5-2-5. Market Research

(1) Measuring Body Lengths with Photos

In general, there are many differences between the sizes of catches in the market and the sizes of them taken on board. In particular, in case that small catches are not seen in the market, they may have been discarded at sea or consumed at home. We took these possibilities into consideration when measuring body lengths of catches.

We carried out the measurement of body lengths with the 4-points method which enables us to measure lengths with photo images. The 4-points method adjusts distortions of photo images based on the known 4-point location coordinates (such as the four corners of the fish-containing box) on a photo image, and correctly measures the distance of arbitrary two-points (such as the length from head top to fin end). For this reason, we prepared a square metal frame and a rectangular measurement plate. The scale lengths of both tools are known to us. We placed landed fish in the metal frame or on the rectangular plate to take photos with a digital camera (Plate 5-2-5-1). This method allowed us to hardly touch any catches and to take photos as many as possible in a short time. The method was also easily accepted by fishermen because it took only a short time and landed fish did not get damaged and also kept them fresh. In the second survey, when we adopted this method first time, we prepared the metal frame and took photos of landed fish. However, when catches were put in a deep tub, we could not measure the fish covered with the fish on the surface. So the measurement efficiency was not so good. From the third survey onward, we mainly used the measurement plate to take photos of landed fish which were arranged not overlapped with each other on the plate. In the second survey, we found that there were many Sparidae whose looks are similar. So we found difficulty in identifying those species exactly with their photos. From the third survey onward, we bought some fishes whose species were unknown to us on the spot. We took them to the laboratory at Tema for identification.

As mentioned in “3-2. Land survey”, the survey was carried out at Ahwiam, Tema, Mumford, Apam and Sekondi. Semi-Industrial fisheries at Tema targets pelagic fish such as sardines. When large-scale trawl fishing boats (Industrial fishery) sail into Tema harbor, the body lengths of demersal fish can be measured at the port.

From the third survey onward, the counter part of land survey took photos of landed fish at Ahwiam and Tema during the intervals of our field surveys using a digital camera which Japanese survey team let him use. We also measured the length of those fish.

The major fishing methods at each landing point are as follows:

	Trawl	Gill net	Hook & line
Tema	O		
Ahwiam		O	O
Apam			O
Mumford	O		O
Sekondi	O		O

Table 5-2-5-1 and 5-2-5-2 indicate comparisons between the measurement results at the market and the measurements of fish on board taken through trawl survey.

All evaluation target species are sold at market. The lengths of fish at market are almost same with those of major groups of fish measured in the survey, except for *Pseudotholitus senegalensis*, and *Galeoides decadactylus* (Table 5-2-5-1).

Individuals of *Pseudotholithus senegalensis* were sold at Sekondi and Mumford(second and fourth survey, stable period) and individuals of *Galeoides decadactylus* were sold at Sekondi(third survey, upwelling period). The lengths of both species were shorter than those of the two species taken in trawl survey. These individuals seem to have been taken at trawl fishery. As mentioned earlier, although mesh selectivity of both species were unknown, these species of individuals are considered to be caught soon after recruitments.

Of the survey target species, individuals of *Penaeus notialis*, which is not listed in Table 5-2-5-2, were sold at market. However, we could not check the two species of *Lutjanus agennes* and *Pomadasys jubelini*. Like evaluation target species, the major groups of the species for the target of catch almost matched those of fishes we measured, except for *Selene dorsalis* (Table 5-2-5-2). The catches of 45 to 65 mm long *Selene* *dorsalis* we measured at Sekondi were not the ones sold at market. They were left in a bucket at beach. A fisherman told us that these would be discarded later. They were half dry and seemed to be not consumed at home.

As mentioned above, the lengths of target species sold at market are almost within the length composition of the fish caught in the sea survey. This fact implies that Artisanal fishery and Semi-Industrial fisheries target fish whose lengths are the same of fishery that Industrial fishery targets. The fact also implies that effects of fishery management over industrial fishery can be seen in catches by Artisanal and Semi-Industrial fisheries. For example, when small fish are preserved from Industrial fishery and when the ratio of large individuals increases, large individuals are expected to increase in catches in Artisanal and Semi-Industrial fisheries. Therefore, tendencies of stocks can be observed through monitoring fish at markets.

(2) Interview with Industrial Fishing Companies

For our reference to the formulation of management guidelines, at third survey, we made interviews with eight fishing companies which operate industrial fishery in Ghana (namely, AFKO, GYINAM, HOLIDAY, ICECO, LEGON, SHIMBA, SOLI, TEMA FISHERIES & FREEZING). We interviewed with people assuming a managerial position or the executive director of their companies. These people were, in principle, had experience of going out fishing on board. Our hearing items are as follows:

- Recognition of target species in terms of stock conditions
- Reasons of deteriorated stocks, if any
- Problems of fishery management and operation
- Problems of distribution of catches and value-added activities
- Means that the government or fishery operators should take to improve stock conditions.

Results are indicated in Table 2-4-2 of Data book.

[1] Recognition of target species in terms of stock conditions

We classified answers from the fishing companies into three types: good, moderate, and bad. For many species, some companies told the condition was "good" while other companies told "bad". But the fishing companies and fishery operators who have a longer experience in Ghana recognize that the condition of stocks has deteriorated compared with 20 to 30 years ago.

Recognitions of stocks by fishing companies are based on their catch quantity or increase or decrease in CPUE. Thus, their recognitions do not necessarily reflect actual stock conditions. However, any species seems to have been on the decease although the degree varies.

[2] Reasons of deteriorated stocks

Most answers indicate that fishery is the primary cause of deteriorated stocks. More specifically, those answers indicate that "over-catch (including poaching)," "over-catching of small fish (immature fish)," and "devastation of fishing areas by fishing gear such as beach seine and trawl net" are the causes of the deteriorated stocks.

Some answers indicate that "general environmental deterioration" and "El Niño occurred in 1999" are the causes of stock deterioration. But they did not elaborate on the causes how these phenomena brought about the deterioration.

Though people know that changes in the environment bring about changes in stocks, concerning the deterioration of demersal fish stock in the seawater of Ghana, fishing companies seem to think that fishery *is the major cause of the deterioration*.

[3] Problems of fishery management and operation

Many answers indicate the problems that fuel and lubrication oil are expensive and that harbor charges are also expensive. In addition, it is a serious problem that spare parts for fishing boats and gears are hard to obtain. Actually, one of the fishing companies accepted our interview told us that the company has suspended operation since six months ago due to the inability to repair the boat (however, that company still continues operations of other lines of businesses).

Another problem is also indicated that very limited room is available at Tema Harbour for anchoring active fishing boats because many discarded boats are moored there. Some fishery operators are dissatisfied with slow procedures by the authorities (e.g. inspection on leaving the port and boat inspection), causing late going out fishing. When these boats try to enter Tema Port after fishing, they frequently have to wait outside the port for several days. There are even cases that fishing boats which are ready for the next navigation are kept anchored at the port owing to malfunctioned practices by the authorities. These cases cause large loss because the fishing companies increased expenses of personnel.

[4] Problems of distribution of catches and value-added activities

Some answers indicated that excess imports fish is a problem, besides insufficiency of the infrastructure such as the shortage of freezing facilities. More specifically, fish taken by Russian fishing boats in the offing of Mauritania are purchased and imported to Ghana for marketing within the country. Because these Russian fishing companies sell fish at an extremely low price, import fish can compete with domestic fish in terms of prices even when import duties are imposed on those import fish. In addition, there are rumors of smuggling that some fishing boats of Ghana leave port with fishing gear as if they go out fishing in the offing of Ghana. Actually, these boats buy fish from Russian fishing boats in the offing and return to the port as if they have completed fishing (since no import duties are imposed on domestic fish, the portion of import duties turns profits for the fishing companies).

[5] Means that the government or fishery operators should take to improve stock conditions.

Fishery management amid of deteriorated stocks will lead to enlarged mesh size and taking measures for stock preservation (no fishing), including making a closed season and area. Thus, fishery operators will naturally come to face reduced catch quantity and sales until recovery of stocks.

Fishery operators usually do not like fishery management. However, a number of fishing companies in Ghana answered us that they really want the government to set a closed season. Because of the present fierce competitions, fishery operators have to continue operation even when their fishing boats or gears malfunction. When a complete closed season for one to two months is set, fishery operators have the opportunity to repair their fishing boats and gears. Some fishery operators are of the opinion that such a closed season will eventually contribute to an efficient operation of fishing.

Many fishing companies recognize the importance of small fish (immature fish) preservation and of the opinion that an immediate enforcement of mesh size regulation is feasible.

Some regulations must be enforced under all control measures so that all fishing companies can observe the measure keeping step with others. It seems that fishery operators engaging in Industrial fishery may be able to set a closed season and mesh size regulation voluntarily.

A fishing company answered that the sizes of fishing boats must be reduced while another fishing company answered that an individual quota (IQ) system must be implemented. A fishing company proposed the government to regulate fishing gears (for example, ban on trawling which demolishes fishing grounds). Concerning the reduction of fishing boat sizes, a fishing company answered as follows: Many trawl boats in Ghana belong to the 300-ton class. However, smaller fishing boats are enough for trawling. Thus, the government should no longer issue fishing licenses to larger fishing boats. When a fishery operator tries to replace their boat expiring the useful life, the operator should adopt a small boat instead of the large fishing boat.

Concerning the controls other than voluntary measures, many fishing companies answered us that the government should take more strict measures to control illegal fishing. An example of measure is to monitor by helicopter. This is because a patrol boat takes time to reach the area of illegal fishing, and fishing boats engaging in illegal fishing can escape from the area before the patrol boat reaches the area.

For our reference, we questioned the fishery operators engaging in Artisanal fishery about problems and requests to the government. Their answers were requests only, such as "we want the government to provide us with on-board anoraks"; "we want the government to provide us with flashlights to communicate with other fishing boats"; and "we want the government to provide us with a new powerful outboard motor." Thus, we could not obtain answers contributing to the formation of management guidelines.

(3) Interview with Fishermen

In order to know the management of fishery households who engage in Artisanal and Semi-Industrial fisheries targeting demersal fish, at second survey, we made interviews with 14 fishermen operating 15 fishing boats in total at four points, namely Apam, Mumford, Elmina, and Sekondi. A fisherman at Elmina had two boats--a trawler and a fishing canoe, so we heard the operating situation of the both boats. In principle, we interviewed the owners of the fishing boats. In many cases, owners had on-board experiences as captain when fishing. In some cases, however, owners leased their fishing boats. In these cases, we interviewed the captain of the boat. The number of fishermen we interviewed is as follows:

Number of fishermen interviewed

	Hook and line	Trawl	Gill net	Total
Apam	3	–	–	3
Mumford	–	1	2	3
Elmina	2	2	–	4
Sekondi	2	3	–	5
Total	7	6	2	15

The abovementioned four places have a branch of the Fisheries Department

At Apam, Mumford, and Sekondi, a good relationship was formed between local Fisheries Department officials and fishermen who were also cooperative with us. At these points, we made hearings at beach right after the fisherman unloaded the boat. In case the time passed long since unloading the boat, the fishermen visited the local Fisheries Department to answer questions. Meanwhile, at Elmina, many fishermen were not cooperative, so we had to visit their residences for hearing. In some case, during the interview, a fisherman criticized the Fisheries Department for easy control of foreign fishing boats, and the angry hearing atmosphere shortened our interview time.

Table 2-4-1 of Data book indicates the interview results.

In Ghana, fishery by canoe (longline) and bottom gill net are classified into Artisanal fishery while the trawl fishing by small trawlers is classified into Semi-Industrial fisheries. Some canoes are powered by engine and can accommodate up to 16 crewmembers on board. Thus, classifications by fishing boat are not so appropriate to examine patterns of management of fishery household. Therefore, we used the classifications of the powered boat and the non-powered ship in this section instead of using the classifications of Semi-Industrial and Artisanal.

All the fishermen were engaged in fishery full-time, except for one at Elmina who had a side job.

Most owners of fishing boats didn't know their exact income by month and by year. When we questioned them about annual income and repair expense of fishing gears, they gave answers, which were often contradicted with expenses on other items. For example, Mr. Kow Ackon at Apam, answered us that his monthly revenue is 15,000 cedis (after deducting wages of the crew, fishing gear expense, and allowance for boat repairs from the landing value). Meanwhile, he answered us that his daily landing value amounts to 600,000 cedis at average. However, when diverse operating expenses are deducted from the daily revenue and when taking it into consideration that his boat goes out fishing everyday except fishing holidays (Tuesday), his alleged monthly revenue of 15,000 cedis was still extremely small.

As mentioned above, knowing the management situation of fishermen by questioning them seemed almost impossible. However, based on wages of crew, fuel expense, and other reliable data, we can make a model of management of fishery household.

Most wages of crew are not fixed. Most individual crewmembers receive their wages at a prefixed ratio of profit distribution after fuel expense and other necessary expenses are deducted from the landing value. A typical profit distribution system is that the crew takes 1/3 of the profits while the owner of the fishing boat takes 2/3 (including allowances for repairs of fishing boat and gears). In this case, 1/3 of the profits is subdivided by the number of crewmembers for the profit distribution. When the number of crewmembers is over 10, however, there are cases that the crew takes about 2/3 of the profits.

Two fishermen at Mumford answered us that wages of the crew are fixed. Specifically, a crewmember on a trawler (powered boat) receives a monthly salary of 500,000 cedis while a crewmember on a gill netter (non-powered ship) receives a weekly wage of 100,000 cedis.

During our survey (September to November 2000), Ghana suffered high inflations. Thus, exchange rates of the cedi against the US dollar dropped rapidly within one and half a month. More specifically, the dollar was exchanged at the rate of 6,300 cedis at the beginning and at 6,800 cedis one and half a month later. Thus, we calculated the following landing values and expenses at a more stable exchange rate of US dollar.

When wages of crew are converted into US dollars at the average exchange rate (1 US dollar = 6,500 cedis) during the survey period, 500,000 cedis of wage amount to about 77 US dollars, and 400,000 cedis of wage amount to about 62 US dollars (weekly wage 100,000 cedis x 4 weeks). For this survey, we charted a commercial fishing vessel, LAIDA. We heard that the crewmembers of this vessel received a monthly salary of 25 US dollars. These crewmembers remain on board most of their life (the number of sailing days amounts to nearly 300 days per year). When taking it consideration that living space (cabin) and meals are provided for the crewmembers of LAIDA, it seems reasonable that monthly salary of a crewmember who is on board for small scale fisheries in coastal seas amount to about 70 US dollars. Let's take examples of other jobs. For example, the driver of a rental car receives about 3 dollar of daily wage. When the driver works 25 days a month, his monthly wages reach 75 dollars. The weekly wage of a Fisheries Department official (high school graduate) who will reach the mandatory retirement age soon receives 200,000 cedis of weekly wage. When this weekly wage is converted into a monthly wage, it amounts to over 120 dollars. When these examples are taken into consideration, 70 dollars of monthly wage seems not far different from standard wages of salaried people in Ghana.

Although wages of crew members whose wages are not fixed vary depending on large or poor catch volumes, they are supposed to receive about 70 dollars of monthly wage at average. Based on this, we will examine the balance of the powered boat.

The 11 powered boats that we made interviews had 6 to 17 crewmembers. The average is about 12 crewmembers per boat. The crew is supposed to receive 1/3 (33%) to 2/3 (67%) of the total profits. At average the crew receives 48% of the total profits. In other words, the crew receives a half of the profits. In case each of 12 crew members receive 70 dollars of monthly wage, the total of personnel expenses amounts to 850 dollars a month. Since the amount accounts for a half of the total profits, the owner of the fishing boat is also supposed to take about 850 dollars a month. A portion of the earnings is appropriated to allowances to repair the boat and fishing nets. Therefore, we may assume that the total profits of the fishing boat reach about 1,700 dollars a month (850 dollars x 2). Adding necessary expenses per navigation to the total profits will represent a landed value. In case of the powered boat, fuel accounts for almost all of the necessary expenses. The price of fuel per gallon costs about 6,000 cedis. Some fishermen answered us that they spend 15 to 50 gallons of fuel per fishing navigation (a day's one, leaving port early in the morning and returning port in the afternoon) and another fisherman answered that he spends 400,000 cedis for fuel per fishing (equivalent to nearly 70 gallons). The figure can be converted to 40 gallons of fuel per fishing, which is equal to 240,000 cedis (about 37 dollars) in value at average. In case a boat goes out fishing 25 days a month, the monthly fuel expenses amounts to about 900 dollars. Based on these figures, we estimate that the landed value of a powerboat per month amounts to about 2,600 dollars (1700 + 900).

Next, let's take examples of the non-powered ship. The numbers of crewmembers of the four non-powered ships we interviewed amounted to 5, 4, 4, and 2. We therefore assume the number of crewmembers on board is 4 at average. Since we could not get answers on their profit distribution systems, we assumed that the crew receives 1/3 of the total profits and that the owner of the boat takes 2/3 of the total profits (including allowances to repair the boat). In case that a crewmember receives about 70 dollars of wage a month, the total personnel expenses amount to 280 dollars a month. The owner of the boat earns 560 dollars, which is twice the payment to the crew. Although the non-powered ship needs no fuel, the owner often has to purchases fishing gears (long lines) if the boat engages in longline fisheries. Unlike trawl fisheries and gill net fisheries which require a large sum of casual expenses for repair and replacement of nets, longline fisheries require only a small amount of periodical expenses. Thus, we accounted fishing gears as an expense necessary for fishing. A fisherman answered us that their long lines cost about 500,000 cedis (nearly 80 dollars) per month. Since this is based on the multiplications of 7000 cedis (a pair of fishing gears) x 24 packets x 3 times purchase per month (7000 x 24 x 3 = 504,000), the amount is factual. Thus, we estimated that the landed value of a non-powered ship per month amounts to about 920 dollars (280 + 560 + 80).

In conclusion, the balances of the powered boat and of the non-powered ship are as follows:

Monthly Balances of Fishing Boat(unit: US dollars)

Powered boat

Landed value 2600 → 900 Expenses (mainly fuel)
→ 850 Crew (12 persons)
→ 850 Owner

Non-powered ship

Landed value 920 → 80 Expenses (mainly fishing gears)
→ 280 Crew (4 persons)
→ 560 Owner

Balances seem to fluctuate largely depending on the season. However, these figures would reflect average monthly balances of the powered boat and of the non-powered ship.

Concerning species of fishing targets, fishermen do not make a conscious effort in catching specific species. They catch whatever fish they could. Concerning the discard catches, a fisherman told us that he usually discards a species of fish called "Otoo" because the species makes the value of other fish low when it is mixed. This is the only information on the discard of fish that we obtained. Although we suppose that this species may smell bad, details are unknown. Even our counterpart in Ghana didn't know "Otoo." Another fisherman answered us that he also discards small fish. The rest of the fishermen seem to take any fish when they are valuable for merchandise. Judging from the result of our interviews, fishermen engaging in small scale fisheries in coastal seas seems to have no perception that natural stocks must be preserved and managed.

A part of catches is purchased by a woman, called "fish mammy," from fishermen. In many cases, the wives of boat owners are fish mammies, and they buy landed fish from their husband. In this case, it seems husbands and wives are economically independent.

A portion of catches is sold as fresh fish by fish mammies at the market nearly landing point. Since freezing facilities and other infrastructure are not furnished, most of catches are sold to smokers who smoke fish before distributing them to markets. Most of the fish found in markets of Accra, the capital of Ghana, are smoked ones. Fresh fish are usually obtained only when you visit a landing point.

Most Ghanaians like fresh fish rather than smoked ones. When they happen to have a certain amount of fresh fish, they customarily share them with colleagues at workplace and neighbors. Thus, demand for fresh fish seems very large. When stocks are becoming managed effectively and when large amounts of fish are becoming provided regularly, demands for storage facilities such as freezers and chill rooms and for transportation facilities will follow.

(4) Survey of Fish Prices

The prices of fish catches not only serve as basic material for keeping track of the actual management conditions of fishermen (fishery companies) but also assume greater importance when implementing the resource management.

A unit price (price per unit weight) for a given species of fish quite often varies depending on the fish size. Take, for example, a weight of 1 kg, there are many cases that the price of a single 1kg fish is higher than that of five 200-gram fishes. On the other hand, in Japan, a larger size does not necessarily fetch higher prices. For example, it is a general rule that the smaller, the higher when it comes to whitebaits of sand lance. In the case of another species of fish, the right sized fish may fetch the highest price -- for example, fish whose size is just about right for serving on a plate (as a single person's portion).

Control designed to check overfishing (overexploitation) and augment resources includes various means such as mesh size regulation, setting a closed seasons/areas for fishing, and the institution of fishermen's holidays. With the successful implementation of whichever means, the effects of the control will show up in the increasing proportion of fishes of advanced age or large-sized individuals among resources. This will, of course, be reflected in fishing operations in the form of increased proportions of large-sized individuals among fish catches.

When there are variations in unit price according to size, even if control has been successful and catch quantity has increased, the total value of gross landing may not simply increase proportionately. For example, an increase of 20% in the catch quantity may translate into an increase of 40% in terms of value if the catches consist of fishes that go up in value with increasing size (because the percentage of large-sized individuals increases among the fish catches). Conversely, in the case of fishes that come down in price with increasing size, the total value of gross landing may remain unchanged.

As discussed above, it is necessary to make studies by factoring in not only possible changes in catch quantity impacted by control but also probable changes in value of gross landing when devising methods/means of control.

To this end, it is indispensable to get a grasp of the relationships between the size of fishes and their unit prices.

Therefore, efforts were made to try to ascertain fish prices from statistical material and through market research.

[1] Industrial Fisheries

Fishing companies (engaged in Industrial fisheries) are obliged to submit to the Fisheries Department each month an activity report detailing species-by-species catch quantities and value of gross landing for each fishing boat they possess. However, the main objective of the Fisheries Department is to know the operating conditions of each fishing boat and its catch quantities and is not interested in the value of gross landing. In actuality, individual fishing companies enter the values of gross landing as they like -- in the form of values derived from groups, each consisting of two or more species, and sometimes in the form of a mixture of all species but classified into quality levels such as A, B and C. Material revealing prices on a species-by-species basis is extremely few. As a sole example, the results of unit-price calculations based on a fishing company's material characterized by somewhat high degrees of detail are shown in Table 5-2-5-3.

However, these results are saddled with some puzzling points including the ones discussed hereafter. The table provides a compilation of the monthly reports the company submitted on all its fishing boats for the months of January through December of 2001. With the exceptions of the per-kg prices of mackerels and sepiola (one kind of cuttlefish) fluctuating from 800 to 1,200 cedis and from 1,000 to 1,200 cedis, respectively, the prices of all other species remain constant. Furthermore, *Pagellus bellottii* and *Sparus caeruleostictus* for the domestic market are priced at 2,400 cedis and 2,000 cedis per kg, respectively. On the other hand, with the exception of *Sepia officinalis* priced at 2,400 cedis per kg, the export prices of all other species are below 2,000 cedis, resulting in a situation where export-bound fish are cheaper than domestic-bound fish.

Since the Fisheries Department has no means of substantiating the values of gross landing reported by fishing companies, this data should be regarded as for reference only.

On the other hand, export statistics on fish products published by the Government of Ghana and unit prices calculated from them are shown in Table 5-2-5-4. In terms of export volume, canned tuna comes out on top, followed by tuna and frozen fish. When survey target species are exported, most of them are considered to be included in the frozen fish with the exceptions of shrimps and cuttlefishes. The unit prices (US$/kg) for frozen fish have been sharply coming down in recent years. Although export amounts in the statistics are denominated in U.S. dollars, it may be appropriate to think that prices are first determined in cedis, and then equivalent amounts are paid in dollars converted at going exchange rates. With this being the situation, recent steep declines in the value of the cedi against the U.S. dollar must also be taken into consideration.

Under the circumstances, the unit prices for frozen fish are also indicated in cedis. Based on the information posted on "The World Factbook 2001" (http://www.odci.gov/cia/publications/factbook/), the exchange rate between the cedi and the dollar was set as follows: 2,050 cedis to the dollar in 1997, 2,314 cedis to the dollar in 1998, 2467 cedis to the dollar in 1999, and 5,322 cedis to the dollar in 2000.

Taking a look at unit prices in cedis over the recent 3 years, the price of frozen fish has been in excess of 4,000 cedis per kg and has rather been on an upward trend. If we let 1 kg = 4,000 cedis, unit prices turn out to be approximately two times higher than figures that have been calculated from the data reported by the fishing companies.

[2] Semi-Industrial And Artisanal Fisheries

As to artisanal fisheries, we obtained material compiled by the Fisheries Department detailing the value of 1999 gross landings on a species-by-species monthly basis. This material and unit prices (in cedis/kg) as calculated from month-by-month catch quantities are shown in Table 5-2-5-5.

Although no material showing the value of gross landing from the semi-industrial fisheries was available to us, fish catches are considered to be marketed at unit prices similar to those of fish catches harvested by the artisanal fisheries in light of the fact that the same landing ports and customers are shared by both semi-industrial and artisanal fisheries.

Taking a look at the unit prices for species whose catch quantities are large, Sparidae species such as *Sparus*, *Pagellus* and *Dentex* fetch approx. 2,000 cedis; *D. rhonchus* brings approx. 1,200 cedis; *B. auritus* and *C. chrysurus* go for approx. 600 cedis. Although catch quantities are small, unit prices of Serranidae (including *E. aeneus*) and *S. officinalis* are a little over 4,000 cedis and a little over 3,000 cedis, respectively, -- outdistancing all other species.

Since the relationships between unit prices and size cannot be inferred from this material either, studies of size-price relationships were made by actually purchasing fishes at markets in course of the fourth and fifth field surveys.

Fish were purchased mainly at the following three places: Tema Fish Market, James Town (an artisanal fisheries landing site in the city of Accra), and Salaga Market (several minutes' walk from James Town's beach). These markets are located close to urban areas and it is not rare for foreigners to come shopping. At all markets, relatively large sized fishes weighing in excess of 500 g were sold on a one-by-one basis. Other fishes were sold in sets of three to ten like-sized fish. Furthermore, small-sized fishes each weighing less than 100 g and lighter were sold by the lot in mixtures of different species.

In addition, for the purpose of making comparisons of prices between urban and rural areas, purchases of some species were conducted also in Ahwiam. For information, although there were plans to make purchases also in Apam and Mumford, where the body length measurements by photographic method were conducted, fish mummies (female middlepersons dealing in fish catches) there were exclusive and refused to sell to neither Japanese nor our Ghanaian rent-a-car driver (who lives in Accra).

The results are shown in Table 2-5-3 of Data Book.

The persons who served as buyers were the study team crew, Mr. Teye who is an ex-staffer of the Fisheries Department (he used to be our counterpart charged with biological surveys in the first year and took age-limit retirement in 2001), and our rent-a-car driver (Ghanaian) who usually does not buy fresh fish. Purchasing prices were fairly higher than average unit prices (Table 5-2-5-5) as calculated from the Fisheries Department's statistics. Two factors are considered to be responsible for this. One is difference between wholesale prices (statistical material) and retail prices (purchase results). The other is higher-than-normal prices demanded as a result of the presence of Japanese persons (foreigners).

Since the prices of fish are determined by negotiations between the seller and buyer, higher prices are tended to be presented to foreigners and Ghanaians who are strangers. Through observations, it has been found out that the extent of overpricing were approx. 20% higher than normal prices. For example, after seeing (from a location out of the sight of the seller) Ghanaian woman buy a cuttlefish at a price of 15,000 cedis, we asked the seller about the price of a similar-sized cuttlefish. The answer was 20,000 cedis. Judging from our experience in purchasing other fish, when price-haggling starts at 20,000 cedis, the price is considered to eventually come down to 17,000 to 18,000 cedis. If a purchase is made at 18,000 cedis, this price is 20% higher than the normal price (15,000 cedis).

From the above, the cause of the differentials between purchasing prices on the market and average prices derived from the Fisheries Department's statistics is considered to be ascribable to the difference between wholesale and retail prices.

Taking a look at the relationships between unit price and size, in the case of *P. senegalensis* and Sparidae which could be bought over a fairly wide range of size, the unit prices for both fishes rose with increasing size up to a certain size. Beyond that size, it seems that they tend to level off. (Fig. 5-2-5-1) For both fish species, no significant differences were observed between Tema and Accra. Furthermore, putting plots of both species on the same graph showed that the size-vs.-unit-price relationships are nearly the same. (Fig. 5-2-5-2)

As discussed above, although the purchasing price itself is much higher than the value of gross landing which fishermen get, it is considered possible to grasp the relative relationships between the size and the unit price (for example, the unit price of 400g fish is twice that of 200g fish, which means the price is fourfold, and so on.) Even when no absolute value is known, the use of size-by-size relative unit prices makes it possible to perform a simulation to explore how the value of landings would vary when control is implemented. In this simulation, unit prices are to be set in relation to one another in a manner such as the following: A unit price of 1 point (1 point/kg) for 100g or lighter fishes, a unit price of 1.2 points/kg for 200g or heavier fishes, ..., a unit price of 2 points/kg for 1kg or heavier fishes. If, for example, the value of gross landing of 100,000 points has augmented to 130,000 points as a consequence of the implementation of control, it becomes possible to make a projection that the value of gross landing would increase by 30 % from what they are today even when absolute values remain unknown.

For comparisons with other species, the following unit-price functions (or relational expressions between unit price (UP) and body weight (BW)) were formulated based on data concerning *P. senegalensis* and Sparidae. (Fig. 5-2-5-3) In this case, two pieces of data (both exceeding 35,000 cedis/kg) that were way too high from the other data have been excluded.

$$UP = 35{,}000BW + 10{,}000 \quad (BW<0.4)$$
$$UP = 25{,}000 \quad (BW \geqq 0.4)$$

Where UP = Unit price (cedis)

BW = Body weight (kg)

In other words, the unit price increases linearly as far as to a body weight of 0.4 kg (400 g) whereas it remains constant above 0.4 kg (at 25,000 cedis/kg). With the above being reference unit-price functions (Standards), the unit prices of other evaluation target species were compared, and the results are shown in Fig. 5-2-5-4.

Data concerning Ahwiam are included for *D. rhonchus* and *P. incisus* in Fig. 5-2-5-4(1) and 5-2-5-4(3), and an inspection reveals that unit prices at Ahwiam are obviously lower than in Tema. *P. prayensis* is the sole species for which both Tema's data and Accra's data are available. Just as is the case with *P. senegalensis* and Sparidae, the unit price of this species appears to be the same in Tema and Accra.

Even though some species vary fairly widely in unit price, it can be judged, with the exceptions of *D. rhonchus* and *B. auritus*, no significant differentials are present with respect to the standard unit-price functions. *D. rhonchus* is approx. 80 % of the standard on the average whereas *B. auritus*, for which only one data is available, is approx. 70% of the standard. For simulations of future projections (Chapter 5-2-7), these relationships were employed.

(5) Monitoring technique

This report describes the resource evaluation for each of the evaluation target species and the predictive calculation of the management effects. Although the best data currently available was used for the evaluation and calculation, the results obtained through the predictive calculation are not necessarily correct. The cause of this error is attributable to natural factors such as a change in the survival rate and growth caused by an environmental influence and artificial factors such as fluctuation in fish price of management target species as well as incorrect parameters at the predictive calculation stage.

For this reason, it is necessary to establish a system that enables around-the-clock monitoring of the management effects, prompt feedback of the monitoring results, updating of parameters according to a change of situation, repetition of the simulation calculation, and review of the management method as the case may be.

In many cases, the fishery management progresses step by step. Even if we set a final goal such as the achievement of a catch quantity at the MSY level or an increase of a certain percentage in catch quantity, we cannot necessarily carry out immediately a management method directly leading to the target. For example, supposing we know that we can achieve the MSY for many species if we change a current 60-mm mesh size to a 100-mm mesh size. A sudden enlargement of the mesh size to 100 mm, however, will have a serious impact on fishery household operation because there will be a sharp drop in catch quantity at an initial stage. In such a case, it is advisable to enlarge the mesh size from 60 mm to 70 mm and from 70 mm to 80 mm step by step. It is possible to predict through simulation how many years are required to shift to the next step. As mentioned above, however, many uncertainties remain for a predictive calculation. Therefore, the simulation results should be considered as a rough standard. It is dangerous to decide from the beginning that the mesh size will be changed to 80 mm in five years and to 90 mm in 10 years according to the simulation results. The resource condition must be checked every year through monitoring and whether to shift to the next step at a certain time must be judged on a case-by-case basis.

As described above, if the fisheries management is carried out, it is essential to monitor the management effects.

Since Ghana has no special fisheries research vessel, it is necessary for the country to monitor the management effects from landed fish catches.

Some researchers in the Fisheries Department of Ghana recognize that proper monitoring is not possible without a fisheries research vessel. As long as a monitoring system is fully established, the absence of a fisheries research vessel will not be a big disadvantage. Artisanal fisheries and Semi-industrial fisheries are being operated throughout the country along the coastline. It is no exaggeration that the Industrial fisheries are covering all the continental shelf more than 30-meter deep. A variety of fishing methods for demersal fish is used, including the trawl fishery, beach seine fishery, gill net fishery, and longline fishery. If we understand the characteristics of each fishing method, the Ghanaian fisheries will provide a large-scale and effective sampling system for monitoring, with which one fisheries research vessel is not to be compared.

The most important thing in monitoring is to regularly determine a change in catch quantity of target species and age composition of fish catch. It is difficult to read the age of a fish directly from the age character, but the age composition can be estimated from the body length composition. In order to do so, a system to survey the catch quantity and body length composition is required.

As described in the fishing statistics (Chapter 5-1-7), the Artisanal and Semi-industrial fisheries make up the majority of the catch of target species and the Industrial fisheries account for only a small fraction of the catch quantity. Among the evaluation target species, only cuttlefishes (*S. officinalis)* is caught in large quantity through Industrial fisheries. As shown in Tables 5-2-5-1 and 5-2-5-2, the body length range of fish catch (through Artisanal and Semi-industrial fisheries) obtained in a market research agrees with the body length range of fish catch obtained in a trawl net survey (through Industrial fisheries). Consequently, it is sufficient, as a rule, to survey the fish catch through Artisanal and Semi-industrial fisheries for monitoring.

As described in detail in the fishing statistics (Chapter 5-1-7), Ghana has a system in which a local staff in the Fisheries Department conducts a survey of the catch quantity by species concerning Artisanal and Semi-industrial fisheries in order to prepare fishing statistics. The survey results are collectively sent to the Marine Fisheries Research Division (MFRD) in Tema of the Fisheries Department. This survey is conducted at 53 fish landing sites out of 276 for Artisanal fisheries and at all the four landing sites for Semi-industrial fisheries. The survey is carried out for at least two weeks out of one month for Artisanal fisheries and on the day of fish landing without fail for Semi-industrial fisheries. The survey is thorough enough in terms of time and space.

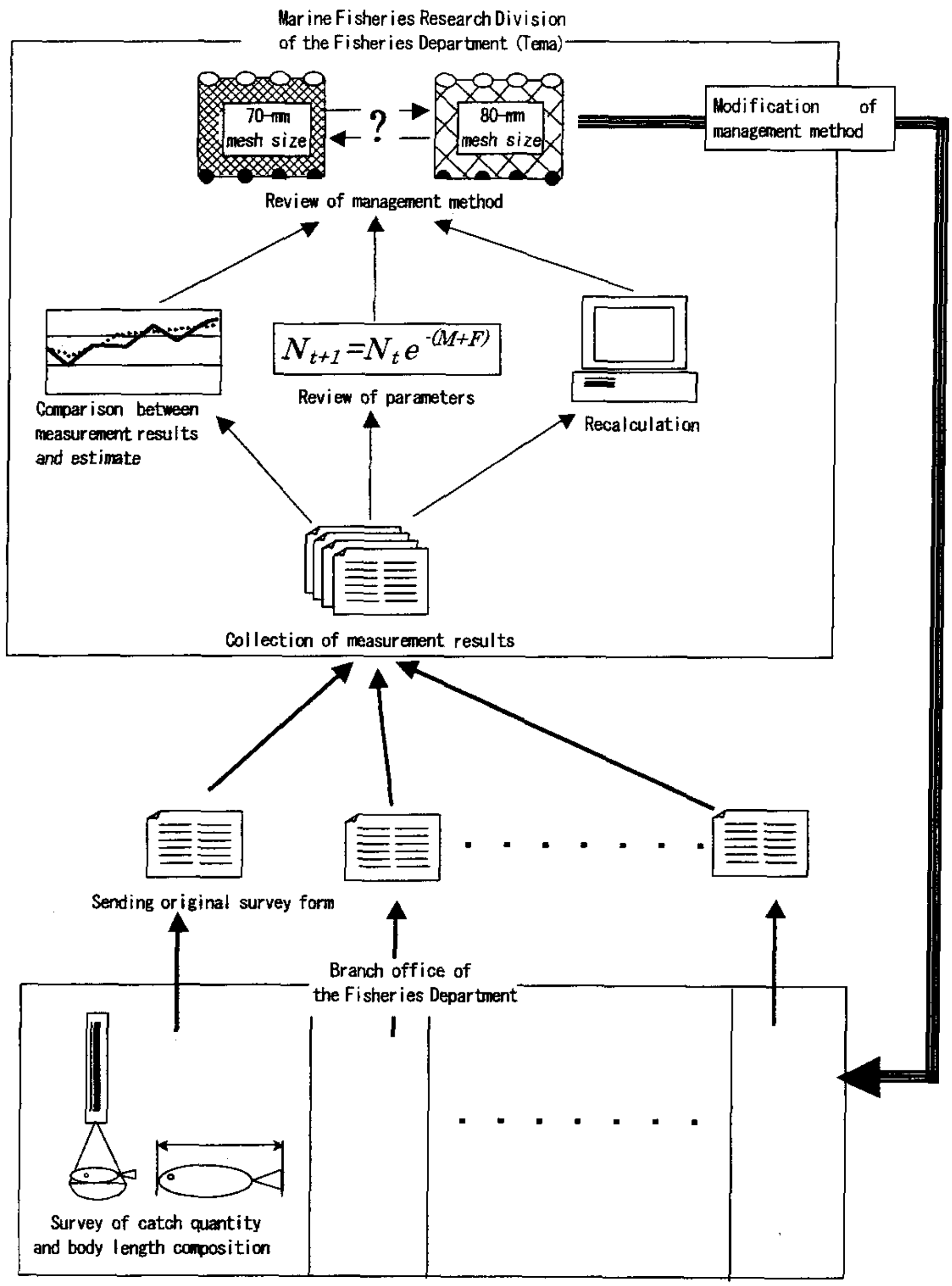
Basically, the present method does not cause any problem to determine the catch quantity by species. Note that even a local staff in the Fisheries Department cannot clearly distinguish from one species to another such as Sparidae (for example, between *S. caeruleostictus* and *D. canariensis*). These species are currently classified under the same classification item in the statistics. For at least evaluation target species, however, it is necessary to prepare a manual for the identification of species and train the local staff so that they can identify the catch quantity by species.

It is necessary to investigate about twice a month the body length composition of all evaluation target species landed from a vessel chosen randomly. At this time, if the body length measurement method by photography used in the present survey is adopted and only pictures are sent together with the original survey form for catch quantity to MFRD of the Fisheries

Department, the load imposed on the local staff and fishery operators may be minimized. For cuttlefishes (*S. officinalis*) caught mostly through Industrial fisheries, a responsible person in MFRD must go to the Tema Harbor at the right time when a trawler enters the port and measure the body length composition.

The responsible person in MFRD then classifies data on the catch quantity and body length composition collected throughout the country and converts the body length composition into the age composition to compare it with the simulation results. The parameters will be updated and used for the predictive calculation as required.

The conceptual diagram of the monitoring system is shown on the following page.



Conceptual Diagram of Monitoring System

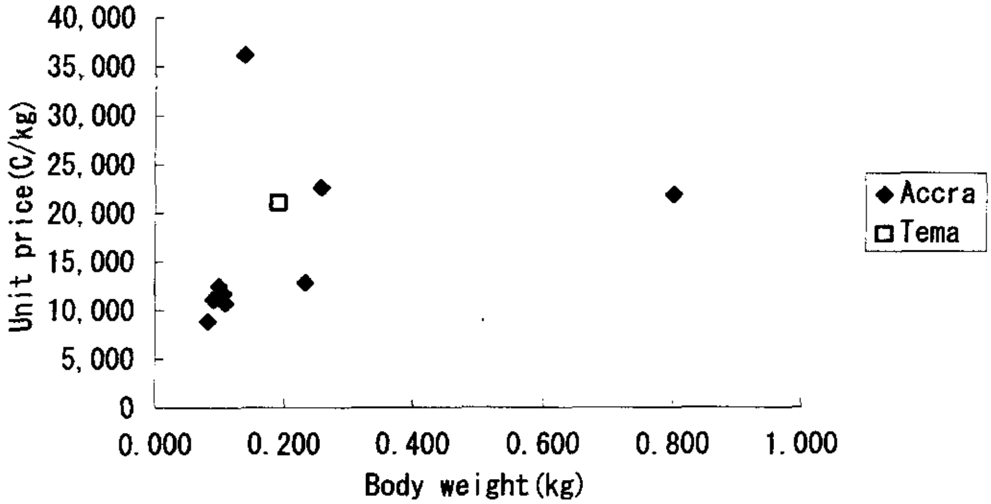


Fig. 5-2-5-1(1) Relationship between body weight and unit price (*P. senegalensis*)

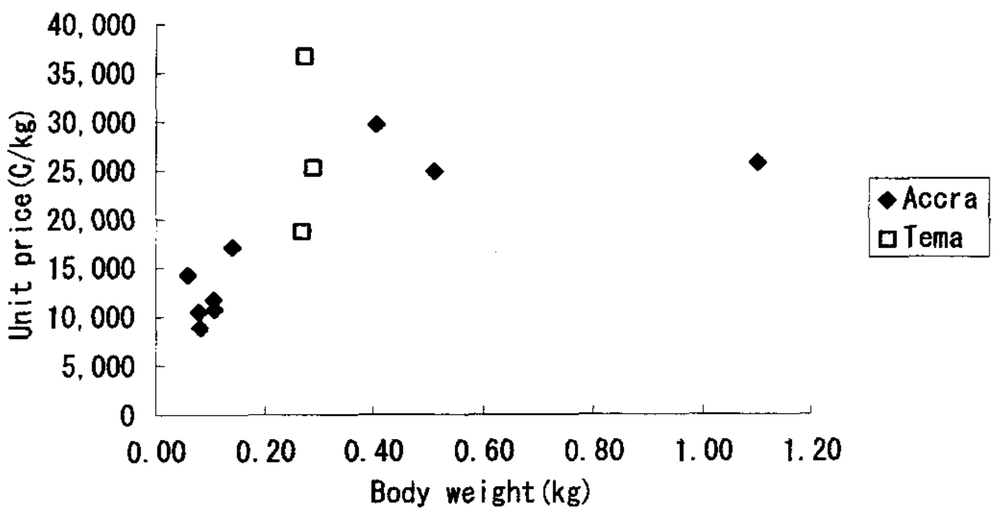


Fig. 5-2-5-1(2) Relationship between body weight and unit price (Sparidae)

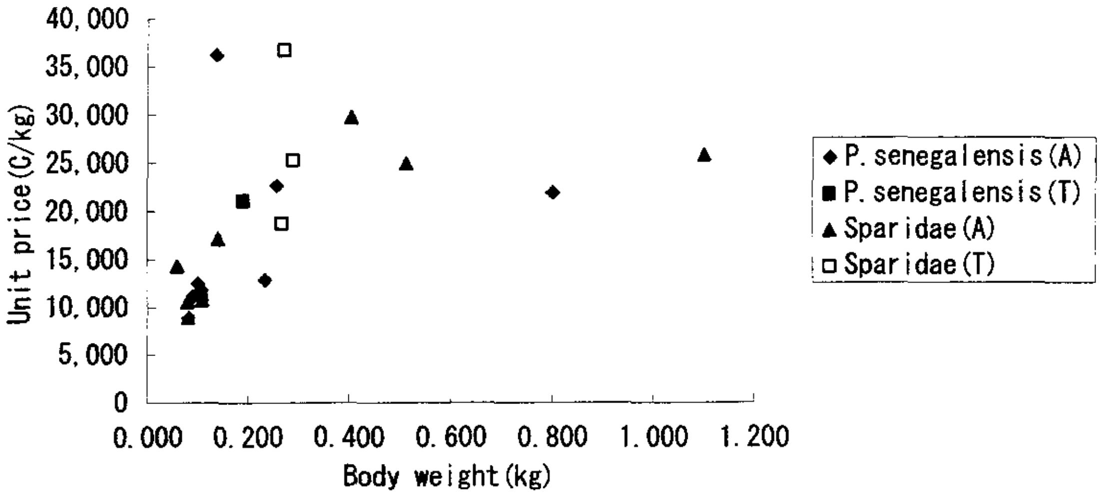


Fig. 5-2-5-2 Relationship between body weight and unit price (*P. senegalensis* and Sparidae)
(A and T stand for Accra and Tema, respectively.)

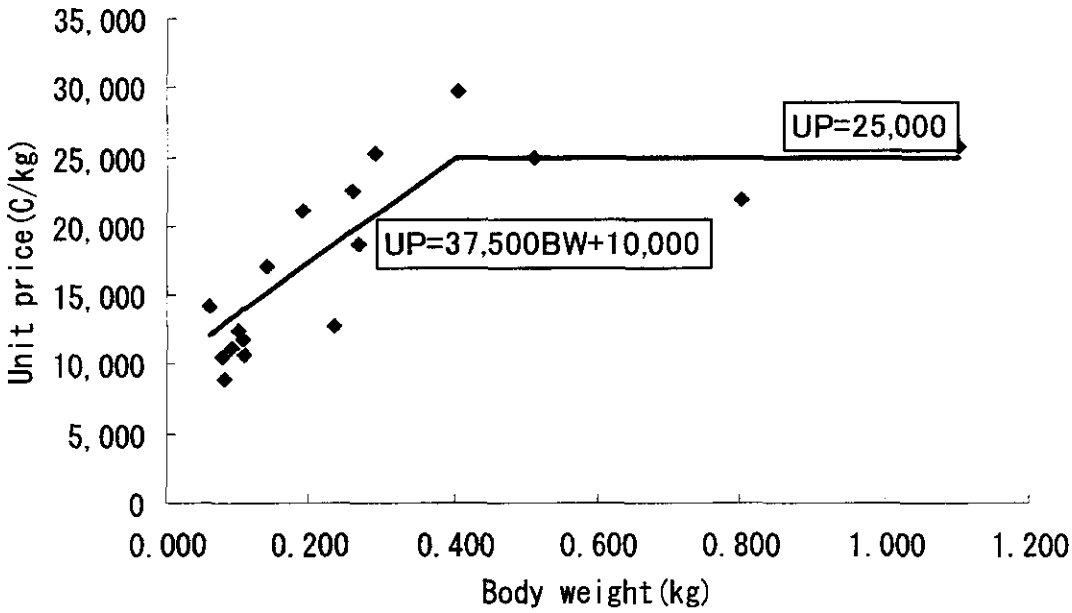


Fig. 5-2-5-3 Relational expressions (reference expressions) between body weight (BW) and unit price (UP)

Note: In Fig.5-2-5-3, two data that are way too high from others have been excluded from Fig.5-2-5-2.

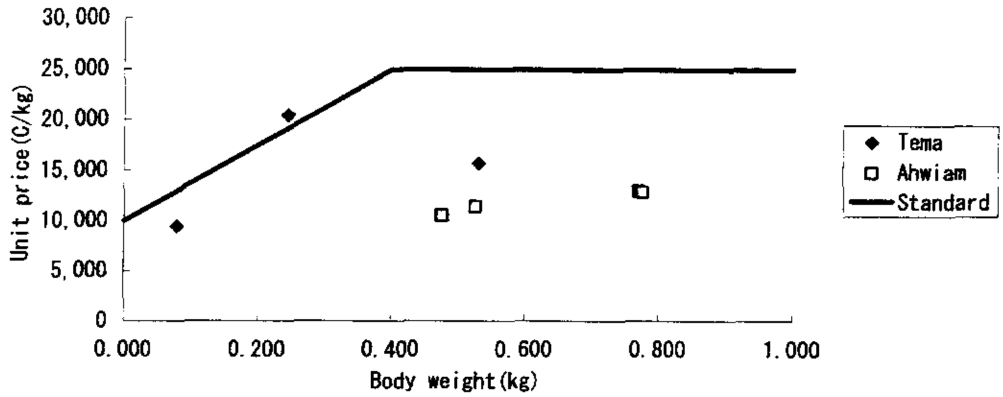


Fig. 5-2-5-4(1) Relationship between body weight and unit price
(*D.rhonchus*)

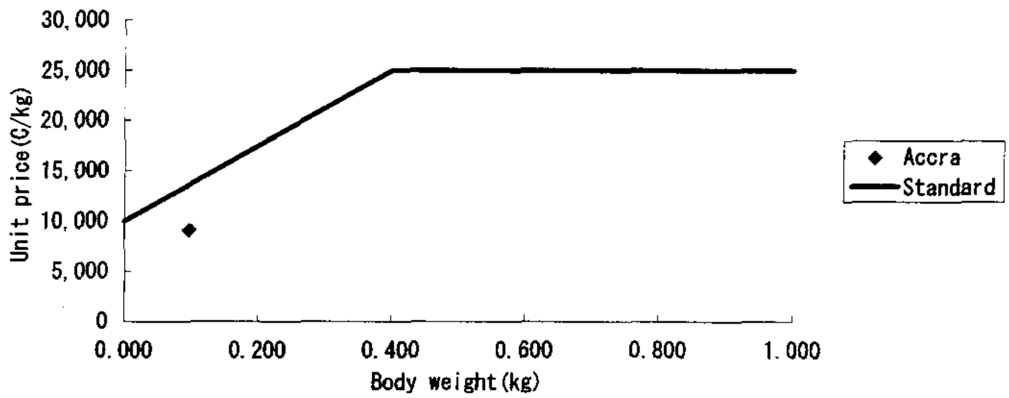


Fig. 5-2-5-4-(2) Relationship between body weight and unit price
(*B. auritus*)

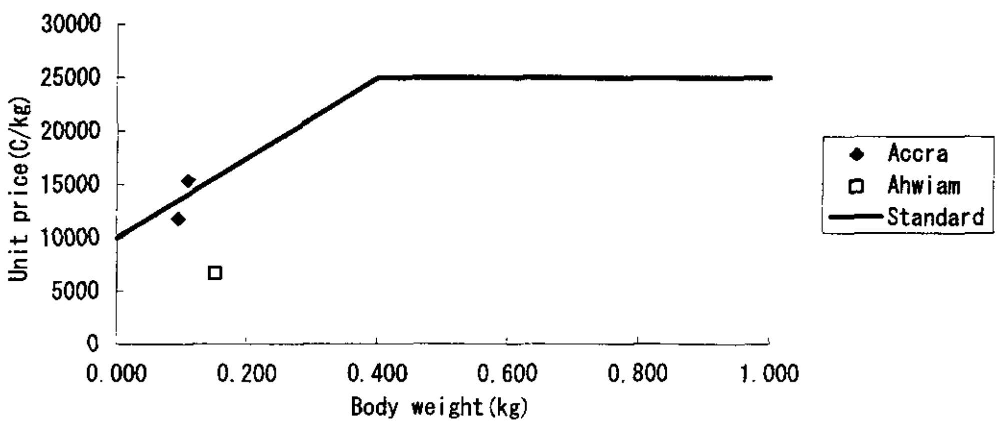


Fig. 5-2-5-4(3) Relationship between body weight and unit price
(*P. incisus*)

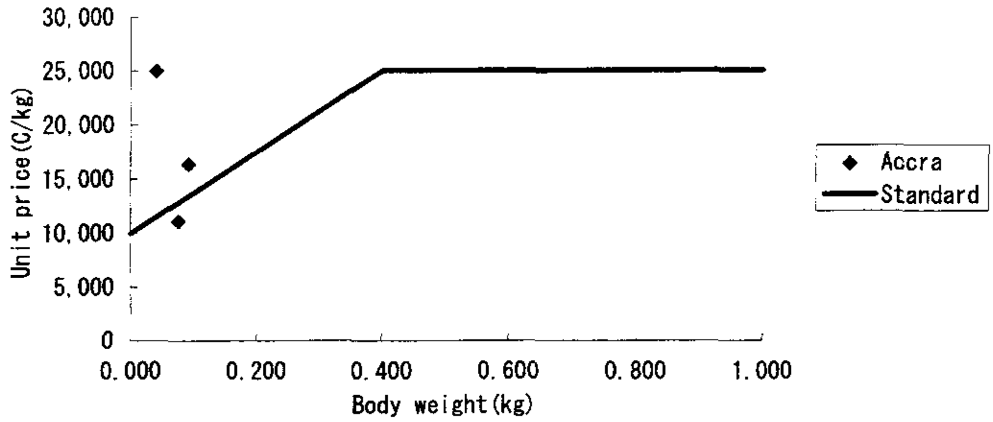


Fig. 5-2-5-4(4) Relationship between body weight and unit price (*G. decadactylus*)

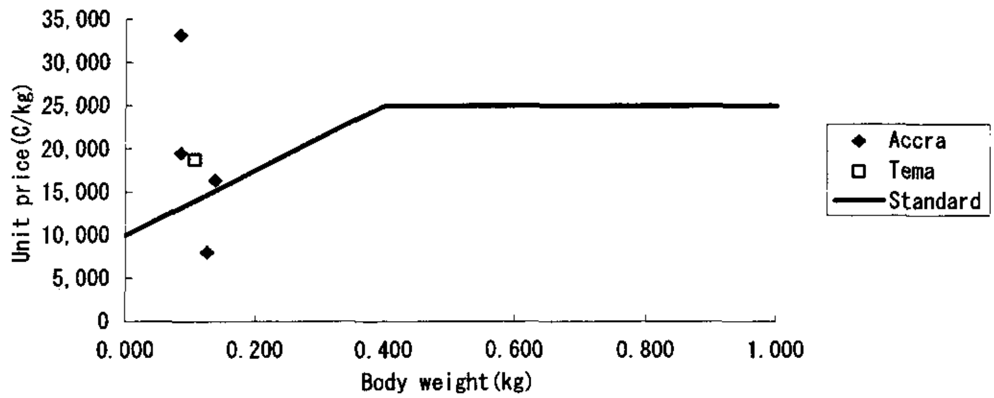


Fig. 5-2-5-4(5) Relationship between body weight and unit price (*P. prayensis*)

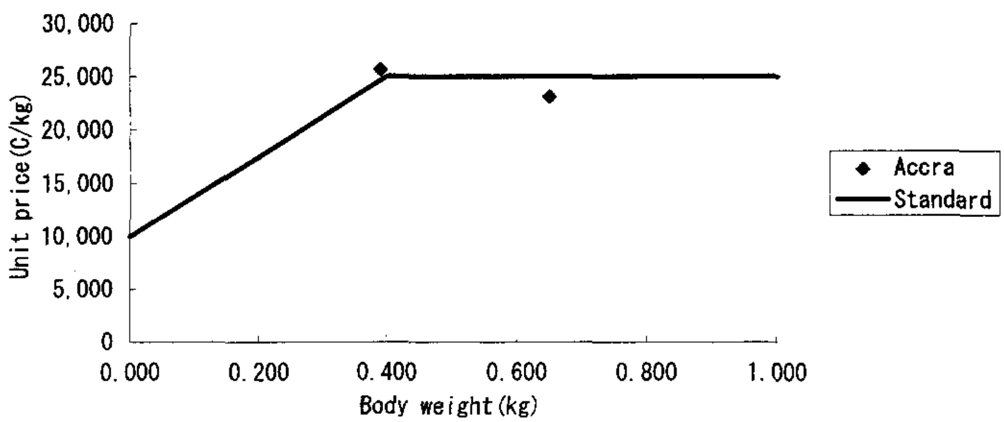


Fig. 5-2-5-4(6) Relationship between body weight and unit price (*S. officinalis*)

Table 5-2-5-1(1) Total length frequency distributions of evaluation-target sepecies caught by trawling survey and sampled at fish markets

Species	Period	TL(mm)	75	85	95	105	115	125	135	145	155	165	175	185	195	205	215	225	235	245	255	265	275	285	295	305
Pagellus bellottii	2nd	Survey					2	2	3	12	19	17	14	5	15	4	4	5	1	2		2	1			
	3rd	Survey			1	3	5	16	18	26	37	57	30	26	16	8	4	8	5	2	2	4	5	2	2	
		Ahwiam															2	2								
		Secondi													1	1										
		Tema									4	4	1													
	4th	Survey	4	6	6	10	6	4	2	3																
		Ahwiam							1	1	1						1		1	1						
		Apam	2	3	5	2	2																			
		JamesTown											1													
	5th	Tema							4	4	12	23	9	10	1	3										
Dentex canariensis	2nd	Survey			1		1	1	2	4		1		3	2	4	3	7	8	7	5	3	5	10	4	7
		Apam													1	1		1	1	1						
	3rd	Survey				1		2	2	7	7	9	15	12	12	6	6	4	3	3	3	5	8	6	2	4
		Ahwiam																				1	1		2	1
		Tema								1	1	3	1	1												
	4th	Survey			1	1	5	3	8	7	5	3									1					
		Ahwiam															1									
		Apam		1	4	5	7	3	4																	
Sparus caeruleostictus	2nd	Survey					4	8	5	13	10	21	8	10	4	7	10	4	2		2	2	2		2	3
		Apam									1									1	1	1				
	3rd	Survey		1	6	19	19	37	33	27	25	15	8	11	14	17	12	13	10	8	7	2	5	5	6	9
		Ahwiam									1	2	2	1	1	2	1	2	1	1	3				1	1
		Secondi															1									
	4th	Survey			2	20	36	50	20	14	5	6		3			1									
		Apam		1	3	7	9	4																		
		JamesTown								3	4	6	1	5	2	2	1									
		SalagaMarket												1	1	2		1								
		Mumford							1					1		1										
Pseudotolithus senegalensis	2nd	Survey																				2	1	2	3	1
		Mumford											2			1										
		Takoradi						1	2	1	3	1	1	1	1											
	3rd	Survey						1	5	6	12	16	24	27	21	16	11	6	3	2	6	3	3	6	8	2
		Secondi												1	3			1	2							
	4th	Survey												1												
		Ahwiam															1							1		1
		JamesTown													2	7	7	5	3	4	2					
		SalagaMarket																					1	1		
		Mumford						1			2	4	6	7	3	4	1	1					3	3	1	
	5th	Tema									1	1	1	1			2		1		1	1			3	
Galeoides decadactylus	2nd	Survey							3	3	5	14	13	18	13	12	10	6	3	1	1	1		1		
		Takoradi									2															
	3rd	Survey									1	4	7	6	8	15	12	4	9	8	6	4	2	1	1	1
		Ahwiam													1				1	1		1	2	1		1
		Secondi					2	3	2	5	7	1											1			2
	4th	Apam				4	7	4	7		1							2	1							
		Ahwiam					1	1	2	4		4	11	15	4	1	3	2			1					
		Mumford				5		2	3	7	6	1	4	1												
	5th	Tema								6	4	2	3	1	3	1	1	1			1	1		1	2	1

Table 5-2-5-1(2) Total length frequency distributions of evaluation-target sepecies caught by trawling survey and sampled at fish markets

Species	Period	TL(mm)	315	325	335	345	355	365	375	385	395	405	415	425	435	445	455	465	475	485	495	505	515	525	535	545
Pagellus bellottii	3rd	Survey			1																					
Dentex canariensis	2nd	Survey	4	5	3	4	2	5	1	1	1		1	2	1			1					1			
	3rd	Survey	1	2	4		5	3	1	2	2	1		1				1	1	1				2		
		Ahwiam			1	1		2	1	1		1										1				
		Secondi				1	1	1	1	1				1			1									
	4th	JamesTown									1							1								
Sparus caeruleostictus	2nd	Survey			1	1	1		1																	
		Apam				1																				
	3rd	Survey	4	6	2				1																	
		Ahwiam	1				1																			
		Secondi	1									1														1
	4th	JamesTown										1														
Pseudotolithus senegalensis	2nd	Survey	4	3	2	2	2	2	2	1				1									1			
		Takoradi	1															1								
	3rd	Survey	2	1	2	2	3	1	1	1	1	1					1	1					1	1		
		Secondi										1														
	4th	Survey						1	1		1		1													
		SalagaMarket	1																							
		Mumford			1	1		1	2		1		1	1		1										
	5th	Tema		1	1	2	2		1	1																
Galeoides decadactylus	2nd	Survey								1			1													
	3rd	Survey		2	2		1																			
		Ahwiam	4	3	1	2	3																			
		Secondi	1		2				1		1															

Table 5-2-5-1(3) Total length frequency distributions of evaluation-target sepecies caught by trawling survey and sampled at fish markets

Species	Period	TL(mm)	35	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195	205	215	225	235	245	255	265
Decapterus rhonchus	2nd	Survey	1		1				7	1	1	2	1		2	4	3					3	1	1		
		Takoradi																1	1		2		3	1		
	3rd	Survey												3	2	7	28	49	56	48	37	29	9	7	5	3
	4th	Ahwiam																		1						
Brachydeuterus auritus	2nd	Survey										6	2	19	19	13	16	5	3							
		Mumford					3	18	26	11	9	4	3	3	2											
		Takoradi						3	4	3	2	2	5	5	9	1	4	1								
	3rd	Survey					2		6	10	17	45	69	36	23	14	12	6	5	5		1	2			
	4th	Apam						1	3	4	6	12	10	2												
		Ahwiam								3	3	1	2	2	4	1										
		Mumford								1	1	3	7	5	1	1										
		Tema								1		1		1	1											
Pomadasys incisus	2nd	Survey												4	5	15	17	14	2	6	1					
	3rd	Survey												1	1	2	18	27	42	37	21	18	16	4	2	1
		Ahwiam																					1	1	2	
		Tema												2			3			2				1		
	4th	Apam							2	8	7	4	1													
		Ahwiam									2	4				1										
		Tema													1	2	3	1								
	5th	Tema								3	16	16	21	18	8	5	11	9	1	6	1					
Pseudoupeneus prayensis	2nd	Survey							1		1			2	1	3	7	4	10	11	1	7	8	5	3	1
		Mumford								1	2															
	3rd	Survey										1	7	14	26	31	34	36	48	39	23	22	12	13	8	10
		Ahwiam															2		3	3						
		Tema																1	3		1	1			1	
	4th	Apam								1	4	8	13	4												
		Ahwiam												2												
		SalagaMarket														1	1	1				2			1	
Sepia officinalis	2nd	Survey	1	3	19	27	24	6	5	4	3	5	6	6	4	7	11	10	3	1	2	3				1
		Mumford															1	2	1	1						
	3rd	Survey			2	8	2	3	4	1	8	1	4	4	4	9	8	5	6	5	9	8	1	4	5	1
		Tema																					1			
	4th	Survey		1	9	9	29	15	15	6	16	20	12	14	14	11	8	4	7	7	7	2	1	3	2	2
		Apam																	1		2	1	2	3		
		Ahwiam	1	4	3																					
		Mumford																		1			1			
	5th	Tema															1			1						

Species	Period	TL(mm)	275	285	295	305	315	325	335	345	355	365	375	385	395	405	415	425	435	445	455	465	475	485	495
Decapterus rhonchus	2nd	Survey																				1			
		Apam	1						1																
		Takoradi	1																						
	3rd	Survey	4		1											1	1								
		Ahwiam									3		7	5	15	6	3	5	2	3					1
	4th	Ahwiam									1														
Pomadasys incisus	3rd	Ahwiam	1																						
Pseudoupeneus prayensis	3rd	Survey	5																						
Sepia officinalis	2nd	Survey	1		1																				
	3rd	Survey	1	2	1																				
	4th	Survey	2	3	1	3																			
		Apam		2	1																				

Table 5-2-5-2(1) Total length frequency distributions of survey-target sepecies caught by trawling survey and sampled at fish markets

Species	Period	TL(mm)	105	115	125	135	145	155	165	175	185	195	205	215	225	235	245	255	265	275	285	295	305	315	325	335	345
Lutjanus fulgens	2nd	Survey									1				1		2		2	2	2	7	6	7	7	2	3
	3rd	Survey		1	2	8	6	2			1	3	7	5	2		1	2	3	2	7	3	9	16	11	8	12
		Tema																				2		1			
	4th	Survey					2	2	25	31	14	4	1								1	2	4	1	5	4	
Balistes capriscus	2nd	Survey								3	3	1	3	1		1	1		2	1	2	1	2	2			10
		Apam																	1	1							
	3rd	Survey				2		5	1	4	3	2	5	1	4		1	1	4	4	2	1	4	3	4	3	4
	4th	Survey											2	3		3	7	11	6	3	4	4	2	4	3	4	1
		Ahwiam													1	1											
Drepane africana	2nd	Survey					3	1	2		1																
		Mumford	1	1																							
		Takoradi		1																							
	3rd	Survey		3	7	3	3	2	3	2	1																
		Secondi	3		1																						
	4th	Survey									3	12	8	12	3	3	3	2		1	1			2			
		Apam							1	1																	
		Mumford	1			1		1																			
	5th	Tema		2	2	8	4	6	4	2	1	2	2														

Species	Period	TL(mm)	355	365	375	385	395	405	415	425	435	445	455	465	475	485	495	505	515	525	535	545	555	565	575	585	595
Lutjanus fulgens	2nd	Survey	2	1	1	1		1	1																		
	3rd	Survey	6	2	4		2		1	1			1														1
		Ahwiam	1																								
	4th	Survey	2		1	2						1		1			1								1		
Balistes capriscus	2nd	Survey	1	2	3	1	1	3	2	1	2	1	1		1												
	3rd	Survey	6	2	2	3		1	1	1	2	1	1	1		1		1									
	4th	Survey	2	2	1	2	3	2	2	1	1	1			1		1	1								1	

Table 5-2-5-2(2) Total length frequency distributions of survey-target sepecies caught by trawling survey and sampled at fish markets

Species	Period	TL(mm)	45	55	65	75	85	95	105	115	125	135	145	155	165	175	185	195	205	215
Selene dorsalis	2nd	Survey										1				2	3	8	14	13
		Mumford					1	3	6	3			1							
		Takoradi									1									
	3rd	Survey									1	11	7	3		2	1	1	5	1
		Secondi	2	16	11															
	4th	Survey					1	4	27	70	33	8				1	1			
		Apam																	1	
		Ahwiam		3			1			1	2	1								
		Mumford								2	1									
	5th	Tema							1			1					2	4	2	5
Dentex angolensis	2nd	Survey					1	3		5	10	15	8	3	2	3				
	3rd	Survey							8	30	5			21	74	32	12	21	7	10
		Secondi																1		1
Dentex congoensis	2nd	Survey			1		5	7	13	10	1	7	4	3	5	2	1			
	3rd	Survey					1	2	5	10	13	27	38	32	30	16	15	6	5	
		Secondi										1			1	2	3	6	3	2
Chroloscomburus chrysurus	2nd	Survey	1	2	2	2					3	2	8	21	5	9	10	6	4	1
		Mumford					1	3	2	1	1		2		2		2			1
		Takoradi								2		3	3	4	3	6	4	3		
	3rd	Survey									4	21	18	13	21	27	19	15	18	8
		Secondi												1						
		Tema									1	3	1	1	2	1				
	4th	Apam																1		
		Ahwiam			2	7	23	10	3	4	5	10	9	5	1	4	2		1	
		JamesTown												1	3	7	1	1		
		Mumford											1		2					
		Tema											4		3	2	1			1
	5th	Tema											1	1	1		1		1	

Species	Period	TL(mm)	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
Selene dorsalis	2nd	Survey	10	6	9	7	3	4	2		2		5	2						
	3rd	Survey	5	4		2					1	1	1			1				1
	4th	JamesTown		1																
	5th	Tema	1	3	2		1													
Dentex angolensis	2nd	Survey	1			1														
	3rd	Survey	9	6	2	5	4		1											
		Secondi	1	5	4	3	4	2	1	1										
Chroloscomburus chrysurus	2nd	Survey							1	1	1									
		Mumford			1															
	3rd	Survey	8	5	4		2		2	1										
	5th	Tema		1																

Table 5-2-5-2(3) Total length frequency distributions of survey-target sepecies caught by trawling survey and sampled at fish markets

Species	Period	TL(mm)	155	165	175	185	195	205	215	225	235	245	255	265	275	285	295	305	315	325	335	345	355	365	375	385	395
Epinephelus aeneus	2nd	Survey																2		2	1	1	1		1	1	1
	3rd	Survey								1						1	2			1		2		3			
		Ahwiam	1																								
		Secondi																									
		Tema																									
	4th	Survey			1	1				1					1		1	1	1	1	4	3	2	3		1	

Species	Period	TL(mm)	405	415	425	435	445	455	465	475	485	495	505	515	525	535	545	555	565	575	585	595	605	615	625	635	645
Epinephelus aeneus	2nd	Survey		1		1		2	1		1			1		1							1				
	3rd	Survey								1					1		1	1									
		Ahwiam																	1								
		Secondi																									
		Tema																									
	4th	Survey		2	2		1		3											1						1	

Species	Period	TL(mm)	655	665	675	685	695	705	715	725	735	745	755	765	775	785	795	805	815	825	835	845	855	865	875	885	895
Epinephelus aeneus	2nd	Survey				1		1			1													1		1	
	3rd	Survey				1		1				1											1				
		Ahwiam																									
		Secondi																									1
		Tema																			1						
	4th	Survey			1									1			1					1					

Species	Period	TL(mm)	905	915	925	935	945	955	965	975	985	995	1005	1015	1025	1035	1045	1055	1065	1075	1085	1095
Epinephelus aeneus	2nd	Survey		1																		1
	3rd	Survey	1	1																		
		Ahwiam																				
		Secondi															1					
		Tema																				
	4th	Survey																				

Table 5-2-5-3 Unit prices of target species (Cedi/kg)

Domestic	Target species	Unit price (C/kg)
* Red pandora	*Pagellus bellottii*	2,400
* Sea bream	*Sparus caeruleostictus*	2,000
Herring		1,200
Sardine		
Mackerel		800-1,200
Export		
* Cuttlefish(Mongo)	*Sepia officinalis*	2,400
Choco(Cuttlefish of lower grade)		1,600
* Denton	*Sparus caeruleostictus*	1,200
Lengua (Sole)		1,200
Pulpo (Octopus)		1,200
* West African goatfish	*Pseudupeneus prayensis*	1,200
* Grouper	*Epinephelus aeneus*	1,200
Sepiola(Squid)		1000-1200
* Cassava fish	*Pseudotolithus senegalensis*	800
Peluda		800
Mixed		800

*: Target species or the category including target species

Table 5-2-5-4 Export statistics on fish products published by the Government of Ghana

Export volume(ton)

Year	1997	1998	1999	2000
Tuna	6,959	6,607	15,409	13,733
Frozen Fish	4,813	4,716	4,061	6,720
Prawns	0	1	1	0
Shrimps	168	139	226	106
Crabs	0	0	0	0
Lobsters	108	77	123	141
Octopus	10	39	-	-
Cuttle Fish	858	2,023	1,853	-
Dried/smorked Fish	2,651	2,825	2,855	5,185
Salted Fish	9	7	4	13
Shark Fins	61	3	5	1
Aquarium Fishes	-	-	0	-
Canned Tuna	-	24,880	27,093	26,977
Mackerel	31	0	20	185

Export amounts (US $)

Year	1997	1998	1999	2000
Tuna	7,511,720	7,017,738	8,715,123	5,437,038
Frozen Fish	7,508,023	8,389,752	6,176,083	5,585,970
Prawns	1,257	1,351	3,000	383
Shrimps	592,026	484,528	783,244	332,055
Crabs	28	339	56	80
Lobsters	428,808	425,367	818,188	570,101
Octopus	5,453	81,256	-	-
Cuttle Fish	827,842	4,940,207	2,992,429	3,997,451
Dried/smorked Fish	1,709,243	1,570,431	1,441,629	2,639,719
Salted Fish	12,545	6,881	4,668	16,780
Shark Fins	108,028	103,600	3,640	2,025
Aquarium Fishes	291	-	640	-
Canned Tuna	49,821,614	77,283,091	61,890,751	65,101,237
Mackerel	31,760	7,327	45,978	161,623

Unit prices(US$／kg)

Year	1997	1998	1999	2000
Tuna	1.08	1.06	0.57	0.40
Frozen Fish	1.56	1.78	1.52	0.83
Prawns	5.44	2.70	5.03	15.32
Shrimps	3.53	3.49	3.46	3.13
Crabs	1.42	4.13	4.00	2.00
Lobsters	3.96	5.55	6.65	4.04
Octopus	0.53	2.07	-	-
Cuttle Fish	0.96	2.44	1.61	-
Dried/smorked Fish	0.64	0.56	0.50	0.51
Salted Fish	1.41	1.03	1.31	1.33
Shark Fins	1.77	39.24	0.66	2.18
Aquarium Fishes	-	-	15.61	-
Canned Tuna	-	3.11	2.28	2.41
Mackerel	1.03	366.36	2.27	0.88
Unit prices (Cedi／kg)				
Frozen Fish	3198	4116	4026	4424
Rates (C/US $)	2050	2314	2647	5322

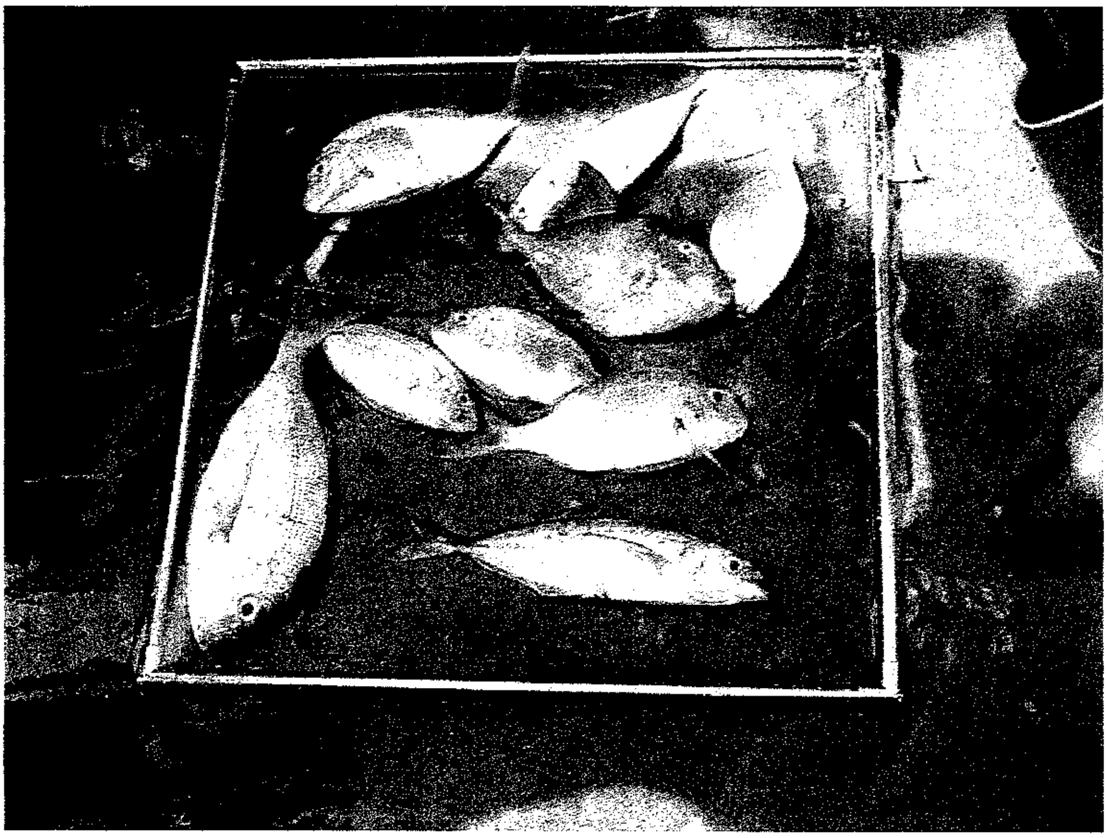
Table 5-2-5-5 The value of gross landing and unit prices on Artisanal fisheries

Landing (million cedi)

Species\Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
S. caeruleostictus/D. canariensis	229	587	775	417	323	826	496	281	261	179	474	164	5,012
P. bellottii	1,624	2,723	366	2,208	1,813	1,073	2,508	1,146	764	905	2,825	3,132	21,086
D. angolensis	176	122	259	245	147	332	120	249	906	487	230	670	3,944
D. congoensis	68	112	18	137	77	32	43	44	762	627	124	161	2,204
Pseudotolithus sp.	66	20	12	12	181	9	16	14	7	7	39	25	408
P. prayensis	1	2	7	0	15	0	0	1	1	2	1	3	34
B. auritus	602	453	415	260	410	214	196	295	787	629	2,152	487	6,900
P. incisus	13	25	53	23	5	21	13	8	24	5	8	32	228
P. jubelini	17	6	7	12	32	5	4	3	2	3	2	3	96
L. fulgens/L. agennes	18	54	12	20	66	18	10	7	9	21	15	7	257
Serranidae(Groupers)	42	20	57	95	13	83	59	66	247	27	11	6	724
D. africana	0	0	29	2	7	1	0	0	0	0	0	0	39
Caranx rhonchus(D. rhonchus)	217	122	247	49	249	242	83	284	426	129	2	25	2,076
C. chrysurus	395	227	168	86	222	207	72	647	665	1,003	492	199	4,384
S. dorsalis	11	5	5	5	6	6	1	45	82	38	57	99	359
Galeoides sp.	49	43	30	27	60	64	21	21	34	102	83	40	575
B. capriscus	0	0	0	0	0	0	0	0	0	0	0	0	0
Penaeidae(Shrimps)	9	22	39	24	32	38	37	88	162	134	237	25	848
S. officinalis	0	0	132	637	8	0	0	604	32	15	2	0	1,430

Unit prices(Cedi/kg)

Species\Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average
S. caeruleostictus/D. canariensis	1,870	2,046	1,746	2,459	2,702	1,896	2,674	2,493	2,599	2,044	2,775	2,548	2,180
P. bellottii	1,565	1,768	530	1,680	1,512	1,598	1,531	1,798	1,855	1,269	2,033	2,040	1,650
D. angolensis	1,437	1,700	2,212	1,914	1,756	2,205	1,760	2,508	2,568	2,129	2,567	2,638	2,232
D. congoensis	1,140	1,280	1,323	1,333	1,585	1,212	1,238	2,187	2,142	1,942	1,987	1,934	1,811
Pseudotolithus sp.	770	630	744	929	1,037	1,397	2,363	1,177	959	1,141	848	707	926
P. prayensis	3,003	2,264	1,433	2,899	1,138	-	-	1,403	2,706	3,971	2,553	885	1,360
B. auritus	481	490	602	624	473	772	1,052	808	845	324	732	815	606
P. incisus	1,098	1,263	1,495	1,341	1,354	1,288	897	1,016	1,212	1,163	939	751	1,139
P. jubelini	569	1,606	1,075	820	794	831	853	802	1,080	1,162	1,001	1,000	812
L. fulgens/L. agennes	2,230	2,399	4,186	2,405	2,067	2,220	1,802	1,201	1,725	3,407	4,232	3,711	2,335
Serranidae(Groupers)	4,647	4,787	2,726	4,016	1,945	3,402	5,624	5,516	4,497	4,702	4,218	5,625	4,137
D. africana	-	-	2,686	1,061	1,017	1,062	-	-	-	-	-	-	1,887
Caranx rhonchus(D. rhonchus)	1,267	490	1,622	1,146	2,094	1,467	1,543	800	1,349	1,465	1,696	1,239	1,197
C. chrysurus	417	478	654	593	740	776	689	624	674	577	524	514	578
S. dorsalis	589	972	899	980	1,138	1,080	1,032	2,004	1,037	624	439	926	807
Galeoides sp.	872	750	1,092	1,397	1,022	1,040	1,075	1,070	1,470	1,183	1,201	945	1,062
B. capriscus	-	-	-	-	645	-	-	-	-	-	-	-	645
Penaeidae(Shrimps)	635	980	747	556	1,005	811	716	499	1,115	663	1,743	576	877
S. officinalis	-	-	2,205	3,049	1,998	-	-	4,001	4,998	703	3,992	-	3,164



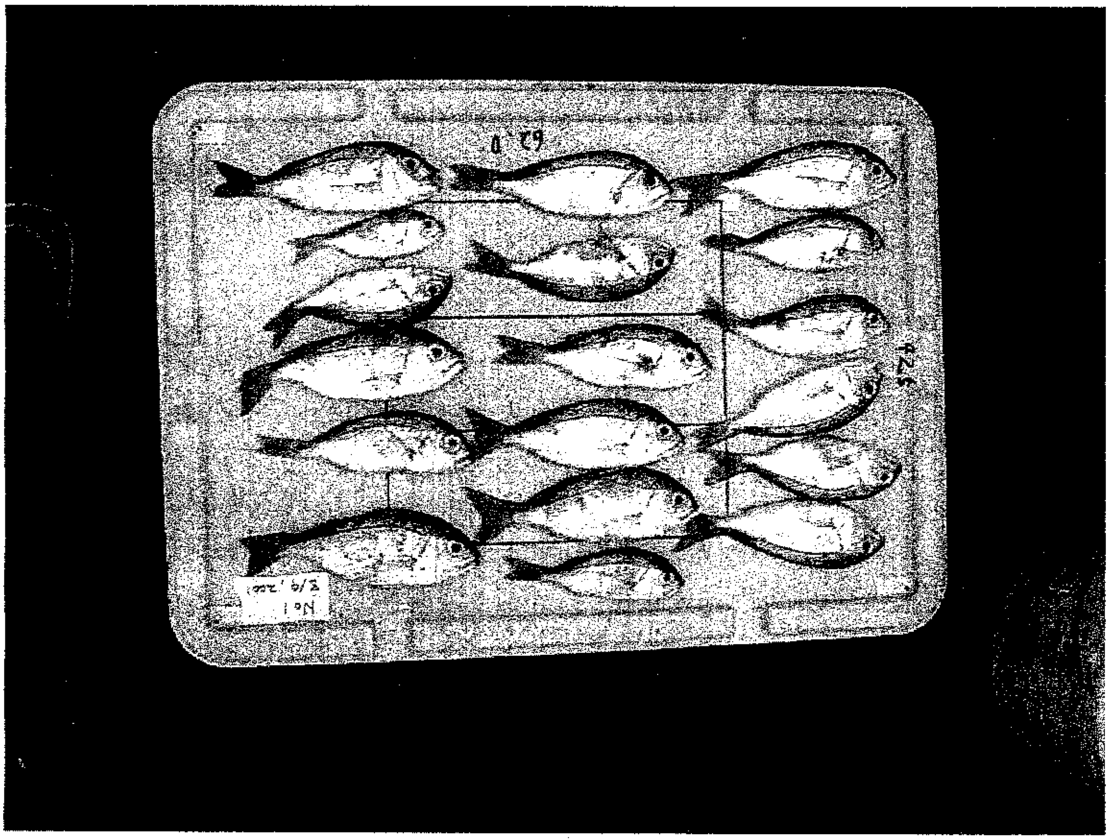


Plate 5-2-5-1 Fish for photo-metric measurement of body length using digital camera

5-2-6. Information Obtained on Stocks of Evaluation Target Species

(1) *Pagellus bellottii*

[1] Spawning season

The gonad analysis of *Pagellus bellottii* caught in the second survey (stable period: October and November, 2000) and the third survey (upwelling period: July and August, 2001) confirmed that upwelling period is the spawning season of this species. (For details, see Chapter 5-2-2.) This corresponds to the period from June to August reported (Research Division of Japanese Fisheries Agency:RDJFA, 1989). For this reason, the median month of spawning of this species to be used for the stock analysis is set to July.

[2] Maturity

A fish at maturity stage III (i.e., although the ovary is developed well and spawn can be seen clearly, little transparent spawn can be recognized) or higher is considered to be mature. The proportion of the fish at maturity stage III or higher caught in the third survey was examined within the body length range by age calculated from the growth equations described later. As a result, since no individuals were collected within the body length range at the age of three, the proportion was unknown, but 50%, 60%, and 100% of the individuals were mature at the ages of one, two, and four or older, respectively.

RDJFA(1989) said that the rate of group maturity at a fork length of 151 mm and that at a fork length of 171 mm were 50% and 100%, respectively. The fork lengths are equivalent to 168 mm and 188 mm in terms of total length and both of them correspond to a two-year-old fish group. Judging from this, in addition to the above results, the maturity rates of 50%, 75%, and 100% at ages of one, two, and three or older, respectively, will be used for the stock analysis

[3] Sex ratio

The investigation of the body length range by age calculated from the growth equations described later revealed that the proportion of females is 38%, 45%, 44%, 50%, and 67% at ages of one, two, three, four, and five or older, respectively. Though the proportion of females appears to increase with the age, this could not be considered a solid tendency because the number of individual investigated of age five or older was only five. Because the proportion of females was 25% at age 3 (two out of eight individuals were females) in the second and third survey, we attached importance to this age in the fourth survey and investigated eight individuals. The proportion of females then was 63% (five out of eight were females). Summarizing those data, we got the value of 44% described above. The proportion of females at age 3 is considered to be 50% approximately. Since RDJFA (1989) did not mention the sex ratio, there is no comparable report available. We are compelled to use these investigation results as the sole information. From the result above, the sex ratios used for the stock analysis are assumed to be 40%, 45%, and 50% at ages of one, two, and three or older, respectively.

[4] Growth

From the fitting of normal distributions to the body length composition of *Pagellus bellottii* caught in the second survey (stable period: October and November, 2000) and the third survey (upwelling period: July and August, 2001), the results shown in the following table were obtained. The growth equations shown below were derived from the results.

Results obtained from the fitting of normal distributions to length composition (the second survey)

Age	TL(cm)	SD	Nos.(%)
1	11.1	0.976	10.0
2	16.4	1.311	74.7
3	20.8	1.572	13.7
4	25.1	1.729	1.7

Results obtained from the fitting of normal distributions to length composition (the third survey)

Age	TL(cm)	SD	Nos(%)
1	12.5	1.420	11.3
2	16.5	1.827	73.3
3	23.1	1.926	11.0
4	27.6	1.988	4.3

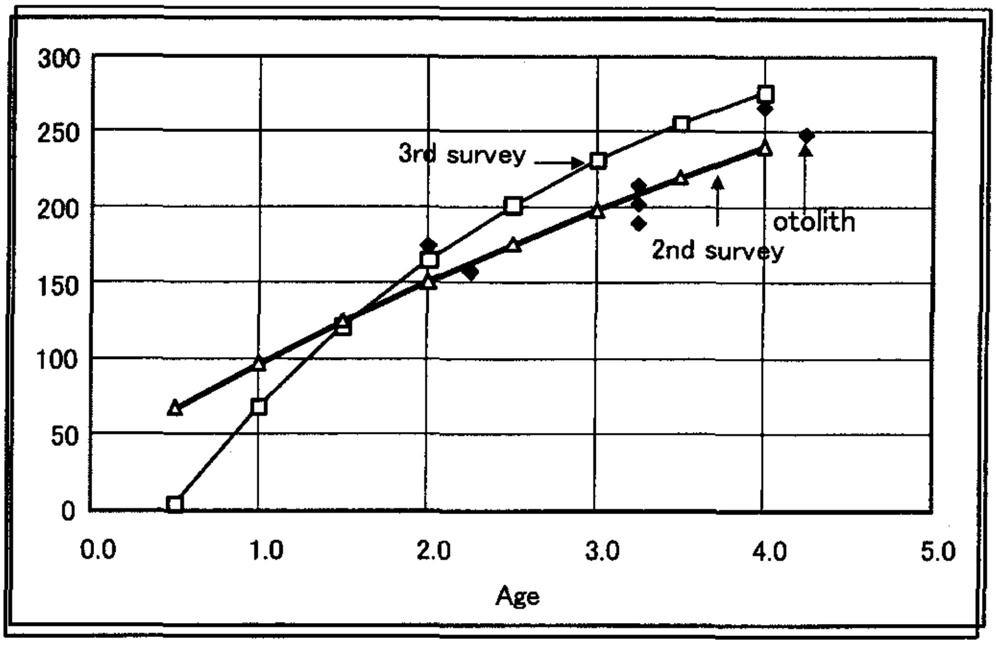
The second survey: $L_t = 559\{1 - e^{-0.1237(t+0.5384)}\}$

The third survey : $L_t = 372\{1 - e^{-0.3830(t-0.4719)}\}$

L_t: Total length at the age of t (mm)

t: Age

On the other hand, a growth equation could not be obtained from the age determination results from the otolith described in Chapter 5-2-2. Such being the case, the age determination results and the growth equations above were superimposed for further study.



The absolute age of the otolith shown in the figure differs subtly in the same age group, which is attributable to the fact that 0.25 year was added to the absolute age of the otolith in the second survey because it was considered that about three months had already passed from July, the median month of the spawning. As a matter of course, the absolute age in the third survey is an integer because it corresponds to the median month of the spawning.

This figure shows that the growth curve in the second survey corresponds well with the results of the otolith. The growth curve in the third survey, however, is different from this. It is clear that the growth curve does not correspond with the otolith results.

Both of the growth curves may not agree for the following reason. A model of the fitting of normal distributions used in this report to obtain the growth curve is Hasselblad's model. The solution is generally not unique and depends on the initial value in many cases (Tanaka, 1990). For this reason, various initial values were used until an appropriate resolution image was obtained by cut-and-try methods. The most appropriate result obtained from the third survey is shown in the table below.

Result of fitting of normal distributions to length composition (the third survey)

Age	TL(cm)	SD	Nos(%)
1	12.5	1.420	11.3
2	16.5	1.827	73.3
3	23.1	1.926	11.0
4	27.6	1.988	4.3

This table clearly shows that a difference in the body length between the ages of one and two is smaller than that between the ages of two and three and the resolution of the one-year old group is clearly insufficient. For this reason, the body length at the age of two or more was used to obtain the growth equation in the third survey. It was thought that the disagreement above occurred because the resolution of this one-year-old group has an influence upon all the age groups.

Judging from the above, the growth curve obtained from the body length composition in the second survey can be considered to be appropriate as a growth curve of this species.

[5] Natural mortality coefficient

According to Pauly's (1980) method, the natural mortality coefficient was assumed from the parameter of the growth equation and the water temperature. Pauly's natural mortality coefficient estimation formula is as shown below.

$$Log_{10}(M) = -0.0066 - 0.279Log_{10}(L_{\infty}) + 0.6543Log_{10}(k) + 0.4634Log_{10}(T)$$

M: Natural mortality coefficient

L_{∞} : Asymptotic length of growth equation (cm)

k: Growth coefficient of growth equation

T: Annual average water temperature in the habitat (°C)

The water temperature at a depth of 30 m or more ranges from 18°C to 20°C at both stable period and upwelling period. Calculating M by substituting the above equation for parameters of the growth equation (L_{∞}=55.9, k=0.1237) and changing the water temperature by 1°C within the range from 16°C to 22°C, which is a range slightly wider than the actual measurements. M will be a value from 0.30 to 0.34. The value of M does not vary so much with a change in water temperature. Consequently, 0.32, a value calculated when the water temperature is set at 19°C, was assumed as the natural mortality coefficient.

The annual natural mortality coefficient (M) can be converted into an annual survival rate (S) using the relation formula of $S = e^{-M}$. If M is 0.32, $S = e^{-0.32} = 0.726$ (72.6%). In other words, if any thinning by fishing is not performed, about 27% of the stock will die in a year and 73% will survive until the following year.

[6] Current survival rate

The length composition in the second and third surveys was averaged by the following method to estimate the current survival rate.

Convert each body length composition (Table 5-2-2-5) in the second and third surveys into percentage. Assign weights to the values by the CPUE (catch quantity/towing time) in each period (upwelling and stable) and total them. Then, convert them into percentage. In this regard, the CPUEs in the stable period (second and fourth survey) and the upwelling period (third and fifth survey) are 31.5(kg/hour) and 17.7(kg/hour), respectively.

Calculation process of body length composition

	A	B	C (=A/ΣA)	D (=B/ΣB)	W2:31.5 E (=C×W2)	W3:17.7 F (=D×W3)	G (=E+F)	H (=G/ΣG)
	No of specimen		Percentage		Assigned weights			Total
TL(mm)	2nd	3rd	2nd	3rd	2nd	3rd		
91 - 100		1	0.0	0.4	0.00	6.37	6	0.1
101 - 110		3	0.0	1.1	0.00	19.10	19	0.4
111 - 120	2	5	1.9	1.8	58.33	31.83	90	1.8
121 - 130	2	16	1.9	5.8	58.33	101.87	160	3.3
131 - 140	3	18	2.8	6.5	87.50	114.60	202	4.1
141 - 150	12	26	11.1	9.4	350.00	165.54	516	10.5
151 - 160	19	37	17.6	13.3	554.17	235.58	790	16.1
161 - 170	17	57	15.7	20.5	495.83	362.91	859	17.5
171 - 180	14	30	13.0	10.8	408.33	191.01	599	12.2
181 - 190	5	26	4.6	9.4	145.83	165.54	311	6.3
191 - 200	15	16	13.9	5.8	437.50	101.87	539	11.0
201 - 210	4	8	3.7	2.9	116.67	50.94	168	3.4
211 - 220	4	4	3.7	1.4	116.67	25.47	142	2.9
221 - 230	5	8	4.6	2.9	145.83	50.94	197	4.0
231 - 240	1	5	0.9	1.8	29.17	31.83	61	1.2
241 - 250	2	2	1.9	0.7	58.33	12.73	71	1.4
251 - 260		2	0.0	0.7	0.00	12.73	13	0.3
261 - 270	2	4	1.9	1.4	58.33	25.47	84	1.7
271 - 280	1	5	0.9	1.8	29.17	31.83	61	1.2
281 - 290		2	0.0	0.7	0.00	12.73	13	0.3
291 - 300		2	0.0	0.7	0.00	12.73	13	0.3
301 - 310			0.0	0.0	0.00	0.00	0	0.0
311 - 320			0.0	0.0	0.00	0.00	0	0.0
321 - 330			0.0	0.0	0.00	0.00	0	0.0
331 - 340		1	0.0	0.4	0.00	6.37	6	0.1
Total	108	278	100.0	100.0	3150.0	1770.0	4920	100.0

On the other hand, the total lengths at each age calculated from the growth equations are as shown below.

Age	TL(mm)
1	97
2	151
3	198
4	240
5	277

Based on this data, the frequency by total length class obtained (column H in the above table) is assigned to each age to estimate the age composition. For example, an individual having the total length from 97 mm or more to less than 151 mm is classified as a one-year-old fish and that having the total length from 151 mm or more to less than 198 mm is classified as a two-year-old fish. As for the total length class spreading over two ages, the frequency is distributed proportionately on the boundary of the total length, which delimits each age. For example, individuals having the total length of 191 to 200 mm are divided into two-year old fish and three-year-old fish on the boundary of 198 mm, and 70% (191 – 197 mm) of the frequency of this class is categorized as two-year-old fish and 30% (198 – 200 mm) is classified as three-year-old fish. The age composition thus obtained is as shown below.

Age composition of *Pagellus bellottii*

Age	Ratio(%)
1	20.1
2	59.7
3	14.8
4	4.3
5	1.0

From this age composition, the age of two is considered to be an age at complete recruitment. Also, since the composition at the age of two or older decreases almost exponentially, the average age method was used to estimate the fishing mortality coefficient on the assumption that the current stocks are in steady state.

In the average age method, the average age (K) of a catch at and after the age at complete recruitment is found. In this case, it is calculated as shown below.

$$K = \frac{59.7 \times 2 + 14.8 \times 3 + 4.3 \times 4 + 1.0 \times 5}{59.7 + 14.8 + 4.3 + 1.0} = 2.33$$

On the other hand, assuming that the annual survival rate at the age of two or older is S and the number of two-year-old fish is N, the numbers of three-year-old, four-year-old, and five-year-old fish are NS, NS^2, and NS^3, respectively. The average age X in this case is calculated by the following equation.

$$X = \frac{2N + 3NS + 4NS^2 + 5NS^3}{N + NS + NS^2 + NS^3} = \frac{2 + 3S + 4S^2 + 5S^3}{1 + S + S^2 + S^3}$$

X varies depending on the value of S. The value of S at which X is equal to the average age K of the actual catch is considered to be the current survival rate.

$$X = \frac{2 + 3S + 4S^2 + 5S^3}{1 + S + S^2 + S^3} = 2.33 \quad (= K)$$

$$\therefore \; S = 0.259 \quad (25.9\%)$$

The annual survival rate in the case where fishing is not practiced is 73%. It is thought that the current survival rate of two-year-old or older fish has dropped to 25.9%.

The current survival rate (S) can be converted into the total mortality coefficient (Z) using the following equation.

$$S = e^{-Z} \Leftrightarrow Z = -\log_e S$$

The annual mortality coefficient of *Pagellus bellottii* is $Z = -\log_e 0.259 = 1.352$. Since the total mortality coefficient (Z) is the sum ($Z = M + F$) of the natural mortality coefficient (M) and the fishing mortality coefficient (F), the fishing mortality coefficient (F) is $F = Z - M = 1.352 - 0.32 = 1.032$.

A concept of availability (Q) is introduced to find the survival rate of one-year-old fish. The availability indicates the proportion of one-year-old fish to be caught. If all of the one-year-old fish are caught like the age at complete

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Note: In these analyses, stocks are assumed to be in the stable status.

recruitment (two years old) or older, $Q = 1$. If no one-year-old fish is caught, $Q = 0$.

Usually, the annual survival rate is expressed as e^{-Z} or $e^{-(M+F)}$ using the total mortality coefficient (Z) or natural mortality coefficient (M) and the fishing mortality coefficient (F). The proportion Q of one-year-old fish in this case decreases due to the natural death and fishing. The remaining $(1 - Q)$ decreases due to the natural death only. Therefore, the stock number at the age of two (N_2) can be calculated by the following equation using the stock number at the age of one (N_1).

$$N_2 = N_1\{Qe^{-Z} + (1 - Q)e^{-M}\} \quad (1)$$

Also, if the exploitation rate is E, the numbers of fish caught at the age of one and two, C_1 and C_2, can be calculated each by the following equation.

$$C_1 = QN_1E \quad (2)$$

$$C_2 = N_2E \quad (3)$$

From equations (2) and (3), $N_2 = QN_1C_2/C_1$. When this is substituted in equation (1), the following is obtained.

$$QN_1C_2 / C_1 = N_1\{Qe^{-Z} + (1 - Q)e^{-M}\}$$

Equation (4) can be obtained by converting the above equation.

$$Q = \frac{1}{(C_2/C_1)e^{M} - e^{-Z}e^{M} + 1} \quad (4)$$

C_2/C_1, the proportion of the catch number of two-year-old fish to one-year-old fish, is the ratio of age composition of catch (Two-years-old fish: 59.7%, one-year-old fish: 20.1%). If a calculation is done by substituting the values M and Z in equation (4), using this proportion, $Q = 0.211$ (21.1%). In other words, 21.1% of all of the one-year-old fish is to be caught like two-year-old or older fish (survival rate of 25.9%) and the remaining 78.9% decreases due to the natural death only (survival rate of 72.6%). Consequently, the survival rate of all of the one-year-old fish is $\{Qe^{-Z} + (1 - Q)e^{-M}\} = (0.211e^{-Z} +$

$0.789e^{-M}) = 0.627$ (62.7%).

From the above, assuming that 1,000 one-year-old fish is recruited, the comparison of the survival process between the status where fishing is not practiced (at the time of virgin stock) and the current status is shown below.

Survival process between the time of virgin stock and the present status

Age	Virgin stock Number	Virgin stock Survival rate%	Present Number	Present Survival rate%
1	1000	72.6	1000	62.7
2	726	72.6	627	25.9
3	527	72.6	162	25.9
4	383	72.6	42	25.9
5	278	72.6	11	25.9

The exploitation rate (E) at and after the complete age of recruitment (two years old) is expressed by the following equation.

$$E = \frac{F}{M+F}(1-e^{-Z}) = \frac{1.032}{0.32+1.032}(1-e^{-1.352}) = 0.566\ (56.6\%)$$

The exploitation rate of one-year-old fish is a value obtained by multiplying the exploitation rate at and after the complete age of recruitment (E) by the availability (Q).

$$QE = 0.211 \times 0.566 = 0.120\ (12.0\%)$$

Using the above, assuming that 1,000 one-year-old fish are recruited under the current fishing pressure, a change in the stock number and the number of the catch can be calculated as shown below.

Age	Number of stock	Survival rate (%)	Exploitation rate (%)	Number of catch	Catch composition (%)
1	1000	62.7	12.0	120	20.0
2	627	25.9	56.6	355	59.5
3	162	25.9	56.6	92	15.4
4	42	25.9	56.6	24	4.0
5	11	25.9	56.6	6	1.0

The catch composition obtained above is used for subsequent analysis.

[7] Estimation of stock number

In order to estimate the stock number, the catch in number has to be calculated from the annual catch quantity. The average of the annual catch quantity for five years from 1997 to 2001 (Table 5-1-7-2), 7387 tons, was used as the annual catch quantity. In order to convert the catch quantity into the catch in number, an average body weight of the catch is necessary. In order to calculate the average body weight of the catch, age composition of the catch obtained above and an individual weight by age are necessary. An individual weight by age changes depending on the month because of the fish growth. For example, an individual weight of a certain age fish at the spawning month (the time when the fish just reached that age) is smaller than the one at six months after spawning. Therefore, the individual weight at the middle of fishing season is required for calculating the average body weight of the catch. According to the monthly catch (Table 5-1-7-2), fishing is practiced throughout the year. Accumulated monthly catch quantity from the spawning month (July) exceeds a half of the annual catch quantity at January (six months after the spawning month, July). Therefore January was set to be the middle of fishing season (the median month of the fishing season) and the weight of the fish at each age in January is used to calculate the average weight. The weight by age in January obtained from the growth equation and length-weight relationship is as shown below.

Body weight at the middle of fishing season

Age	Body weight(g)
1	24
2	69
3	140
4	233
5	344

From this data and the catch composition obtained above, the average weight of the catch can be calculated.

Age	A Body weight (g)	B Catch composition (%)	C A×B/100
1	24	20.0	4.9
2	69	59.5	41.3
3	140	15.4	21.6
4	233	4.0	9.3
5	344	1.0	3.6
Total			80.5 ←Average weight

From the annual catch quantity (7387 tons) and the average weight of the catch (80.5g), the annual catch in number can be calculated.

7387 x 1000 x 1000/80.5 ≒ 91.7 (million fish)

Distribute this value by age according to the catch composition and the following catch in number by age can be obtained.

Catch in number by age

Age	Number of catch (x1000)
1	18,388
2	54,600
3	14,131
4	3,657
5	947
Total	91,724

At and after the age at complete recruitment (two year old), the relationship among the catch in number (C), exploitation rate (E), and stock number (N) is N = EC. Since the catch in number (C) is obtained as shown in the table above and the exploitation rate (E) is also estimated at 0.566 as mentioned above, the stock number (N) can be calculated. Where, the stock number is the number of fish in the spawning season

Note: The numbers of catch are calculated from the catch quantity, age composition and body weights at the median month of the fishing season.

(July). Also, the stock number (N) of one-year-old fish can be calculated because the relationship N = QEN holds for a one-year-old fish and the availability (Q) is estimated at 0.211.

The stock biomass by age can be calculated by multiplying the stock number of each age by the weight of fish in the spawning month. The weight by age in the spawning season calculated from the growth equation and length-weight relationship is as shown below.

Age	Body weight(g)
1	11
2	44
3	102
4	184
5	287

The estimation results of the stock number by age and stock biomass are as shown below.

Stock number and biomass by age

Age	Stock Number (x1000)	Biomass (ton)
1	153,835	1,712
2	96,517	4,202
3	24,980	2,537
4	6,465	1,189
5	1,673	480
Total	283,471	10,120

[8] Stock Assessment by SPR

Up to this process, the stock number by age has been estimated. It is necessary to evaluate whether or not the stocks can be effectively utilized under the present circumstances, the area is overfished, or there is still room to catch more fish (underdeveloped).

Note: Stock number and biomass are the values at the spawning month.

The MSY analysis using the reproduction relation is the most rational way to evaluate the stocks. At present, however, neither the reproduction relation of the stocks is known nor the estimation of this relation is easy. As a stock evaluation technique in this case, the SPR (Spawning stock biomass Per Recruit) analysis is used.

The SPR is an index showing the contribution ratio of a recruited individual to the reproduction. In other words, in case a certain number of fish (usually, one-year-old fish) recruited for a catch survive until they become mature and spawn, calculated is how much spawning biomass can be obtained.

The calculation process of the SPR *at the time of* virgin stock($SPR_{F=0}$) when the number of one-year-old fish are 1000 individuals is shown in the table below. Incidentally, although the original life span of *Pagellus bellottii* is considered to be 13 or 14 years, the maximum age found in the present sample is 4 or 5 yeas at most. For this reason, the calculation was done for fish up to five years old in the present evaluation.

Calculation of SPR at the time of virgin stock

Age	Number	Female (%)	Maturity (%)	Number of Adult (*1)	Weight of an individual (g)	Spawning biomass (kg)(*2)
1	1000	40	50	200	11	2.2
2	726	45	75	245	44	10.7
3	527	50	100	264	102	26.8
4	383	50	100	191	184	35.2
5	278	50	100	139	287	39.9
						Total:114.7

*1: Number of Adult = Number of individual x (proportion of female fish/100) x (maturity ratio/100)

*2: Spawning biomass : Number of adult x weight of an individual/1000

$$SPR_{F=0} = 114.7\ (kg)/1000\ (individuals) = 0.115\ (kg)$$

It follows that the spawning biomass of 0.115 kg, can be obtained from one recruited individual at the time of virgin stock.

On the other hand, the present SPR (SPR_{now}) is calculated in the same way as shown below.

Calculation of present SPR

Age	Number	Female (%)	Maturity (%)	Number of adult	Weight of an individual(g)	Spawning Biomass(kg)
1	1000	40	50	200	11	2.2
2	627	45	75	212	44	9.2
3	162	50	100	81	102	8.2
4	42	50	100	21	184	3.9
5	11	50	100	5	287	1.6
						Total:25.1

SPR_{now} = 25.1 (kg)/1000 (individuals) = 0.025 (kg)

Under the present circumstances, since the fishing pressure is strong and only a few individuals can survive until they become mature, the spawning biomass obtained from one recruited individual is 0.025 kg at present.

Since the weight at maturity differs from species to species, the absolute values of $SPR_{F=0}$ and SPR_{now} do not count for much. The percentage (%SPR) of SPR_{now} to $SPR_{F=0}$, however, can be handled as a universal stock evaluation criterion, which does not vary from species to species.

$\% SPR = SPR_{now} / SPR_{F=0} \times 100 = 0.025 / 0.115 \times 100 = 21.9\ (\%)$

The closer to 100 (%) the %SPR is, the closer to the virgin status the stock is. If the %SPR is 0, in other words, SPR_{now} is 0, all recruited individuals will die before they become mature and the stocks will go extinct. It can be said that the closer to 0 the %SPR is, the closer to extinction the stocks are.

The spawning biomass of 0.115 kg can be obtained from one recruited individual at the time of virgin stock. With as much as this spawning biomass, the steady state is maintained by recruiting an individual to the stocks again. In other words, the reproduction ratio at the time of virgin stock (the number of recruited fish per kilogram of spawning biomass) is 1/0.115 (the reciprocal of the $SRR_{F=0}$) = 8.7.

On the other hand, the spawning biomass of 0.025 kg is obtained from one recruited individual under the present circumstances, and the steady state is maintained by recruiting an individual to the stocks again from this spawning biomass.

Therefore, the current reproduction rate is 1/0.025 (the reciprocal of the SPR_{now}) = 40. It is considered that the reproduction rate has increased due to the density effect under the present circumstances because the stocks have decreased, compared to the time of virgin stock. The reproduction rate, however, does not increase limitlessly, the stocks cannot maintain a steady state and collapse when the SPR is below a certain level.

Mace (1994) studied various kinds of fish to find a point where the stocks collapse caused by a decrease in %SPR. She discovered that there is a threshold value of the collapse of the stocks for many kinds of fish when the %SPR is within the range of 5 to 20. She pointed out that fishery management must be performed so that the %SPR can be maintained at 20 or more for a kind of fish whose characteristic value such as the reproduction relation is unknown. In USA, it is a general management standard to maintain the % SPR at 20 or more for a kind of fish whose data on the stock characteristic value is insufficient. Mace also studied the relationship between %SPR and MSY. She found out that MSY could be obtained when %SPR is about 40 in most species.

Therefore there are two criteria in stock evaluation using SPR; %SPR=20 as the minimum threshold and %SPR=40 as the goal for maximum sustainable use of the stock.

Though the present %SPR (21.9) of *Pagellus bellottii* is slightly higher than the minimum threshold (20), it is expected that more annual catch could be obtained steadily if %SPR get closer to 40 by management.

This section has described the calculation process in detail. It is possible to estimate the survival rate and stock number and conduct the SPR analysis by using the computer program "KAFS (Kinetic Analysis of Fisheries System) model."

(2) *Dentex canariensis*

[1] Spawning season

The gonad analysis of *Dentex canariensis* caught in the second survey (stable period: October and November, 2000) and the third survey (upwelling period: July and August, 2001) confirmed that the period from July to November is the spawning season of this species (See Chapter 5-2-2.). Based on this data, the median month of spawning of this species to be used for the stock analysis is set to September.

[2] Maturity

Some one-year-old individuals having mature spawn were recognized through the second and third surveys. A fish at maturity stage III (i.e., although the ovary is developed well and spawn can be seen clearly, little transparent spawn can be recognized) or higher is considered to be mature. The proportion of the fish at maturity stage III or higher was examined within the length range by age calculated from the growth equation described later. As a result, no yearling fish was mature, and 21%, 71%, and 100% of the individuals were mature at the ages of one, two, and three or older, respectively. These values will be used for the stock analysis.

[3] Sex ratio

The investigation of the length range by age calculated from the growth equation described later revealed that the proportion of the female yearling fish is 33% and that of the females at the ages of one, two, three, four, and five or older is 49%, 48%, 44%, 10%, and 40%, respectively. Because the number of yearling fish analyzed is only three, it is reasonable to consider the proportion of the female yearling fish is probably equal to one-year-old fish. The proportion of the female at the ages of one and two is about 50%. From ages of three and older, the proportion tends to decrease with the ages. Combining the data of the ages of four and five, the proportion is calculated to be 20%. In conclusion, the proportion of yearling to two-year-old females, three-year-old females, and four-year-old and older females is 50%, 44%, and 20%, respectively. These values will be used for the stock analysis.

[4] Growth

From the fitting of normal distributions to the length composition of *Dentex canariensis* caught in the second survey (stable period: October and November, 2000) and the third survey (upwelling period: July and August, 2001), the results shown in the following table were obtained.

Results obtained from the fitting of normal distributions to length composition (the second survey)

Age	TL(cm)	SD	Nos.(%)
1	23.0	1.721	54.0
2	29.7	1.957	27.3
3	35.3	2.118	13.2
4	40.1	2.231	5.5

Results obtained from the fitting of normal distributions to length composition (the third survey)

Age	TL(cm)	SD	Nos.(%)
1	17.2	2.535	44.3
2	27.3	2.388	26.1
3	35.9	2.336	19.6
4	45.9	2.294	9.9

From these results, the following growth equations were found. Note that the growth equation from the results of the third survey was obtained from the total length of one- to three-year-old fish because a difference in total length between three- and four-year-old-fish was larger than that between one- and three-year-old fish.

The second survey : $L_t = 662\{1 - e^{-0.1680(t+1.3732)}\}$

The third survey : $L_t = 887\{1 - e^{-0.1508(t+0.5180)}\}$

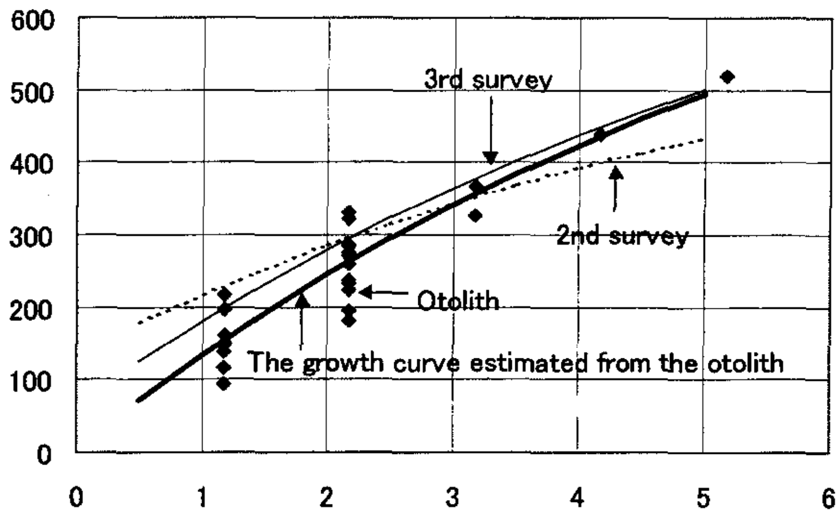
L_t: Total length at the age of t (mm)

t: Age

On the other hand, from the age determination results from the otolith described in Chapter 5-2-2, the average total length by age was found. From this average total length by age, the following growth equation was obtained. Note that the age group of one to four was used. Also, since the present survey was conducted at a period from the end of October to November, when about two months had already passed since September, the median month of spawning. Therefore, 0.17 year was added to absolute age.

$$L_t = 930\{1 - e^{-0.1513(t+0.0231)}\}$$

The following figure shows the superposition of the three growth curves above and the age determination results from the otolith.



In the growth equation from the results of the second survey, t_o takes an abnormal value. In the growth equation from the results of the second survey, as described above, the analysis of the maximum age is insufficient. For these reasons, it can be concluded that obviously, the growth curve estimated from the otolith is the most appropriate.

Based on the above, the growth equation obtained from the otolith is used to analyze the stock of this species.

[5] Natural mortality coefficient

According to Pauly's (1980) method, the natural mortality coefficient was assumed from the parameter of the growth equation and the average water temperature in the habitat, as in the case of the *Pagellus bellottii*. The natural mortality coefficient was calculated by changing the water temperature at intervals of 1°C within the range from 16 to 22°C, as in the case of the *Pagellus bellottii*. The natural mortality coefficient ranges between 0.29 and 0.34 and does not indicate wide fluctuations with the water temperature. Consequently, 0.32, a calculation value at the water temperature of 19°C, was assumed as the natural mortality coefficient.

[6] Current survival rate

The length composition of the catch in the second and third surveys was integrated in the same way as in the case of *Pagellus bellottii* and was converted into the age composition.

The results are as shown below.

Age	Ratio(%)
1	46.5
2	36.9
3	12.6
4	2.8
5	1.2

From this composition, assuming that the age at complete recruitment is two years old, the current survival rate was estimated in the same way as in the case of *Pagellus bellottii*. The current survival rate, availability, and exploitation rate are as shown below.

Age	Survival rate(%)	Availability(%)	Exploitation rate(%)
1	47.5	59.9	30.3
2	30.6	100.0	50.6
3	30.6	100.0	50.6
4	30.6	100.0	50.6
5	30.6	100.0	50.6

[7] Estimation of stock number

The stock number was estimated in the same way as in the case of *Pagellus bellottii*. The average catch quantity for five years from 1997 through 2001 (Table 5-1-7-2), 676 tons, was used for this estimation. The median month of the fishing season is set to March, when the accumulated monthly catch quantity from the spawning month (September) exceeds a half of the annual catch quantity.

The estimated stock number and stock biomass by age are as shown below.

Stock number and biomass by age

	Stock	
Age	Number (x1000)	Biomass (ton)
1	3,279.6	107.9
2	1,556.9	307.0
3	476.5	248.5
4	145.9	143.9
5	44.6	69.4
Total	5,503.6	876.7

[8] Stock assessment by SPR

The SPR was calculated in the same way as in the case of *Pagellus bellottii*. The results are shown below.

$SPR_{F=0} = 0.337$ (kg)

$SPR_{now} = 0.083$ (kg)

$\%SPR = 24.6$

As in the case of *Pagellus bellottii*. the present %SPR of this stock is higher than the minimum threshold (20). However, it is expected that more annual catch could be obtained steadily if %SPR get higher by management.

(3) *Sparus caeruleostictus*

[1] Spawning season

The gonad analysis of *Sparus caeruleostictus* caught in the second survey (stable period: October and November, 2000) and the third survey (upwelling period: July and August, 2001) confirmed that the period from July to November is the spawning season of this species (See Chapter 5-2-2). Based on this data, the median month of spawning of this species to be used for the stock analysis is set to September.

[2] Maturity

Some two-year-old and older individuals having mature spawn were recognized through the second and third surveys. A fish at maturity stage III (i.e., although the ovary is developed well and spawn can be seen clearly, little transparent spawn can be recognized) or higher is considered to be mature. The proportion of the fish at maturity stage III or higher was examined within the length range by age calculated from the growth equation described later. As a result, neither yearling fish nor one-year-olds were mature, and 33% of the two-year-olds and 100% of the three-year-old and older fish were mature. These values will be used for the stock analysis.

[3] Sex ratio

The investigation of the length range by age calculated from the growth equation revealed that the proportion of female yearling fish is not known, one-year-old females, two-year-old females, three-year-old females, four-year-old females account for 58%, 50%, 60%, and 67%, respectively, and the proportion of five-year-old and older females is 0%. Since the number of samples of three-year-old and older fish is few (the number of three-year-old, four-year-old and five-year-old fish is only five, three, and one respectively), all the samples of three-year-old and older fish are combined. The proportion of the female of the combined samples is 56%, which could be considered roughly equal to that of two-year-old female. For the stock analysis, assuming that the same proportion applies to both yearling females and one-year-old females, and three-year-olds and older account for the same proportion as two-year-olds, the proportion of yearling and one-year-old females is set at 58% and that of two-year-old and older females is set at 50%.

[4] Growth

A fitting of normal distributions to the length composition could not be conducted of *Sparus caeruleostictus* caught in the second survey (stable period: October and November, 2000). The analysis shown in the table below, however, was obtained from the results of the third survey (upwelling period: July and August, 2001).

Results obtained from the fitting of normal distributions to length composition (third survey)

Age	TL(cm)	SD	Nos.(%)
1	13.3	2.042	55.3
2	20.9	2.400	26.2
3	28.2	3.389	18.6

Based on the results above, the following growth equation was obtained. The value of the asymptotic length is abnormally high and the growth coefficient is extremely low. This is attributable to the fact that a difference in length between ages obtained from the analysis results is almost the same (a difference in length between one- and two-year-olds and two- and three-year-olds is almost the same).

$$L_t = 2058\{1 - e^{-0.0403(t+0.7386)}\}$$

L_t: Total length at the age of t (mm)

t: Age

On the other hand, from the age determination results obtained from the otolith described in Chapter 5-2-2, data containing an obvious reading error was excluded. Also, the age of fish was converted into an absolute age (0.17 year was added in the stable period and 0.08 year was subtracted in the upwelling period), with September, the median month of spawning, described above, being a starting point. Thus, usable data was arranged as shown below.

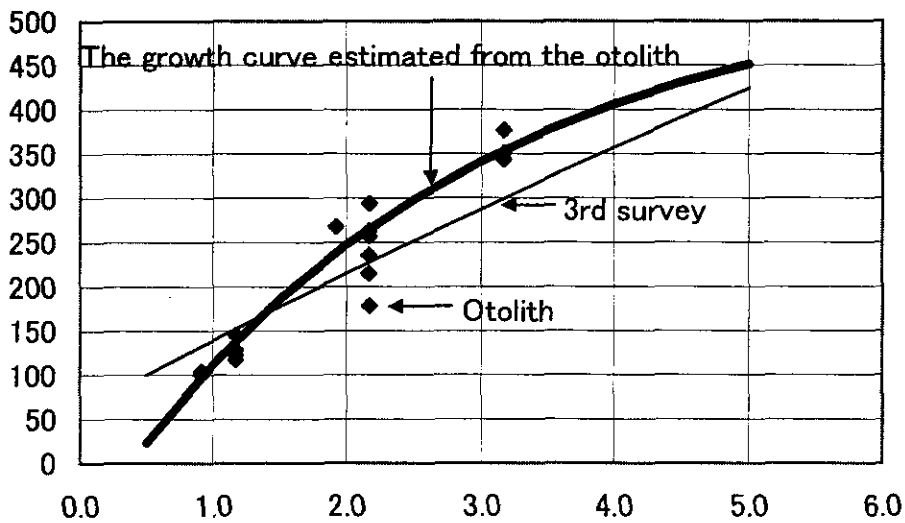
Absolute age and total length (mm) organized from reading of otolith

Age	TL	Age	TL	Age	TL	Age	TL
0.92	101	1.17	145	2.17	236	2.17	215
0.92	104	1.17	117	2.17	294	3.17	377
1.17	123	1.92	268	2.17	235	3.17	351
1.17	128	2.17	257	2.17	178	3.17	344

Based on the results, an average total length by age was found and the following growth equation was obtained from this average total length by age. An attempt was made to estimate the growth equation using the data shown in the table as it was, instead of the average total length by age, but a coefficient deemed reasonable could not be obtained.

$$L_t = 554\{1 - e^{-0.3672(t-0.3862)}\}$$

The following figure shows the superposition of these growth curves, the curve obtained above from the length composition, and the age determination results from the otolith.



The curve obtained from the length composition reflects the unnaturalness described above and does not agree well with the otolith. It can be judged that obviously, the growth curve estimated from the otolith is appropriate.

Judging from the above-mentioned, the growth equation obtained from the otolith will be used for the stock analysis of this species.

[5] Natural mortality coefficient

According to Pauly's (1980) method, the natural mortality coefficient was assumed from the parameter of the growth equation and the average water temperature in the habitat, as in the case of the *Pagellus bellottii*. The natural mortality coefficient was calculated by changing the water temperature at intervals of 1°C within the range from 16 to 22°C, as in the case of the *Pagellus bellottii*. The natural mortality coefficient ranges between 0.60 and 0.70 and does not indicate wide fluctuations with the water temperature. Consequently, 0.65, a calculation value at the water temperature of 19°C, was assumed as the natural mortality coefficient.

[6] Current survival rate

The length composition of the catch in the second and third surveys was integrated in the same way as in the case of *Pagellus bellottii* and was converted into the age composition.

The results are as shown below.

Age	Ratio(%)
1	85.7
2	12.8
3	1.5

From this composition, assuming that the age at complete recruitment is one year old, the current survival rate was estimated in the same way as in the case of *Pagellus bellottii*. The current survival rate and exploitation rate are as shown below.

Age	Survival rate (%)	Exploitation rate (%)
1	14.3	57.1
2	14.3	57.1
3	14.3	57.1

[7] Estimation of stock number

The stock number was estimated in the same way as in the case of *Pagellus bellottii*. An average catch quantity for five years from 1997 through 2001(Table 5-1-7-2), 1076 tons, was used for this estimation. The median month of the fishing season is set to March, when the accumulated monthly catch quantity from the spawning month (September) exceeds a half of the annual catch quantity

The estimated stock number and stock biomass by age are as shown below.

Stock number and biomass by age

Age	Stock Number (x1000)	Biomass (ton)
1	10,920.5	230.3
2	1,560.8	360.9
3	223.1	136.0
Total	12,704.4	727.3

The stock biomass is 727 tons, which is less than the catch quantity of 1076 tons. There seems to be a contradiction between the two figures, This is, however, attributable to the fact that the stock number and stock biomass are the values at the point of the spawning season (September). The multiplication of the stock number in the spawning season by the weight at each age is the stock biomass. On the other hand, fishing is operated throughout the year. This species grows rapidly and there is a remarkable difference in weight between the spawning month and six months later even at the same age as shown below.

Change in weight		
Age	Spawning season (g)	After six months (g)
1	21	98
2	231	408
3	610	821

Especially, the weight of one-year-old fish, which account for a large proportion of catch, increases by almost five times in six months. Since individuals which grow up after some time has passed from the spawning season are caught, such a phenomenon that the catch quantity exceeds the stock biomass occurs.

[8] Stock assessment by SPR

The SPR was calculated in the same way as in the case of *Pagellus bellottii*. The results are shown below.

$SPR_{F=0} = 0.103$ (kg)

$SPR_{now} = 0.012$ (kg)

$\% SPR = 11.3$

As conceivable from the age composition in which one-year-old fish is dominant, it is evident that the stock status is bad. It is necessary to take some protective measures for this stock without delay.

(4) *Pseudotolithus senegalensis*

[1] Spawning season

The gonad analysis of *Pseudotolithus senegalensis* caught in the second survey (stable period: October and November, 2000) and the third survey (upwelling period: July and August, 2001) confirmed that the period from July to November is the spawning season of this species. (See Chapter 5-2-2.) The median month of spawning of this species to be used for the stock analysis is set to September.

[2] Maturity

Some three-year-old and older individuals having mature spawn were recognized through the second and third surveys. A fish at maturity stage III (i.e., although the ovary is developed well and spawn can be seen clearly, little transparent spawn can be recognized) or higher is considered to be mature. The proportion of the fish at maturity stage III or higher was examined within the length range by age calculated from the growth equation described later. As a result, neither yearling nor one-year-old nor two-year-old females were mature, and 36% of the three-year-old females and 100% of the four-year-old or older females were mature. These values will be used for the stock analysis.

[3] Sex ratio

The investigation of the length range by age calculated from the growth equation described later revealed that the proportion of the female yearling fish is unknown and that of the females is 44%, 28%, 52%, 13%, and 71% at the ages of one, two, three, four, and five or older, respectively. The sex ratio at the ages of two and four is extreme. Since this ratio is based on the analysis result of as many as 46 and 15 individuals respectively, which constitute a random sample, it is judged that this is not a negligible result. This may be a result of some difference in ecological characteristic, but it remains in the realm of speculation. No further discussion is possible.

Also, four-year-old individuals and five-year-old or older individuals indicate a completely opposite sex ratio. It is also difficult to understand because the number of analyzed five-year-old or older individuals is seven and it is not too few. An average proportion of the female at the ages of four and older is 42%. The sex ratio of males and females at the age of three and older should be considered to be almost the same. Consequently, the sex ratio of 44%, 28%, and 50% at the ages of one, two, and three and older, respectively, will be used for the stock analysis.

[4] Growth

The fitting of normal distributions to the length composition of this species caught in the second survey (stable period: October and November, 2000) could not be conducted, but the analysis shown in the table below was obtained from the third survey (upwelling period: July and August, 2001).

Results obtained from the fitting of normal distributions to the length composition (the third survey)

Age	TL(cm)	SD	Nos.(%)
1	18.7	2.312	72.0
2	28.8	2.551	21.8
3	36.7	2.603	6.2

The following growth equation was obtained from the results above.

$$L_t = 651\{1 - e^{-0.2457(t-0.5408)}\}$$

Lt: Total length at the age of t (mm)

t: Age

On the other hand, the age determination results obtained from the otolith described in Chapter 5-2-2 was converted into an absolute age (0.17 year was added in the stable period), with September, the median month of the spawning, described above, being a starting point. Thus, usable data was arranged as shown below.

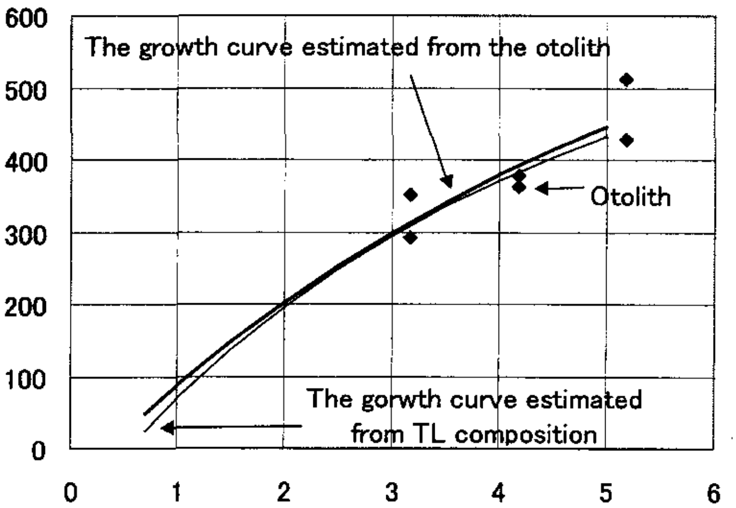
Absolute age and total length (mm) organized from the reading of otolith

Age	TL
3.17	293
3.17	351
4.17	362
4.17	379
5.17	428
5.17	512

The growth equation estimated using the results above is shown below.

$$L_t = 801\{1 - e^{-0.1754(t-0.3423)}\}$$

The following figure shows the superposition of this growth curve, the curve obtained from the above length composition, and the age determination results from the otolith.



Since all of these three agree well, it is judged that any of them can be used as a growth curve for the stock analysis. The growth curve obtained from the otolith will be used for the present stock analysis.

[5] Natural mortality coefficient

According to Pauly's (1980) method, the natural mortality coefficient was assumed from the parameter of the growth equation and the average water temperature in the habitat, as in the case of the *Pagellus bellottii*. The natural mortality coefficient was calculated by changing the water temperature at intervals of 1°C within the range from 16 to 22°C, as in the case of the *Pagellus bellottii*. The natural mortality coefficient ranges between 0.34 and 0.39 and does not indicate wide fluctuations with the water temperature. Consequently, 0.36, a calculation value at the water temperature of 19°C, was assumed as the natural mortality coefficient.

[6] Current survival rate

The length composition of the catch in the second and third surveys was integrated in the same way as in the case of *Pagellus bellottii* and was converted into the age composition.

The results are as shown below.

Age	Ratio(%)
1	5.6
2	24.3
3	56.5
4	10.4
5	0.1
6	3.1

From this composition, assuming that the age at complete recruitment is three years old, the current survival rate was estimated in the same way as in the case of *Pagellus bellottii*. The current survival rate, availability, and exploitation rate are as shown below.

Age	Survival rate (%)	Availability (%)	Exploitation rate (%)
1	67.9	3.9	2.3
2	58.0	25.0	14.6
3	22.8	100.0	58.4
4	22.8	100.0	58.4
5	22.8	100.0	58.4
6	22.8	100.0	58.4

[7] Estimation of stock number

The stock number was estimated in the same way as in the case of *Pagellus bellottii*. The average catch quantity for five years from 1997 through 2001 (Table 5-1-7-2), 1140 tons, was used for this estimation. The median month of the fishing season is set to February, when the accumulated monthly catch quantity from the spawning month (September) exceeds a half of the annual catch quantity.

The estimated stock number and stock biomass by age are as shown below.

Stock number and biomass by age

Age	Stock Number (x1000)	Biomass (ton)
1	6,244	48
2	4,242	413
3	2,461	777
4	561	365
5	128	137
6	29	45
Total	13,664	1,785

[8] Stock assessment by SPR

The SPR was calculated in the same way as in the case of *Pagellus bellottii*. The results are shown below.

$SPR_{F=0} = 0.392$ (kg)

$SPR_{now} = 0.066$ (kg)

% SPR = 16.9

Present %SPR is lower than the minimum threshold (20). It is necessary to take some protective measures for this stock without delay.

(5) *Brachydeuterus auritus*

[1] Spawning season

The gonad analysis of *Brachydeuterus auritus* caught in the second survey (stable period: October and November, 2000) and the third survey (upwelling period: July and August, 2001) confirmed that the upwelling period is the spawning season of this species. (See Chapter 5-2-2.) Consequently, the median month of spawning of this species to be used for the stock analysis is set to July.

[2] Maturity

Although adult female having mature spawn was not found in the third survey, adult male having sperms was caught. The gonad index (gonad weight/weight x 1000) of this male (Total length: 177 mm, weight: 75 g) is 20. This individuals has the highest gonad index including females in the third survey. The maturity rate of the specimen in the second survey was II at most (i.e., the ovary is slightly developed and spawn can be recognized), but the gonad index was 7 – 74. It is thought that this data indicates the existence of an adult female which is in the process of spawn absorption after the spawning season. Originally, the maturity rate should be obtained from the result of the third survey, which is the spawning season. As described above, however, it cannot be obtained from the results of the third survey. For this reason, for the sake of convenience, the maturity rate was obtained from the results of the second survey, assuming that the gonad index of 20 is an index of a mature individual. As a result, no one-year-olds were mature and 33% of the two-year-olds, 38% of the three-year-olds, 63% of the four-year-olds, 50% of the five-year-olds, and 0% of the six-year-old and older females were mature. No females at the age of six or older were mature. Obviously, this should be regarded as a result of the absorption of spawn. Since mature males obtained in the third survey above correspond to four-year-olds, 100% of the four-year-old fish will be matured. Consequently, the maturity rate of the one-year-olds, the two-year-olds, the three-year-olds, and the four year old and older fish used for the stock analysis is set at 0%, 33%, 38%, and 100%, respectively.

[3] Sex ratio

The investigation of the length range by age calculated from the growth equation described later revealed that the proportion of the yearling females is not known, and that of the females is 50%, 14%, 42%, 54%, 83%, and 100% at the ages of one, two, three, four, five, and six or older, respectively. As a general tendency, the proportion of the females increases with age. The proportion of the female at the age of two had been estimated to be 25% from the results of second and third field surveys. Although a great emphasis was put on this age at the fourth survey, only one female occurred out of 13 two-year-old individuals investigated. For the stock analysis, 50% will be used for the ages of one to three and the above values as they are for the ages of four and older will be used.

[4] Growth

The fitting of normal distributions to the length composition of this species caught in the second survey (stable period: October and November, 2000) and the third survey (upwelling period: July and August, 2001) could not be conducted.

On the other hand, the age determination results obtained from the otolith described in Chapter 5-2-2 was converted into an absolute age (0.25 year was added in the stable period because about three months had already passed since July, the median month of the spawning), with July, the median month of the spawning, described above, being a starting point. Thus, usable data was arranged as shown below.

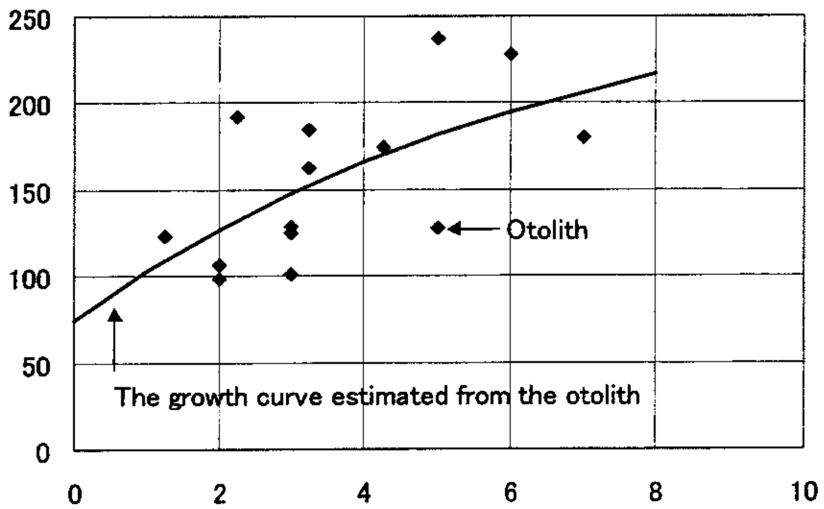
Absolute age and length (mm) organized from the reading of otolith

Age	TL	Age	TL	Age	TL
1.25	123	3.00	125	4.25	175
2.00	98	3.00	129	5.00	128
2.00	107	3.25	163	5.00	237
2.25	192	3.25	163	6.00	228
3.00	101	3.25	185	7.00	180

The growth equation estimated using the results above is shown below.

$$L_t = 279\{1 - e^{-0.1484(t+2.0948)}\}$$

The following figure shows the superposition of this growth curve and the age determination results from the otolith.



The age determination results from the otolith greatly vary, and as a result, t_0 of the growth equation takes a great value. Although this equation is used for the stock analysis, it is obvious that the study of this growth equation is one of the future challenges.

[5] Natural mortality coefficient

According to Pauly's (1980) method, the natural mortality coefficient was assumed from the parameter of the growth equation and the average water temperature in the habitat, as in the case of the *Pagellus bellottii.* The natural mortality coefficient was calculated by changing the water temperature at intervals of 1°C within the range from 16 to 22°C, as in the case of the *Pagellus bellottii*. The natural mortality coefficient ranges between 0.40 and 0.47 and does not indicate wide fluctuations with the water temperature. Consequently, 0.44, a calculation value at the water temperature of 19°C, was assumed as the natural mortality coefficient.

[6] Current survival rate

The length composition of the catch in the second and third surveys was integrated in the same way as in the case of *Pagellus bellottii* and was converted into the age composition.

The results are as shown below.

Age	Ratio(%)
1	10.8
2	30.7
3	29.7
4	20.3
5	5.4
6	2.3
7	0.8

From this composition, assuming that the age at complete recruitment is four years old, the current survival rate was estimated in the same way as in the case of *Pagellus bellottii*. The current survival rate, availability, and exploitation rate are as shown below.

Age	Survival rate (%)	Availability (%)	Exploitation rate (%)
1	61.9	7.6	3.2
2	53.0	35.0	14.6
3	43.7	64.0	26.7
4	32.0	100.0	41.8
5	32.0	100.0	41.8
6	32.0	100.0	41.8
7	32.0	100.0	41.8

[7] Estimation of stock number

The stock number was estimated in the same way as in the case of *Pagellus bellottii*. The average catch quantity for five years from 1997 through 2001 (Table 5-1-7-2), 13695 tons, was used for this estimation. The median month of the fishing season is set to November, when the accumulated monthly catch quantity from the spawning month exceeds a half of the annual catch quantity.

The estimated stock number and stock biomass by age are as shown below.

Stock number and biomass by age

Age	Stock Number (x1000)	Biomass (ton)
1	996,558	13,007
2	617,226	15,660
3	327,433	13,397
4	142,966	8,388
5	45,725	3,552
6	14,624	1,420
7	4,677	544
Total	2,149,209	55,966

[8] Stock assessment by SPR

The SPR was calculated in the same way as in the case of *Pagellus bellottii*. The results are shown below.

$SPR_{F=0} = 0.046$ (kg)

$SPR_{now} = 0.015$ (kg)

$\%SPR = 32.8$

The %SPR exceeds 30. Judging from the current information, there seems to be no problem with the stock status of this species. Although it might be possible to obtain more sustainable catch quantity by an appropriate management, at least there is no symptom of collapse of the stock at present.

(6) *Pomadasys incisus*

[1] **Spawning season**

The gonad analysis of *Pomadasys incisus* caught in the second survey (stable period: October and November, 2000) and the third survey (upwelling period: July and August, 2001) confirmed that the upwelling period is the spawning season of this species. (See Chapter 5-2-2.) Consequently, the median month of spawning of this species to be used for the stock analysis is set to July.

[2] **Maturity**

Many adult females having mature spawn were found in the third survey. A fish at maturity stage III (i.e., although the ovary is developed well and spawn can be seen clearly, little transparent spawn can be recognized) or higher is considered to be mature. The proportion of the fish at maturity stage III or higher was examined within the length range by age calculated from the growth equation described later. As a result, the maturity rate of the one-year-old and two-year-old fish is not known because there are no specimens available, and 100% of the three-year-old and older fish were mature. Concerning the fact that the maturity rate of the one-year-old and two-year-old fish is not known, the growth equation indicates that the two-year-old fish are less than 150 mm. In view of the results of the mesh selectivity test, it may be difficult to estimate the maturity rate of the present species because less than 150-mm individuals have been hardly caught. The maturity rate of the fish up to the age of two is set to 0% and that of the fish at the age of three and older is set to 100%.

[3] **Sex ratio**

As described above, less than 150-mm individuals have hardly been caught. The sex ratio of only one individual (male 148 mm) in the second survey and two individuals (both females and 117mm) in the fourth survey were clarified.

. Therefore, it may be appropriate to consider that the sex ratio up to the age of two is unknown. As opposed to this, the sex ratio of the three-year-old, four-year-old, and five-year-old and older are 45%, 61%, 100%, respectively. Note that further study will be required for the five-year-old and older fish because only six individuals were examined. As a general tendency, the proportion of the females increases with age. The same percentage as that of the three-year-olds will apply up to the two-year-olds. Consequently, for the stock analysis, the sex ratio of 45% will be used for the fish up to the age of three, and the above values will be used as they are for the fish over the age of three.

[4] Growth

The fitting of normal distributions to the length composition of this species caught in the second survey (stable period: October and November, 2000) could not be conducted, but the analysis shown in the table below was obtained from the third survey (upwelling period: July and August, 2001).

Results obtained from the fitting of normal distributions to the length composition (the third survey)

Age	TL(cm)	SD	Nos.(%)
3	15.0	0.994	1.3
4	19.2	1.180	56.4
5	21.9	1.372	33.9
6	24.1	1.409	8.5

The following growth equation was obtained from the results above.

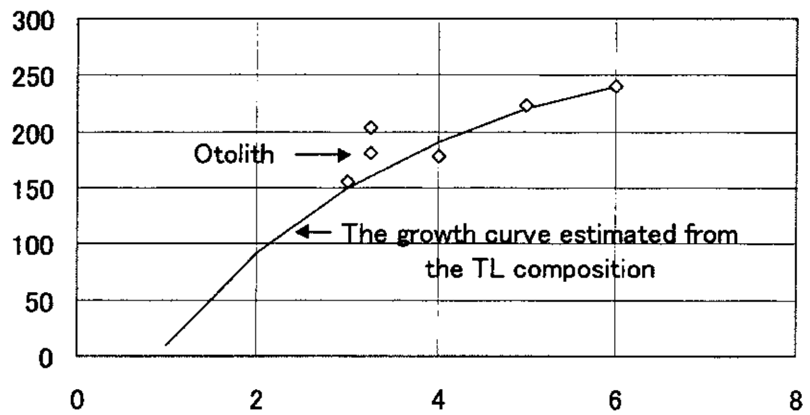
$$L_t = 290\{1 - e^{-0.3463(t-0.8927)}\}$$

L_t: Total length at the age of t (mm)

t: Age

On the other hand, the age determination results obtained from the otolith described in Chapter 5-2-2 was converted into an absolute age (0.25 year was added in the stable period because about three months had already passed since July, the median month of the spawning), with July, the median month of the spawning, described above, being a starting point. The estimation of the growth equation was attempted using the result, but a reasonable coefficient could not be obtained.

The following figure shows the superposition of the growth curve estimated from the length composition and the age determination results from the otolith.



It seems that the growth curve almost agrees with the age determination result from the otolith. Consequently, the growth curve above estimated from this length composition will be used for the stock analysis.

[5] Natural mortality coefficient

According to Pauly's (1980) method, the natural mortality coefficient was assumed from the parameter of the growth equation and the average water temperature in the habitat, as in the case of the *Pagellus bellottii*. The natural mortality coefficient was calculated by changing the water temperature at intervals of 1°C within the range from 16 to 22°C, as in the case of the *Pagellus bellottii*. The natural mortality coefficient ranges between 0.70 and 0.81 and does not indicate wide fluctuations with the water temperature. Consequently, 0.75, a calculation value at the water temperature of 19°C, was assumed as the natural mortality coefficient.

[6] Current survival rate

The length composition of the catch in the second and third surveys was integrated in the same way as in the case of *Pagellus bellottii* and was converted into the age composition.

The results are as shown below.

Age	Ratio(%)
1	0.0
2	2.1
3	42.8
4	39.6
5	13.0
6	1.8
7	0.7

From this composition, assuming that the age at complete recruitment is four years old, the current survival rate was estimated in the same way as in the case of *Pagellus bellottii.* The current survival rate, availability, and exploitation rate are as shown below.

Age	Survival rate (%)	Availability (%)	Exploitation rate (%)
1	47.2	0.0	0.0
2	47.0	1.0	0.3
3	38.6	41.7	13.3
4	26.5	100.0	32.0
5	26.5	100.0	32.0
6	26.5	100.0	32.0
7	26.5	100.0	32.0

[7] Estimation of stock number

The stock number was estimated in the same way as in the case of *Pagellus bellottii*. The average catch quantity for five years from 1997 through 2001 (Table 5-1-7-2), 112 tons, was used for this estimation. The median month of the fishing season is set to January, when the accumulated monthly catch quantity from the spawning month exceeds a half of the annual catch quantity.

The estimated stock number and stock biomass by age are as shown below.

Stock number and biomass by age

Age	Stock Number (x1000)	Biomass (ton)
1	15,673	0
2	7,403	82
3	3,482	162
4	1,344	128
5	356	51
6	94	18
7	25	6
Total	28,378	447

[8] Stock assessment by SPR

The SPR was calculated in the same way as in the case of *Pagellus bellottii*. The results are shown below.

$SPR_{F=0} = 0.025$ (kg)

$SPR_{now} = 0.014$ (kg)

% SPR = 57.9

The %SPR, which is close to 60, takes a great value. It has been already confirmed that this species becomes mature at the age of three. Although the maturity rate of one-year-old and two-year-old fish is not known, few one-year-old and two-year-old fish have been caught. In this context, female spawn at the age of three once and the fishing is started. If the fishing is operated on an "as-is" basis without catching smaller fish in the future, the stock may not be depleted by fishing. If anything, a stable catch quantity larger than the present one can be expected, depending on how to catch. In order to achieve this, one of the future challenges is to study how to catch fish of this species.