The most frequent appearance of skipjack was a catch of 13 to 19 kg or 6 to 9 fish. For yellowfin tuna, this was 50 to 79 kg by weight or 15 to 24 fish, by number. Both of these species are spread over roughly normal distribution curves, the centers. Therefore, their distributions are relatively even.

In other words, they can both be said to have random distributions. The maximum frequency for rainbow runner was the same as for skipjack: 13 to 19 kg by weight and 6 to 9 fish by numbers caught. However, their peak frequency of appearance is evident in the area below 7 kg, with fewer than three fish were caught. Therefore, there are two schools, of high and low density respectively, in separate locations. This distribution is considered similar to the "clumping" distribution.

<u>The number of operations and catch weight by cruise</u>

Next, the number of fishing operations, total catch, and catch for each fishing operation were obtained for each cruise, from the first to the fourth cruise. Their values are shown in Table 25. The number of fishing operations reached the peak, i.e., 20 times on the second cruise, later, decreased to half in the fourth cruise. Total catch showed almost the same trend as the number of operations, but the rate of decrease was greater than the decrease in the number of operations, so the catch of each operation showed a continuous decrease, and the catch of each operation in the fourth cruise was less than half of that of the first cruise.

Time of each operation was sometimes only 10 minutes minimum while 7 hours 20 minutes maximum. And this strikingly large difference indicates that the number of operation cannot always be proportional to the catch of efforts thereto made. So for each operation, the catch per hour was obtained by dividing the catch by the hours spent (referred to as CPUE). Then, CPUE for each cruise was compared and understood that third and fourth cruise had 84 to 85 kg. CPUE was almost double of 44 kg of second cruise.

The number of operations and catch weight in each area

The number of fishing operations per cruise was next separated into the seven areas which were shown previously. This is seen in Table 29, which shows that the fishing operations of the first cruise were conducted in the south-eastern section of Koro, in Northern Lau, and in Southern Lau. Fishing operations on the second cruise were conducted in south-western section of Kadavu. The operations of the third cruise were in Kia, Yasawa, and Rotuma, on the north side. The operations of the fourth cruise were back in the south, mainly in Koro and Kadavu. There were 20 operations in Kadavu, the largest number. Next was Koro at ten times, followed by eight in North Lau and South Lau. Least was Kia at five times.
When these operations were divided into the previously mentioned three groups (Table 30), the over 120 kg group was concentrated in Koro and Kadavu, and around 70% of the 50 to 120 kg group was concentrated in Kadavu, Southern Lau, and Yasawa.

Next, when the catch for each species was divided into the individual small areas (Table 31), the rate of catch of skipjack was 17 to 20% in Northern Lau and Southern Lau, 28% in Koro, 34 to 36% in Kadavu and Kia, and 43% in Yasawa. This catch rate increased with movement westward in the fishing ground, and yellowfin tuna was 53 to 59% in Northern Lau and Southern Lau, 44 to 49% in Kadavu and Kia, and 40% in Yasawa, and catch rate decreased in contrast with skipjack.

Comparison of catch within and without the existing fishing grounds

Next, to confirm the differences in catch between inside and outside the existing fishing grounds, the locations of the fishing operations for each group previously surveyed were plotted on the chart (Fig. 33). According to this chart, the operations for the over 120 kg group were carried out in 20 locations inside and 5 locations outside, of the existing fishing grounds. Operations for the 50 to 120 kg group were conducted in 14 locations inside and 11 locations outside, of the existing fishing grounds. Operations for the less than 50 kg group were conducted at ten locations inside and four locations outside, of the existing fishing grounds.

Classification of the catches by species, and the CPUE for inside and outside the fishing ground (Table 32) gave the following results. The total CPUE inside was 61.4 kg, and that outside was 59.9 kg, and these two figures were almost equal.

This is a result of the fact that the CPUE of the main catch of yellowfin tuna was 30.8 kg both inside and outside of existing fishing grounds, but in case of skipjack, inside was 16.3 kg and outside 21.4 kg. On the contrary, as for rainbow runner, inside was 8.3 kg and outside 1.7 kg.

(4) Fork length composition

(a) Skipjack

887 samples of skipjack were extracted from the catch and measured. The fork lengths of the samples were obtained, and are shown in Figure 34. First, when observed fork length, the main group consisted of mediumsized fish of 43 to 54 cm with a mode of 48 cm. A small group of large fish of 55 to 75 cm was included. The pole-and-line fishery was operated in the same fishing ground at the same season, as next year and the mode of fork length composition here was slightly smaller at 45 cm (cf. Fig. 24), but the range for the main group was almost the same as the fork length range in the previous year (42 to 54 cm). Therefore, the fork length composition of skipjack visiting this area annually can be considered as almost fixed at 42 to 54 cm. When this fork length composition is classified by individual cruise (Fig. 34), the 43 to 51 cm group, with a mode of 48 cm, was the main group on the first and second cruise. On the third cruise, however, the mode increased, and group of 46 to 54 cm, with a mode of 50 cm dominated.

However, the fork length composition decreased again on the fourth cruise, the main group was 48 to 51 cm with a mode of 49 cm. The first and second cruise were exclusively in areas on the south side of Southern Lau and Kadavu. On the third cruise, the fishing grounds were the north side of Yasawa and Rotuma areas. The operations of the fourth cruise were conducted in Rotuma area at the beginning, but the survey vessel soon returned to the southern area, and Southern Lau and Kadavu areas were again used as the fishing grounds. Those frequent changes in fishing areas are considered the reason for the variations in fork length compositions shown above. Also, large fish, 60 to 80 cm, were caught in the area on the west side of Yasawa, showing a conspicuous difference from the neighboring areas. This might be because the 2-year-old fish stayed in inhabiting bank of school during growth, as is the case in the sea near Japan.

(b) Yellowfin tuna

774 yellowfin tuna was randomly selected from the samples and measured to obtain the fork length composition. This is shown in Figure 35. As can be seen here, the distribution ranged widely, from 45 to 110 cm, but two peaks can be observed in the areas of 47 to 55 cm and 60 to 70 cm. When this composition is allocated among the first to fourth cruise, as in the case of skipjack (Fig. 35), a 60 to 70 cm group was seen dominant on the first cruise, but on the second cruise, a 45 to 55 cm group joined the first group, creating two peaks. The 60 to 70 cm group disappeared on the third cruise, and only the 45 to 55 cm group remained. Small amounts of large fish, around 80 cm, were added. The results were unclear on the fourth cruise because of the small number of fish measured.

However, the composition can be considered almost the same as that of the third cruise. As stated above, the composition changed greatly on each cruise. This change is considered to be basically due to the changing areas inhabited by yellowfin tuna as they grow. Fry and other young yellowfin tuna inhabit mostly the areas near shoals and islands. As they grow, they move offshore. This trend seems to be obtained in these surveys. In other words, on the first cruise, the survey was done mainly in an offshore area south of Fiji. Here, a 60 to 70 cm group was dominant. The second cruise was on the south side. However, the coastal area, (on the south side of Taveuni Island) was included as part of this range, so the composition showed two peaks, one at around 50 cm and the other at around 70 cm. On the third cruise, the survey operated mainly in the north side coastal area, Kia area, around Yasawa Islands, and west from them. Fish of around 50 cm were caught in Kia, and fish of 75 to 90 cm were caught in Yasawa. On the fourth cruise, the survey returned to the south side, in the coastal areas of Kadavu and Koro. Here, medium-sized fish of around 50 cm composed main group.

(5) Biological survey

Skipjack and yellowfin tuna, 5 to 10 fish per operation, were randomly selected from each fishing operation. Fork length, body weight, and weight of gonads were measured, and the maturity and stomach contents were obtained. 140 skipjack and 123 yellowfin tuna were randomly selected from the trolling catch and surveyed, but the number of specimens was so small that it was decided to put those results together with the catch by pole-and-line, which were described previously.

1.3 Surface Gillnet

(1) Outline of findings

The survey was done jointly with the previously mentioned trolling survey on four separate cruise. Surface gillnets were conducted on average of 15.5 times per cruise. Record of surface gillnet attached in Appendix 7, showed the location of fishing ground, the times of operating netting, catch by species, etc. Table 33 also shows the number of fishing operations and catches by species and cruise, and track for each cruise was shown in Figure 36.

Dates and areas of the survey were almost the same as those in the previously discussed trolling, therefore, they are omitted here. Only the survey findings will be stated as follows.

The first cruise

In the first cruise, thirteen fishing operations were conducted and catches obtained totalled 1,206 kg by weight (93 fish). The average catch by operation was 92.8 kg (7.1 fish) and the average effective nets were 50 tans (nets). Therefore, the average catch per net was 1.9 kg (0.14 fish). Of these catches, requiem shark was in top ranking by weight (59% of total catch), while skipjack exceeded other species by number of fish (48% of the total caught).

The second cruise

In second cruise, fishing operations were made 22 times. The weight of the total catch was 968 kg, representing 54 fish. The average catch per operation was 44.0 kg by weight, or 2.5 fish. Catch per net was 0.8 kg (0.04 fish). Marlin (swordfish and striped marlin) were the most common fish in the catch, 48% of total by weight. Skipjack were greatest in number, at 35% of total catch.

The third cruise

In third cruise, a total catch of 1,221 kg was obtained, numbering 120 fish in 17 fishing operations. The average catch per operation was 71.8 kg by weight, and numbering 7.1 fish. The average catch per net was 1.2 kg (0.12 fish). It consisted mostly of requiem shark, both by weight and by number: 57% by weight, and 30% of total catch number.

The fourth cruise

In fourth cruise, 10 fishing operations were conducted, obtaining catches of 278 kg total weight (27 fish). The average catch per operation was 27.8 kg by weight, 2.7 fish in number and the average catch per net was 0.4 kg (0.05 fish). Most of the catch was yellowfin tuna, which was 42% of total weight, and 41% by number.

During the survey period, the total catch comes to 3,673 kg (294 fish). The average catch per cruise was 918.3 kg (74.0 fish), and average catch per operation was 59.2 kg (4.7 fish). Average catch per net was 1.1 kg (0.08 fish). The largest portion of the catch, by weight, consisted of requiem shark (45.2%), next was yellowfin tuna (11.3%), then skipjack (9.4%). These three species together comprised 66% of the total catch.

(2) Composition of catch

More than 20 different fish species were caught using this fishing method, as shown in Table 34. However, in this case all catches were added, to obtain this total. The average number of species in mixed catches per operation was only 1.8 species.

<u>The number of appearances per each fish and the number of fish per operation</u>

The average number caught per operation and the number of appearances through the survey period (Table 35), for all of the five species (skipjack, yellowfin tuna, requiem shark, travally and dolphin fish) appeared at rates of over 10%. These species can therefore be considered as major elements in the composition of surface gillnet catches. The average number per catch per operation, remained very small, at only two to four fish per catch. It is not possible, though, to assume that the distribution density of these fish in this area is so remarkably low. Perhaps these species of fish spend almost no time in school groups at night, and it should thus be assumed that they are less likely to be caught the nets. Both surface gillnet and trolling catch schools in the surface layers. Also, this survey was done in the common fishing ground, so there are as many as nine species of fish commonly caught by both methods. These include skipjack, yellowfin tuna, mackerel tuna, etc. However, the catch rates for catch species relative to the total catch varied considerably with each method.

Yellowfin tuna was the largest element in trolling catches, at 50%. Skipjack was next, at 29%. In contrast, the total catches of skipjack and yellowfin tuna totalled only 20% with surface gillnets. Requiem sharks, however, which were only 0.2% of the trolling catch, became the dominant species, with a 45% share of the surface gillnet catch. There were 13 species caught only by surface gillnet, mainly marlin and sharks. All of these are pelagic species. Trolling catches, however, seem to be mainly from fish schools inhabiting banks.

Relationship between catch weight and composition of catch

The results of the 49 fishing operations (omitting the 12 operations which has almost no catches) were categorized into three groups, according to catch weight per operation: less than 50 kg, between 50 and 120 kg, and over 120 kg. The number of operations and the catch by species was determined for each group. These results are shown in Table 36.

Catch composition was as follows, form 54% of the over 120 kg group was sharks, mainly requiem sharks. Marlin, yellowfin tuna, and skipjack were each 18%. In the 50 to 120 kg group sharks were especially dominent, with a 78% share, and there were few of any other species. In the 50 kg or less group, the number of sharks decreased drastically, and yellowfin tuna and skipjack constituted the major share of the catch.

For mixed catches per operation, there were 3.8 species for the over 120 kg group. 1.9 species for the 50 to 120 kg group, and 1.5 species for the under 50 kg group. The number of mixed catches decreased as the total number of catches decreased. Therefore, the catch in surface gillnets is affected both the number of species in mixed catches and by the weight of sharks, particularly requiem sharks. If only sharks are caught, and no other species are caught the net, the catch is 50 to 120 kg. If no sharks are caught in the net, and only yellowfin tuna and skipjack enter the net, the catch will remain below 50 kg.

(3) Catch

Observation of survey findings from the first to the fourth cruise, shows that the total catch was less than half the trolling catches that by trolling which were operated in parallel. The average body weight per fish, however, is 12.5 kg in surface gillnet, that is 3 times larger, compared with 3.5 kg by trolling, since large fish such as marlin, shark, etc., often enter surface gillnets. The average body weight per species commonly found in both types of fishing, such as skipjack and yellowfin tuna, are larger by 50% to 70% in surface gillnets. Large skipjack and yellowfin tuna often travel alone. Therefore, they may have more opportunities to be caught surface gillnets.

Frequency distribution of appearance in catch and the number of fish per operation

The catch per operation ranged widely, from 0.2 kg to 578 kg by weight and from 1 to 34 fish. When these values are categorized, and classes are separated using logarithms, the frequency of appearance in each class is obtained, as shown in Figure 37. The one fish class, the minimum, had the greatest number of catches. The number of classes decreased as the number of fish increased.

The distribution of catches showed almost the same pattern. The class of minimum catches, of less than 7 kg, was at the peak. Classes decrease with increased weight. However, the 80 to 120 kg class and the 120 to 200 kg class both show slight increases. These can be considered due to the catching of small quantities of large-sized fish in the nets, as stated previously.

The number of operations and weight in each area

In Fiji waters, there are divided into seven areas, as shown in Figure 2. When the number of fishing operations was first divided by these areas, (Table 37), it was seen that most operations (20 of them) were done in Kadavu. Next, were the 11 times in Southern Lau, followed by 8 times in Northern Lau, and 4 times in Kia, which has the smallest number of operations.

Dividing the number of these operations into the three groups, as stated before, catches of over 120 kg were obtained four times in Southern Lau, twice each in Koro and Rotuma, with the rest only once each. In contrast, the catch group of less than 50 kg (which included catches which were nearly zero), occurred very often (14 times) in Kadavu, 6 times each in Northern Lau and Southern Lau, 5 times in Yasawa, and 4 times in Rotuma and Koro.

Next, the catches by species, and catches by each operation, were determined for each of these areas. The results are shown in Table 38. The largest catch per operation was 105 kg, in Southern Lau, followed by 72 kg in Kia, 70 kg in Yasawa, with the least of 33 kg in Kadavu. The catch composition varied greatly with the area. Requiem shark, which is the dominant species, was especially notable in Southern Lau, Yasawa, Rotuma, and Kia. About 80% of the total catch was taken in these four areas. Skipjack, especially, was relatively more abundant in inhabiting bank such as those in Northern Lau, Southern Lau, and Yasawa. Yellowfin tuna were relatively more numerous in offshore areas such as Yasawa and Rotuma. Marlin are concentrated in the two areas of Koro and Southern Lau.

Relationship between transparency and catch

The transparency of water in the fishing grounds has received attention as one of the factors regulating the catch. This relationship was examined next. Table 39 shows the number of fishing operations, the average values for catches, and the standard deviation for each transparency factor observed in the fishing grounds. Transparency factors in this area, range from 17 to 35. Catches are concentrated in areas where transparency factors range from 24 to 30. Catches for each value showed quite large fluctuations, making it difficult to accurately identify the effect of transparency. As far as this table is concerned, however, the average catch values tended to decrease as transparency increased, so it can be assumed that transparency does have some effect on catch size.

Comparison of catch weight inside and outside the existing fishing grounds

Next, when the locations on the charts were observed for each of the weight groups previously discussed (Fig. 38), it was seen that fishing operations which had catches greater than 120 kg, were carried out in seven locations within the existing fishing grounds, and in five locations outside the existing fishing grounds. Operations resulting in catches of 50 to 120 kg occurred in four locations inside and four locations outside the existing fishing grounds. Operations with catches of less than 50 kg were made in 21 locations inside and 9 locations outside, the existing fishing grounds.

Table 40 shows the catch by species, inside and outside the existing fishing grounds, and the catches obtained with each operation. Consideration of this table shows that the total catch for each operation within the fishing grounds was 60.8 kg, compared to 56.4 kg outside, showing no significant difference. Quantities of requiem sharks, yellowfin tuna, and skipjack, the major catches, were almost identical inside and outside the existing fishing grounds. However, there was a considerable difference in the number of species comprising the catch.

In other words, the catch outside contained eight fewer species. In each fishing operation, 11.8 kg of fish were caught, less than inside the existing fishing grounds. The catch of marlin outside was greater, however, with the catch by operation averaging 10 kg more than the catches inside. Since the probability that marlin will enter the net is very low, a continuous stable catch of marlin cannot be expected. Thus, when marlin are not included, the total average catch outside is 40 kg, quite different from the average catch inside.

(4) Fork length composition

(a) Skipjack

Fork lengths of 63 skipjack and 46 yellowfin tuna, samples randomly selected from the catch, were measured to determine the fork length composition for both types of fish. This is shown in Figure 39.

From this composition for skipjack, there is almost no evidence of a peak mode which could be considered as a main group. Fork lengths of fish, which ranged widely from 42 cm to 78 cm, were unevenly distributed, in small numbers.

The reasons for this are considered to be that the number of fish measured was very small and that the surface gillnet fishing method does not catch large groups of fish. Catches are limited to fish moving individually or in small schools.

On the basis of the theory of Iizuka (Iizuka 1984 .. (1)), with age estimated from the proviously stated fork length composition, fish of all ages from 2 to 5 years seem to be those caught.

(b) Yellowfin tuna

Yellowfin tuna fork length composition is randomly scattered in a wide range from 50 to 110 cm. However, there are slightly more fish in the 75 to 85 cm range.

According to the results of age estimations done by Yabuta, et al. (Yabuta, others - 1960 .. (12)).
Yellowfin tuna in the Pacific Ocean will grow to 54 cm in the first year after hatching, to 92 cm in the second year, and to 120 cm in the third year. When these results are matched with the previously stated composition, the catch by surface gillnets consisted of 1 to 3 year old fish. The major group is evidently 2-year-old fish.

1.4 Bottom Line Fishing

(1) Outline of findings

The survey was conducted from December 1985 to March 1986 and October to November 1986 in Fiji, while conducted in Tuvalu waters in September and October, 1986, including Rotuma area. This survey was carried out alternately with pole-and-line fishery as stated before. Therefore, fishing operation was made only 70 times. The survey was divided into nine segments, accordingly cruise was carried out nine times separately and each cruise covered 7 or 8 operations on the average.

Appendix 8 are obtained the location of each fishing operation, times when lines were dropped, the catch for each species, etc., in utmost details. A mixture of nearly 100 species of fish were caught, as shown in Table 41. To avoid complexity, species other than the main ones have merely been summarized, and are shown only by the names of their genus or family. Appendix 9 shows detail of catch per species for each operation. Table 42 shows the catch, classified by species, and the number of fishing operations for each cruise. It also shows the catch rate and the number of effective hooks for each cruise. Tracks for each cruise are shown in Figure 40.

The first cruise (December 4 - 12, 1985)

The first cruise was conducted mainly around Northern Lau. Six fishing operations were done, for a total catch of 1,707 kg (374 fish). Perhaps because the crew members were unfamiliar with the fishing operation, the rate of the average number of effective hooks was a low 36%, and the average catch per fishing operation was 284.5 kg (63 fish) which was a fairly good result. Ribbon tail were the largest component of the catch, both by weight and by number of fish, and next were red snapper and short tail. These three species represented a 74% share of the total catch.

The second cruise (December 24, 1985 - January 6, 1986)

The second cruise was conducted around Southern Lau, with nine fishing operations. A total catch of 3,920 kg (1,016 fish) was obtained. The effective number of hooks averaged 50%, slightly better than in the previous cruise. The catch per fishing operation was 435.6 kg (113 fish), a great increase over the previous cruise. In the catch, red snapper was the largest component, followed by ribbon tail, bedfords, and amberjacks. These four species comprised 60% of the total catch.

The third cruise (January 22 - February 6, 1986)

The third cruise was conducted to start around Kadavu Islands, then traveled around many of the fishing grounds. The survey was carried out nine fishing operations during its travels around Balmoral Reef, Bligh

Waters, and off the coast of Savusavu and Viti Levu Island. A total catch of 1,747 kg (484 fish) was obtained. During these fishing operations, branch lines were cut often, and entangled by rapid currents, etc. Therefore, the effective hook rate decreased to 49%, and the catch per fishing operation also decreased, to less than half that of the previous cruise, to 194.1 kg (54 fish). Most of the catch consisted of sharks, groupers and barracudas, which have low market value. Prime fish such as ribbon tail and red snapper were less than 30% of the catch.

The fourth cruise (February 22 - March 11, 1986)

The fourth cruise was centered around Northern Lau, and traveled around each of the fishing grounds in Kia and Koro, carrying out 11 fishing operations. A total catch of 3,128 kg (710 fish) was obtained. Effective hook rate averaged 51%, relatively high, but branch lines were entangled frequently during operations. Therefore, the catch per fishing operation remained a low as 284.4 kg (64.5 fish). The catch consisted of red snapper, ribbon tail, bedfords, and red jobfish. These four species together made up 71% of the total catch.

The fifth cruise (August 19 - September 8, 1986)

In the fifth cruise, only four fishing operations were carried out. These were centered around Nanumanga Island in Tuvalu waters. A total catch of 2,400 kg (595 fish) was obtained. The hook effectiveness rate was 61%, and the catch per fishing operation was 600 kg (149 fish). Both of these values greatly exceeded those of the previous cruise. Ribbon tail, in particular, dominated the catch, with this species alone making up 60% of the total catch.

The sixth cruise (September 9 - 22, 1986)

In the sixth cruise, eight fishing operations were conducted around Niulakita Island in the southern part of Tuvalu waters, obtaining a total catch of 2,468 kg (616 fish). The effective hook rate was an average of 56%, and the average catch per fishing operation was 308.5 kg (77 fish), less than the previous cruise. The catch also contained coarse fish of snapper family, jacks, as well as other species. The fish of snapper family were 70% two-spot red snapper. The sale of these fish is forbidden because they are cignatoric (poisonous).

The seventh cruise (September 23 - October 8, 1986)

The seventh cruise was conducted in the southern part of Tuvalu waters, continuing, from the previous cruise later was centered around Rotuma. The eight fishing operations, obtained a total catch of 1,015 kg (324 fish). The hook effectiveness rate increased greatly, to 63%, but the catch per fishing operation decreased to less than half, to 126.9 kg (40.5 fish). The reason for this decrease was that the slopes of the fishing grounds in the southern part of Tuvalu waters and in the waters around Rotuma are very steep and deepen suddenly from a depth of around 100 m. In addition to this, the southern equatorial counter-current flow was strong, and fishing gear was lost constantly. There were also fewer prime fish such as ribbon tail, red snapper, etc. caught, but there were more coarse fish such as sharks, barracudas.

The eighth cruise (October 9 - 20, 1986)

In the eighth cruise, seven fishing operations were conducted while traveling from south to north in Rotuma, Kia, Northern Lau, and Koro. A total catch of 2,077 kg (530 fish) was obtained. The hook effectiveness rate was relatively high, at 61%, but average catch per fishing operation was only 296.7 kg (75.7 fish). Results were not very good because this operation encountered spring tides and the current flow was so rapid that it caused frequent losses of fishing gear. The major types of fish caught were red snapper, ribbon tail, and bedfords. These three species together accounted for 60% of the total catch.

The ninth cruise (October 21 - November 4, 1986)

In the ninth cruise, eight fishing operations were carried out while sailing south along the Lau Islands. The total catch was 4,6343 kg (1,204 fish). The hook effectiveness rate average 73.5%, the highest so far. The average catch per fishing operation was 580.4 kg (150.2 fish), which was quite high. Ribbon tail were the main component of the catch, followed by red snapper, groupers, and bedfords, with these four species together sharing 72% of the total catch.

When the above data were combined, the grand total catch was 23,105 kg (5,853 fish), the average catch per cruise was 2,567 kg (650 fish) and the average catch per fishing operation was 330 kg (83.6 fish). Ribbon tail were the largest component of the total catch, followed by red snapper and bedford. These three species made up roughly 60% of the total catch. As it will be discussed later, these fish species have high market value as exports. Their development is thus expected to provide new prospects for the fisheries here. However, the distribution of these demersal fish is limited to a very narrow range around the seamounts, and thus, if these species are attacked by intense fishing, there is some danger of overcatching within a short time. Therefore, in order to continue steady long-term catches, thorough consideration of fisheries control will be need (regulations on fishing seasons and fishing grounds, restrictions on fishing vessels and catch, etc.).

(2) Catch composition and catch weight

Relationship between average number in catch and appearance frequency of each individual species constituting the catch for each fishing operation

As previously stated, the fish subject to catches by this fishing method total nearly 100 species, and this is the total catch. As seen in Appendix 9 attached, the number of species per mixed catch in a single fishing operation varied between 1 and 23, with an average of 13.5. Here, for each species the average number of fish caught per operation was plotted on the vertical axis, and the frequency was plotted horizontally to observe their relationship (Fig. 41). All points plotted are scattered in a wide range, but they could be classified into the four groups listed as follows.

i) Species which have a high frequency of appearance and for which the average number caught per fishing operation is large.

ii) Species which have a high frequency of appearance but for which the number caught per fishing operation is small.

iii) Species which have a low frequency of appearance but which are caught in large numbers in each individual fishing operation.

iv) Species which have a low appearance frequency and for which the number caught per fishing operation is small.

The species in category i) have wide distribution ranges, and their distribution density is relatively high. These include ribbon tail and red snapper. In 70 fishing operations, ribbon tail appeared 63 times, and red snapper appeared 61 times. The number of ribbon tail caught per fishing operation averaged 25, and the average catch per operation for red snapper was 12.

The species in category ii) seem to be distributed over a wide area, but their distribution density is not very high. (Snake mackerel, short tail, granulose shark, and oblique-banded snapper are all in this category.) Snake mackerel appeared 46 times, short tail, granulose shark, and oblique-banded snapper each appeared about 30 times. The average catch per fishing operation, however, was only 3 to 7 fish.

Species in category iii) are distributed in limited areas, but within their limited range, their distribution densities seem relatively high. Bedfords (Paracaesio kusakarii, P. Stonei), red tail opakapaka, etc., are in this category. Paracaesio kusakarii appeared 28 times, red tail opakapaka appeared 18 times, and P. stonei appeared 16 times. Their appearances were less frequent, but their average catch per operation was 10 to 13 fish.

Species in category iv) have very limited distribution, in limited areas, and their distribution densities are low. Most species, other than those listed above, belong to this category.

Frequency distribution of the number of the catch per operation

To determine the appearance of the above species, the numbers caught per fishing operation were separated into several classes (by their logarithms), and the frequency of appearance was obtained for each class. The results are shown in Figure 42. According to this, ribbon tail appeared in numbers covering 1 to 182 fish. However, appearance frequencies were higher for the classes of 3 to 5 and 19 to 27 fish, so the distribution of ribbon tail can be considered as clumping distribution with a mixture of two groups, one very dense, and the other a scattered school.

Red snapper appeared in a range of 1 to 84 fish, but appearance frequency is concentrated particularly in six to eight fish class, and frequencies above and below this decrease, so the distribution seems to be nearly normal. This is a relatively even distribution and can be considered as opportunistic with only a small degree of unevenness.

Snake mackerel, short tail, granulose shark, and oblique-banded snapper, all have appearance modes with one to two fish, are in the minimum class. Their frequency of appearance decreases as the number of fish increases. Therefore, their distribution can be considered as one type of opportunistic distribution, with very low density. Other species are also generally considered to fall within this category.

Relationship of catch weight and catch composition

The catch for each fishing operation was scattered in a wide range, from 12 kg to 923 kg, so these values were divided into four groups (less than 200 kg, 200 to 399 kg, 400 to 599 kg, and over 600 kg). Catch classified by species, for each group was determined, as shown in Table 43. Observation of the number of fishing operations showed 26 for the 200 to 399 kg group, the largest number for any group (37%). Next were the 21 operations for the 200 kg or less group (30%), followed by the 16 operations for the 400 to 599 kg group (23%), and 7 operations for the over 600 kg group (10%), which was the minimum. Next, the group composition of the catches for each group was determined.

In groups of less than 200 kg, the catch of ribbon tail was only 14%, but as the catch increased, this rate increased, reaching 40% in the over 600 kg group. In contrast, the catch rate for dogfish shark was 12% in the less than 200 kg group, and this decreased to 3% in the over 600 kg group. For other species, the decrease was from 19% to 2%, with the rates for both species decreasing as catches became greater. Therefore, an increase in the amount of catch means not only an increase in quantity, but also a change in the content of the catch, from a larger amount of coarse fish to more prime quality fish.

Catch weight and catch composition in each area

The number of fishing operations and the catch for each species were obtained for nine areas which consists of seven areas around Fiji and Northern and Southern of Tuvalu waters. These results are shown in Table 44. 14 fishing operations were made in Northern Lau, followed by 13 in Southern Lau, 11 in Southern Tuvalu, 8 in Koro and 3 in Kadavu.

Observation of the catch compositions showed different dominant species, varying with each area. In the areas of Southern Lau, Kadavu, and Northern Tuvalu, the dominant species was ribbon tail. In the areas of Northern Lau, Yasawa, Koro, and Rotuma, it was red snapper. Bedfords were dominant in Kia, and snapper family were dominant in Southern Tuvalu. Even for the same dominant species, catches differed greatly. Observation of the average catch per fishing operation showed that the catch of ribbon tail in Kadavu was only 42 kg, remaining at less than 1/8 of the ribbon tail catch in Northern Tuvalu, which was 363 kg. For red snapper, the catch in Northern Lau was 147 kg, but in Yasawa it was 38 kg, only about 1/4 of that in Northern Lau. The catch per day generally showed great differences, depending on the area. In Northern Tuvalu, it was 600 kg per day but was only 145 kg in Rotuma, that was 1/4 of Northern Tuvalu. Naturally, these values are often affected by the timing of the fishing operation, the weather, and sea condition. It is therefore hard to generalize, but areas which have these low values also seam to have other problems such as difficult environmental condition in the fishing ground, including the topography of the ocean bottom, which affect bottom line fishing.

When the total number of fishing operations in each area was classified into the previously mentioned 4 groups (Table 45), the over 600 kg group was seen to occur in four out of seven operations in Southern Lau. The 400 to 599 kg group occurred eight times in 16 operations, in both Southern and Northern Lau. This data therefore shows that the area around Lau group is well-suited for this fishing method.

(3) Frequency of distribution of fork lengths

Fork length was measured, regardless of species, for all individual fish caught by bottom lines. However, in consideration of the availability of data, the nine species having particularly higher market values and relatively higher figures in fish number were selected for this survey.

(a) Ribbon tail

The fishing grounds were divided into three areas:
The north side of Fiji (Yasawa, Kia, and Rotuma), the area on the south side of Fiji (Kadavu, Koro, and both Southern Lau and Northern Lau), and Tuvalu. The distribution of appearance frequencies for various fork lengths of ribbon tail was obtained and is shown in Figure 43. The number of fish measured was very small on the north side of Fiji. Therefore, fork length composition was scattered in a wide range, from 30 to 90 cm. The fork length composition on the south side of Fiji also showed the same range, of 30 to 90 cm, with no particularly dominant fork length group within this composition. Almost identical frequencies are continuous for each class. In other words, a mixture of fish of all ages, from young to old, is considered to inhabit the same location in the same densities. In Tuvalu waters, the composition range was narrower than in Fiji waters, from 60 to 80 cm, with medium-sized fish of 65 to 70 cm as the main. It can therefore be assumed that small fish, shorter than 60 cm, and large fish, over 80 cm, are almost absent from the distribution in Tuvalu. The distribution of fork length appearance frequencies per month in Fiji waters is shown in Figure 44. This is the fork length composition for five months only, from December 1985 to March 1986,

and for October 1986. The fork length composition each month was in the 30 to 90 cm range, and no remarkable changes were found.

(b) Red snapper

The fishing ground for red snapper was divided into three waters (the north side of Fiji, the south side of Fiji, and Tuvalu waters) as in the case of ribbon tail. The frequency and distribution of fork lengths for each area were determined and are shown in Figure 45. The fork lengths of red snapper on the south side of Fiji showed a very wide range, from 25 to 100 cm, and there were two peaks of fork length frequency, before and after the lowest figure which was 45 to 60 cm. Because an insufficient number of fish was measured on the north side of Fiji and in Tuvalu waters, it is not completely clear, but the distribution of fork length frequency seems to be divided into two groups, 25 to 40 cm and 60 to 90 cm, with a boundary at around 50 cm. The monthly fork length distributions continued roughly in the same pattern (Fig. 46). The rates of small fish (less than 50 cm), increased slightly in October and November and seem to have decreased from January to March 1986.

(c) Other species

Fork length frequency distributions were determined for seven fish species: short tail, red job fish, red tail opakapaka, sweeper pomfret, bedfords (Paracaesio stonei, P. Kusakarii) and large-eye bream. These are shown in Figure 47. Except for sweeper pomfret, almost none of these species were caught in Tuvalu waters. Therefore, the fork length distribution of the catch is shown only for Fiji waters. Both short tail and red job fish ranged from 45 to 95 cm. These showed a gentle bell curve for fork length composition, with no particularly dominant fork length group. Red tail opakapaka and bedford (P. Stonei) were in the 35 to 65 cm range. The main group of red tail opakapaka was in the 50 to 55 cm range, and the main group of bedford (P. Stonei) was in the 44 to 47 cm range. Sweeper pomfret were caught not only in the Fiji waters but also in quite large numbers in Tuvalu waters, so fork length frequency distributions were obtained for both Fiji and Tuvalu waters. According to these, the composition range in Fiji waters was from 55 to 70 cm, and in Tuvalu waters, it was 40 to 65 cm, quite a different composition. Bedford (Paracaesio Kusakarii, P. Stonei) ranged from 35 to 75 cm, and large eye bream from 32 to 58 cm. The main group of bedford (Paracaesio Kusakarii, banded fusilier) was around 55 cm, and the main group of large-eye bream was around 40 cm in length.

As stated above, a large proportion of the major species seems to show unnatural patterns of fork length distribution, with many deviations, only a limited amount of the fish resources was subjected to fishing here, and the results seem to indicate that almost all the resources are still hidden.

(4) Distribution of major species by depth

The catch of each of the major species was sorted according to the depth of bottom line hauling, and the results below were obtained.

NAMES OF MAJOR SPECIES	DEPTH RANGE (m)
Ribbon tail	200 - 400
Short tail	200 - 300
Red snapper	200 - 500
Red job fish	100 - 300
Broad alfonsino	400 - 600
Bedfords	100 - 300
Large-eye bream	100 - 300
Bigscale pomfret	200 - 400

Figure 48 shows the catch composition of major species, classified by water depth.

Prime fish with high market values seem to be distributed in water depths from 200 to 500 m.

Drop line

Drop lines were conducted around seamounts in Fiji and Tuvalu. However, the survey vessel was large for this method and deep sea anchoring was impossible and, in consequence, the survey vessel was much influenced by current and Lee way, therefore she was difficult to keep same condition for fishing for a long time.

As a result, required records could not be made for the above reason, although drop lines were useful for detecting demersal fish there.

2. SEAMOUNT SURVEY

During shift from one fishing ground to another, searches for fishing grounds for each survey method, and during fishing ground environment survey, the cruise tracks shown in Figure 49 were surveyed by echo sounder. As a result of this survey, seven new seamount locations which had not previously been described on the charts were found. Their locations are shown in Figure 50 and Table 46.

Figure 51 also gives a cross-sectional diagram of the course of the seamount survey. The shapes of the newly discovered seamounts are shown here, in addition to other major seamounts which have become major fishing grounds for the various survey fishing methods such as surface gillnet, pole-and-line fishing, bottom line fishing, etc. Water depths are also shown in cross-sectional diagrams.

2.1 Topographic Characteristics of Survey Area

Fiji

In northern Yasawa and in Rotuma of Fiji, the inclination of the slopes from the shore to the ocean bottom is steep. West of Yasawa and in Rotuma, there were shallow areas, also flat and wide tops of seamounts were found in many places 10 to 50 meters under the sea. This area can be considered to be sinking towards the north Fiji ocean basin.

Seamounts are scattered in various locations on the island shelves of the areas around Kia, Koro, and Kadavu in the central section of Fiji. Northern Lau and Southern Lau of the east side of Fiji is the Lau Group. These islands form part of the tops of a series of rocky reefs at water depths of less than 1000 m. This series of reefs is known as the Lau Ridge. Numerous seamounts should be located here.

The southern area of Kadavu is known as the south Fiji ocean basin. There is a ridge between Kadavu Island and New Caledonia, but the water depth is great and seamounts have not been confirmed here.

Tuvalu

Tuvalu is on the east side of the north Fiji ocean basin, part of the archipelago on an uplift of the earth's crust which is gradually moving down toward the basin. Changes in the earth's crust here are small and steady. The archipelago consists of islands with steep coral slopes.

In Niulakita area on the south side of Tuvalu waters, the sea is shallow, and there are many seamounts with flat and wide tops, at water depths of 10 to 50 m.

2.2 Newly Discovered Seamounts

Seamounts which were not indicated on the charts were discovered in two locations in Northern Lau, two locations in Southern Lau, one location in Koro, one location in Kadavu, and one location in Yasawa.

These have been designated as: (1) Ngelelevu, (2) Vanuabalavu South, (3) Yagasa, (4) Tuvana-i-tholo, (5) Ngau, (6) Mbeqa, and (7) Balmoral Reef. Their cross-sectional diagrams are shown in Figure 51.

In the seamount areas of Vanuabalavu South, Yagasa, Ngau, and Mbeqa, previous fishing operations were done with pole-and-line fishing vessels belong to IKA Corporation. It is assumed that some of the fishing masters on these vessels have already noted the existence of these seamounts, but no reports have yet been made. Water depths at the tops of these seamounts vary from 10 m to 320 m. The shapes are also varied, including single peaks, multiple peaks and trapezoidal shapes, with each area having different local characteristics.

There were no discoveries of new seamounts in the survey course in Tuvalu waters. The main reasons for this lack of discoveries are that Tuvalu is part of the archipelago which is gradually submerging, and that the island is located in an area whose topographic characteristics are such that there is a low probability of discovery of seamounts which consist of islands with steep slopes.

2.3 Possibility to Discovery of New Seamounts

Fiji

There is a possibility of the discovery of seamounts in the shallow parts of Rotuma and in the western part of Yasawa of Fiji where topographic characteristics are almost identical to those of Niulakita.

In Northern and Southern Lau, rocky reefs at water depths of less than 1000 m, continue from south to north, which are known as Lau Ridge. The existence of quite a number of seamounts can thus be expected in this area. Figure 52 shows the part of Lau Ridge where the water is shallower than 1000 m. As can be seen on the map, there is a deep section near the center of Lau Ridge, which separates the rocky reefs into south and north parts. This deep section is the boundary. It is considered that topographic characteristics of the northern and southern parts are different. With the assumption at this time that for the northern part, which has already been relatively well surveyed, the existences of seamounts have already been accurately noted around Vanuabalavu Island in the northern part, and around Ono-i-lau Island (the shaded area in Fig. 52). Each of these shaded areas has been used as a model for estimating the number of seamounts on Lau Ridge, using these area size ratios.

Four seamounts in the Vanuabalavu Island area (shaded section A) in the northern part and six seamounts around Ono-i-lau Island (shaded section B) in the southern part, were confirmed by the survey. Here, these area sizes will be considered to be A and B. When the area of the section with a water depth less than 1000 m in the northern section is [A], and the same type of area in the southern part is considered to be [B], the number of seamounts in the northern area is considered to be (a), and the number of seamounts in the southern area is considered to be (b), then the following equation will apply:

(a) = [A]/A x 4 (b) = [B]/B x 6

When each area size is obtained from the charts:

[A] = 14,410 km^2 A = 1,710 km^2

[B] = 15,030 km^2 B = 2,890 km^2

Therefore,

(a) = 33.7 and (b) = 31.2

Thus it is estimated that a total of 65 seamounts exists in the entire Lau Ridge, 34 in the northern part, and 31 in the southern part.

Tuvalu

The existence of new seamounts suitable for the use of bottom lines was confirmed by this survey on the north side of the Nanumanga Island, in Tuvalu waters. The charts, however, show scattered sections which have depths shallower than 1000 m from the northern part of Tuvalu to Kiribati. The survey to detect seamounts on north of the Nanumanga Island could not be done at this time, due to the limitations of the survey schedule, which shortened the survey period. If sufficient time is available for the study of seamounts in future, it seems to be possible that new seamounts will be found.

There is also a shallow area in around Niulakita Island, in the southern part of the Tuvalu, which contains numerous seamounts with steep slopes, and wide and flat tops, in water depths of 10 to 30 m.

Bottom line fishing survey results in this waters, which were as good as those from other areas could not be obtained. However, it was felt that there is a possibility of discovery of new seamounts here, as there is in the northern section of Tuvalu. Other areas in the central section of Tuvalu are mostly deep water areas, so the possibility of discovery of new seamounts here is very small.

3. OCEANOGRAPHY

3.1 Meteorological Condition

A total of 338 meteorological observations was made during the survey period. Table 47 shows the weather appearance rate for each month, and Figures 53 and 54 show the appearance rates for wind direction and wind force. Surveys were not done, however, during from April to June in each survey year, so observations were not made for these months.

In the survey period, there was 52% partly cloudy. When cloudy weather was added to this, the rate was 77%. The wind forces less than 3 by beaufort scale were 64%. Weather was almost fine during the entire survey term.

During July and August, when trade winds predominated, the weather was fine. In October and November, strong migratory high-pressure systems passed north of New Zealand, and the area around Fiji was in a wide low-pressure area. Whereas depression accompanying front passed over the south of Fiji, as its result, rainy and overcast cloudy weather increased. Also, during December 1984 to March 1985, cyclones and depressions with vast amounts of clouds approached, therefore overcast cloudy and rainy weather were observed frequently. In March 1985, they had two cyclones and some depressions approached then 5 days were unavailable for operation. During this month, rainy and overcast cloudy weather totaled 44%. There were four days with wind force of greater than 6 by beaufort scale.

As seen in Figure 53, wind directions in the survey area were overwhelmingly south east. Other wind direction components were generally limited to times when depression with fronts were approaching. The reason for so many south east wind constituents in 1986 is that surveying was done from July to November when trade winds predominated. For 1986, the figure was 83%; for 1985, it was 62%; and for 1984, it was at its lowest, at 55%.

In 1986, the appearance rate of winds of force levels above 4 by beaufort, shown in Figure 54, was relatively higher than in other years. The reason for this, however, is that the survey was done during the season when trade winds predominate. Scouting and fishing operations were greatly affected by these strong winds in case of pole-and-line.

In 1984, there were eight days when fishing was stopped due to stormy weather, none in 1985 and two days in 1986.

3.2 Surface Water Temperature

Figure 55 shows the average surface water temperature for each month in the surveyed areas (except for the areas of Funafuti, Niulakita and Rotuma). Kia was included in Yasawa, and Koro was included in the Kadavu for convenience in this survey.

The surface water temperatures in the survey areas generally started to decrease from April to May when the trade winds began to blow, and reached their lowest, 23°C, in August. The surface water temperature began to increase from September and reached a maximum of 30°C in February to March. No great change could be seen in these trends through the survey. In 1984, average air temperature decreased greatly because the duration of sunlight was extremely short. The surface water temperature in August 1986 was slightly higher than for July, because a greater part of the survey was conducted in the northern Fiji area.

3.3 Mid-water Temperature

Vertical distribution of water temperature was observed 155 times in Fiji and Tuvalu waters by X.B.T. (expendable bathythermograph) through the survey.

Figure 56 shows the 55 designated observation station points. The water temperature observation lines of X.B.T. were designated as Line-1 to Line-9.

Using these lines, extraordinary observations were carried out in December 1984 and January 1985, for Line-1 and Line-2, then in February and March 1985 for Line-3, next, in September 1985 and July 1986 for Line-6, and finally in October 1985 and July 1986 for Line-7. Figure 57 shows the vertical cross-section diagram of water temperatures for the observation stations on the water temperature observation lines. Figure 58 shows the vertical distribution of water temperatures obtained from five observations at station No. 16 (14°-10'S, 179°-05'E). As clearly shown in the water temperature vertical cross-section diagram in Figure 57, on Line-7, a deep-sea, weak thermocline which was located with its upper limit at around 170 m, was noted in almost the entire observation line area. Many schools of skipjack were also observed in this area.

As a result, thermocline and tidal currents were not observed on the other water temperature observation lines.

Surface water temperatures changed seasonally, but hardly any change of water temperature was observed in layers deeper than 100 m on Line-1, Line-2, Line-3, Line-6 and Line-7.

The vertical distribution of water temperature was also measured during the operations of bottom line and pole-and-line fishery. The water temperature at depths of 300 to 450 m, was 12° to 15°C.

4. PAYAO DEPLOYMENT

4.1 Locations Payao Deployed

During the survey period, a total of 33 payaos (23 in Fiji and 10 in Tuvalu) were deployed (Fig. 59 and Table 48), however, in selecting locations, consideration was given to following factors.

i) Locations with rapid tidal currents must be avoided.
ii) Payaos should be around seamounts.
iii) Payaos should be deployed in locations considered to be fishways.
iv) The setting up of payaos must consider on site requirements.

Figure 60 is a sketch of a payao and the method of deployment.

4.2 Aggregating State

In the first year, fourteen payaos were set up in Fiji waters. The result of this survey was as follows.

The environment of the fishing ground in the first year was worse than in the average year, and the number of fish schools was small, but two to three weeks after the payaos were deployed, coarse fish such as rainbow runner, dolphin fish, etc., began to aggregate. A school of skipjack tended together in the area 0.5 miles under the tidal current in the morning and evening, leaving in the morning and moving to a distance of 1 to 2 miles from the tidal current for the daytime. Record of echo sounder response was detected at depths of 20 to 70 m, and fish swarmed particularly at depths of 30 to 40 m (Fig. 61). This response was detected at about 10 a.m. when trolling was being done around the payao, and 70% of the catch here at this time was yellowfin tuna. From these results, it can be assumed that coarse fish swarmed to payaos at first, and that yellowfin tuna and skipjack gathered next. The skipjack school seems to have left payaos in the daytime and approached them in the morning and evening.

Situations similar to the above were confirmed from the payaos with setting numbers (1), (2), (3), (4) and (6), but it was not possible to confirm any signs of fish from payaos (7) and (10). Confirmation was not possible for payaos (12), (13) and (14), due to the insufficient number of days after these payaos were deployed. Payaos (5) and (11) were set up close to shore, at the request of Fisheries Division of Fiji. Fourteen payaos used rafts assembled from domestic bamboo materials in the first year. Payaos (2), (3) and (7) were lost away because of the cyclone which approached the area in January, 1985.

When the second year came and survey of Payao continued again, it was found that payaos set in the first year had drifted away except for payao (6). However, even this Payao (6) was lost soon after the first survey was over. The reason for the loss of payaos is assumed to be that the domestic bamboo materials absorbed waters and lost buoyancy, so that the resistance of each raft was great, and the ropes were cut by cyclone which passed through Fiji in the previous year. In this period, four payaos were deployed in Tuvalu waters, and six in Fiji waters. These rafts used PCV (polychloride vinyl) pipes, but the procuring of materials was delayed, and continuous surveys of aggregating conditions were not possible due to the survey schedule after setting up the payaos.

In the third year, six payaos were set up in Tuvalu waters and three in Fiji waters, but little opportunities were available to survey the payaos except the pole-and-line fishery survey for both waters. Therefore, only a part of them was checked for aggregating conditions after the payaos were deployed.

During July to October, when fishing was never previously done in Fiji waters, domestic fishing boats were reported to IKA Corporation and had a catch of 30 to 50 tons around the payaos. The captains of domestic fishing boats were interviewed and stated that they fished for many days around the payaos, so it can be assumed that the payaos are sufficiently effective, but the catch could not be confirmed as the catch around the payaos was not clearly entered on the fishing reports.

5. DISPOSITION OF CATCHES

Catches were turned over to IKA Corporation. However, pelagic species and demersal fish disposed of as follows to suit sales purposes in accordance with the requests of local officials.

5.1 Pelagic Species (skipjack, yellowfin tuna, etc.)

The catch was processed by brine-type freezing whenever possible.

5.2 Demersal Fish

IKA Corporation wanted to export ribbon tail and red snapper, etc., to Hawaii and the west coast of the U.S.A. and elsewhere through a domestic company, so that the catch was processed by spiking to kill the fish immediately and placed in chilled storage. Therefore, support for the freshness of catches was paid careful attention, the maximum cruise length was regulated at two weeks.

Fish other than the above, such as the various bedfords, tunas, etc., were traded with a domestic company and with the National Marketing Authority of the Ministry of the Economy. Deep sea shark were also used in the Fisheries Division of Fiji for collecting liver oil.

Table 49 shows details of the catches landed by surface gillnet, trolling and pole-and-line fishery, and Table 50 shows details of the catches landed by bottom line fishing, those information obtained from IKA Corporation.

IV. DEVELOPMENT OPTIONS FOR OFFSHORE FISHERIES RESOURCES IN FIJI AND TUVALU

1. SUITABLE FISHING METHODS

1.1 Fiji

As a result of this survey, it is believed that bottom line fishing and trolling are most suitable for local fishermen in Fiji because of the abundance of fishing grounds, possible good catches, economical operation cost and easy accessible technique. Therefore a model vessel, which is capable of year-round operations both bottom line fishing and trolling, was designated and was studied its various aspects.

(1) Estimating catch by a model vessel

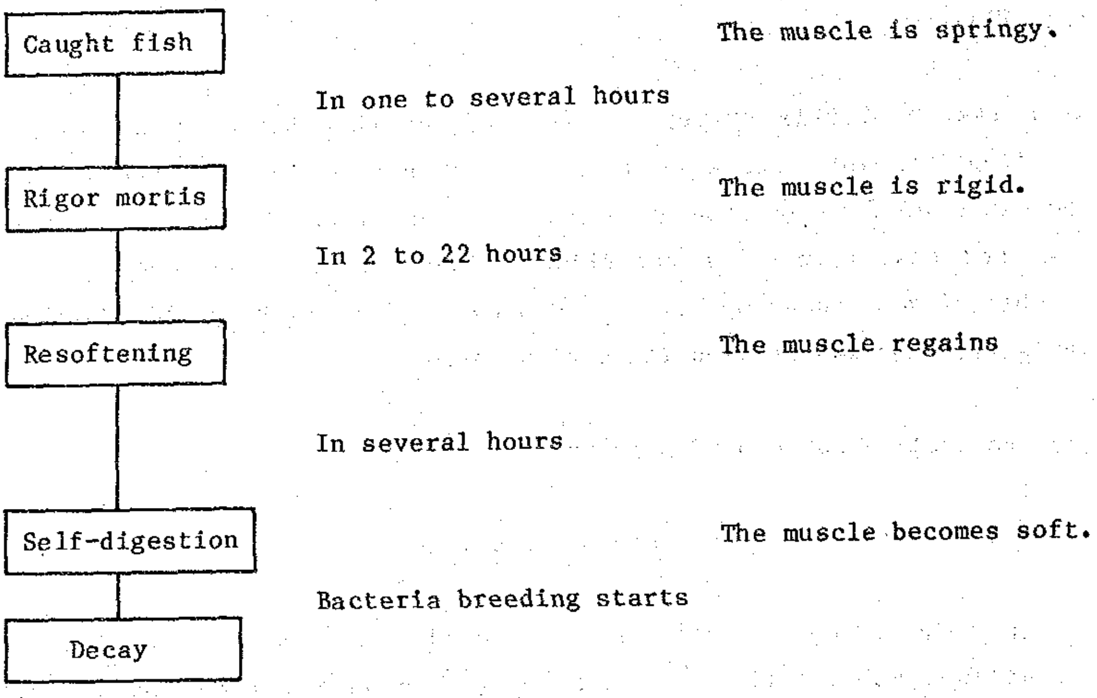
(a) Fishing gear and fishermen required

In this survey, buttom line was conducted once a day, also surface gillnet and trolling were both performed once a day or more. For the model vessel, the operation twice a day was assumed, once each in the morning and in the afternoon, for both bottom line fishing and trolling, as shown in Figure 62. The appropriate number of branch lines for bottom line fishing was set at 100 to control soaking time of the fishing gear within three hours and hauling time within two hours, and only six hooks be attached to each branch line to avoid wasteful fishing caused by entanglement (15 - 20 hooks in this survey) and six lines for trolling.

Under these conditions eight fishermen are needed for bottom line fishing and four for trolling, i.e. the model vessel must have eight men.

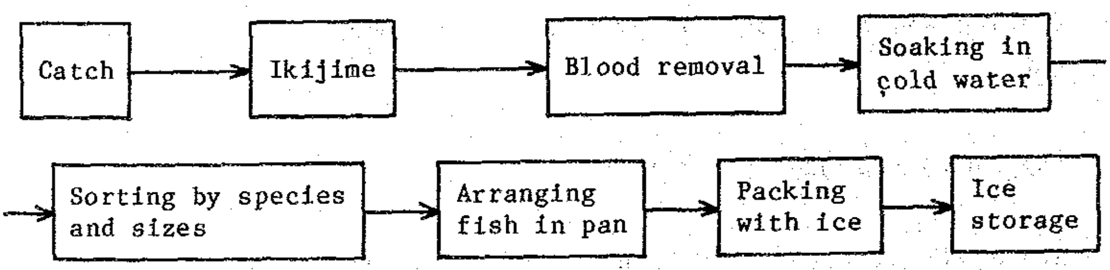
(b) Number of days per trip

Since the demersal fish caught by bottom line fishing must be kept fresh (edible in the raw state) for export, the freshness is maintained by iced storage. The number of days in which the perishability can be maintained by iced storage is therefore the first factor to determine the number of days per trip. The process of decaying of fish is shown below (Tanaka, 1981 .. (13)).



Being fresh fish means fish in the fresh condition before being putrefied or in the early stage of putrefaction. In case of yellowfin tuna, it could stay fresh for 4 days when left in 10°C air, while could remain fresh for 10 days when stored in 0°C. If processed by heating, edible period is 10 days for the fresh in 10°C, while one in 0°C stays edible for 35 days (Tanaka, 1981...(13)).

The processes currently applied in Japan from the catch to ice storage are as follows:



On this survey, the processes of soaking in cold water and arranging fish in pan were omitted due to measurement of the caught fishes and the limited storage space, but the fish was kept fresh for ten days at the maximum. The process of soaking in cold water rapidly lowers the body temperature, and this process is considered to extend the period of being fresh by one to three days. If there are nine days from departure to return, the number of days necessary for one trip can be estimated as follows:

Number of days for round-navigation	2 days
Number of operating days	7 days
Landing of catch	1 day
Loading of materials	1 day
Day-off	1 day
Total	12 days

(c) Catch per vessel per day

Bottom line fishing

The average catch by bottom line fishing per operation is 327.6 kg (Table 51). But, taking the operation cost of bottom line fishing, the Rotuma fishing ground, which is far from the landing port, and the Yasawa fishing ground, which provided poor catch during the survey, must be excluded. When those two fishing grounds are excluded, the average catch per operation is 376.4 kg, as shown in Table 52, and the number of effective hooks is 697.4.

The number of effective hooks in Fiji waters, as shown in Table 52, is 713.8 (ratio of effective hooks in 55.0%) per operation. For the model vessel, since the number of branch line is set to 100 and the number of hooks attached to each branch line is set to six to avoid entanglement, if the operation is conducted twice a day, the total number of hooks is 1,200 [100 (branch line) x 6 (hooks) x 2 (operations)].

Generally, the ratio of effective hooks in bottom line fishing is 95 to 100% when the same fishing gear as for the survey (20 hooks per branch line) is used. Although improved fishing gear is used by the model vessel so that there could be few ineffective hooks, the ratio of effective hooks to the total number of hooks used, was assumed to be 80%, and based on which the catch per day was calculated as follows:

$$376.4 \text{ kg} \times \frac{1,200 \times 0.8}{697.4} = 518 \text{ kg}$$

Table 51 indicates that 91.4% (excluding sharks) of all species caught in Fiji consumed as fresh fish for domestic consumption and export. Therefore, the amount of useful fishes among 518 kg calculated above is 473 kg (518 kg x 0.914).

Trolling

Trolling was tested on the same day as surface gillnet testing, alternating these two test types.

Trolling was tested in the vicinity of a seamount area. When the catch was favorable, the trolling test was quickly stopped and surface gillnet fishing was tested around the seamount. Therefore, there is not a day of full scale fishing with trolling only. As Table 25 shows, the average trolling operation time is two hours and four minutes and the catch is 126.3 kg per operation.

When the trolling method is utilized as an economical fishing method like the bottom line fishing method, fishing grounds which are far from the landing port and proved a poor catch must be excluded. Accordingly, the trolling catch was estimated from the figures of Table 32 as described below.

Table 32 shows that the catch per hour in established fishing grounds is 61.43 kg (including 40.07 kg of skipjack and yellowfin tuna).

When this quantity is applied to the model vessel operating for five hours and 30 minutes, the catch per vessel per day is estimated as follows:

61.43 (kg) x 5.5 (hours) = 338 (kg/day)

Since skipjack is used as bait for bottom line fishing, the quantity of skipjack must be deducted from 338 kg/day. The survey results indicate that sliced bait meat for 20 hooks can be made out of a skipjack weighing 2 kg. Therefore 60 skipjacks (120 kg in weight) are consumed for bottom line operation per day (1,200 20 skipjacks). When this consumption is excluded from the catch shown above, the marketable catch is 218 kg.

On the trolling tests conducted this time, the vessel shifted to investigate seamounts even if the catch was favorable and so the operation was not conducted more than once in one place. Therefore, the catch is considered to be larger than that estimated if the fishing effort is concentrated in good fishing grounds.

Annual operation rate of model vessel

The appearance rate of wind force in the coast and offshore in Fiji are shown in Figure 63. A bottom line fishing/trolling boat has difficulty in operating when the force of the wind (beaufort scale) becomes 4 or higher. Figure 63 shows that winds of scale 0 to 3 occur 59.8% during the year. The annual number of operable days calculated on this rate is 218 (365 days x 59.8%). Therefore, assuming that the number of days per trip is 12 days, as described earlier, the number of trips that a vessel can make in a year is 18 (218 days 12 days).

Estimated annual catch per vessel

The annual catch per boat is estimated as shown below based on the values calculated in the preceding description.

(Unit: kg)

Fishing method	Catch per day	Catch amount	
		per trip	Annual
Bottom line	473	3,311	59,598
Trolling	218	1,526	27,468
Total	691	4,837	87,066

(Note) The number of operating days per trip is seven.

(2) Type of model vessel and its fishing gear

(a) Type of model vessel

The type of vessel based on the factors of the fishing gear, fishing methods, and estimated catch above-mentioned is estimated as follows.

Number of crew	8 persons
Ice and fish hold	15 m^3
	4.8 t/trip x 1.2 ÷ 0.4 (loading factor)
Oil tank	9 m^3 [(2 days x 0.8 KL) + (7 days x 0.6 KL)] x 1.2 ÷ 0.8
Main engine horsepower	200 HP (high-speed engine)
Speed	9 knot (5 - 7 knot during operation)
Fresh water tank	4 m^3
Refrigerating engine	1 (storage temperature 0°C) unit
Auxiliary engine	1 (2.5 kW) unit

Dimensions of a boat to meet these conditions will be 16.4 m (Length) x 4.0 m (Breadth) x 1.4 m (Depth). This is a 16GT type FRP boat according to shipyards. Table 53 shows the specifications of the model ship.

(b) Fishing gear

Bottom line

The largest shortcoming of bottom line fishing found through this survey is the large ratio of ineffective hooks, reaching as high as 45%. This shortcoming was caused by entanglement of branch lines and a main line which was cast by unskilled crew in the slacking state from the stern at low speed of 3 - 5 knot. At the same time, since the snood connected with each branch line were too long, some of them became entangled with branch lines.

Therefore, taking the following points into consideration, the gear was simplified as much as possible.

- Easy-handling fishing gear with high work efficiency to reduce the labor cost
- Durable fishing gear to reduce the fishing gear expenses
- Fishing gear appropriate for operation on board a small boat to reduce the cruise expenses

In bottom line fishing, consumption and entanglement of branch lines and snoods are the main factors increasing the work load. To make handling easier and reduce wear, the branch lines and snoods should be thick. However, thick branch lines and snoods affect fish response to bait adversely and decrease the catch amount. Therefore, the branch line and snood were improved as shown in Figure 64, considering all these points.

For the branch line, 8 m of No. 120 Nylon gut (No. 60 was used during the survey) is to be used with six hooks attached (20 during the survey). For the snood, 40 cm of No. 60 Nylon gut (No. 25 to 30 was used during the survey) is to be used. Each snood is attached to the branch line with a snap during setting the line and is removed during hauling. Each branch line is attached to the main line with a snap and removed branch lines are stored separately (Fig. 62).

When the main line is set in some tight state at high speed, the entanglement of main line and branch lines can be avoided. However, from the standpoint of the safety of fishermen, the ship speed should be increased (maximum 7 to 8 knot) as their skill improves.

The number of branch lines per operation was limited to 100 in order to operate early in the morning and in the evening when the fishing efficiency of a small boat is high. Figure 62 shows the necessary working time. When the fishermen's skill improves, this working time can be reduced further and the amount of fishing gear can be increased.

Trolling

The objective of trolling in this survey was pelagic fish. It is considered necessary that a trolling be conducted in combination with the mid water fishing in the future. Figure 65 shows a schematic diagram of the mid water trolling and the fishing gears being applied. If mid water trolling is conducted using a submarine board, large fishes like yellowfin tuna and bigeye tuna can be caught.

Vertical long line

Although drop line fishing was not tested on a full scale in this survey, this is a useful fishing method in a fishing ground where the anchors of bottom line cannot be set because of the steep seamount slope. Bottom line fishing is impracticable there. This method has already been adopted by enterprises in Fiji, therefore vertical long line with increased number of hooks, i.e. 30, while ship is drifting, instead of local fishing by drop line usually using 5 - 6 hooks is recommendable as the appropriate fishing method to be applied to around seamounts.

That is that, when the vertical long line is caught on the sea floor, the part of main line caught on the bottom should be cut to save other part of fishing gears. Therefore, the main line is made thicker as it goes from the sea bottom to the surface. Branch lines (30 cm long and with hooks) are set at intervals of 1 m. The appropriate number of hooks is 30, and a swivel is attached to the main line every five branch lines (Fig. 66).

Three sets of vertical long line can be set by a boat per operation. This fishing method should be conducted after investigating the bottom topography, current, and the fish reaction on the echo sounder at the fishing ground. The methods of setting and hauling are shown in Figure 13. To haul the line efficiently, a reel (manual or electric) is necessary.

1.2 Tuvalu

A report of Fisheries Division of Tuvalu indicates that nobody has been exclusively engaged in fishing because of the self-supporting economy. People have been fishing using hand line fishing or trolling on canoes and outboard-engine boats while not doing other work (mainly work on copra).

Except the two islands of Funafuti and Nukufetau, Tuvalu has no adequate anchorage for fishing boats. Besides, these two islands do not have adequate fishing port facilities (wharf, cold storage facilities, fuel supply facilities, etc.) and there is no place that can be used as a fishing base in other islands.

Cold storage facilities controlled by Fisheries Division are located in Funafuti. The scale is only equivalent to three home refrigerators (total volume about 1.5 m^3) and the storage capacity of fish in about 800 kg. No cold storage facility and ice-plant exists in other islands.

Therefore, to develop fisheries in Tuvalu, there are many related areas to be developed or improved. It is desirable to make efforts to develop economical and easy fishing methods to utilize the resources of pelagic and demersal fish resources.

During this survey, a number of skipjack schools was observed in the area around Funafuti. The majority of them were schools associating with bait.

The current flows from south to north in this waters, and small pelagic fishes gather around the island. It seems that these small fishes are the bait for skipjack, and so a good skipjack fishing ground is formed.

Since live bait fishes for skipjack fishing inside lagoons are scanty, a simple and economical trolling method which does not use live bait is more suitable for skipjack fishing in Tuvalu than pole-and-line fishing.

The demersal fish resources were not confirmed during this survey, but a good fishing ground was discovered on the seamount in the northwestern part of Nanumanga Island (Table 51). Since the average catch of 15 operations was 339 kg here, it is presumed that demersal fish are inhabiting along the coasts and on the slopes of the reefs of other islands.

Considering that the islands in Tuvalu have steep coast lines and are surrounded by reefs, drop line fishing method using a manual reel is more suitable and economical method for demersal fish than bottom line fishing method.

(1) Type of model vessel

At present, canoe fishing is dominant in Tuvalu. But it will be possible to increase the fishing efficiency by using a small boat equipped with an outboard motor for one to three persons. This small boat should be available for trolling, hand line and drop line fishing, as well as for one day fishing trip along the coast and inside and outside a reef, and should have iced storage facility. The specifications of such a boat, considering its stability, are as follows:

Material	Wood or FRP
Gross tonnage	0.8 G/T
Crew members	3 persons
Size	12.0 m (Length) x 2.0 m (Breadth) x 1.1 m (Depth)
Outboard motor	30 to 40 SP
Speed	8 knot
Fish hold	3 m^3
Ice hold	1 m^3

Therefore as previously mentioned, if trolling and drop line fishing have been developed furthermore, technique of full time fishermen upgraded and all necessary facilities (such as ice-plant, cold storage etc.) set up for fishing industry in future, it will be possible to start the project of developing demersal fishery there using such a suitable size of fishing vessel like the on already introduced to Fiji.

(2) Fishing gears and methods

Figure 65 shows the set-up of fishing gears for trolling. Two trolling lines are extended from the both sides of the stern respectively, or three lines, i.e. two lines extended from the pole protruding from each side in the central part of hull and one from the stern are provided. Figure 66 shows the set-up of fishing gears for vertical long line fishing. For this fishing, it is recommended to install a manual reel on each side.

2. RESOURCE POTENTIAL

2.1 Fiji Waters

(1) Pelagic fish (skipjack and yellowfin tuna)

In Fiji waters, 268 fish schools were observed between the first pole-andline fishing cruise and the seventh cruise, and 160 schools were fished. As described earlier, the group size ratios of these 160 schools are 1 for large, 0.5 for medium and 0.3 for small, and the chumming ratios are 1 for good, 0.5 for natural, and 0.2 for poor respectively. It should be noted that the judgment of school size and chumming is subjective and that an analysis based on such judgment may lack objectivity. Nevertheless, it is clear that the only clue to study the relation between the sizes of fish schools and the catches is these records of visual observation at fishing grounds. Therefore, an attempt was made to estimate the population of pelagic fish in Fiji waters (within the visibility range of observers) based on these records even though they may be not complete.

The first explanation is on estimating a quantity of fish comprised a school. Assuming a constant "k" which is common to all schools (large, medium, and small), a large school can be expressed as 10 k, a medium one as 5 k, and a small one as 3 k based on the proportions shown above. When this value is multiplied by the number of schools and the result of each group size is summed up, an index of fish quantity in the fishing ground is obtained. Next is estimation of catching rate. A comparison between the catch of a pole-and-line fishing boat and a purse seiner may provide a clue for estimation. A purse seiner is far superior to a pole-and-line fishing boat in catch efficiency. If the conditions are favorable, a purse seiner can catch the majority of the target school. Naturally, there are some differences in the fishing ground and desired catch between a pole-and-line fishing boat and a purse seiner. However, it does not seem that there is a great difference in the aspect of school size regardless of the difference in the fishing method.

The maximum catch per operation of a purse seiner operating in Fiji waters is 45 tons with an average of 11.8 tons (catch report of the "Western Pacific" for 1983 to 1985). The maximum catch of a pole-and-line fishing boat is 12.7 tons at the best chumming and average of 4.7 tons (survey results of the "Te Tautai" and the "IKA-No. 5" for the current term), that is, about one third of that of a purse seiner. Therefore, if the catching rate per school of a purse seiner is assumed to be 0.9, the catching rate of a pole-and-line fishing boat is only 0.3 even at the best chumming. Another clue to estimating catching rate is the result of several operations attempted to the same school. When the fish quantity of the target school is expressed as "N" the catching rate as "f" and the catch of the first operation as "C_1" the first catch quantity is expressed as

$$C_1 = fN$$

The catch quantity of the second operation, expressed as "C_2" is

$$C_2 = f\,(N - C_1) = C_1 - f\,C_1 = C_1\,(1 - f)$$

Therefore: $f = 1 - C_2/C_1$

Since this estimation is based on such essential conditions as the school being the same for the first and second operations, the chumming must be the same, and there should be no recruit or scattering of the school during the period between the first and second operations, this calculation may not be applicable frequently. However, several such cases were found in the operation records of this survey.

The following is one such case. On November 11, 1985, a skipjack school containing some number of yellowfin tuna was sighted at 17°11'S and 179°14'W and caught 3,511 kg. On the next day, the catch of 2,519 kg was made at the same point (bait response was good in both cases). Since the fishing ground was the same and so was the fork length composition, it is reasonable to assume that the two are the same school. Accordingly, the "f" value was calculated using the above equation and obtained 0.28. In several other cases, the "f" value was about 0.3, approximating the value obtained by the comparison with purse seiner's catch.

For this reason, the catching rate of a pole-and-line fishing boat was determined to be 0.3 when the bait response was good. Then determined the catch rate for natural bait response was determined to be 0.15 and for poor bait response to be 0.06 based on the proportions described earlier. The fish quantity index was determined for all large, medium and small target schools. When the fish quantity index thus obtained for each group is multiplied by the catching rate determined for each chumming state and then all resulting values are added, a catch volume index can be obtained. Also, the value of constant "k" can be determined based on the actual catch quantity shown on the operation records and the catch quantity index. Although "k" should be constant, the value thus obtained varied to considerable extent by sea areas. This seems to be attributable to the fact that individual catch quantity caught from schools which were assumed to be the same in size and bait response varied significantly.

Here, the fish quantity of each area was calculated using a value of "2.067" obtained by putting all four areas together temporarily. Then the ratio of catch quantity (catching rate) to the value was calculated. The values thus obtained are shown in Table 54. The value for overall result of the four areas is 8.5% and is 10 to 11% in Kadavu, Koro and Northern Lau where the operation concentrated. This means only 10% of the migrating resources are exploited, indicating sufficient allowance in the resources.

In this area, the South Pacific Commission tagged 11,646 skipjack in April 1980 and caught 953 of them in the same area by May next year (Kearney, 1984 .. (2)).

The recatch rate is 8.4%, roughly coinciding with the overall catching rate of the four sea areas mentioned above. Kearney stated that the skipjack resources in Fiji waters were large enough to sustain a catch as large as several times the current catch level. This is agreeable, considering the ratio of fish quantity and catch quantity described above. However, if the catch volume of live bait cannot be increased beyond a certain level, as described later, the catch quantity of pole-and-line fishing boats is restricted.

(2) Live bait

Live bait is caught by stick-held dip net (Boukeami) at night in lagoons along the coast, kept in live bait tanks on board, and used for fishing the next day. The life span of bait in the tank varies by the species. Some may live as long as a month but most die in 10 to 20 hours. Therefore, the stay in a fishing ground including the time of round trip is limited to about 20 hours, restricting the operation range of boats to a 40 mile radius. Also, the catch of live bait fluctuates largely by year and season and thus forms another major cause of restricting the operation of pole-and-line fishing boats.

Figure 67 shows the trend of the monthly fish catch and live bait catch by pole-and-line fishing boats in Fiji from November 1979 to June 1982 (Fisheries Division, 1982 .. (3)). The both trends agree well to indicate close association of the fish catches with those of live bait. Also, yearly trends in live bait catch, the number of stick-held dip net operations (number of set), and catch per set between 1976 and 1985 are shown in Figure 68 (Fisheries Division 1982, 1983, 1984, and 1985 ...(3)).

The number of stick-held dip nets that catch live baits has increased yearly since 1976, reaching to 2,400 sets in 1982, but later, in 1984 and 1985, that sharply declined in the same level of catch as poor 1978 to 1980. Corresponding with the increase in the number of set, the amount of live bait caught has increased, although it temporarily decreased in 1979 and 1980, reaching 79,000 buckets in 1982, then dropped down.

On the other hand, the catch of live bait per set has gradually decreased after the peak of 66 buckets in 1976. However, the number of set substantially decreased in 1984 and the catch per set increased. When the relation between the catch per set and number of set is reviewed on a graph (Fig. 69) on which the catch volume is expressed on the vertical axis and the number of set on the horizontal axis, the plotted dot line goes diagonally downward in a linear form, indicating a negative correlation between the two. Therefore, when the relation between the two is expressed in a linear equation, excluding 1980 in which the quantity was particularly small (the live bait catch was extremely small in the year, which applies to skipjack also, affected by the very-low sea water temperature), the following equation is obtained:

$$C/F = 67.51 - 0.0158F$$

where C .... Total live bait caught annually

F .... Total number of stick-held dip-nets used annually

The relation between C and F can be rewritten from the above equation as

$$C = 67.51\,F - 0.0158\,F^2$$

The above equation plotted on a graph forms a parabola shown on the upper column of Figure 69, and C (total live baits caught annually) is maximum when F (number of set) is about 2,200. Assuming that C and C/F are dependent (i.e., assuming that the decrease of live bait catch per set was derived from the increase in number of set), the live bait catch is balanced with the number of set, which is an indication of fishing effort, reaches until a certain level. When the level is exceeded the catch is then unbalanced and is decreased abruptly. No phenomenon that negates this supposition has yet occurred. Therefore, the distribution of live bait in this waters is almost constant every year unless the number of set, which is an indication of fishing effort, exceeds a certain level and unless an unusual case like abnormally low water temperature occurs. Thus if the total number of set increases, the live bait catch of individual boats decreases, or if the total number of set decreases, the live bait catch amount of an individual boat increases.

(3) Demersal fish

Data and information which can be used as the basis for estimating the demersal fish resources for bottom line fishing on the slopes of coastal area and a seamount is extremely scanty. Therefore the analysis was made by using assumptions on some of the conditions. For this purpose, the following equation to show population changes in the past year was used, by expressing the starting population in the beginning of one year as P_1 and the population in the beginning of the next year as P_2.

$$P_2 - P_1 = A + G - D$$

Here, "A" means annual recruitment, "G" means increase of the weight resulting from growth, and "D" means reduction resulting from death. If the population is balanced, $P_2 - P_1$ is equal to zero, which means A + G is equal to D. If the catch of the population is expressed as Y, the above equation is rewritten as follows:

$$P_2 - P_1 = A + G - D - Y$$

Unless Y exceeds a certain level, both A and G will increase and D will decrease because of recuperative power of the resource and the population will remain unchanged. Accordingly, from a standpoint of conservation of resources, it is desirable that Y should be equal to G. In other words, the allowable annual catch should be restricted within the annual increase of the population. The amount of annual population increase must therefore be determined.

Before determining the amount of annual increase, an attempt was made to roughly estimate the population of demersal fish in this waters. Based on the results of this survey, it was concluded that Yasawa and Rotuma would not be suitable for bottom line fishing. Thus areas to examine were limited to Kia, Koro, Kadavu and Northern and Southern Lau areas. The total coastal line length in these areas is estimated to be 5,300 km, but the length of land slope that can be actually utilized for fishing is estimated to be about one tenth of the total length mainly because of the sea bottom topography and current. Since the fishing ground on the slope in water is limited to the depth of 200 to 500 m, the width of fishing ground is estimated to be about 2 km. The area will thus be 1,060 km^2 (530 x 2).

The estimated number of seamounts in the depth of 100 to 1000 m, which can be considered as fishing ground, is about 65 including unconfirmed ones. Although the size of individual seamounts varies, if one seamount fishing ground would be a circle of 1 km radius, its area is 3.14 km^2 and the total fishing ground area would be 200 km^2. When this is added with the land slope area, the total is 1,260 km^2. This would be the total area of fishing grounds of demersal fish in Fiji.

The scale of bottom line fishing is various. Here, assuming that the fishing gear used by a boat is of 2,000 m long with 100 branch lines and that fish in a circle with a radius of 50 m with a connecting point of each branch line with the main line as the centre could be fished and that the ratio of effective hooks is 60%, the fishing area is 1,200 m long and 50 m wide on both sides of 60 branch lines. The area is therefore 120,000 m^2 or 0.12 km^2. This is equivalent to 1/10,500 of the total area. If demersal fish are distributed uniformly there and 80% of the fish are caught in the range covered by bottom line, the quantity of fish caught in one operation is equivalent to 1/13,000 of the total population.

According to the results of this survey, the average number of fish caught per operation in areas of Kia, Koro, Kadavu and Northern and Southern Lau was 93 (376 kg). If this value is indicative of density of the demersal fish distribution, the total fish population is 12 x 10^5 (4,900 tons).

Since the target schools consisted of a variety of species, several major species were selected to show the relationship between their fork length and weight in Figure 70. Since the data is not abundant, details cannot be known, but this figure shows that the relationship between the increases in length and weight seems to be common to all species. The maximum length of these demersal fishes is 70 - 100 cm, and their life span is assumed to be 10 to 15 years. Therefore, the annual length increase is assumed to be 7 to 10 cm, and the annual weight increase is assumed to be 1 to 1.3 kg from the Figure 70, thus, the annual weight increase of the whole population is assumed to be 1,200 to 1,600 ton. If the annual catch per boat is 60 ton, this increase can support 20 boats' activities.

2.2 Tuvalu Waters

(1) Pelagic fish (skipjack and yellowfin tuna)

As described before, the mean catch of each operation calculated by school size and by chumming did not show a definite proportional relation in Tuvalu waters and so it cannot be used as a measure estimation of the fish quantity of school and catching rate. However, the catch quantity corresponding with the group size or bait response may be regarded to be basically the same as that in Fiji waters.

For this reason, the school size for each operation was calculated by applying the index obtained by analyzing the catch amount in Fiji waters and the catching rate compared with the catch quantity was calculated. The results are shown in Table 55. This table indicates that the catching rate is almost equal to that in Fiji waters in the first cruise. This is, it seems, due to the concentration of the operations in a comparatively narrow area. However, on the second cruise since the visual observation survey range was expanded to 4°S, the number of schools increased to almost four times that of the first cruise, proving the abundance of resources in this waters. Schools were sought in wider range during the third cruise, but this time large and medium schools were not observed and the stock biomass of pelagic fish remained comparatively low.

(2) Live bait

This area has only two lagoons suitable for baitfishing as mentioned before. Furthermore, the distribution of small fish suitable for live bait was very poor and could not satisfy the need of the survey vessel. Nevertheless, small fish that can be used as live bait are abundant offshore, so this area will become a very promising fishing ground if they can be well collected.

(3) Demersal fish

Since the survey in this area was limited to the northwestern area of Nanumanga island and around Niurakita island, the overall size of fishing grounds on seamounts and land slopes could not be determined, though that is necessary for appropriate estimation of the resource potentials there. However, on four operations in the northwestern area of between Nanumanga Island and Nanumea Island, the catches of 2.4 tons or 600 kg per operation was made, the largest in both Fiji and Tuvalu waters. Furthermore, since the majority of catch was "ribbon tail" of a high market value, this area can be a very promising fishing ground for demersal fishing. Additionally, charts show a lot of shallow areas of up to 1,000 m in the northern area of Tuvalu and around Niurakita island, implying the existence of several seamounts. Development of new fishing grounds can thus be expected.

3. HANDLING AND DISPOSAL OF CATCHES

3.1 Fiji

(1) Marketing

Pelagic fish caught by the survey vessel were delivered to the national canning company after brine freezing. Of the demersal fish, "ribbon tail", "red snapper" and others, as fresh fish, were exported to Hawaii and the west coast of the United States through local fishing company. Table 50 shows the sales of these fishes based on data from IKA Corporation. The prices of these fish fluctuate seasonally and according to supply and demand (Figure 71). "Bedford" and "tuna" are sold for domestic consumption and the average price was about F$1.60/kg.

For other marketing facilities, National Marketing Authority of Fiji (NMA) has cold storage facilities and ice-making plants transferred from the Fisheries Division. These are installed in Lami, Lambasa, Lautoka, Taveuni, Savusavu and Nabouwalu. NMA purchases fish in three ranks of A (F$1.50 to 2.30/kg), B (F$1.00 to 1.50/kg) and C (F$0.50 to 1.00/kg) and sells them to the public with value-added, and the majority is consumed by hospitals and schools in the form of government supply. As shown in Figure 72, the NMA sales in 1984 to 1986 are on the upward trend.

(2) Expansion of marketing for the catch increase by trolling and bottom line fishing

The trolling catches are fully consumed by the canning company and the domestic market. However, an export market for demersal fishes as fresh fish is very limited, as only a few distributors can export to Hawaii, the United States, New Zealand and Australia. Thus the supply of fresh fish is apt to be excessive, resulting in a potential price decrease (Fig. 71). To stabilize the prices, efforts must be made to export them to countries other than those mentioned above or to process them by filleting and packing, etc., aiming at domestic and foreign markets.

(3) Recommendation on the handling method

As described in 1.1, (1), (b) in Page 80, "Number of days per trip", attention must be paid to the following points on the process of handling fishes;

(a) To avoid exposing fishes to the sun during handling and process as quickly as can.
(b) To avoid leaving fishes on the deck. To kill them immediately, wash them thoroughly in water, and chill them in cold water.

(c) To chill them in cold water for 30 to 40 minutes (Fig. 73).

(d) To sort them by species and sizes and then arrange them on a pan.

(e) After arranging the fish on a pan, to place a vinyl sheet over it and cover it with crushed ice. (The weight of crushed ice should be 80 to 100% of the weight of fishes.)

(f) To maintain the temperature in the hatch fish hold at 0°C so as not to refreeze the crushed ice and melting water. If refreezing occurs, the crushed ice pieces become a solid lump, creating a space between the ice and fish body. The fish is therefore not chilled by the ice or cold air, adversely affecting the freshness of the fish.

(g) To provide the pan with a height enough not to press fishes below when pans are stacked.

(h) To drain water periodically since melted water flows in the fish hold during storage.

3.2 Tuvalu

(1) Marketing

The Fisheries Division is dealing with about 300 kg of fishes daily, selling in Funafuti at the price of one Australian dollar per kg. Hand line fishing and trolling are conducted inside and outside reefs of individual islands, but there are no statistical data on the catches, consumption, and marketing in islands other than Funafuti.

(2) Expansion of marketing for the catch increase by trolling and drop line fishing

As fisheries are developed in Tuvalu, the production of fresh pelagic and demersal fish will gradually increase. However, since Tuvalu consists of widely scattered islands, there are many points to study on the transit system of catches such as collection, storage and transport. The products may be exported in the future, but since Tuvalu is distant from importing countries and the transport conditions in Tuvalu are not good, the costs of collection, storage and transportation will be high. How to reduce these costs, must be an important problem to resolve. One suggestion is that fishes be processed in Tuvalu, adding more value and removing inedible parts, in order to reduce the cost of transportation.

While the demersal fish catches as fresh fish are partly exported to foreign markets in Fiji, it is very difficult for Tuvalu to sell them to the same foreign markets under the various conditions mentioned above, in addition to the higher cost rising from the necessity of maintaining the freshness. Therefore, it is suggested, as one of practicable methods in Tuvalu, that salted fishes or frozen fillet packs be sold to neighboring countries.

Annex 1

MEMBER LIST FOR THE FISHERIES RESOURCES SURVEY IN FIJI AND TUVALU

1 Represetive of Japan

1) Adviser in Committee

Name	The Field of Assignment
Mr. Norio OTSURU	Leader
Mr. Keiichiro MORI	Survey Planning
Mr. Keiki IIZUKA	Resource Analysis
Mr. Masahiro ASANO	Resource Analysis
Mr. Minato YASUI	Fishing Methods

2) Survey Team

Name	The Field of Assignment
Mr. Tsutae SATOH	Team Leader of Survey
Mr. Kohei KASAHARA	Resource Analysis
Mr. Hitoshi MIZOKOSHI	Fisheries in General
Mr. Yukihiro MONMA	Fishing Boat Engine
Mr. Misao YOKOYAMA	Fishing Operation
Mr. Takashi MORITA	Resource Analysis

2 The Government of Fuji

Dr. p. c. Hunt
Ratu Tui s. Cavuilati
Dr. A.D. Lewis
Mr. A. Sesewa
Mr. M. McGregor
Mr. J. Harrison

3 The Government of Tuvalu

Mr. Elisala Pita
Mr. M.J. Batty
Mr. D. Schupp
Mr. F. Hersheid

Annex 2

REFERENCES

(1) Keiki Iizuka (1984)
Report of Meeting to discuss Skipjack Fisheries Research 1984.
Tohoku Reg. Fish. Res. Lab.

(2) Kearney, R.E. (1982)
Skipjack Survey and Assessment Programme Final Country Report No. 1
SPC.

(3) Fisheries Division Annual Report in 1981, 1982, 1983, 1984 and 1985.,
Ministry of Agriculture and Fisheries of Fiji.

(4) Tohoku, Reg. Fish. Res. lab.,
Atlas of Skipjack Tuna Fishing Grounds in Southern Waters (1978-1979).

(5) Tester, A.L. and E.L. Nakamura (1957)
Spec. Scient. Rep. Fish. U.S. Fish. Wild serv., (250).

(6) Brock, V.E. (1954)
Pacific Science 8(1).

(7) Orange, G.T. (1961)
Bull. Inter-Am. Trop. Tuna Comm. 2(3).

(8) Kearney, R.E. (1979)
SPC Occasional Paper No. 11.

(9) Tsuyoshi Kawasaki (1985)
Series of Fisheries Research 8(1).
Japan Fishery Resources Protection Association.

(10) Hiroshi Yabe (1954)
General View of Fishery Science, Japan Association for the Advancement of Science (Nihon Gakujitsu Shinkokai).

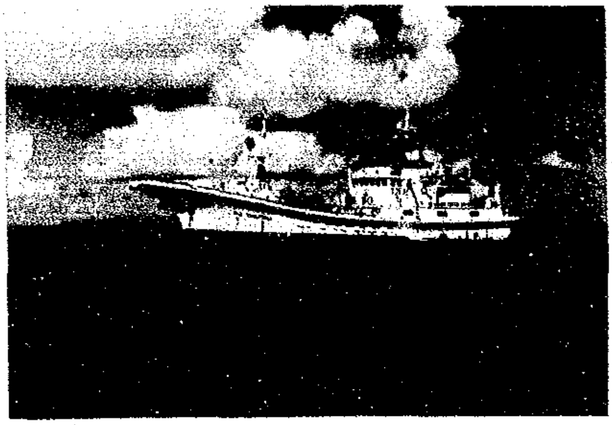
(11) Shoji Kigawa (1966)
Bull. Nankai. Reg. Fish. Res. Lab., (23).

(12) Yoichi Yabuta, Mori Yukinawa and Iku Warashina (1960).
Bull. Nankai. Reg. Fish. Res. Lab., (23).

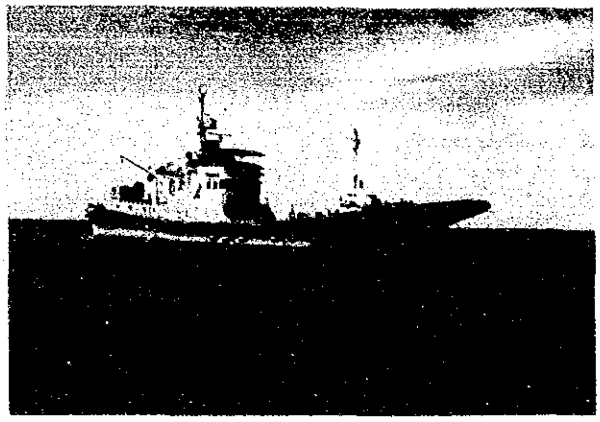
(13) Kazuo Tanaka (1981)
Maguro no Reizo Reito Gijitsu in Japanese, (Temporary translationTechnology of refrigeration and ice storage for tuna).

Annex-3. Photograph of the survey

SURVEY VESSEL



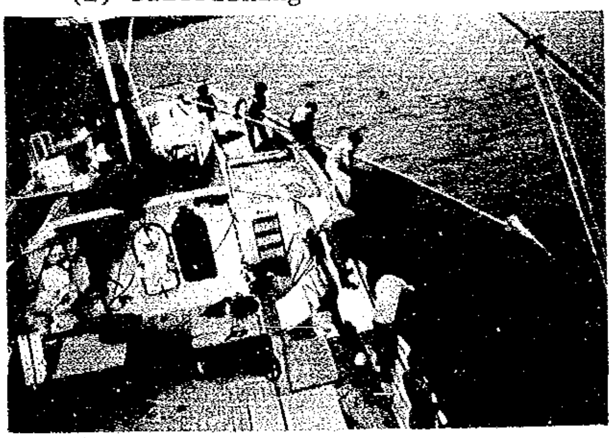
TE-TAUTAI
(National Fisheries Corporation of Tuvalu)



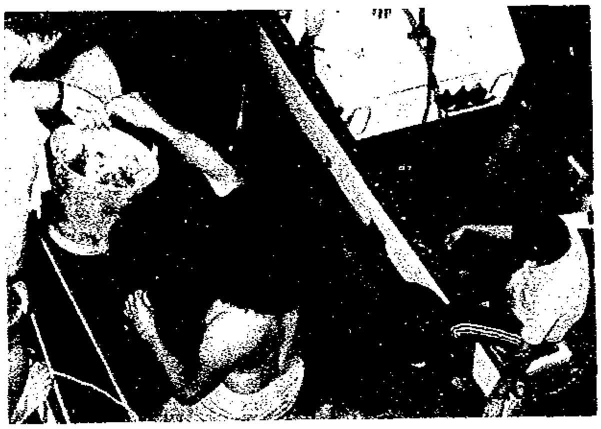
IKA-No.5
(IKA Corporation, Fiji)

POLE-AND-LINE SURVEY

(1) Baitfishing

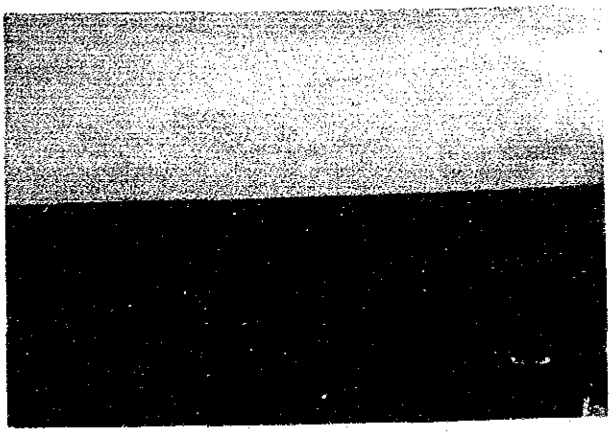


Stick-Held Dip Net



Taking baitfish(Sardines) into baitfish hold.

(2) Pole-and-line fishing



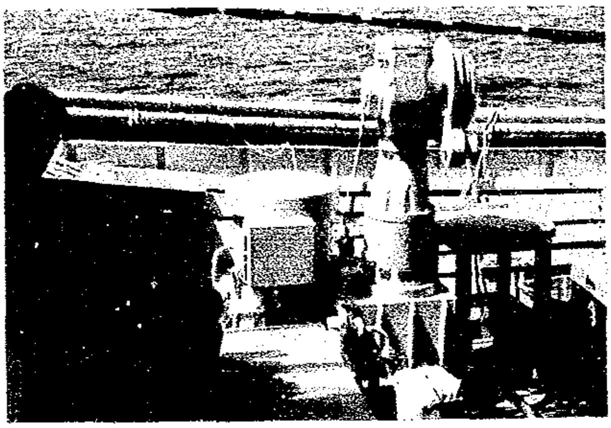
Boiling skipjack school in Tuvalu waters

Poling

BOTTOM LINE SURVEY

Prepared branch-line casks on the poop deck.

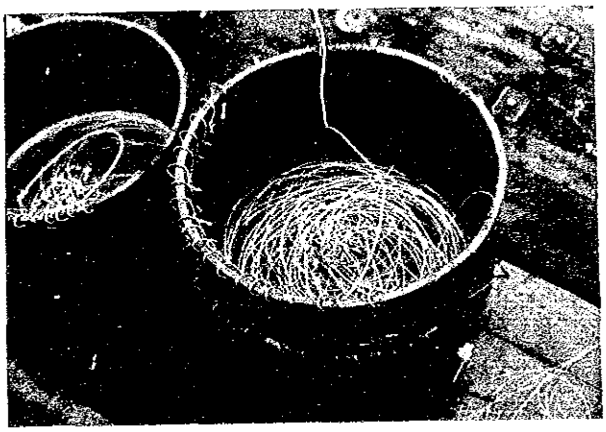
Setting bottom line gears from the poop deck.



Making branch lines and set in the casks during hauling line.

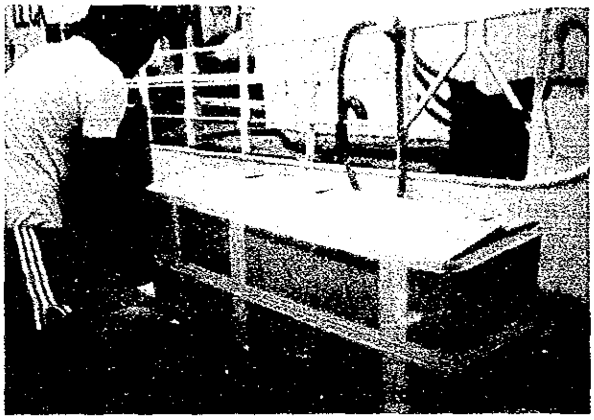
Hauling line

Making main line during hauling line.



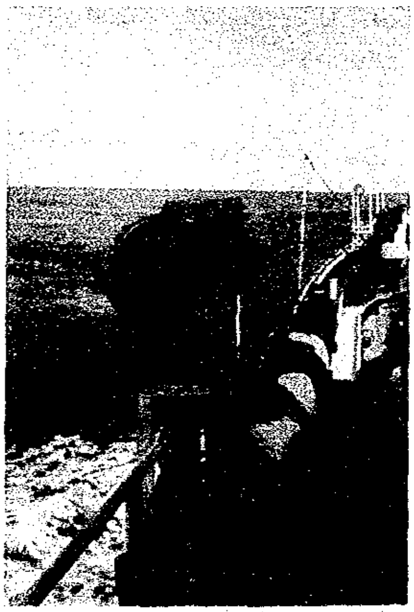
Branch line cask after setting branch line.

PACKING FOR EXPORTED CATCHES



Major species, ribbon tail, short tail, red snapper and red job fish were exported to Honolulu and West Coast market by air cargo after packed as shown on above.

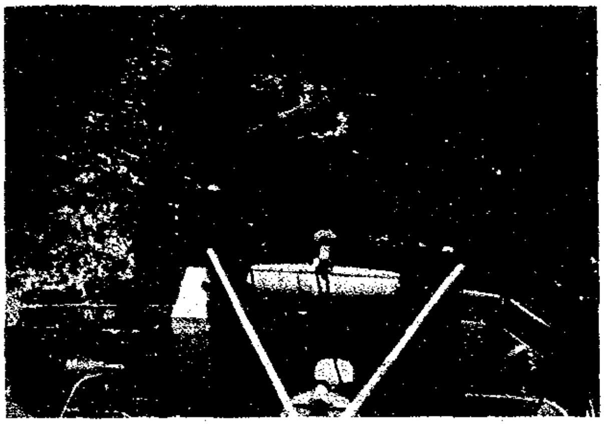
DROP LINE SURVEY



Deep Sea Reel

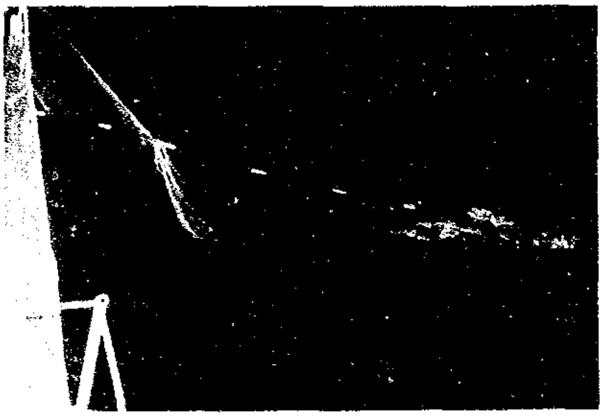
Fishing

SURFACE GILLNET SURVEY



Setting surface gillnet gear from the poop deck.

Hauling gears.



Scenery of enmeshed fish.

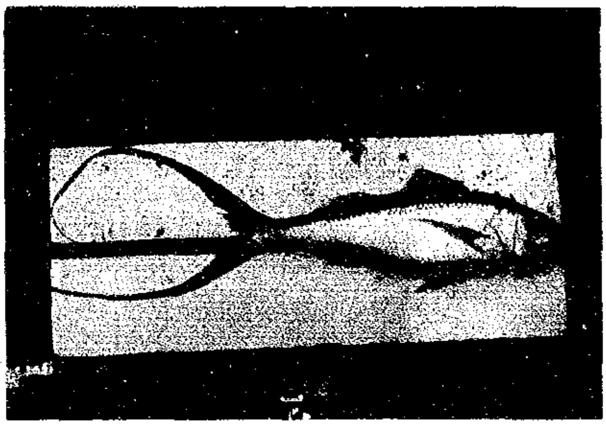
Biological measurement after fishing.

PAYAO (FAD) SETTING

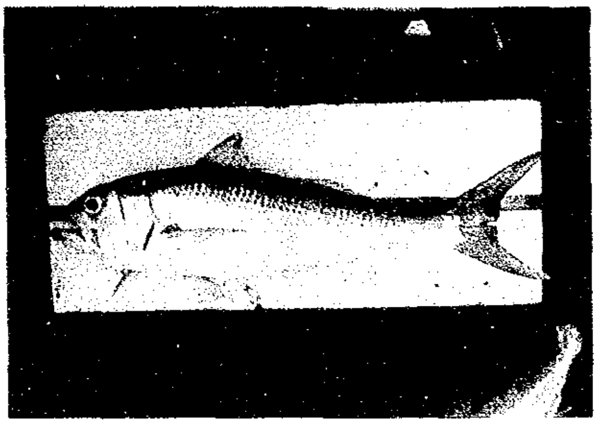
Complete Set of Payao after tied together.

Scenery after Setting Payao

MAJOR SPECIES CAUGHT IN BOTTOM-LINE SURVEY

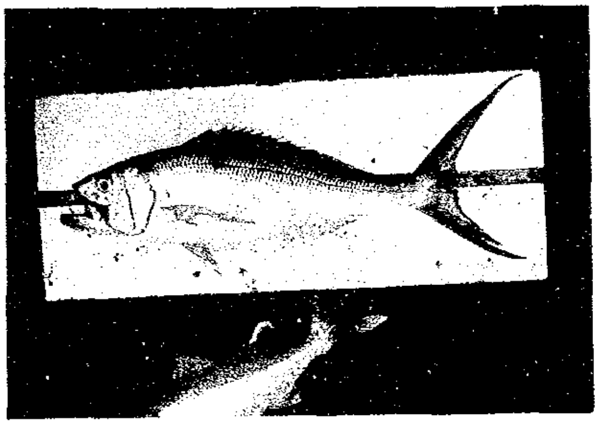


Ribbon tail
(Etelis coruscans)

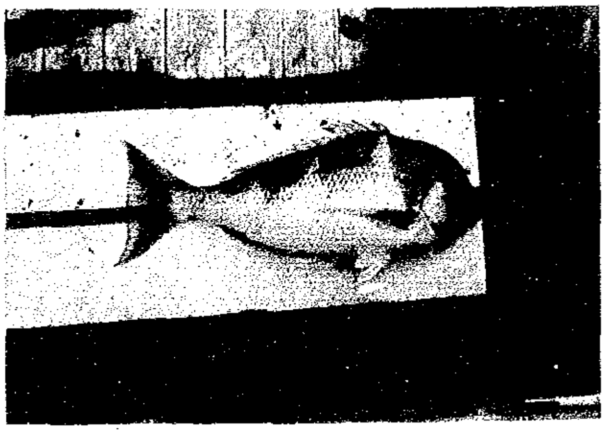


Short tail
(E. radiosus)

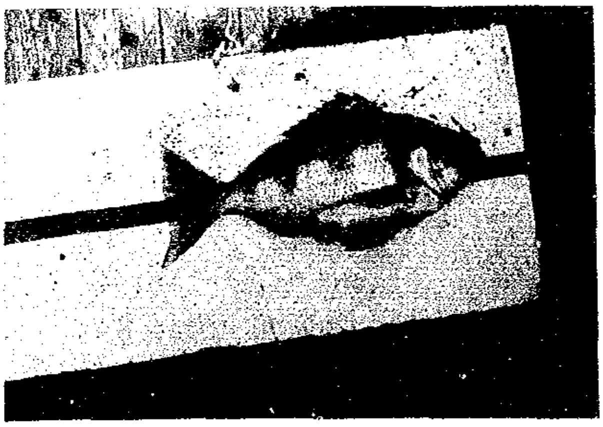
Red snapper
(E. carbunculus)



Red job fish
(Aphareus rutilans)

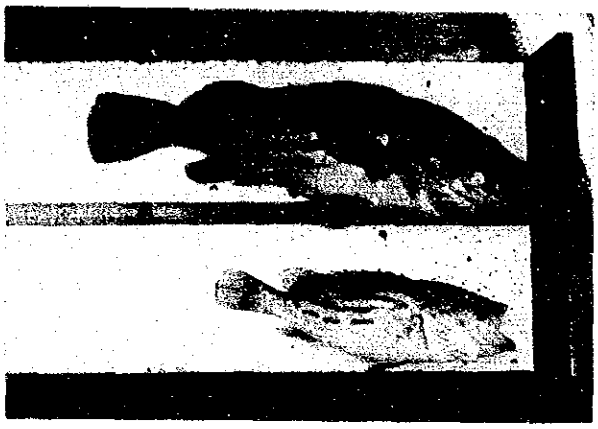


Kusakar's snapper
(Paracaesio kusakarii)



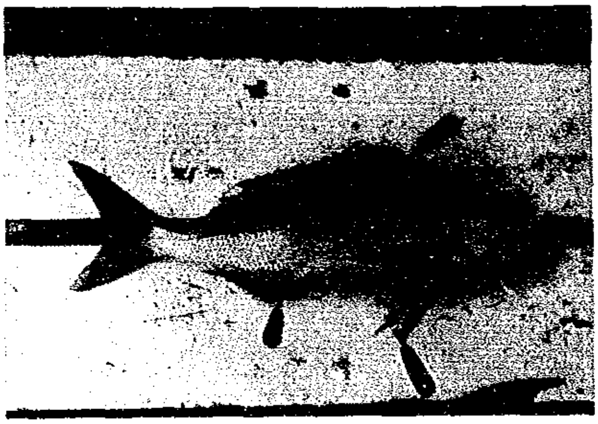
Stone's snapper
(P. stonei)

Large eye bream
(Wattsia mossambica)

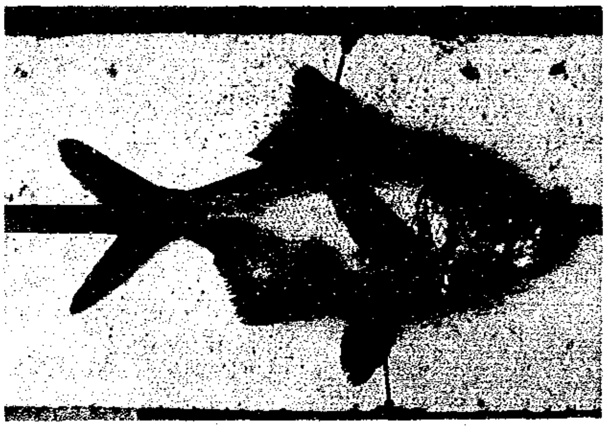


Curve bended grouper
(Epinephelus morrhua)

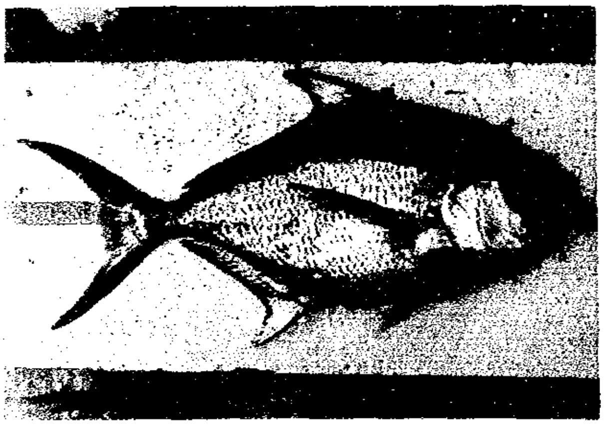
Sevenbended grouper
(E. septemfasciatus)



Red tail opakapeka
(Pristipomoides filamentosus)

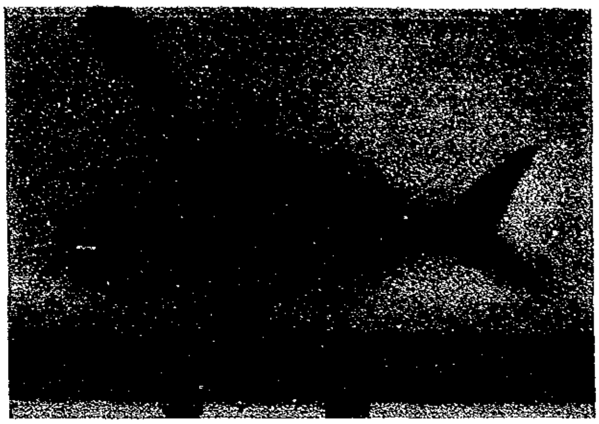


Broad alfonsino
(Beryx decandactylus)



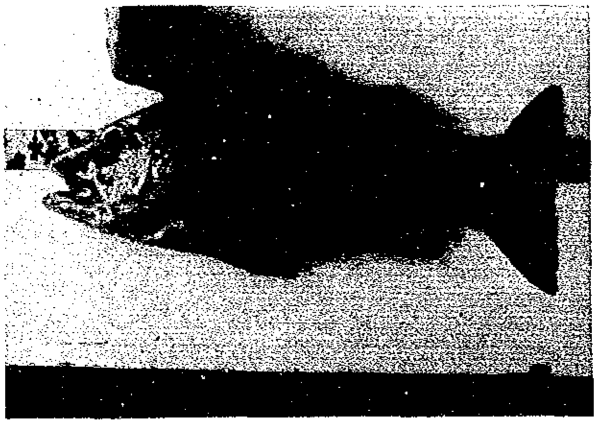
Sweeper pomfret
(Eumegistus illustris)

Crimeon snapper
(Pristipomoides sieboldii)



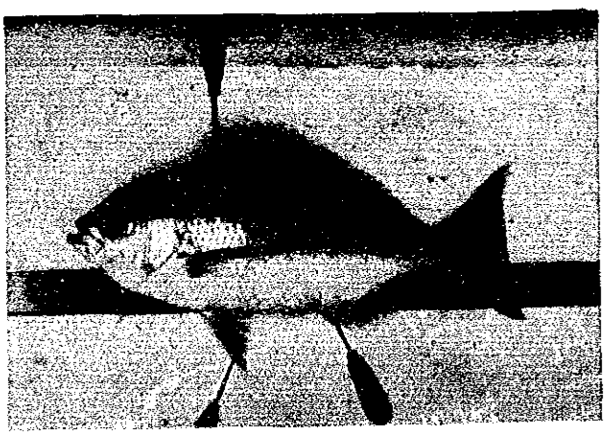
Yellowfin fusiform snapper
(P. auricilla)

Maori sea perch
(Lutfanus rivulatus)



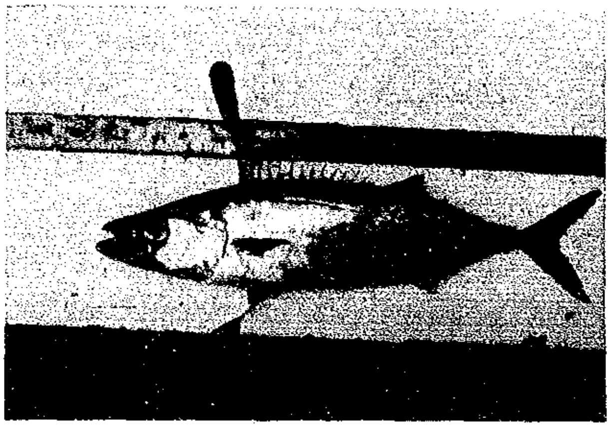
Two spot red snapper
(L. bohar)

Maori sea perch and two spot red snapper were well known as ciguatoxic species and inhibited selling in market.

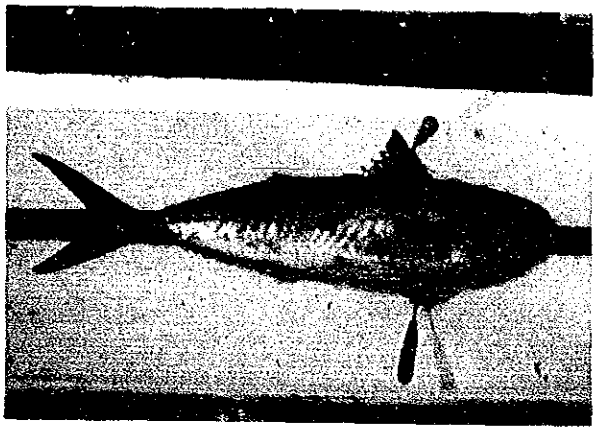


Snappers
(Paracaesio gonzalesi)

Longfinned bullseye
(Cookeolus boops)

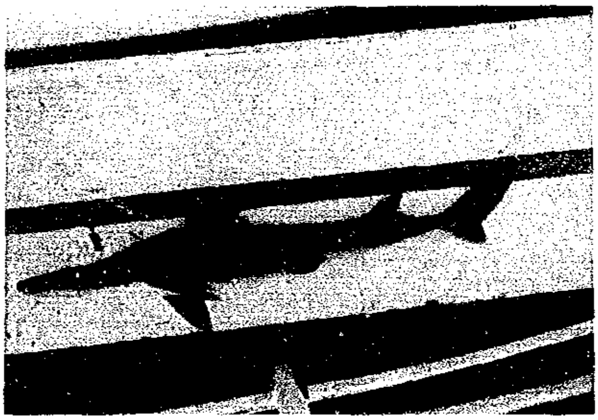


Snake mackerels
(Tongaichthys robustus)

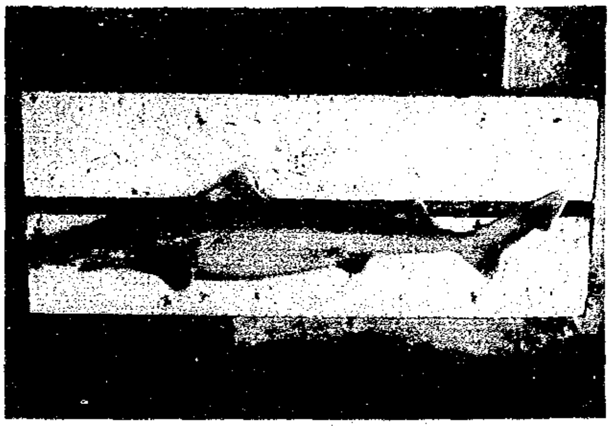


Evermannanomeid fish
(Ariomma evermanni)

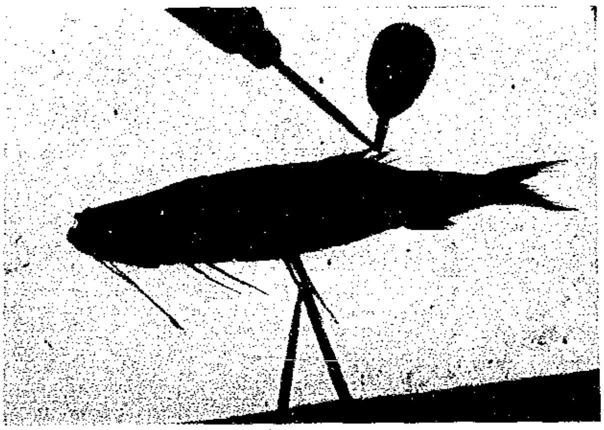
Deep sea bream
(Hyperoglyphe antarctica)



Spiny dogfish
(Squalus blainvillei)

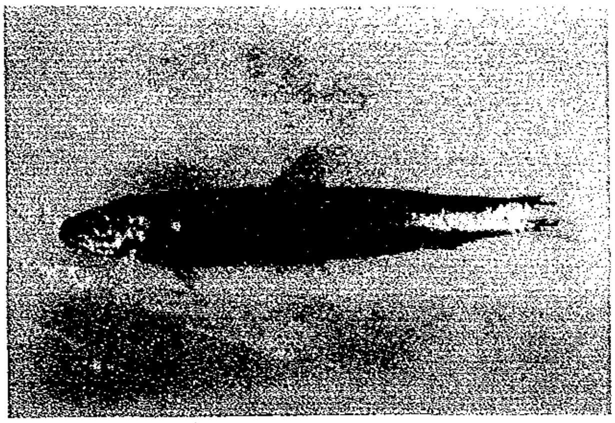


Granulose shark
(Centrophorus atromarginatus)

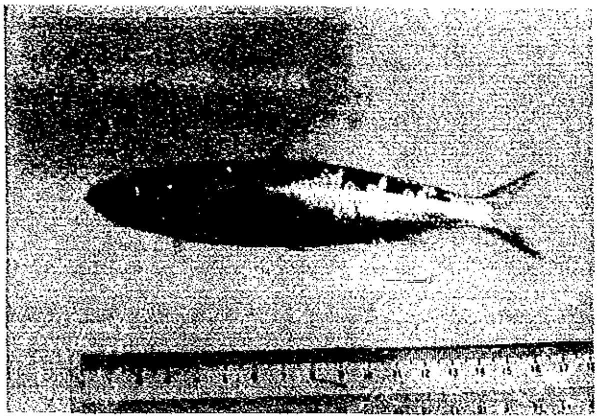


Snaggle toothes *(Astronesthides)* Collected from the stomach contents of ribbon tail.

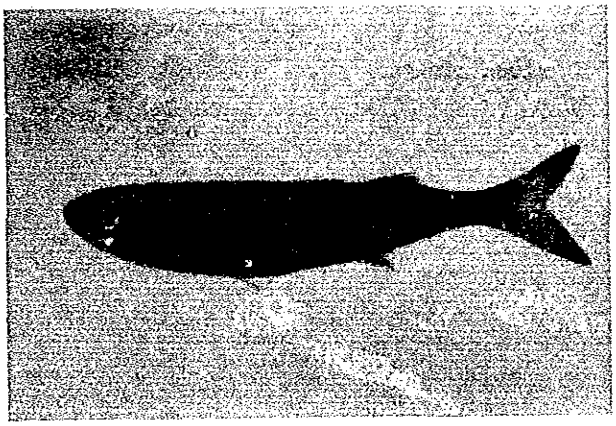
MAJOR BAITFISH SPECIES CAUGHT IN STICK-HELD-DIP-NET FISHERY



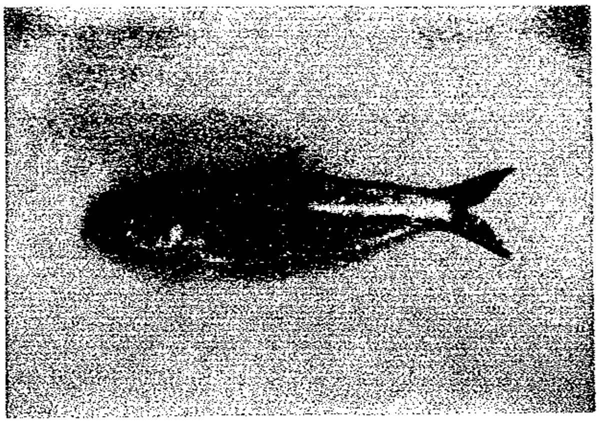
Blue sprat
(Spratelloides delicatulus)



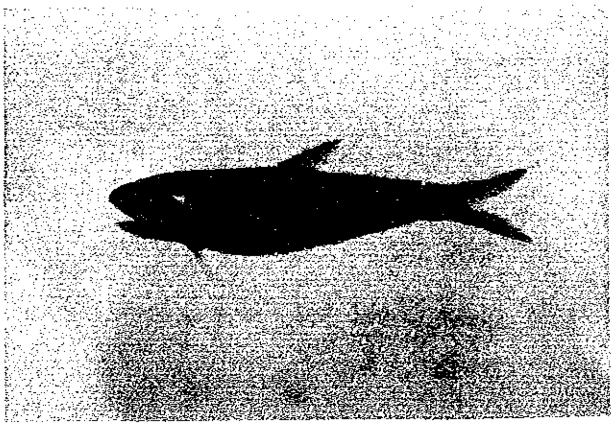
Sardines
(Amblygaster sirm)



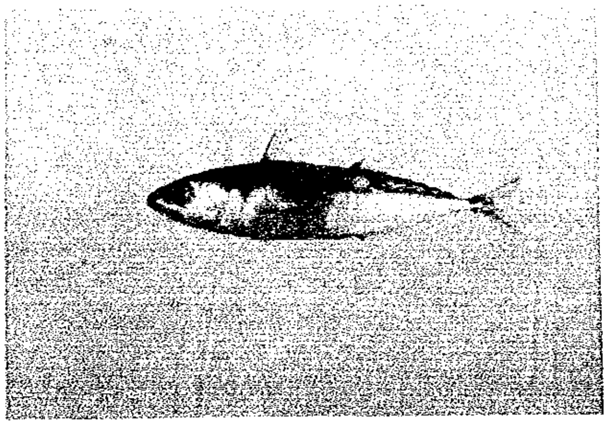
Silver sides
(Hypoatherina ovalaua)



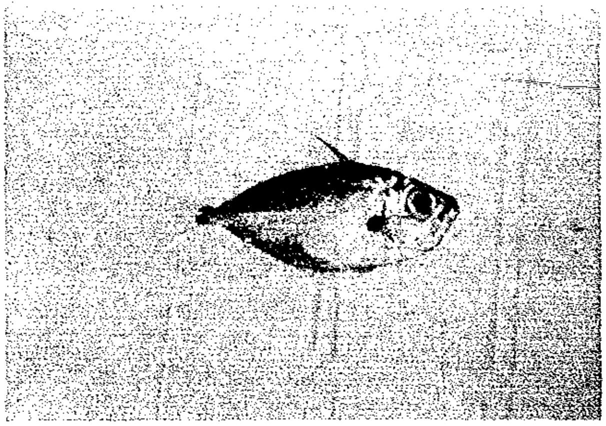
Gold spot herring
(Herklotsichthys quadrimaculatus)



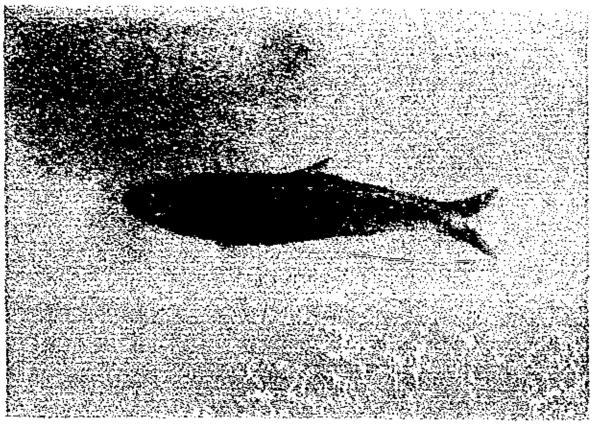
Little priest
(Thrissina baelama)



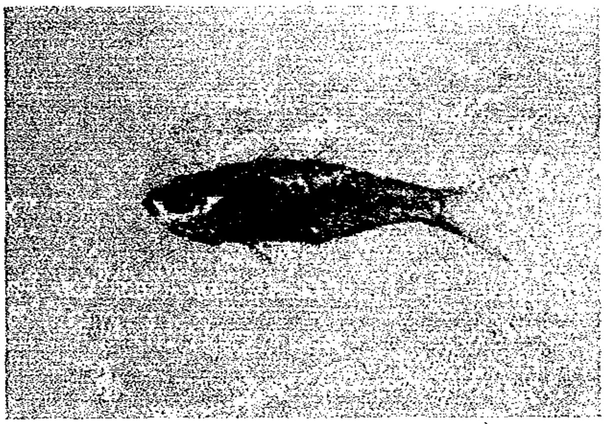
Longjaw mackerel
(Rastrelliger kanagurta)



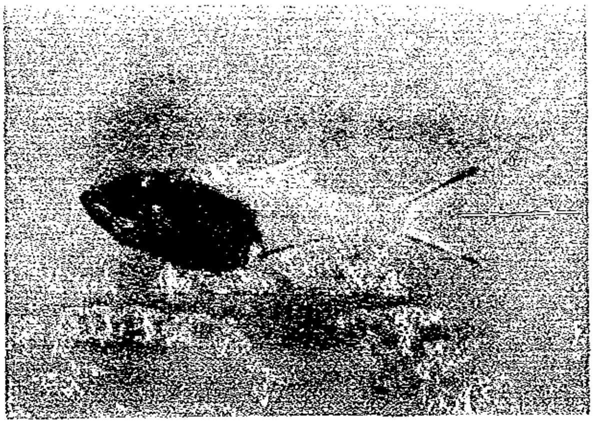
Orangefin ponyfish
(Leiognathus bindus)



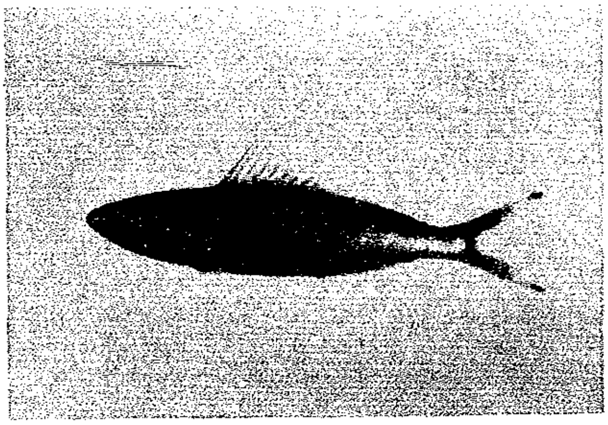
Anchovies
(Stolephorus heterolobus)



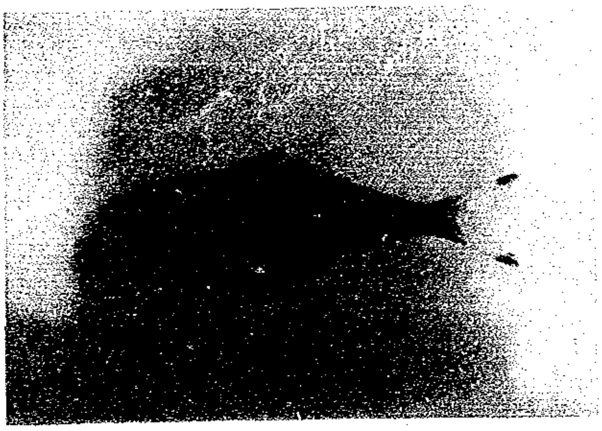
Arrow cardinal
(Phabdamia graoillis)



Cardinals
(Phabdamia sp*)*



Slender fusilier
(Caesio pisang)



Gold bended fusilier
(Caesio chrysozonus)