).

The dories presently operating are 7.5 m long, equipped with citizen-band radios, and inboard Ford[4] engine with Hamilton jet pump. Among the fishes caught by trolling were skipjack and yellowfin tunas, wahoo, marlin, mahimahi, rainbow runner, dogtooth tuna, and other offshore pelagic species. Reef and bottom fishes caught by handlining or spearfishing included grouper, snapper, parrotfish, and jack crevally.

Data on fishing effort, catch, and catch per effort for the Ponape dory fleet for March 1973-March 1974, showed that during this period, 443 trolling trips for tuna and tunalike fishes produced 38.3 MT or an average of 85.6 kg/trip. Sixty-four handlining and spearfishing trips yielded only about a tenth of the trolling trips or 3.9 MT of reef fishes for an average of 60.5 kg/trip. Monthly indices of apparent abundance of tuna and tunalike fishes tended to be high in July, August, and October and low during other months of the year.

In surveys conducted in the Yap District, trolling gear, usually used when weather condition did not permit bottom fishing, produced catches of dogtooth tuna, wahoo, green snapper, Aprion virescens, barracuda, and small amounts of yellowfin tuna. Catches were relatively good in the passes of the larger atolls and along submerged reefs and banks at the 21-36 m depth contours. On days with good catches, for example, McCoy (1977) reported that up to 454 kg of dogtooth tuna were caught. In February-April 1976, catch of troll-caught species varied from 159 to 227 kg/day. In experimental handline fishing from skiffs, catches of red snapper (mostly Lutjanus bohar) and jack crevally varied from 122 to 272 kg/day/skiff.

6.4.11 Tuvalu

In 1976, a project to survey the outer-reef fishery resources around Tuvalu got underway. Fishing with handline for bottom fish along the outer slope of the barrier reef was very disappointing. Because of the steepness of the outer slope, the dory used in the bottom fishing survey encountered difficulty anchoring over the drop-off. To hold the dory in place over the fishing ground, an anchor was lowered in shallow water and enough warp paid out to fish over the desired depth. This was possible, however, only if the wind remained constant and blew offshore. Deepwater species such as Ruvettus sp., Etelis sp., and Pristipomoides sp., which were the major target species of the survey, occurred in well-defined depth ranges. Night fishing usually proved to be more productive than day fishing (Eginton 1977).

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

In 62 days of trolling and bottom fishing conducted by two dories in September-November 1976, 180.5 kg of pelagic fishes were caught by trolling and 2,417.5 kg of bottom fish by handline. The catch from troll and bottom gear reached 2,598 kg or an average of 41.9 kg/day. Ruvettus pretiosus constituted the largest proportion of the catch, by weight, accounting for 14% whereas lethrinids (13%), L. bohar (12%), and Katsuwonus pelamis (11%) were also important in the catch.

A small-craft evaluation project was also begun to assess the type of boat and engine most suitable for Tuvalu's fishermen (South Pacific Commission 1977c). Studies showed that trolling was economically feasible because of the presence of a substantial tuna resource on grounds that were readily accessible to small-craft operation. Gill-netting experiments also proved that a low-cost, small-craft fisheries could be a viable enterprise as catches by local fishermen proved profitable. And fishing for flyingfish demonstrated possible catches of up to 30 kg/h.

Because of the short time involved in the Tuvalu outer-reef fishing survey, data were insufficient to attempt even a preliminary evaluation of the fish resources. Reports from the local troll fishermen and from the survey staff indicate, however, that the skipjack tuna stock off the atoll appear to be quite substantial. More observations are necessary to obtain an index of school density in space and time. Deepwater fish resources, on the other hand, appear to be quite limited because of the very narrow band of shelf area just outside the barrier reef. Furthermore, there are no off-lying banks and seamounts rising sufficiently close to the water surface to support a possible offshore fishery. The fish resources of the lagoon appear to be underexploited at the present time, but because the lagoon area is only about 260 km^2, it appears doubtful that the lagoon fisheries could be expanded or support anything other than one at a subsistence level for local consumption.

6.4.12 Wallis and Futuna Islands

It was not until the latter part of 1970 that the government, through their Department of Rural Economy, set up a boat-building center to train the local natives in boatbuilding (South Pacific Commission 1977b). The dory and flat-bottomed skiff, both widely used in Canada, Newfoundland, and along the United States Atlantic coast, were selected as most suitable for local use. These crafts were seaworthy, economical to operate, and well-adapted to local, small-scale fishing needs. By the end of 1974, 80 crafts were in operation.

Because the lagoon fishery resources were seriously depleted by dynamiting and plant-poison method of fishing, it soon became evident that still larger crafts were needed to fish the outer-reef resources. Construction of several 8-m St. Pierre dories began in 1974. By 1976, the fishing fleet of small and large dories, skiffs, and marine plywood canoes reached 115 crafts. Demand for fishing crafts remains strong as more of the islanders return to sea to obtain fresh fish for their villages. The Department of Rural Economy anticipates yearly boat production to be maintained at about 10-15 small and 2-3 large crafts. Also included in the fisheries plan are construction of insulated ice chests and installation of an ice-making machine.

6.4.13 Western Samoa

A demonstration team of two boats with outboard motors and each manned by two fishermen taught fishing techniques in Western Samoa for an 11-mo period (Gulbrandsen 1977). The results demonstrated that an 8.5-m boat operated by an experienced crew can catch up to 10 MT of bottom fish in about 115 trips per year.

Two types of fishing crafts were deemed sufficiently seaworthy to remain at sea for night fishing and also provide reasonable comfort in the choppy waters often encountered around Samoa. One was a catamaran-type boat, a modified version of the local double-hulled canoe but built of pressure-treated marine plywood. The other was an 8.5-m, 20-hp, diesel-powered boat averaging speeds of 9 knots.

Data that can be used for resource assessment of outer-reef bottom fishes are practically nonexistent. For comparison, however, the catch rate of 3 kg/reel-hour, achieved by bottom fishing in Samoan waters, is less than half of the 6.8 kg/reel-hour obtained by the UNDP/FAO Carribean Fishery Development Project. Gulland (1971) estimated that the potential yield for groupers and snappers in the Carribeans is 2-10 kg/ha, similar to figures in other less productive parts of the world. Gulbrandsen, applying a catch rate of 0.5 MT/km^2 and a shelf area of 2,000 km^2 for Western Samoa, estimated that the annual potential catch of bottom fish could reach 1,000 MT. (The depth to which the shelf area was estimated is not given.)

The Government of Western Samoa has also embarked on upgrading the existing fishing fleet. Traditional fishing canoes, once the foundation of the island's nearshore fishing fleet, are rapidly being replaced by catamaran-type and diesel-powered boats. In 1976, Philipp (1977) estimated that the Western Samoan fleet of 160 small, miscellaneous boats of under 2 tons carrying capacity caught a wide variety of fish totaling 500 MT. An additional 200 MT were taken by net and spear fishermen primarily inside the reef.

6.5 Crustaceans

Crustaceans constitute only a minor proportion of the Hawaiian catch. Presently, the species exploited include spiny lobsters, *Panulirus marginatus* and *P. penicillatus*, squat lobster, *Scyllarides squammosus*, shrimp, *Penaeus marginatus*, kona crab, *Ranina serrata*, white crab, *Portunus sanguinolentus*, red crab, *Podophthalmus vigil*, and mangrove crab, *Scylla serrata*. The gear most commonly used to capture crustaceans include traps, anchor nets, and lift nets. Yaldwyn (1973) estimated that there are at least 450 species of decapod crustaceans in Hawaiian waters.

The decapod crustacean fauna of South Pacific reefs and islands probably total somewhere between 400 and 800 species (Yaldwyn 1973). The two most strongly represented families in the South Pacific region are the snapping shrimps, Alphaidae, and the dark-fingered crabs, Xanthidae. Other well represented and ecologically important groups include the commensal and freshwater shrimps, Palaemonidae, the large spiny lobsters, Palinuridae, the nocturnal land hermit crabs, Coenobitidae, and the related land crab, Gecarcinidae, the swimming crabs, Portunidae, and the shore crabs, Grapsidae, most of which are important as food. Yaldwyn suggested that based on a mid-figure of 600 species, there are at least 150 species of shrimps, 325 species of crabs, and 125 others. The decapod fauna of the South Pacific region is part of that within the Indo-Pacific region and shows strong attenuation in genera and species from west to east.

6.5.1 Frog crab

Of the 33 MT of crustaceans caught in Hawaiian waters, kona crab is usually the most important, constituting about a third and sometimes up to three-fourths of the landings (Table 11). Virtually the entire catch of kona crab is taken over sandy bottom in waters which range from less than 6 m up to 90 m in depth. Onizuka (1972) has shown that a large proportion of the catch comes from Penguin Banks off the western coast of the island of Molokai; the northern coastal waters off Niihau is next in importance. Knowledge of the resources of this species throughout the rest of the major Hawaiian Islands is relatively poor.

Catches of this species in 1961-72 rose from 4 to 33 MT but declined in subsequent years and by 1975, only 8 MT or about one-fourth of the 1972 catch was reported.

Regulations presently in effect prohibit capture of ovigerous females and marketing crabs with carapace width or length of less than 10.2 cm. The regulation on size, however, does not afford the protection intended for the immature crabs, because those that are undersized are taken for home consumption (Onizuka 1972).

Catches of white crab in Hawaiian waters, which have also shown an upward trend in recent years, varied between 1 and 4 MT in 1961-68, but rose to higher levels and fluctuated between 10 and 26 MT in 1969-75.

Table 11.--Nominal catches of marine crustaceans, marine crabs, lobsters, shrimps and prawns, molluscs, and marine shells in western central Pacific islands (in metric tons) (FAO 1970, 1975c, 1976b).

	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Marine crustaceans											
Cook Islands	00	00	00	00	00	00	00	00	00	0	0
Fiji Islands	--	--	--	--	--	--	--	--	100	188	196
New Caledonia	100	100	100	100	100	100	100	100	200	268	250
Marine crabs											
Hawaiian Islands[1]	13	12	14	21	29	39	46	52	37	44	25
Papua New Guinea	--	--	--	--	--	--	--	--	--	150	450
Lobsters											
American Samoa	00	00	00	00	00	00	--	--	--	1	--
French Polynesia	--	--	--	--	--	00	00	00	00	0	2
Hawaiian Islands[1]	4	2	2	2	4	3	3	2	3	2	--
Papua New Guinea	--	--	--	--	--	--	--	--	--	340	265
Trust Territory of the Pacific Islands	--	--	--	--	--	--	00	00	00	5	5
Shrimps and prawns											
French Polynesia	00	00	00	00	00	00	00	00	00	0	0
Guam	--	--	--	--	--	--	--	--	--	--	0
Hawaiian Islands	<1	<1	<1	<1	<1	1	1	<1	<1	2	3
Papua New Guinea	--	--	--	--	--	--	300	800	1,000	668	417
Trust Territory of the Pacific Islands	--	--	--	--	--	--	00	00	00	0	0
Molluscs											
Cook Islands	600	600	600	600	600	600	600	600	600	600	600
Hawaiian Islands[1]	11	19	16	16	13	16	17	14	21	14	14
New Caledonia	200	200	00	00	00	00	00	00	00	0	0
Marine shells											
Fiji Islands	--	--	--	--	--	--	--	500	600	271	320
French Polynesia	--	--	--	--	--	00	100	100	00	0	0
New Caledonia	100	100	00	00	00	00	00	00	00	0	0
Papua New Guinea	300	300	400	400	400	400	--	--	--	--	--
Solomon Islands	--	--	--	--	--	--	--	--	--	317	534

00 = More than zero but less than 50 MT.

0 = More than zero but less than 0.5 MT.

[1]Data are from Hawaii Division of Fish and Game, commercial fish catch, by species, 1965-75, mimeo.

6.5.2 Spiny lobsters

Whereas the commercial catch of spiny lobsters in Hawaii has declined significantly from nearly 60 MT in 1900 (Morris 1968) to about 2 MT in 1974, surveys show that there are probably unfished resources of spiny lobsters at depths not fished by present methods in waters around not only the major Hawaiian Islands but also around the Northwestern Hawaiian

Islands. In 1965, scientists in a small research submarine, explored the ocean bottom to depths of 183 m off the coast of Oahu and observed rather large quantities of spiny lobsters at depths between 24 and 107 m (Strasburg et al. 1968). From one small viewing port, about 70-80 lobsters were seen. At 107 m, about 20 lobsters were crowded in a small cave. The largest of these lobsters was estimated to be about 3.2 kg in weight as compared to 0.5-0.9 kg of an average reef-caught lobster.

Experimental fishing with the 1.5 x 1.5 x 1.2 m and the 0.6 x 0.6 x 1.2 m traps for the spiny lobster, Panulirus marginatus, showed that catches from various locales within the Northwestern Hawaiian Islands were quite variable (Uchida and Hida 1977). For example, the best catches occurred off Necker Island where 17 traps fished at 27-57 m produced 160 lobsters or an average of 9.4 lobsters/trap. Here, the average size reached 0.6 kg. Traps fished near the edge of the bank in 44-57 m of water produced the best catches. At a station north-northwest of Nihoa Island, 11 traps, fished in 44-48 m of water produced 41 lobsters or an average of 3.7 lobsters/trap, weighing an average of 0.9 kg each. Catches were relatively poor at stations occupied near Pearl and Hermes Reef, Kure Island, Lisianski Island, Laysan Island, and Gardner Pinnacles. The commercially valuable kona crab occurred in traps set in 46-55 m of water off Pearl and Hermes Reef and Kure Island. Three traps at Kure produced 4.5-27.2 kg/trap or an average of 13.9 kg/trap.

Fishing with the 1.5 x 0.9 x 0.6 m Hawaiian trap and the 0.9 x 0.6 x 0.4 m California two-chambered lobster pots on another cruise also yielded good catches of spiny lobsters around Necker Island. Among six sets made during the cruise, one set produced a spectacular 428 lobsters. At this particular set, the Hawaiian traps produced 229 lobsters or an average of 19.1/trap. The California pot, being much smaller in size and total volume, yielded 199 lobsters or an average catch of 16.5/trap. The maximum catch at one station, consisting of a string of four traps, was 106 lobsters or an average of 26.5/trap. For individual traps, one Hawaiian trap yielded a maximum of 49 lobsters while the maximum for a California pot was 33 lobsters.

In the Gilberts, commercial concentrations of spiny lobsters, P. penicillatus, have been reported from many of the islands in the group, but development of this fishery has been delayed because of problems involved in transporting live lobsters from the place of capture to the markets (Gibson 1975). Experiments on live storage indicated that feeding during storage and transporting did not reduce mortalities significantly and that lobsters fed daily and transported in wet or dry sawdust had a higher survival rate than unfed ones transported in wet jute sacking, particularly for journeys longer than 8 h (Prescott 1977).

The commercial development of the Papua New Guinea spiny lobster, Panulirus ornatus, fishery, which began in 1961-62 with establishment of shoreside cold storage and processing facilities at Yule Island, has been described by Pyne (1970), George (1972), and Wilson (1976).

Briefly, fishing from small canoes or dinghies, either towed to the grounds by 7-m diesel-powered dories or with sail, takes place over shallow reef tops at night with the use of kerosene lamps and pole nets and during the day by divers using surround nets, spears, and tangle nets.

At Yule Island, because the fishery depends on seasonal migration of spawning aggregation of P. ornatus, major fluctuations occur in annual landings. At Daru reefs, however, the fishing is not seasonal. Studies indicate that the Daru reefs stock is not a local population but part of a much larger migratory population, which continuously restocks the reefs as it moves north from the large reef complexes in Torres Strait (FDNIDA 1976; Moore and McFarlane 1977).

Spiny lobsters in Papua New Guinea are also taken by trawlers. This fishery began in 1973, and is active from August to December when the lobsters migrate and captures the largest proportion from Papua New Guinea waters. Of the larger trawlers (>20 m), 24 fished for lobsters in 1973 and 1974, but the number declined to 4 in 1975 and 12 in 1976.

6.5.3 Shrimp

In 1967-68, the National Marine Fisheries Service's research vessel, "Townsend Cromwell," surveyed 4,974 km^2 of bottom area in Hawaiian waters and found 2,106 km^2 trawlable, 2,280 km^2 untrawlable, and 587 km^2 marginally trawlable (Yoshida 1972). One relatively large, uninterrupted area of trawlable bottom was located north of the island of Hawaii. One hundred and nineteen drags made with the Gulf of Mexico-type, flat shrimp trawl yielded penaeid shrimp, Penaeus marginatus, flatfishes, Bothidae and Pleuronectidae, spiny lobster, Panulirus marginatus, and white crab.

Yoshida reported that the shrimp, caught in depths between 27 and 234 m on sandy and sand-mud substrate, was the most promising species for the development of a commercial fishery. The catches of this species, which ranged from 0.45 to 16.10 kg/drag, were always better at night than during daytime.

In attempts to capture Penaeus marginatus in Hawaiian and Northwestern Hawaiian Islands waters with other types of gear, Struhsaker and Aasted (1974) conducted deepwater shrimp trapping surveys. A total of 82 sets involving 306 traps and 3,960 h of fishing time in the 135-825 m depth range yielded poor results. More success, however, was experienced in trapping caridean shrimps, Heterocarpus ensifer and H. laevigatus. For these caridean shrimps, burlap cloth-covered traps outfished uncovered traps by factors of 2.5 to 10.

Heterocarpus ensifer was most abundant in depths of 365-455 m where catches ranged from 6.8 to 28.6 kg/trap for sets of less than 24-h duration. The larger H. laevigatus was abundant in deeper waters ranging from 440 to 685 m where catches ranged up to 15.8 kg for four traps.

Struhsaker and Aasted indicated that traps are a much more efficient means of harvesting H. ensifer in Hawaii and concluded that an annual yield of 1 or 2 MT/km^2 for Hawaiian waters does not seem like an unreasonable estimate. The total area of optimum depth range for H. ensifer within the major Hawaiian Islands has not been precisely determined but probably exceeds 1,000 km^2.

Comparison of catch rates for H. ensifer showed that in the western Atlantic, exploratory trawl catches by the NMFS were of the same magnitude as those in Hawaiian waters (Struhsaker and Aasted 1974). Limited trapping experiments near Guam in the western Pacific also produced catches similar to those in Hawaii. Struhsaker and Aasted speculated that H. ensifer and other members of this genus represent an unexploited resource of considerable magnitude.

Scientists aboard the "Townsend Cromwell" also surveyed waters of the Northwestern Hawaiian Islands with a 12.5-m headrope, semiballoon shrimp trawl at depths of 29-37 m and in deeper waters ranging from 400 to 785 m. Catches were small; the deeper hauls produced the caridean shrimps, H. ensifer and H. laevigatus, at the rate of 0.7-0.9 kg/h.

Papua New Guinea's shrimp fishery, concentrated in waters less than 55 m (30 fathoms) along the coast in the Gulf of Papua and the western provinces, is based on three species--banana shrimp, Penaeus merquinensis, the endeavour shrimp, Metapenaeus endeavouri, and the tiger shrimp, P. monodon. The fishery is seasonal, primarily from March to July with much of the fishing occurring in the Gulf of Carpentaria. In January-February endeavour shrimps are plentiful off Kikori, whereas from March to July, banana and endeavour shrimps occur in the Gulf of Papua but are most abundant off the mouth of the Fly River and Kerema. In 1976, Wilson (1976) reported that the trawling fleet consisted of four 100-250 GT (gross tons) and three 15-m single-rigged shrimp trawlers based at Port Moresby. Two other trawlers operated out of Yule Island.

6.6 Molluscs

In Hawaii, there are several large beds of American oysters, Crassostrea virginica, in

West Loch, Pearl Harbor. According to standards established by the U.S. Public Health Service for oyster growing waters, the estuarine waters of Pearl Harbor are grossly polluted; therefore, no harvesting of oysters is permitted. The Hawaii Division of Fish and Game, nevertheless, actively pursues research in oyster culture. In 1962, there were 19 major beds in West Loch containing about 36 million live oysters (Hawaii DLNR 1971; Kawamoto and Sakuda 1973). The total area of the beds, which was estimated to be 125,400 m^2 in 1962, increased to an estimated 175,600 m^2 by 1971, an increase in culturing area of about 40%. The number of live oysters, on the other hand, decreased during this period by about 3%; however, the larger sizes of oysters encountered in 1971 resulted in a 127% increase in estimated production to 126,459 bushels.

Kawamoto and Sakuda (1973) determined that oysters attain maturity at 2 mo and legal harvesting size at 15 mo in West Loch. The annual mortality rate was estimated at 68.7%. Studies also showed that oysters increased from a subcommercial quality (condition index 6.1) to a commercially acceptable quality (condition index 8.0) in 3 weeks by using an artificial feeding regime. A depuration experiment demonstrated that oysters previously in a restricted area could be cleansed within 1 week to an acceptable condition for marketing.

Reported landings of molluscs in the Hawaiian Islands, which averaged about 15 MT in 1961-75, are lower than the actual catch, but it is difficult to estimate the unreported landings of the recreational fishermen. Nearly 60% of the reported catch is composed of limpet, Cellana exarata and C. sandwicensis, locally called "opihi," whereas the remainder of the catch consists of octopus, Polypus marmoratus and P. ornatus, and squids, mostly Notodarus hawaiiensis. Harvesting of clams, Venerupis philippinarum, is regulated by the Hawaii Division of Fish and Game and is usually allowed for 3 mo--September-November--after it has been determined that clams are sufficiently abundant to allow fishing and provided that waters in the clamming grounds have been declared free of bacterial contamination.

In French Polynesia, one of the important fisheries is that for blacklip pearl shell, Pinctada margaritifera. Because of the heavy fishing pressure exerted by pearl shell divers, government regulations have been instituted to protect the resources of pearl shell (Van Pel 1961). Each year, some lagoons or sections of lagoons are opened for pearl shell harvesting once every 4 yr. A minimum size regulation is also enforced. Each lagoon includes one reserved area where absolutely no harvesting is permitted.

In 1957, Trochus niloticus was introduced on reefs of Tahiti from New Caledonia. The success of these plantings have resulted in the establishment of a fishery where methodical harvesting is allowed (Doumenge 1973). Harvesting is strictly supervised through a special ordinance of the Governor of French Polynesia.

Harvested in large quantities by the local residents in Tonga are arc shell, Andara maculosa, which comprises nearly 50% of the shellfish sold, giant clams, Tridacna gigas and T. maxima, up to 45 cm long, small scallops, blacklip pearl shell, venus shell, and thorny oyster, Spondylus sp. Popular gastropods include spider shell, Lambis lambis, tiger and egg cowries, Cypraea tigris and Ovula ovum, various species of Murex, and the triton, Charonia tritonis (Lorimer and Maclean 1974).

6.7 Echinoderms

Sea urchins and, in particular, sea cucumbers form a very important segment of the bottom fauna within the coral reefs of many of the central and western Pacific islands. They also constitute part of the diet of many Pacific islands.

Bêche-de-mer formed the basis of a very prosperous fishery in the Pacific region before World War II. Truk Island in Micronesia, for example, exported 450 MT (20-30/yr) mostly to Japan during the period of Japanese administration prior to World War II (1914-41). Two world wars interrupted the growth and continued development of this fishery in Micronesia and New Hebrides, but there is growing interest among the Pacific islands government to revive it (Smith 1947; South Pacific Commission 1974). In Papua New Guinea, Solomon Islands, and Fiji, the fishery has made a modest revival in recent years.

Among the commercially exploitable species of sea cucumbers are teatfish, Microthele nobilis, blackfish, Actinopyga miliaris, deepwater redfish, A. echinites, surf redfish, A. mauritiana, stonefish, A. lecanora, pricklyfish, Thelenota ananas, sandfish, Holothuria scabra, leopardfish (tigerfish), Bohadschia argus, chalkyfish, B. marmorata marmorata, "Suthuwalu," B. marmorata vitiensis, lollyfish, Halodeima atra, and a species, Stichopus variegatus, which has no common name but is similar to the pricklyfish. According to FAO (1976b), catches of sea cucumbers in the Solomons were 200 MT in 1972 and 300 MT in 1973 but they declined sharply in 1974 and 1975 reaching only 18 and 9 MT, respectively. Catches from Fiji were very small reaching only 2 MT in 1974.

At present, the only processing plant for sea cucumbers in the Pacific region is located in the Solomon Islands. Here, four species are of commercial importance--teatfish, blackfish, pricklyfish, and deepwater redfish (James 1977a). In New Hebrides, several commercially important species are found in the lagoons and an active fishery could be organized in various parts of this island group. Fiji exports bêche-de-mer to Australia and the United States but the trade is not well organized. Palau in the Trust Territory has good prospects for the establishment of a bêche-de-mer fishery as large quantities of commercially important species are found inside the lagoon. At present, there is no obstacle to the reestablishment of this fishery in the Palau District. At Yap, however, the lagoon area is small and probably cannot support an active large-scale fishery.

Surveys conducted in Truk lagoon showed that teatfish and pricklyfish are abundant and can support an active fishery to command dominance in the Trust Territory (Sachithananthan 1972). The potential for development is extremely good and the sooner it is started, the firmer will be its foothold in Truk. On the other hand, teatfish and pricklyfish are rarely seen at Ponape, but sandfish and lollyfish are predominant. At Kwajalein in the Marshalls, several commercially important species are abundant and a fishery for them can be established by organizing the small groups of fishermen in each atoll.

7. CIGUATERA

Ciguatera fish poisoning, also known as ichthyosarcotoxism in medical terminology, is a disease with certain characteristic neurotoxic and gastroenteric symptoms produced by ingestion of a variety of fish including snapper, Lutjanidae, groupers, Serranidae, jacks, Carangidae, barracuda, Sphyraenidae, and surgeonfish, Acanthuridae, from toxic areas (Halstead and Lively 1954; Helfrich, Piyakarnchana, and Miles 1968). According to Helfrich et al. ciguatera and tetraodon poisoning can be distinguished from each other by the character of the toxin and symptomatology, and from scombroid poisoning by distinct etiological agents which have been isolated. Clupeoid poisoning also appears to be distinct from ciguatera fish poisoning on the basis of symptomatology. Recent evidence shows that ciguatera is probably caused by more than one toxin and includes what has been described as Gymnothorax poisoning and elasmobranch poisoning; the toxins from snappers, shark livers, and moray eels have been isolated and appear to be identical (Ralls and Halstead 1955; Halstead 1959; Banner et al. 1964).

Ciguatera appears to be widespread through the oceanic islands of the Pacific between the 30° parallels of latitude (Helfrich et al. 1968). Although the occurrence of ciguatera poisoning has a discontinuous distribution, the condition has been reported from at least some of the islands of all the archipelagoes of the tropical Pacific with the exception of the Carolines and the Philippines (Helfrich and Banner 1968). For an exhaustive review of investigations on ciguatera, the reader is referred to Halstead (1965-70). Abstracts of papers presented at a seminar on ichthyosarcotoxism may be found in South Pacific Commission (1968).

The occurrence of ciguatera in some species found in the central Pacific affects not only the population by causing illness, but also as is often the case, deprives them of a major source of protein. In some areas that are seriously affected, it could restrict the full development of an outer reef handline fishery and utilization of the demersal stocks. Table 12 gives the results of toxicity tests conducted on fishes caught in waters around the Line Islands.

Table 12.--Line Islands fishes tested for toxicity at Hawaii Institute of Marine Biology (Helfrich et al. 1968).

Family	Species	Results: Toxic	Results: Nontoxic
Acanthuridae	Acanthurus triostegus triostegus (Linnaeus)	x	
	A. xanthopterus Cuvier and Valenciennes	x	
	Ctenochaetus striatus (Quoy and Gaimard)	x	
	C. cyanoguttatus Randall	x	
Albulidae	Albula vulpes (Linnaeus)		x
Carangidae	Caranx ignobilis (Forskål)	x	
	C. melampygus Cuvier	x	
Chaetodontidae	Chaetodon auriga Forskål		x
Elopidae	Elops machnata Forskål		x
Labridae	Cheilinus undulatus Ruppell		x
Lutjanidae	Lethrinus miniatus Bloch and Schneider	x	
	L. variegatus Cuvier and Valenciennes	x	
	Lutjanus bohar (Forskål)	x	
	L. monostigmus (Cuvier and Valenciennes)	x	
	L. gibbus (Forskål)	x	
	Monotaxis grandoculis (Forskål)	x	
Mugilidae	Mugil crenilabis (Forskål)		x
	Neomyxus chaptalii (Eydoux and Souleyet)		x
Muraenidae	Gymnothorax javanicus (Bleeker)	x	
Serranidae	Anyperodon leucogrammicus (Cuvier and Valenciennes)	x	
	Epinephelus fuscoguttatus (Forskål)	x	
	E. tauvina (Forskål)	x	
	Variola louti (Forskål)	x	
	Cephalopholis argus Bloch and Schneider	x	
Sphyraenidae	Sphyraena barracuda (Walbaum)	x	

In Tonga, ciguatera poisoning does not appear to be serious--a species which is usually suspect is Lutjanus bohar. At times, this species is excellent eating whereas in some months, it may affect the consumer (Wilkinson 1977a).

In Western Samoa, ciguatera poisoning also is not a serious problem. Lutjanus bohar which is the only species thus far implicated in poisoning cases, constitutes only 5% of the total catch (Gulbrandsen 1977).

The problem of ciguatera poisoning in the Yap District occurs only at Ulithi Atoll and only in certain sections. Species occasionally implicated in poisoning cases in other localities in the Pacific--barracuda, lutjanids, and large carangids--have not caused poisoning cases in Yap (McCoy 1977).

At Penrhyn in the northern Cook Islands, a recent increase in cases of fish poisoning has been attributed to a hurricane which struck the islands and caused widespread damage to the reef coral (Brandon 1976). It was suggested that a rapid increase in new corals could have initiated the sudden increase in ciguatera poisoning. Brandon stated that this theory is partially supported by the decline in incidence of fish poisoning cases with time following a peak shortly after the hurricane.

Among the fishes implicated in fish poisoning cases at Penrhyn were snappers, L. bohar and L. vaigiensis, coral cod, Cephalopholis miniatus, moray eel, Gymnothorax sp., red emperor, Lethrinus sp., white parrot, Scaridae, wrasse, Cheilinus undulatus, and surgeonfish, Ctenochaetus striatus.

Not all the deepwater fish caught in Tuvalu are salable. Ciguatera poisoning, although not a serious problem in Tuvalu, could have a detrimental effect on fishery development because of the relatively high proportion of poisonous fishes in the catch. Eginton (1977) estimated that about 17% of the survey project's fish landings were poisonous and included such species as L. bohar, Variola louti, Plectropoma maculatus, and other large groupers, and several unidentified lutjanids.

8. DISCUSSION

The high population growth rate in many of the Pacific islands over the past decade has had a significant effect on the pattern of fishing. In some islands, the tradition of fishing has practically been lost. For example, copra plantation operators encourage the local population to earn cash income through copra production and to obtain their fish through purchases at the plantation store (Murphy 1973). Thus, the ability to fish and the tradition of going to sea eventually is lost after a few generations of this type of pressure. Furthermore, fishing pressure on fish resources in the lagoons and adjacent reef and shallow-water areas has increased steadily resulting in serious depletion of some stock. In many cases, resources that have been the basis of subsistence fishing for generations no longer exist.

It has been suggested that among the species presently being harvested within the western central Pacific, skipjack tuna, together with other small tunas, will dominate fishery production (Wilkinson 1977b). It appears unlikely that a commercial fishery for any of the other species can compete. For example, even the deep-swimming tunas and billfishes are under considerable fishing pressure and production from these resources appears to be stabilizing so that substantial increases in catches of these species seem unlikely. This does not mean, however, that the coral reef and outer-reef fisheries do not have the potential for further development. On the contrary, because of the lifestyle of Pacific islanders, these small-scale fisheries will continue to have considerable socioeconomic value to the villages and communities in the region.

The coral reef environment can be harvested with indigenous and relatively uncomplicated fishing techniques that have evolved over the years (Wilkinson 1977b). And it is not likely that the traditional artisanal method of fishing will change drastically in the near future. The problem of estimating sustainable yield levels for coral reef communities, however, is formidable indeed because of the high degree of diversification. The wide variety of species harvested from this environment, coupled with local sociological factors that tend to inhibit proper utilization, will have a significant influence on rational long-term management of the coral reef resource. The economic factors also dictate, to some extent, the expenditure of fishing power; therefore, there will be some degree of management.

It has become abundantly clear in recent years that developmental effort in the future has to concentrate on introducing different methods of fishing to harvest the outer-reef slope and nearshore pelagic resources. The fisheries for these resources will surely emerge in the years to come, but their development will require new or perhaps untried and untested techniques. Among the urgent needs are powered fishing boats which can withstand the choppy offshore waters and also provide reasonable amount of comfort to the fishermen handling gurdies and other mechanical devices for bottom fishing in deep, outer-reef waters, refrigeration to preserve the catch, simple echo sounders, and training in simple navigation.

9. REQUIREMENTS FOR FURTHER STUDY

The preponderance of studies on fish resources has been concentrated in the North Pacific. For the period 1949-68, there were 202 papers dealing with biological oceanography of the North Pacific in contrast to only 18 on similar subjects for the South Pacific (Knox 1970). The main reason for this difference is that the countries engaged in the North Pacific fisheries are highly developed technologically resulting in higher allocations of funds for marine research.

In general, for almost every island or island group covered in this report, the prime requirement is for catch and effort statistics, which, at the present time, are usually incomplete, or, in the case of subsistence fisheries, nonexistent. To obtain any kind of statistical data in such a vast area with many relatively underdeveloped islands, however, presents many problems. For example, lack of communication between the government centers and outlying villages and lack of trained personnel amongst the villagers to record catch and effort data accurately, systematically, and consistently are two very basic problems that need immediate attention.

A considerable amount of work is also needed to better understand the biogeography in the central South Pacific. For example, information is very scanty on the distribution of plankton and benthic animals in the South Pacific. Other measures of biological productivity, such as primary production in the oceanic regions, as well as in the coral reef ecosystem, would be most useful. Estimates of relative abundance of planktonic eggs and larvae of important commercial species, with the exception of the tunas, are sparse and much could be done in this area.

Information on the outer-reef demersal and pelagic resources is also very sparse. Correspondingly detailed data on hydrography and bottom topography are also lacking from around most of the islands. It would appear, then, that apart from statistics, the most urgent need is for extensive surveys of the demersal and pelagic resources. A proposal to assess the marine resources of the Northwestern Hawaiian Islands has already been implemented by the Southwest Fisheries Center, National Marine Fisheries Service, Honolulu, Hawaii and preliminary results from some of these islands and atolls indicate the existence of possible commercial concentrations of demersal fish species and shellfish.

In most western central Pacific islands, there is no basis of past fisheries experience to indicate the size of the coastal and pelagic resources with much accuracy. Furthermore, detailed information about standing stocks or potential sustained yields from the shelf or coastal areas of the many Pacific islands, even in areas of high population density and high market demand such as the Hawaiian Islands, is almost completely absent. It is not expected that potential production from the many coastal areas of these islands, however extensive they may be, would be large enough to withstand the intense fishing pressure of industrial fisheries which occur in temperate coastal regions of the world. Nevertheless, the potential production is probably adequate or ample in many of these coastal areas to supply the local needs for many types of fishery products.

10. REFERENCES

Angot, M., 1959 Tuna fishing investigations in the South Pacific. Q.Bull.South Pac. Comm., 9 (4):48-52, 60-2

Aubray, T., 1976 The fishery of Fiji. Fiji Dept. Fisheries, Investment Centre Joint Working Group, Task Force, 12A:15 p.

Austin, T.S., 1960 Oceanography of the east central equatorial Pacific as observed during expedition EASTROPIC. Fish.Bull.USFWS, 60(168):257-82

Bachman, R., 1963 Fluctuations and trends in the abundance of nehu (Stolephorus purpureus Fowler) as determined from catch statistics. M.S.Thesis, Univ.Hawaii, Honolulu, 100 p.

Banner, A.H., 1952 Preliminary report on marine biology study of Onotoa Atoll, Gilbert Islands. Part I. Atoll Res.Bull., (13):1-42

Banner, A.H., P. Helfrich, P.J. Scheuer, and T. Yoshida, 1964 Research on ciguatera in the tropical Pacific. Proc.Gulf Caribb.Fish.Inst., 16 Sess.(Miami):84-98

Beverton, R.J.H. and S.J. Holt, 1957 On the dynamics of explcited fish populations. Fish. Invest.Minist. Agric.Fish.Food(G.B.)(Ser. 2 Fish.), 19:533 p.

Bogorov, V.G., 1960a Differentiation of geographical zones of central Pacific. Biol.morya,Tr. Okeanogr.Kom.Akad.Nauk SSSR, 10(4):3-7. (Transl. from Russian by Israel Program Sci. Transl., 1964, 5 p. Available U.S.Dep.Commer., Natl.Tech.Inf. Serv., Springfield, Va., as OTS-64-11100.)

__________, 1960b Geographical zones in the pelagial of the central Pacific. Tr.Inst.Okeanol., 41:8-16. (Engl. transl. by W.G. Van Campen; available Natl.Mar.Fish.Serv., Honolulu)

Brandon, D.J., 1976 Poisonous fishes of Penrhyn. In Report of the South Pacific Commission outer reef fisheries project in the Cook Islands (1 December 1975-31 May 1976), Project Manager H. Hume. Noumea, New Caledonia, South Pacific Commission, p. 19-21

Brown, I.W., 1977 Proposals for routine catch data processing and assessment of the Spanish mackerel and tuna baitfish stocks in Fiji waters. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.36:9 p. (mimeo.)

Brun, M. and W.L. Klawe, 1968 Landings of skipjack and yellowfin tuna at Papeete Market (Tahiti). Commer.Fish.Rev., 30(4):62-3

Cannon, G.A., 1966 Tropical waters in the western Pacific Ocean, August-September 1957. Deep-Sea Res., 13:1139-48

Charnell, R.L., D.W.K. Au, and G.R. Seckel, 1967a The Trade Wind Zone Oceanography Pilot Study, Part I: Townsend Cromwell cruises 1, 2, and 3, February to April 1964. Spec.Sci.Rep.USFWS (Fish.), (552):75 p.

__________, 1967b The Trade Wind Zone Oceanography Pilot Study, Part II: Townsend Cromwell cruises 4, 5, and 6, May to July 1964. Spec.Sci.Rep.USFWS (Fish.), (553):78 p.

__________, 1967c The Trade Wind Zone Oceanography Pilot Study, Part III: Townsend Cromwell cruises 8, 9, and 10, September to November 1964. Spec.Sci.Rep.USFWS (Fish.), (554):78 p.

__________, 1967d The Trade Wind Zone Oceanography Pilot Study, Part IV: Townsend Cromwell cruises 11, 12, and 13, December 1964 to February 1965. Spec.Sci.Rep.USFWS (Fish.), (555):78 p.

__________, 1967e The Trade Wind Zone Oceanography Pilot Study, Part V: Townsend Cromwell cruises 14 and 15, March and April 1965. Spec.Sci.Rep.USFWS (Fish.), (556): 54 p.

Charnell, R.L., D.W.K. Au, and G.R. Seckel, The Trade Wind Zone Oceanography Pilot Study,
1967f Part VI: Townsend Cromwell cruises 16, 17, and 21, May and June 1965 and January 1966. Spec.Sci.Rep.USFWS (Fish.), (557):59 p.

Clutter, R.I., Reef and lagoon productivity, South Pacific Islands. FAO FI:DP/RAS/69/102/
1972 10:68 p.

Cole, R.C., Fisheries development and requirements of fishery education and training in
1973 Malaysia, Thailand, Fiji and the Philippines with particular reference to the artisanal sector. FAO Fish.Rep., (143):58 p.

Conroy, W.L., Annual report 1967-69. [Papua New Guinea] Dep.Agric.Stock Fish., 240 p.
1972

Cromwell, T., Mid-Pacific oceanography, January through March 1950. Spec.Sci.Rep.USFWS
1951 (Fish.), (54):9 p.

__________, Circulation in a meridional plane in the central Equatorial Pacific. J.Mar.
1953 Res., 12:196-213

Cromwell, T., R.B. Montgomery, and E.D. Stroup. Equatorial undercurrent in Pacific Ocean
1954 revealed by new methods. Science, Wash., D.C., 119:648-9

Defant, A., Physical oceanography. Vol. I, New York, Pergamon Press, 729 p.
1961

Dietrich, G., General oceanography, an introduction. New York, Interscience Publishers,
1963 588 p.

Doty, M.S., et al., Biological and physical features of Kealakekua Bay, Hawaii. Hawaii
1968 Bot.Sci.Pap., Univ.Hawaii, (8):210 p.

Doumenge, R., The development of tuna and skipjack fishing in French Polynesia and experi-
1973 ence in live-bait techniques. South Pac.Isl.Fish.Newsl., (10):27-30

Eginton, R., Interim report: SPC outer reef fisheries project at Tuvalu, 12 September-30
1977 November 1976. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.30:14 p. (mimeo.)

FAO, Yearbook of fishery statistics. Catch and landings, 1969. FAO Yearb.Fish.Statist.,
1970 (28):324 p.

__________, Fishery country profile - Fiji. FAO FID/CP/RIJ:3 p.
1972

__________, Fishery country profile - Tonga. FAO FID/CP/TON:3 p.
1975a

__________, Fishery country profile - Western Samoa. FAO FID/CP/WES:3 p.
1975b

__________, Yearbook of fishery statistics. Catch and landings, 1974. FAO Yearb.Fish.
1975c Statist., (38):374 p.

__________, Fishery country profile - Cook Islands. FAO FID/CP/CKI:4 p.
1976a

FAO, Yearbook of fishery statistics. Catch and landings, 1975. FAO Yearb.Fish.Statist.,
1976b (40):417 p.

Fisheries Division and the National Investment and Development Authority (FDNIDA),
1976 The Gulf of Papua marine and inland fisheries. [Papua New Guinea] Fisheries Division, Department of Primary Industries and the National Investment and Development Authority, 51 p.

Fishing News International, Samoans learn to build Pacific City dories. Fish.News.Int.,
1972 11(2):19-20

Fourmanoir, P., Deep-water fishing in some islands of the south-west Pacific. South Pac.
1973 Isl.Fish.Newsl., (10):22-6

Fox, W.W., Jr., An exponential surplus-yield model for optimizing exploited fish popula-
1970 fish populations. Trans.Am.Fish.Soc., 99(1):80-8

George, R.W., South Pacific Islands Fisheries Development Agency Rock Lobster Project - a
1972 guide to the rock lobsters of the South Pacific region. South Pac.Bull., 22 (2):31-4

Gibbs, P.E., Survey of the macrofauna inhabiting lagoon deposits on Aitutaki. Atoll Res.
1975 Bull., (190):123-31

Gibson, D.H., Gilbert and Ellice Islands - Country statement. Paper presented to South
1975 Pacific Commission, Eighth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 20-24 October 1975. SPC Fisheries 8/WP.11:2 p. (mimeo.)

Golikov, A.N., Y.V. Krosnov, L.I. Moskalev, and D.V. Naumov, Cooperative ecological analy-
1973 sis of some biocoenoses of the upper parts of island shelves in the western tropical Pacific. Okeanologiya, 13(1):152-72. (Transl. in Oceanology, 13(1): 121-34, 1974.)

Gorbunova, N.N., Vertical distribution of eggs and larvae of fish in the western tropical
1971 Pacific. In Life activity of pelagic communities in the ocean tropics, edited by M.E. Vinogradov. Moscow, Akad.Nauk SSSR, Inst.Okeanol. (Transl. from Russian by Israel Program Sci. Transl., 1973, p. 256-69. Available U.S. Dep.Commer., Natl.Tech.Inf.Serv., Springfield, Va., as TT72-50035.)

Grandperrin, R., Importance of reefs to ocean production. Paper presented to South
1977 Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.9:3 p. (mimeo.)

Gulbrandsen, O., Outer reef fishery in Western Samoa. Paper presented to South Pacific
1977 Commission , Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.25:9 p. (mimeo.)

Gulland, J.A. (Ed.), The fish resources of the ocean. West Byfleet, Surrey, Engl., Fish.
1971 News (Books) Ltd., 255 p. Rev. ed. of FAO Fish.Tech.Pap., (97):425 p. (1970)

Halstead, B.W., Dangerous marine animals. Cambridge, Mass., Cornell Maritime Press, 146 p.
1959

__________, Poisonous and venomous marine animals of the world. Wash., D.C., U.S.Govt.
1965-70 Print.Off., 3 vol.

Halstead, B.W. and W.M. Lively, Jr., Poisonous fishes and ichthyosarcotoxism. U.S.Armed
1954 Forces Med.J., 5:157-75

Hawaii Department of Land and Natural Resources, 1964-1966 Report to the Governor,
1966 Honolulu, 76 p.

_________, 1966-1967 Report to the Governor, Honolulu, 83 p.
1967

_________, 1967-1968 Report to the Governor, Honolulu, 84 p.
1969

_________, 1969-1970 Report to the Governor, Honolulu, 89 p.
1971

_________, Report to the Governor for the fiscal year 1971-1972, 95 p.
1973.

Helfrich, P., The feasibility of brine shrimp production on Christmas Island. Univ.Hawaii
1973 Sea Grant Tech.Rep.UNIHI-SEAGRANT-TR-73-02:173 p.

Helfrich, P. and A.H. Banner, Ciguatera fish poisoning. II. General patterns of develop-
1968 ment in the Pacific. Occas.Pap.B.P.Bishop Mus., 23(14):371-82

Helfrich, P., T. Piyakarnchana, and P.S. Miles, Ciguatera fish poisoning. I. The ecology
1968 of ciguateric reef fishes in the Line Islands. Occas.Pap.B.P. Bishop Mus.,
23(14):305-69

Hessler, R.R. and P.A. Jumars, Abyssal community analysis from replicate box cores in the
1974 central North Pacific. Deep-Sea Res., 21(3):185-209

Hiatt, R.W. Food and feeding habits of the nehu, Stolephorus purpureus Fowler. Pac.Sci.,
1951 5(4):347-58

Hiatt, R.W. and A.L. Tester, The supply of nehu. Univ.Hawaii Mar.Lab.News Circ., (6):3 p.
1950 (mimeo.)

Hinds, V.T., Gilbert and Ellice Islands Colony. In UNDP/FAO South Pacific Tuna Mission,
1969 Annex III, 8 p.

_________, Energetic fisheries service in French Polynesia. South Pac.Bull., 21(3):
1971 figs. and captions.

Hume, H., Report on the South Pacific Commission outer reef fisheries project in the Cook
1976 Islands (1 December 1975-31 May 1976). Noumea, New Caledonia, South Pacific
Commission, 10 p.

Ikehara, I.I., H.T. Kami, and R.K. Sakamoto, Exploratory fishing survey of the inshore
1972 fisheries resources of Guam. In The Kuroshio II, Proceedings of the Second
Symposium on the Results of the Cooperative Study of the Kuroshio and Adja-
cent Regions, Tokyo, September 28-October 1, 1970, edited by K. Sugawara.
Tokyo, Saikon Publ. Co. Ltd., p. 425-37

James, R.H., Beche-de-mer in the Solomon Islands. Paper presented to South Pacific Com-
1977a mission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledo-
nia, 24-28 January 1977. SPC Fisheries 9/WP.17:12 p. (mimeo.)

_________, Country statement - Solomon Islands. Paper presented to South Pacific Com-
1977b mission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledo-
nia, 24-28 January 1977. SPC Fisheries 9/WP.22:10 p. (mimeo.)

Kanayama, R.K. and E.W. Onizuka, Artificial reefs in Hawaii. Hawaii Div.Fish Game Rep., 1973 (73-01):23 p.

Kanudi Fisheries Research Station, The skipjack tuna fishery in Papua New Guinea, 1976. 1977 Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977, 4 p. (mimeo.)

Kawamoto, P.Y., Management investigation of the akule or bigeye scad, Trachurops crumenophthalmus (Bloch). Hawaii Div.Fish Game Completion Rep. prepared for Natl. 1973 Mar.Fish.Serv. under Commercial Fisheries Research and Development Act, P.L. 88-309, Proj. No. H-4-R, 28 p.

Kawamoto, P.Y. and H.M. Sakuda, Commercial oyster fishery development investigation. 1973 Hawaii Div.Fish Game Completion Rep. prepared for Natl.Mar.Fish.Serv. under Commercial Fisheries Research and Development Act, P.L. 88-309, Proj. No. H-2-R/H-13-R, 32 p.

Kazama, T.K. The "akule" fishery of Hawaii. Paper presented to South Pacific Commission, 1977 Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.20:7 p. (mimeo.)

Kearney, R.E., A brief outline of the first years of the Papua New Guinea skipjack fishery. 1973 Paper presented to South Pacific Commission, Sixth Technical Meeting on Fisheries, Suva, Fiji, 23-27 July 1973. SPC Fisheries 6/WP.7:6 p. (mimeo.)

__________, Skipjack research in Papua New Guinea. Paper presented to South Pacific Com- 1974 mission Meeting on Expert Committee on Tropical Skipjack, Papeete, 25 February-1 March 1974, 7 p. (mimeo.)

King, J.E. and J. Demond, Zooplankton abundance in the central Pacific. Fish.Bull.USFWS, 1953 54(82):111-44

King, J.E. and T.S.Hida, Zooplankton abundance in the central Pacific. Part II. Fish. 1957 Bull.USFWS, 57(118):365-95

Knox, G.A., Biological oceanography of the South Pacific. In Scientific Exploration of 1970 the South Pacific, edited by W.S. Wooster. Wash.D.C., Natl.Acad.Sci., p. 155-82

Koblentz-Mishke, O.I., Primary production in the Pacific. Okeanologiya, 5(2):325-37. 1965 (Transl. in Oceanology, 5(2):104-16.)

Koblentz-Mischke, O.I., A.M. Tsvetkova, M.M. Gromov, and L.I. Paramonova, Primary produc- 1977 tion and chlorophyll "A" in the west Pacific. In Life activity of pelagic communities in the ocean tropics, edited by M.E. Vinogradov. Moscow, Akad. Nauk SSSR, Inst.Okeanol. (Transl. from Russian by Israel Program Sci. Transl., 1973, p. 73-83. Available U.S.Dep.Commer., Natl.Tech.Inf.Serv., Springfield, Va., as TT72-50035.)

LaViolette, P.E., Monthly extremes of temperatures in the surface waters south of Japan. 1970 In The Kuroshio: A symposium on the Japan Current, edited by J.C. Marr. Honolulu, East-West Center Press, p. 175-84

LaViolette, P.E. and S.E. Seim, Monthly charts of the mean, minimum, and maximum sea sur- 1969 face temperature of the North Pacific Ocean. U.S.Nav.Oceanogr.Off.Spec.Publ., (SP-123):62 p.

Lorimer, P.D. and J.L. Maclean, Report of an Australian fisheries aid programme for Tonga
1974 compiled for the Australian Development Assistance Agency. Australia Department of Agriculture for Australian Development Assistance Agency, Department of Foreign Affairs, 40 p.

Lyles, C.H., Fishery statistics of the United States, 1963. Statist.Dig.USFWS, (57):522 p.
1965

__________, Fishery statistics of the United States, 1964. Statist.Dig.USFWS, (58):541 p.
1966

__________, Fishery statistics of the United States, 1965. Statist.Dig.USFWS, (59):756 p.
1967

__________, Fishery statistics of the United States, 1966. Statist.Dig.USFWS, (60):679 p.
1968

__________, Fishery statistics of the United States, 1967. Statist.Dig.USFWS, (61):490 p.
1969

Manar, T.A., Pacific fisheries. In Encyclopedia of marine resources, edited by F.E. Firth.
1969 New York, Van Nostrand Reinhold Co., p. 477-83

Mao, H.-L. and K. Yoshida, Physical oceanography in the Marshall Islands area: Bikini and
1955 nearby atolls, Marshall Islands. U.S.Geol.Surv.Prof.Pap., 260-R:645-84

Masuzawa, J., An oceanographic section from Japan to New Guinea at 137°E in January 1967.
1967 Oceanogr.Mag., 19(2):95-118

McCoy, M.A., Report on the first year of operations - February-December 1976 - M.F.V.
1977 Liomaran, Yap District, Western Caroline Islands. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.32:24 p.

McLellan, H.J., Elements of physical oceanography. New York, Pergamon Press, 150 p.
1965

Ministry of Agriculture, Fisheries and Forests, Annual report for the year 1973. Parlia-
1976 ment of Fiji, Parliamentary Paper, (7):34-5

Moiseev, P.A., The living resources of the world ocean. Moskva Izdatel'stvo Pishchevaya
1969 Promyshlennost. (Transl. from Russian by Israel Program Sci. Transl., 1971, 334 p. Available U.S.Dep.Commer., Natl.Tech.Inf.Serv., Springfield, Va., as TT50026.)

Montgomery, R.B. and E.D. Stroup, Equatorial waters and currents at 150°W in July-August
1962 1952. Johns Hopkins Oceanogr.Stud., (1):68 p.

Moore, R. and J.W. McFarlane, Fisheries research in northern Torres Strait by the Papua
1977 New Guinea Government. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977, 10 p. (mimeo.)

Morris, D.E., Some aspects of the commercial fishery and biology of two species of spiny
1968 lobsters, *Panulirus japonicus* (De Siebold) and *Panulirus penicillatus* (Oliver), in Hawaii. M.S. Thesis, Univ.Hawaii, Honolulu, 82 p.

Muller, R.G., Some aspects of the population biology of *Stolephorus heterolobus* from Palau.
In press In Collection of tuna baitfish papers, edited by R.S. Shomura. U.S.Dep.Commer., NOAA Tech.Rep.NMFS Circ.

Murphy, G.I., Fishery development problems in Southeast Asia and the Pacific Island area
1973 (Oceania). Honolulu, Hawaii, East-West Food Inst., 75 p.

Office of Marine Resources, Statistical analysis of American Samoa's fisheries, July 1,
1976 1973-June 30, 1976. Final Rep., Proj. No. 4-26-D, 4 p.

Office of Samoan Information, Annual report to the Secretary of the Interior for fiscal
1974 year 1974, 76 p.

Odum, H.T. and E.P. Odum, Trophic structure and productivity of a windward coral reef com-
1955 munity on Eniwetok atoll. Ecol.Monogr., 25:291-320

Onizuka, E.W., Management and development investigations of the Kona crab, Ranina ranina
1972 (Linnaeus). Final Rep. Hawaii Div.Fish Game, 28 p.

Otsu, T. and H.O. Yoshida, American Samoa fisheries. In Our changing fisheries, edited by
1971 S. Shapiro, Wash.D.C., U.S.Govt.Print.Off., p. 310-23

Parin, N.V., N.N. Gorbunova, and V.N. Chuvasov, Quantitative distribution of near-surface
1972 ichthyoplankton in the western Pacific Ocean (based on hauls with a towed neuston otter trawl). Okeanologiya, 12(6):1078-83. (Transl. in Oceanology, 12(6):894-99.)

Perez, M.A. and B.M. Sablan, The Ponape CAA dory project. Paper presented to South Pacific
1974 Commission, Seventh Technical Meeting on Fisheries, Nuku'alofa, Tonga, 15-19 July 1974. SPC Fisheries 7/WP.4:7 p.

Philipp, A.L., Country statement - Western Samoa. Fisheries development in Western Samoa.
1977 Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.38:3 p. (mimeo.)

Pileggi, J., Fishery statistics of the United States, 1973. Statist.Dig.U.S.Natl.Mar.
1976 Fish.Serv., (67):458 p.

Powell, R., Fisheries development in the Cook Islands. South Pac.Bull., 12(1):60-1
1962

Power, E.A., Fishery statistics of the United States, 1961. Statist.Dig.USFWS, (54):460 p.
1963

Power, E.A. and C.H. Lyles, Fishery statistics of the United States, 1962. Statist.Dig.
1964 USFWS, (56):466 p.

Pownall, P.C., Fisheries of Papua New Guinea. Aust.Fish., 31(9):2-13
1972

Prescott, J., Progress report on the South Pacific Commission lobster project in the Solo-
1977 mon Islands. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.23:12 p. (mimeo.)

Pyne, R.R., Tropical spiny lobsters Panulirus spp. of Papua New Guinea. Search, 1(5):248-
1970 53

Ralls, R.J. and B.W. Halstead, Moray eel poisoning and a preliminary report on the action
1955 of the toxin. Am.J.Trop.Med., Hygiene, 4(1): 136-40

Rechebei, R., 1977 Country statement - Trust Territory of the Pacific Islands. Marine resources development in the Trust Territory of the Pacific Islands. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.14: 3 p. (mimeo.)

Reid, J.L., Jr., 1959 Evidence of a Scuth Equatorial Countercurrent in the Pacific Ocean. Nature, 184:209-10

__________, 1962 On circulation, phosphate-phosphorus content, and zooplankton volumes in the upper part of the Pacific Ocean. Limnol.Oceanogr., 7:287-306

Sachithananthan, K., 1972 South Pacific islands bêche-de-mer fishery. FAO, Report prepared for South Pacific Islands Fisheries Development Agency, FI:DP/RAS/69/102/11, 32 p. (mimeo.)

Sakiura, H., 1972 The pelagic armorhead, Pentaceros richardsoni, fishing grounds off the Hawaiian Islands, as viewed by the Soviets. Suisan Shuho, 658:28-31. (Engl. transl. by T. Otsu, 1977, 7 p., Transl. 17; available Natl.Mar.Fish.Serv., Honolulu, Hawaii 96812.)

Sauvée, J., 1974 Final report of the "M E R" Commission - Seventh Plan (L976-1980). Paper presented to South Pacific Commission, Seventh Technical Meeting on Fisheries, Nuku'alofa, Tonga, 15-19 July 1974. SPC Fisheries 7/WP.6:6 p. (mimeo.)

Schaefer, M.B., 1954 Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bull.I-ATTC, 1(2):27-56.

Seckel, G.R., 1962 Atlas of the oceanographic climate of the Hawaiian Islands region. Fish. Bull.USFWS, 61(193):371-427

Sesepasara, H., 1973 Statistical analysis of American Samoa's fisheries - January 1971-June 1973. Completion Rep., Proj. No. H-18-D, 8 p.

Sette, O., 1955 Consideration of mid-ocean fish production as related to oceanic circulatory systems. J.Mar.Res., 14:398-414

Smith, R.O., 1947 Survey of the fisheries of the former Japanese Mandated Islands. Fish.Leafl. USFWS, (273):105 p.

Sorokin, Yu.I., 1973a Productivity of bacterioplankton in the western Pacific. Okeanologiya, 13 (1):95-106. (Transl. in Oceanology, 13(1):70-80.)

__________, 1973b Productivity of coastal tropical waters of the western Pacific. Okeanologiya, 13(1):669-76. (Transl. in Oceanology, 13(4):551-8.)

Sorokin, Yu.I. and A.M. Tsvetkova, 1972 Vertical structure and productivity of a phytoplankton community in the western Pacific. Okeanologiya, 12(6):1047-56. (Transl. in Oceanology, 12(6):870-8.)

South Pacific Commission, 1968 Seminar on ichthyosarcotoxism, Papeete, French Polynesia, 16th-22nd August, 1968. South Pacific Commission Rep., various pagination.

__________, 1974 Beche-de-mer of the South Pacific Islands. South Pacific Commission, Noumea, New Caledonia, 29 p.

__________, 1977a Country statement - American Samoa. Fisheries development and future plans. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.37:4 p. (mimeo.)

South Pacific Commission, Country statement - Wallis and Futuna. Fisheries of Wallis and
1977b Futuna. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.7:4 p. (mimeo.)

__________, Country statement - Tuvalu. Recent developments and future plans for the
1977c Tuvalu fishing industry. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.5:9 p. (mimeo.)

Strasburg, D.W., E.C. Jones, and R.T.B. Iversen. Use of a small submarine for biological
1968 and oceanographic research. J.Cons.CIEM, 31(3):410-26.

Struhsaker, P. and D.C. Aasted, Deepwater shrimp trapping in the Hawaiian Islands. Mar.
1974 Fish.Rev., 36(10):24-30

Swerdloff, S.N., A determination of the feasibility of developing offshore commercial
1972 fishing in American Samoa. Completion Rep., Commercial Fisheries Research and Development Act, Territory of American Samoa, 14 p.

Takahashi, Y. and T. Sasaki, Trawl fishery in the central North Pacific seamounts (Kita
1977 Taiheiyo chubu kaizan ni okeru torōru gyogyō). Hokuyo soko-uo gyogyō--Shiryo (3) (Northern waters groundfish fishery--Data (3)). Division of northern waters groundfish resources, Far Seas Fish.Res.Lab., 45 p. (Engl. transl. by T. Otsu, 1977, 49 p., Transl. 22; available Natl.Mar.Fish.Serv., Honolulu, Hawaii 96812.)

Tester, A.L., The distribution of eggs and larvae of the anchovy, Stolephorus purpureus
1951 Fowler, in Kaneohe Bay, Oahu, with a consideration of the sampling problem. Pac.Sci., 5(4):321-46

__________, Variation in egg and larva production of the anchovy, Stolephorus purpureus
1955 Fowler, in Kaneohe Bay, Oahu, during 1950-1952. Pac.Sci., 9(1):31-41

Tester, A.L. and R.W. Hiatt, Variation in the vertebral number of the anchovy (Stolephorus
1952 purpureus) in Hawaiian waters. Pac.Sci., 6(1):59-70

Thompson, B.G., Fishery statistics of the United States, 1971. Statist.Dig.U.S.Natl.Mar.
1974 Fish.Serv., (65):424 p.

Uchida, R.N., The fishery for nehu, Stolephorus purpureus, a live bait used for skipjack tuna fishing in Hawaii. In Collection of tuna baitfish papers, edited by R. S. Shomura. U.S.Dep.Commer., NOAA Tech.Rep.NMFS Circ. (in press)

Uchida, R.N. and T.S. Hida, Preliminary results of lobster trapping in Northwestern Hawai-
1977 ian Islands waters. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.19:9 p. (mimeo.)

U.S. National Marine Fisheries Service, Fishery statistics of the United States, 1968.
1971 Statist.Dig.U.S.Natl.Mar.Fish.Serv., (62):578 p.

__________, Japanese trawl operations off Midway Islands. Foreign Fish.Inf.Release,
1975 (75-15):4

__________, Japanese landings of tsubodai off Midway decline sharply. Foreign Fish.Inf.
1976 Release, (76-9):4

Van Pel, H., The fisheries industry of the Cook Islands. Noumea, New Caledonia, South
1955 Pacific Commission, 41 p. (mimeo.)

Van Pel, H., 1961 A guide to South Pacific fisheries. Noumea, New Caledonia, South Pacific Commission, 72 p. (mimeo.)

Venrick, E.L., 1974 The distribution and significance of Richelia intracellularis Schmidt in the North Pacific Central gyre. Limnol.Oceanogr., 19(3):437-45

Vinogradov, M.E., 1968 Vertical distribution of the oceanic zooplankton. Moscow, Akad.Nauk SSSR, Inst.Okeanol. (Transl. from Russian by Israel Program Sci. Transl., 1970, 339 p. Available U.S.Dep.Commer., Natl.Tech.Inf.Serv., Springfield, Va., as TT69-59015.)

Welsh, J.P., 1950 Bait and population studies. A preliminary report of the Division of Fish and Game Bait Program. Sect. 1. Summary of field work with special reference to Hilo Harbor nehu scarcity. Hawaii Div.Fish Game Spec.Bull., (2):1-25

Wetherall, J.A., Catch statistics and the abundance of nehu, Stolephorus purpureus, in Kaneohe Bay. In Collection of baitfish papers, edited by R.S. Shomura. U.S.Dep.Commer., NOAA Tech.Rep.NMFS Circ. (in press)

Wheeland, H.A., 1972a Fishery statistics of the United States, 1969. Statist.Dig.U.S.Natl.Mar. Fish.Serv., (63):474 p.

__________, 1972b Fishery statistics of the United States, 1970. Statist.Dig.U.S.Natl.Mar. Fish.Serv., (64):489 p.

__________, 1975 Fishery statistics of the United States, 1972. Statist.Dig.U.S.Natl.Mar. Fish.Serv., (66):517 p.

Wilkinson, W.A., 1974 Fisheries development in Tonga. Paper presented to South Pacific Commission, Seventh Technical Meeting on Fisheries, Nuku'alofa, Tonga, 15-19 July 1974. SPC Fisheries 7/WP.2:8 p. (mimeo.)

__________, 1977a Country statement - Tonga. Development in fisheries in the Kingdom of Tonga. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP. 6:4 p. (mimeo.)

__________, 1977b Outer reef and near pelagic fisheries. Paper presented to South Pacific Commission, Ninth Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 24-28 January 1977. SPC Fisheries 9/WP.28:6 p. (mimeo.)

Williams, L., 1969 A brief résumé of fishery development in Tonga. In UNDP/FAO South Pacific Tuna Mission, prepared for V.T. Hinds, Annex IV, 29 p.

Wilson, P.T., 1976 A report on the fisheries situation to the Government of Papua New Guinea with recommendations for development. UNDP/FAO Fisheries Advisory Service to the Government of Papua New Guinea, 189 p.

Wyrtki, K., 1967 Oceanographic observations during the Line Islands Expedition, February-March, 1967. Hawaii Inst.Geophys., HIG 67-17:35 p.

Yaldwyn, J.C., 1973 Decapod crustacea from South Pacific reefs and islands. In Oceanography of the South Pacific 1972, compiled by R. Fraser. New Zealand National Commission for UNESCO, Wellington, p. 503-11.

Yamashita, D.T., 1951 The embryological and larval development of the nehu, an engraulid baitfish of the Hawaiian Islands. M.S.Thesis, Univ.Hawaii, Honolulu, 64 p.

Yoshida, H.O., 1972 Exploratory bottom trawling in Hawaiian waters. Proc., IPFC 13 Sess., Sect. 3:255-61