ORGANIZATIONAL STRUCTURE OF THE MINISTRY OF FOOD AND AGRICULTURE

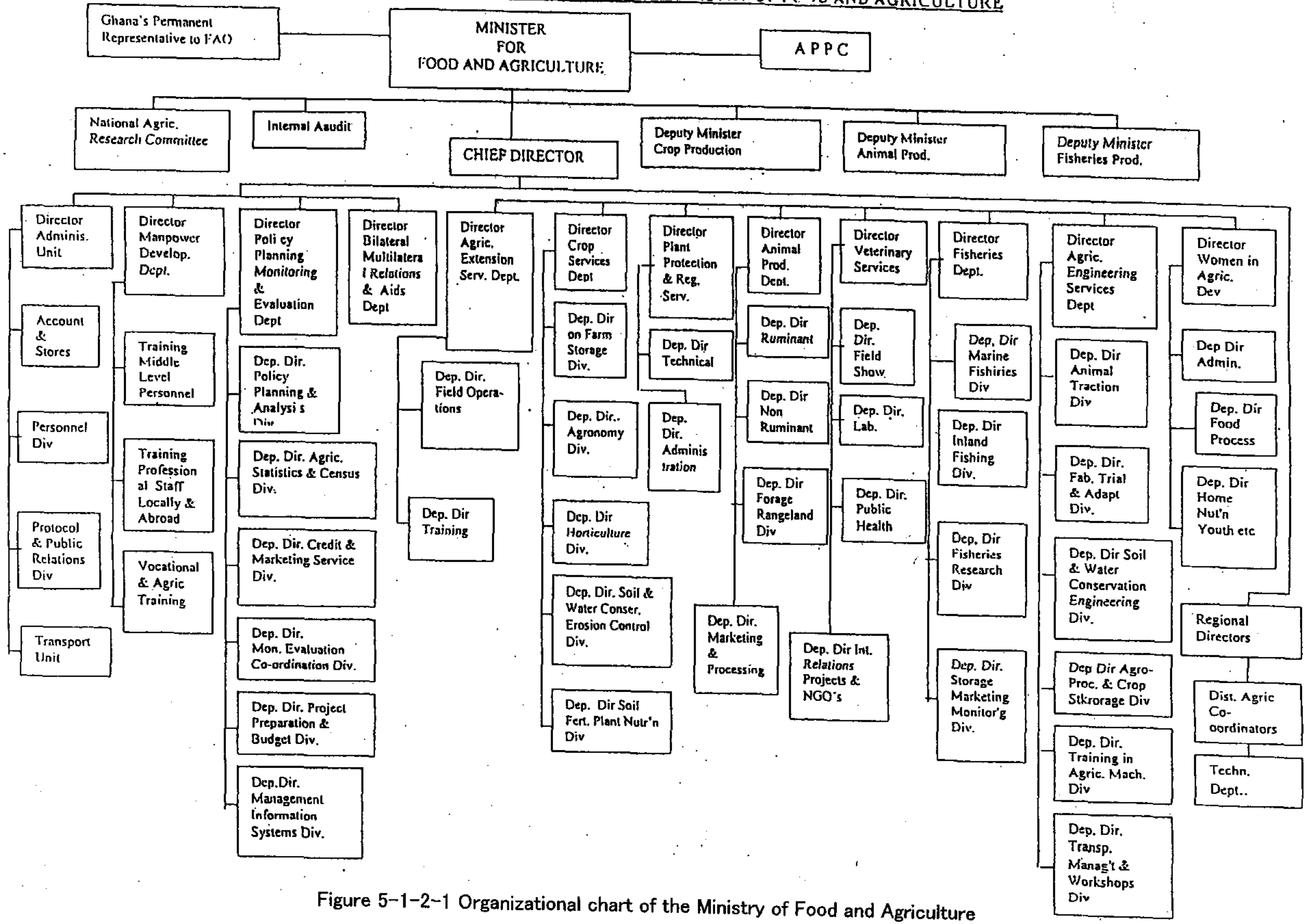

Figure 5-1-2-1 Organizational chart of the Ministry of Food and Agriculture

Department Of Fisheries
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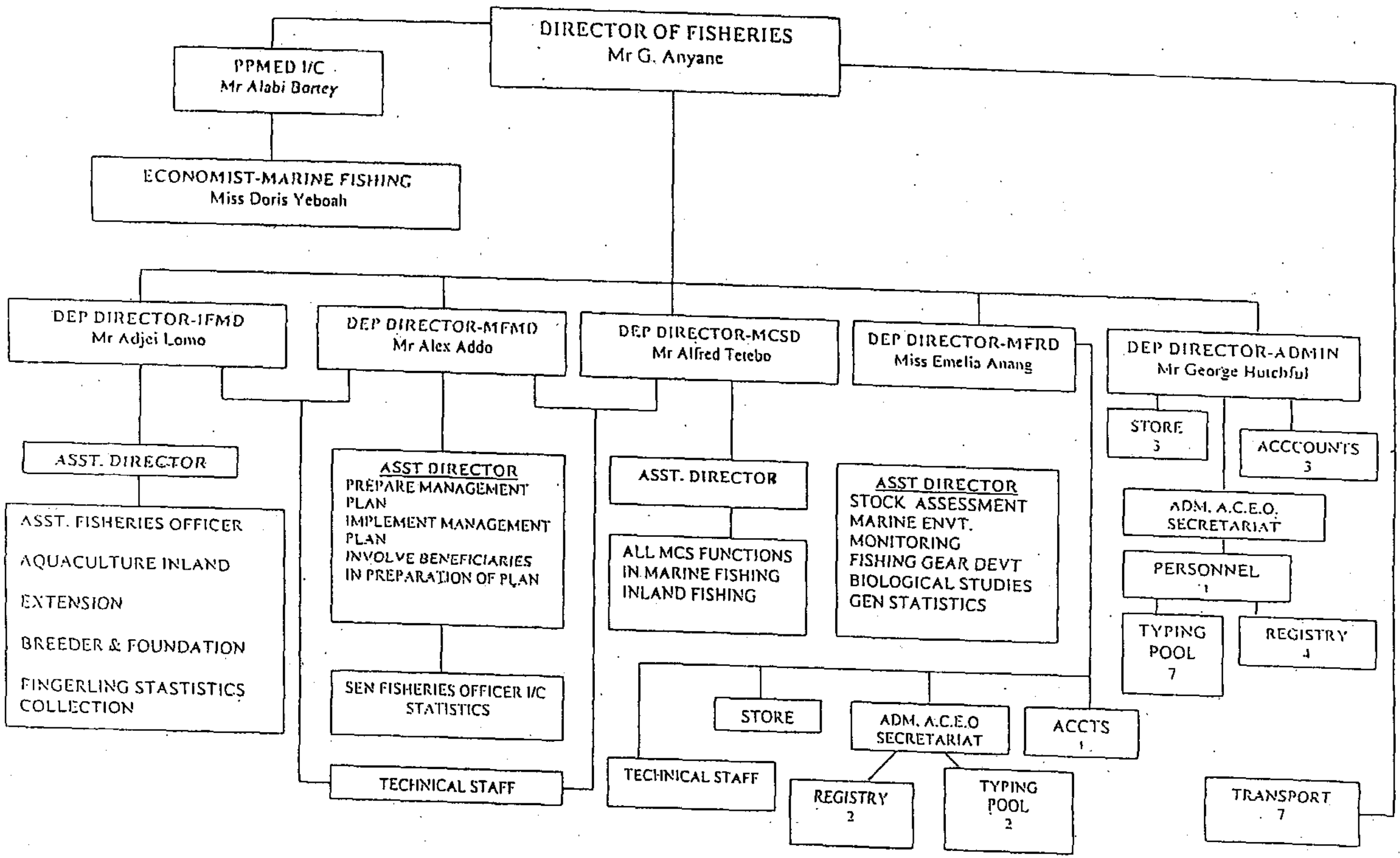


Figure 5-1-2-2 Organizational chart of the Fisheries Department

ORGANISATIONAL CHART
MARINE FISHERIES RESEARCH DIVISION

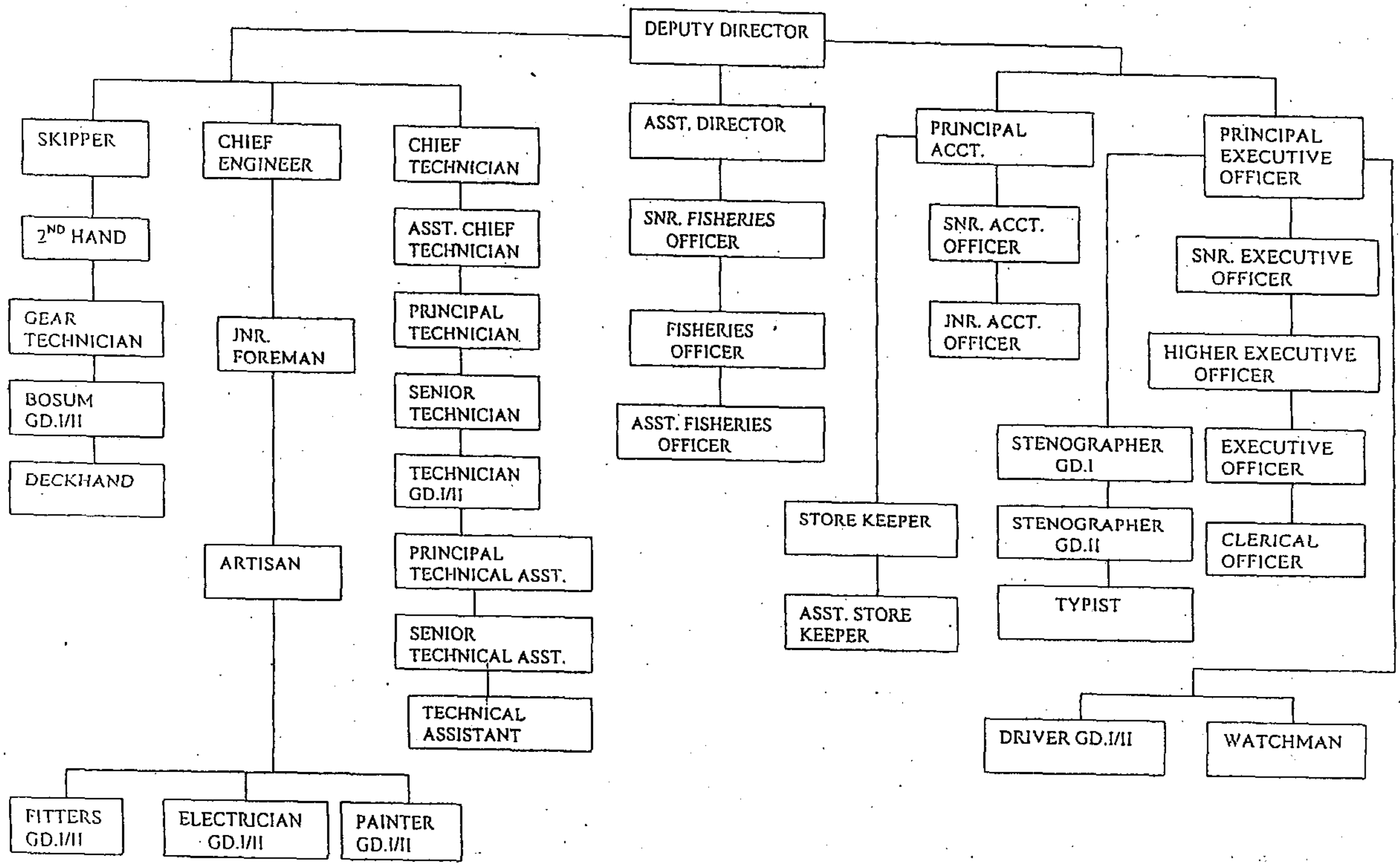


Figure 5-1-2-3 Organizational chart of the Marine Fisheries Research Division

5-1-3 General Conditions of Fisheries

Along the coast of Ghana, there are abundant small-sized pelagic fishes such as sardines and horse mackerels as well as various kinds of demersal fishes, such as sea breams, snappers, grunts, groupers and cuttlefishes etc. Furthermore, the offshore waters are teeming with large-sized pelagic fishes such as skipjack and tunas. Various kinds of marine fisheries have developed to catch these resources. In the Volta Lake, freshwater fisheries are also being conducted. In the future, the aquaculture of freshwater fish is expected to develop still further.

Marine fisheries in Ghana are categorized into small-scale (artisanal) fishery, medium-scale (semi-industrial) fishery, large-scale commercial (industrial) fishery and tuna fishery. Except the small-scale fishery, all boats that are intended to be used for fishing operations are required to obtain a fishing license issued by the Directorate of Fisheries. As for the boats operating small-scale fishery, the license was not required so far. However the Directorate of Fisheries is planning to introduce a license system to this fishery, too, in very near future. The general outlines of each marine fishery category are explained below:

(1) Small-scale fishery (artisanal fishery)

This fishery category constitutes the mainstay of Ghana's coastal fishing. Using small-sized canoes ranging between 5 and 18 m in length, fishermen conduct fishing operations along the entire coast. The number of canoes has been increasing year after year throughout the country; 6938 in 1981, 8641 in 1995 and 9981 in 2001(Ghana canoe frame survey, 2001, P.O Bannerman et al. 2001). At the same time, size of the boat, the number of motorized(outboard engine) boats, the numbers of landing beaches and fishermen involved in this fishery have remarkably increased as follows.

Results of Canoe Frame Surveys conducted in Ghana

Number of	1969	1973	1977	1981	1986	1989	1992	1995	1997	2001
Fishingvillages	198	191	200	174	188	192	189	189	191	185
Fishermen	.		81000	84100	104700	91400	96400	101700	103340	123156
Outboardmotors				3698	4250	4631	4262	5076	5139	5256
Total canoes	8728	8238	8472	6938	8214	8052	8688	8641	8610	9981

Ghana Canoe Frame Survey, 2001 (by P. O. Bannerman et al.,2001)

This sector uses variety of fishing gear types such as Ali net, purse seine, beach seine, set net, hook and line and gillnet, depending on the season and target species. While the purse seine exploit adult sardinellas and chub mackerel during the upwelling season, it targets the anchovies and juvenile sardinellas during the non-upwelling season. The hook and line canoes operate in deep waters of about 80-200 m Some of them have iceboxes for storing fish and are, therefore, capable of staying for three days or more at sea. They target sea breams, snappers and groupers. Drift gillnets operate offshore exploiting mainly large pelagic fish such as sharks, tunas, sailfish and swordfish. The number of fishermen aboard differs according to gear and fishing types, ranging from 1 to more than 10 persons.

The small-scale fishery contribute annually over 70 % of total fish landings in Ghana (Data book Table 2-7-2).

(2) Semi-industrial fishery

The semi-industrial fleet consists of locally-built wooden vessels measuring 8 to 37 m in bow-to-stern length and equipped with an inboard engine (up to 400 horsepower). These are dual-purpose vessels (purse seine/trawler) operating as purse seiners during the upwelling season, and trawlers for the remaining part of the year.

In addition, there exist also imported steel vessels which are generally larger than their locally built counterparts and are outfitted with a 350 to 650 horsepower engine. The recent combined total of both wooden and steel boats stands at approximately 170. Of the entire shore, locations serving as home bases for these vessels are few in number and are limited to several places (such as Tema, Takoradi, Elmina, etc.) that are blessed with a port or an inlet. Fish species caught by trawling are same as those by industrial trawling. Fishes caught by purse seine are mainly round sardine, chub mackerel and frigate mackerel.

(3) Large-scale fisheries(Industrial fisheries)

This category consists of two fishing types: industrial trawling and commercial shrimper.

The industrial trawling is conducted by imported steel trawlers measuring 35 meters or longer in overall length and mounting engines of over 600 horsepower, while the shrimper are up to 30 m in length with engines of over 350 horsepower. Originally, vessels of these types used to operate in higher-productivity waters off the west and south-west coast of Africa(from Sierra-Leone to Mauritania and also from Angola to Namibia). However, with the emergence of 200-miles exclusive fishing zones in the 1970s, most of these vessels became forced to operate within Ghana's waters characterized by narrow continental shelf.

The industrial trawlers are restricted to operate in the waters deeper than 30 m by law. However, due to the untrawlable nature of the sea bottom beyond 75 m depth contour, their fishing ground ranges in a relatively narrow area between the 30 m and 75 m depth contours and their main target species are sea breams, snappers, groupers, soles, cassava fish and cuttlefishes for export.

The commercial shrimpers are restricted by law to operate in the deeper waters than 30 m between 1°45' W and 2°30' W, and between 0°15' E and 1°12' E. These vessels target mainly pink shrimp for export. The by-catch of these shrimpers are soles, cassava fish, sea breams, cuttlefish and red mullet.

The industrial fleet has freezing facility for preserving fish at sea and can stay for months at sea.

Although the number of registered vessels currently stands at 35, those that are actually in operation at sea are considered to be much smaller than that number since all of them are very advanced in ship age.

There are cases where the semi-industrial and industrial fishery categories overlap each other in terms of fishing grounds and target species, and conflicts occur among the fishery categories. The main fishing season begins during late June to early July and last until late September to early October coinciding with the main upwelling period. During this period, the activities of living beings move into high gear; it is considered for this reason that the number of fish schools that come close to the shore increases. Also during the period of minor upwelling (in January or February), there is a small-time fishing season. However, at other times, fish catches are generally small and, in particular, pelagic fisheries become sporadic.

Some of Ghanaian large-scale fishing vessels have their home bases outside Ghana (for example, in Gambia) and are catching sardines only.

(4) Tuna fishery

Bordering the Guinea Bay located in a tropical region, Ghana is blessed with tropical tunas such as skipjack, yellowfin and bigeye tuna. These fishes are harvested chiefly by small-scale vessels and large-scale commercial pole-and-line vessels and tuna purse seine vessels. In some cases, they are captured accidentally by purse seine of semi-industrial fishing vessels.

Small-scale fisheries refer to skipjack/tuna-fishing operations conducted in coastal and inshore waters by canoes by means of pole-and-line fishing and by using surface drift nets. Most large-sized vessels are Japanese-style skipjack pole-and-line fishing vessels. They operate across a wide area aiming at skipjack, young yellowfin and bigeye tunas which swarm in the surface layer in schools all over the Guinea Bay. Tuna purse seine vessels also target same fish school in the same fishing ground. Some of large-scale tuna purse seine vessels converted from pole-and-line fishing vessels. Whichever vessels may be, they usually use fish aggregating devices (payaos) to aggregate fish school around them and to harvest the fish efficiently.

At the outset, fishing operations by skipjack pole-and-line fishing boats have been introduced from Japan and the operations were conducted from Tema which served as a home port. Later on, these vessels were gradually supplanted by their South Korean counterparts. Such foreign vessels peaked out at 40 in number in 1973. However, by virtue of the Ghanaian Government's active measure designed to promote the use of Ghanaian vessels, foreign vessels disappeared by

1984. At present, Ghanaian vessels (including joint·venture vessels) are conducting fishing operations under the guidance of Korean crews.

5-1-4. Fishermen's society and fishing economy

For the detailed description about the fishermen's society and fishing economy, see "5-2-5 Market Research."

5-1-5 Environment around fishing village

The GHANA-VISION 2020 mentions the land management, forestry and natural environment, water management, oceanic and coastal ecosystems, industrial pollutants, mining, toxic chemical substances, and concentration of population in a city as the major factors related to the environmental issue of Ghana. Among them, the following factors are directly connected with the fisheries and fishing village environment.

- Water management: All kinds of wastewater including agricultural, industrial, and household effluent are discharged untreated into the rivers, lakes, marshes, and sea. Diseases related to water are common in the countryside. In Ghana, fish in Lake Volta and in rivers is an important protein source for the people in inland areas. Contamination of the water may decrease the fresh-water fish resources and increase hazardous contaminated fish as food.
- Oceanic and coastal ecosystem: Pollutants, road sewage, and other hazardous substances from factories and houses in an industry center and a city center located in a coastal area will pose a serious threat to a vulnerable coastal ecosystem. Also, unplanned farming in a coastal area may have a land collapse effect and agricultural chemicals used in this area may have a harmful effect on the ambient ecosystem. Coastal erosion is an ongoing problem. Annual erosion of 1 to 5 m can be seen on the Keta Coast, Ada-Foah Beach, Labadi Beach, Nkontompo Beach, and Axim Shoreline.
- Toxic chemical substances: In Ghana, toxic chemical substances have been imported, manufactured, sold, and used for a long time without consideration of the environment. The fact that the type and quantity of these chemical substances are not clear is making the problem more serious.

The local government has an environment protection council, which conducts activities to maintain balance between a rapid economic development and the natural environment protection and to protect the health and welfare of the community. Also, the council is in a position to counsel the government on an environmental problem and to conduct and promote a survey and research for the purpose of improving the environment and maintaining a sound ecosystem. In addition, the council can establish the environmental standards for the local industry and give technical advice to the government and industry about what the best possible way is to decompose industrial waste, an environmental inhibitor to human beings. The government organization has the park department, which controls parks, communication plazas, and tree planting in towns. In a fishing village, each local government makes law to punish against disposal of decrepit fishing boats and fishing gears on the coast and intentional dumping of waste oil and so on.

Ghana has ratified the following international treaties concerning the environment.

Convention on Biological Diversity, U.N. Framework Convention on Climate Change(UNFCCC), Convention to Combat Desertification, Convention on International Trade in Endangered Species of Wild Fauna and Flora, UN Convention on the Low of the Sea, Comprehensive Nuclear-Test-Ban Treaty (CTBT), Montreal Protocol for on Substances that Deplete the Ozone Layer, MALPOL 73/78, ITTA83, ITTA94, and Convention on Wetlands of International Importance Especially as Waterfowl Habitat.

5-1-6 Progress of fisheries resources survey and local resources management mechanism in Ghana

Koranteng(1993) introduced a survey on oceanic resources conducted in Ghanaian waters up to 1992.

According to the report, the West African Fisheries Research Institute carried out the first demersal fish stocks development survey in 1956 on the Ghanaian continental shelf. Eight demersal fish stock surveys by means of a trawl net and 11 stock amount surveys (mainly for pelagic fish) by means of echo sounder were conducted up to 1992 since then. Many of the surveys in the early stage were carried out by foreign companies and research agencies and local research agencies as a part of the stock survey in Gulf of Guinea. Basic information such as the type of distributed fish and fish population density by fishing ground, depth of water, and season was collected. Ghana conducted her original survey from 1979 through 1992, using the Kakadiamaa, a Ghanaian research vessel supplied by Japan. Subsequently, however, the survey has been interrupted up to now by the failure of the Kakadiamaa. The NORAD-FAO/UNDP PROJECT carried out oceanographic investigations using the Dr. Fridtjof NANSEN in Gulf of Guinea and stock amount surveys (including trawl surveys) by means of scientific echo sounder in 1999 and 2000.

Demersal fish stock surveys have been basically conducted based on the Swept Area Method using a trawl net. Among the surveys conducted in and after 1956, the following surveys mentioned the demersal fish stock amount.

- Investigation name and period: THIERY AND LA RAFALE (GTS I and II) Sep. - Dec., 1963 and Feb. - Jun., 1964
  Implementation agency: Organization of African Unity
  Investigation results: Average stock density (all fish types): 21.3 kg/ha at a water depth of 10 to 50 m, 25.6 kg/ha at a water depth of 50 to 200 m
- Investigation name and period: GHANA TRAWLING SURVEY (GhTs), 1969 - 1970
  Implementation agency: Ghanaian Fisheries Department (The Larsen and Engel high-opening net was used.)
  Investigation results: Biomass: 40,000 tons (27 kg/ha)

Out of this amount, biomass of *Balistes capriscus*: 1,800 tons
Potential yield: 11,000 – 19,000 tons

- Investigation name and period: KAKADIAMAA (FRUT 2D), 1979 - 1980
  Implementation agency: Ghanaian Fisheries Department
  Investigation results: Biomass: 161,500 tons (Out of this amount, *B. capriscus*: 61.7%)
  Potential yield (except *B. capriscus*): 40,000 – 54,000 tons
- Investigation name and period: Dr. FRIDTJOF NANSEN 1981
  Implementation agency: CECAF/IMR. Bergen
  Investigation results: The biomass of 378,000 tons was estimated by scientific echo sounder. Out of this amount, 310,000 tons were *B. capriscus*.
- Investigation name and period: KAKADIAMAA (FRUT 3D), 1981 - 1982
  Implementation agency: Ghanaian Fisheries Department
  Investigation results: Biomass: 115,000 tons (62.1 kg/ha) (Out of this amount, the biomass of *B. capriscus* is 52,000 tons (45.2%).)
  Potential yield (except *B. capriscus*): 28,000 tons
  B. capriscus only: 13,000 - 17,000 tons
- Investigation name and period: KAKADIAMAA (FRUT 4D – FRUT 8D), 1987 – 1988 and 1988 – 1992
  Implementation agency: Ghanaian Fisheries Department
  Investigation results: Since the ship was out of order, neither a complete survey nor an analysis was carried out.
- Investigation name and period: Dr. FRIDTJOF NANSEN, 1989
  Implementation agency: CECAF/IMR Bergen
  Investigation results: The biomass of 41,000 tons of sardine and 50,000 tons of horse mackerel and mackerel was estimated by scientific echo sounder in the Ghanaian waters.
- Investigation name and period: LAGOAPESCA (GUINEA – 90), 1990
  Implementation agency: CECAF/Spanish Institute of Oceanography, Malaga
  Investigation results: Although the survey was not complete, there was a catch of 22.9 kg/ha.
  B. capriscus catch was small.
- Investigation name and period: RV Dr. FRIDTJOF NANSEN; SURVEY OF THE FISH RESOURCES OF THE WESTERN GULF OF GUINEA,

1999

Implementation agency: NORAD – FAO/UNDP

Investigation results: A survey by scientific echo sounder and by the swept area method using a trawl net was conducted off Benin through Cote d'Ivoire. The biomass of the pelagic fish in Ghana was estimated at a total of 90,000 tons: 40,000 tons of sardines and 50,000 tons of horse mackerels, mackerels, barracudas, cutlassfish. That of the demersal fish was estimated at 82,000 tons.

Ghana is a member country to the two inter-regional fishery commissions: International Commission for the Conservation of Atlantic Tunas (ICCAT), and Committee for the Eastern Central Atlantic Fishery (CECAF).

The ICCAT enforces fishery regulations with regard to juveniles of yellowfin and bigeye tunas as well as fishery regulations with regard to bluefin tunas. In particular, young yellowfin and bigeye tunas have been caught in large quantities by pole-and-line fishing and purse seine fishing in the Gulf of Guinea. The proportion of the juveniles catch is always a restriction target.

For fish resources other than tunas, the Fishery Committee for the Eastern Central Atlantic composed of 30 member countries (19 intro-Africa and 11 extro-Africa) has discussed the development and management of the resources under the FAO's guidance. However it has not yet taken any concrete international measures such as fishery regulations. The FAO has carried out resource amount survey of pelagic and demersal fish several times in the region and recently the Committee decided to establish a Scientific Sub-committee in the Committee to promote inter-regional scientific investigation and survey of the resources. The first Scientific Subcommittee was started in tandem with the 15th committee held in Nigeria in November 2000. This Subcommittee proposes the establishment of working groups of small-size pelagic fish, demersal fish, and small-scale(artisanal) fishery to promote future activities. Dr. Koranteng of the Ghanaian Directorate of Fisheries was elected vice-chairman of the Scientific Subcommittee.

5-1-7 Fishing Statistics

(1) Fishing Statistics of Ghana

In Ghana, fishing statistics are collected according to five fishing methods of "Canoe", "Inshore", "Industrial", "Shrimpers", and "Tuna". "Canoe" means Artisanal fisheries while "Inshore" means Semi-industrial fisheries. Although the sizes of fishing boats for 'Industrial' and "Shrimpers" belong to the same class, 'Industrial' and 'Shrimpers' are discriminated by species of their major assessment fishes, namely whether they fish shrimps or the other species of fishers. However, both fishing methods belongs to Industrial fisheries.

It is said that the number of canoes for Artisanal fisheries amounts to 9,000 nationwide. Not every canoe is checked in making statistics. Three stage samplings have been applied in collecting fishery data. Specifically, out of 276 landing points in Ghana, 53 points are selected. Separate two weeks in a month are selected to collect fishery data. A number of fishing boats by species of fishes are selected to check their fisheries. Table 2-7-1(1) of Data book lists the entry items of the original check form. For example, landed quantity by species of fishes are supposed to be recorded in units of weight (kg) and value (cedi). The number of fishing boats that go out fishing during the survey weeks are also recorded.

Landing points for Semi-Industrial fisheries numbered 9 at the end of the 1980s. Today landing points number only 4, namely Tema, Mumford, Elmina, and Sekondi. Fisheries are surveyed at these points without fail on the day when there is a landing of fish. Table 2-7-1(2) of Data book lists the entry items of the original check form. In the past, like canoes, a number of fishing boats were selected for sampling to check catch quantity by species of fishes and so on. However, since the number of fishing boats has reduced today, all of the fishing boats are checked to collect fishery data.

The number of active fishing boats that target demersal fishes in Industrial fisheries (meaning "Industrial" and "Shrimpers" fisheries) numbers 20 at most. All of fishery data of these boats are collected. Table 2-7-1(3) of Data book lists the entry items of the original check form. Unlike the method of collection of Artisanal and Semi-Industrial data, every company for demersal fishes may fill out the form with catch quantity and so on and submit it to the Fisheries Department.

Collecting statistic data in this way seems to have no major problem. For Artisanal fisheries, fishery data are collected by sampling a number of fishing boats. Collecting fishery data from all canoes, which amounts to a huge number, requires substantial personnel and budget at the Fisheries Department, which are virtually impossible. Thus, the present check system for sampling density and method are considered reasonable.

For Industrial fisheries, there seems no way of checking fishery reports for catch quantity and so on--whether the reports are true or not--submitted from fishery companies. However, a check system should be established so that Fisheries Department officials can witness catch quantity by species of fishes at the time of landings made irregularly. The boats for Industrial fisheries land fishes at Tema Port. Since the Marine Fisheries Research Division of the Fisheries Department is located close to the port, no heavy burdens are seemingly expected on the Fisheries Department to check fishery data.

The original check form for fisheries has no item to enter the fishing area. The Fisheries Department has neither fishing chart nor charts which indicate distributions of fishery resources. Since the original check form has entry items for catch quantity by species of fishes, landing values, and when and how many boats went out fishing, the Fisheries Department officials should know total fishing effort. In reality, however, catch quantity by species of fishes alone is published.

Table 2-7-2 of Data book lists annual fishing statistics of Ghana for 1985 through 2001 (source:MFRD).

Fishing statistics of Ghana have about 60 species of fishes. The table in next page indicates classifications and corresponding target species in fishing statistics after 1990. More than half of target species for this survey are classified into one species in fishing statistics. Other classifications include different groups of species, for example, "GROUPERS" includes *Epinephelus aeneus* and other groupers.

Statistical classifications and corresponding target species

Classification in the statistics	Corresponding target species
GROUPERS	>> *Epinephelus aeneus*
SNAPPERS/RED	*Lutjanus agennes*
OTHER SNAPPERS	>> *Lutjanus fulgens*
BURRITO	*Brachydeuterus auritus*
BURRO	*Pomadasys jubelini*
RONCADOR	*Pomadasys incisus*
CASSAVA DRUM	*Pseudotolithus senegalensis*
PAGELLUS BELLOTTII(YIYIWA)	*Pagellus bellottii*
DENTEX ANGOLENSIS (BALA)	*Dentex angolensis*
P.EHRENBERGI(SIKASIKA)	*Sparus caeruleostictus* and *Dentex canariensis*
D.CONGOENSIS (YEKE)	*Dentex congoensis*
RED MULLET	*Pseudupeneus prayensis*
SPADE FISHES	>> *Drepane africana*
THREADFINS	>> *Galeoides decadactylus*
TRIGGER FISHES	*Balistes capriscus*
CARANX RHONCUS(EMULE)	*Decapterus rhoncus*
MOONFISH	*Selene dorsalis*
BUMPER	*Chloroscomburus chrysurus*
SHRIMPS	>> *Penaeus notialis*
CUTTELFISHES	>> *Sepia officinalis*
	* >> means plural species including target

These species of fishes are not distinguished by fishermen, and the local Fisheries Department staff have no knowledge of classifying species of fishes. However, obtaining catch quantity by species of individual target species is indispensable for monitoring the effect of fisheries management. Thus, it is necessary to establish a system that enables Fisheries Department staff officials to make periodical visits to landing points and to check catch quantity by target fishes, including checking the ratio of target fishes and the other species of fishes belonging to the same class.

Table 5-1-7-1 lists changes in catch quantity of target species since 1992.

Catch quantity of all species varies considerably from year to year. For example, catches of *P. bellottii* for the years from 2000 to 2001 and those of *P. prayensis* for 2000 tended to be very different from the preceding years. We do not know whether the tendency lasts long or short.

Annual total fish catches of species under 20 statistical classification, including those of target species, have stood at about 40,000 tons in recent years. Ghana has about 300,000 tons of annual catch quantity of marine fishes, and most of them are pelagic fishes. Target species under present survey do not account for a major portion of the entire catch quantity in Ghana.

Concerning classification items including ten evaluation target species, the breakdown of average catch quantity for 1997 through 2001 in industrial fisheries and other fisheries (artisanal and semi-industrial) is as follows:

Ratios of catch quantity in industrial fisheries and other fisheries (average for 1997 through 2001)

	Industrial fisheries Average catch quantity(ton)	Ratio	Other fisheries Average catch quantity (ton)	Ratio
BURRITO (B.auritus)	1114.8	(8.1)	12580.4	(91.9)
RONCADOR (P. incisus)	47.9	(22.7)	162.6	(77.3)
CASSAVA DRUM (P. senegalensis)	139.1	(12.2)	1001.4	(87.8)
PAGELLUS BELLOTTII (YIYIWA)	765.6	(10.2)	6774.1	(89.8)
P. EHRENBERGI (SIKASIKA)	535.7	(28.8)	1324.0	(71.2)
RED MULLET (P. prayensis)	231.5	(52.8)	207.1	(47.2)
THREADFINS (G. decadactylus)	17.5	(1.1)	1523.0	(98.9)
CARANX RHONCUS (EMULE)	453.0	(14.0)	2774.5	(86.0)
CUTTLEFISHES	2855.6	(91.9)	251.5	(8.1)
Total	6160.4	(18.8)	26598.8	(81.2)

Except for cuttlefishes and *P. prayensis* (RED MULLET), catches by other fisheries account for a large portion. Total catch quantity of industrial fisheries account for a little less than 20%, and catch quantity of other fisheries account for over 80% of the total catch quantity in Ghana. These facts indicate that controlling industrial fisheries alone will not bring about sufficient effects on resource management. This is detailed in Chapter 6, Draft Management Guidelines.

Table 2-7-3 in the Data Book lists monthly catch quantity by different fishing methods (1999).

Monthly catch quantity statistics of artisanal and semi-industrial fisheries have been prepared according to almost the same classification items as annual catch quantity statistics. Data of our target species are excerpted from the monthly catch quantity statistics to form Tables 2-7-3(1) and (2) in the Data Book. As is seen in Table 2-7-3(3) in the Data Book, classification items of monthly catch quantity statistics of industrial fisheries are different from those of annual catch quantity statistics. For example, *P. prayensis*, which falls into RED MULLET in the annual catch quantity statistics, is not found in the monthly catch quantity statistics of industrial fisheries.

Data of annual catch quantity is essential to estimate resource amounts. Monthly catch quantity data is also essential to simulate forecasts of management effects. Concerning batch items of multiple species including evaluation target species (P. EHRENBERGI, THREADFINS, CUTTLEFISHES) among statistical classifications, what we needed was to estimate catch quantity of evaluation target species alone. We estimated those catch quantity from the result of our marine surveys. The following table lists the ratios of catch quantity of evaluation target species listed in individual items, based on Table 1-7-1 in the Data Book.

Statistical classification	Species included	Catch quantity data obtained from our marine surveys (kg)					Weight ratio (%)
		2nd survey	3rd survey	4th survey	5th survey	Total	
THREADFINS	*Galeoides decadactylus*	12.4	12.2	39.8	53.3	117.8	99.9
	Pentanemus quinquarius				0.2	0.2	
P.EHRENBERGI (SIKASIKA)	*Sparus caeruleostictus*	392.9	242.1	240.1	267.7	1142.7	61.4
	Dentex canariensis	244.6	177.0	134.0	162.3	717.9	38.6
CUTTLEFISHES	*Sepia officinalis*	385.8	203.2	512.1	392.0	1493.0	98.4
	Other cuttlefishes	1.1	0.6	20.1	2.1	23.9	

From the results shown above, we estimate that catches of *G. decadactylus* account for 99.9% of catches of THREADFINS in statistical classifications; that catches of *S. caeruleostictus* and *D. canariensis* respectively account for 61.4% and 38.6% of P. EHRENBERGI (SIKASIKA) catches; and that catches of *S. officinalis* account for 98.4% of CUTTLEFISHES catches.

As described earlier, catch quantity varies from year to year. Thus, to estimate resource amounts, we have estimated the average catch quantity of individual species for the past five years from 1997 through 2001. Since most of the evaluation target species are caught in artisanal and semi-industrial fisheries, we used ratios of monthly catch quantity of evaluation target species for 1999 (Tables 2-7-3 (1) and (2) in the Data Book) to estimate monthly catch quantity as a rule. However, since industrial fisheries dominates *S. officinalis* catches in Ghana, we used ratios of monthly catch quantity in industrial fisheries (Table 2-7-3(3) in the Data Book) to apply them to monthly fish catches of *S. officinalis*. Table 5-1-7-2 lists the result.

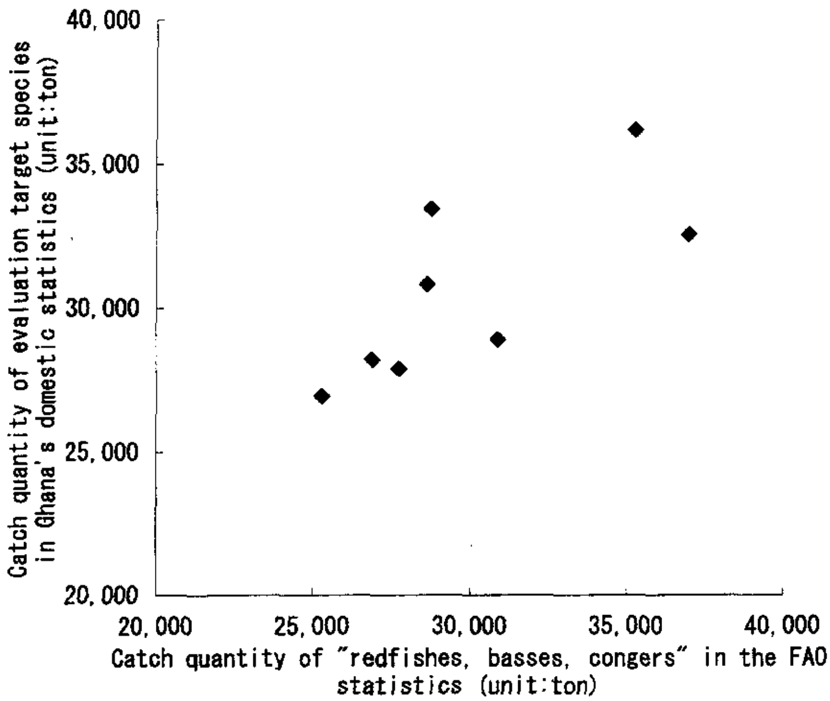
(2) Fishing Statistics in Neighboring Countries

At present, we have no other sources but the FAO fishing statistics to obtain catch quantity data in neighboring countries.

Table 5-1-7-3 lists catch quantity in Togo, Ghana, and Cotê d'Ivoir, which are prepared by FAO. Like Table 5-1-7-3, what FAO prepared is not statistics of individual species but data of batch species where, for example, "flounders, halibuts, and soles" are categorized as one item; similarly, "cods, hakes, and haddocks" are categorized as one item. Among the three nations, catch quantity of Ghana is dominant in most of the classification items. For example, concerning shrimps (*Penaeus notialis*) and squids (*Sepia officinalis*), catch quantity of Ghana is dominanat in "shrimps and prawns" and "squid, cuttlefish, and octopuses", respectively, according to the FAO statistics. Thus, using Ghanaian data alone is likely to cause no problems in assessing the resources of *Penaeus notialis* and *Sepia officinalis*, which fall into our target species.

In the FAO statistics, classification items that seem to cover our target species are "redfishes, bases, congers" and "miscellaneous marine fishes. "

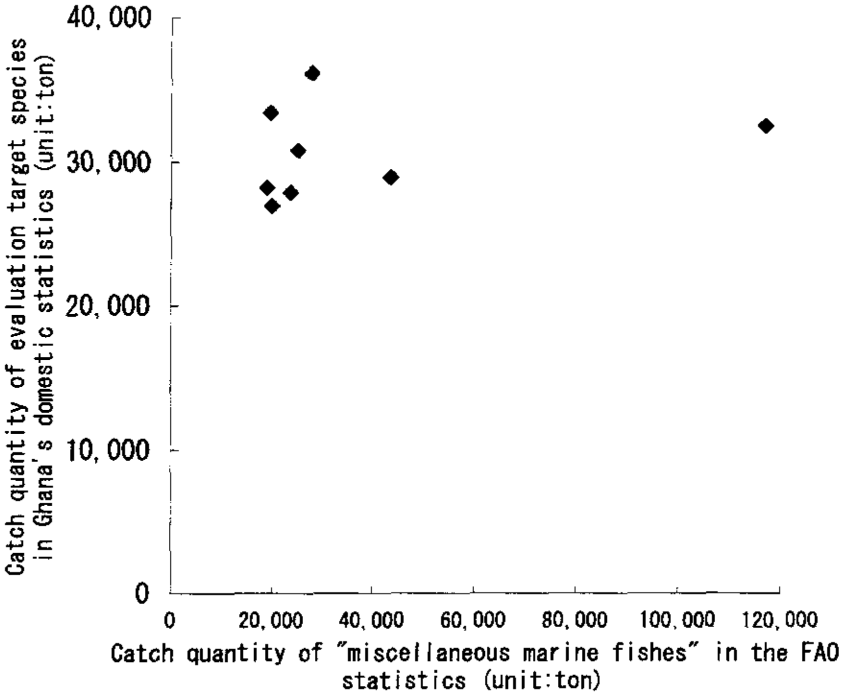
The following is a graph where catch quantity of "redfishes, basses, congers" in FAO statistics are plotted on the horizontal coordinate and where total catch quantity of species, including evaluation target species in Ghana's domestic statistics, except cuttlefishes, are plotted on the vertical coordinate.



Relation between the FAO statistics and Ghana's domestic statistics (1)

As the graph indicates, both statistics have a high correlation and their absolute catch quantity levels are also almost same.

The following is another graph, where catch quantity of "miscellaneous marine fishes" in the FAO statistics are plotted on the horizontal coordinate and where total catch quantity of evaluation target species in Ghana's domestic statistics except cuttlefishes are plotted on the vertical coordinate.



Relation between the FAO statistics and Ghana's domestic statistics (2)

This graph indicates no correlation between the two statistics. It seems that most of the target species in our present survey are included in the item of "redfishes, basses, congers" in the FAO statistics. Ghana's catch quantity of "redfishes, basses, congers" have recently accounted for about 80% of the total catch quantity of the three nations. Thus, we think it is reasonable to assess resources based on Ghanaian data only.

Table 5-1-7-1 Annual changes of catches of the target species in Ghana

Classification	Corresponding species	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
GROUPERS	>> *E. aeneus*	225	385	169	306	426	478	1361	181	94	138
SNAPPERS/RED	*L. agennes*	530	730	597	626	292	137	255	113	215	128
OTHER SNAPPERS	>> *L. fulgens*	0	0	0	0	0	0	13	0	155	1
BURRITO	***B. auritus***	**11024**	**11940**	**18216**	**14529**	**13552**	**19816**	**12059**	**12724**	**10032**	**13845**
BURRO	*P. jubelini*	449	277	576	245	1050	434	303	206	95	694
RONCADOR	***P. incisus***	**51**	**382**	**179**	**279**	**115**	**43**	**108**	**201**	**55**	**153**
CASSAVA DRUM	***P. senegalensis***	**2340**	**1301**	**1104**	**698**	**1128**	**1995**	**962**	**937**	**739**	**1070**
PAGELLUS BELLOTTII(YIYIV	***P. bellottii***	**8724**	**7915**	**5635**	**4380**	**7541**	**7517**	**10029**	**13266**	**2916**	**3206**
DENTEX ANGOLENSIS (BALA	*D. angolensis*	284	428	183	591	489	490	1416	1767	564	838
P.EHRENBERGI	***S. caeruleostictus & D. canariensis***	**1536**	**1862**	**834**	**1546**	**1448**	**1347**	**1682**	**2306**	**1239**	**2189**
D.CONGOENSIS (YEKE)	*D. congoensis*	151	364	112	43	102	119	392	1272	350	571
RED MULLET	***P. prayensis***	**247**	**163**	**190**	**65**	**586**	**619**	**553**	**247**	**39**	**285**
SPADE FISHES	>> *D. africana*	18	20	7	34	6	46	4	24	2	8
THREADFINS	**>> *G. decadactylus***	**1826**	**2120**	**3247**	**1969**	**3146**	**1477**	**774**	**587**	**1947**	**2892**
TRIGGER FISHES	*B. capriscus*	198	9	11	2	17	0	1	1	2	2
CARANX RHONCUS(EMULE)	***D. rhoncus***	**2472**	**2213**	**4040**	**3483**	**3301**	**3337**	**2752**	**2275**	**3800**	**2586**
MOONFISH	*S. dorsalis*	1202	882	501	976	907	712	381	470	738	1101
BUMPER	*C. chrysurus*	5153	6742	4594	2482	2466	3847	7264	7648	6861	6508
SHRIMPS	>> *P. notialis*	2236	1148	1307	2228	1554	1602	1448	1281	1446	1361
CUTTELFISHES	**>> *S. officinalis***	**1541**	**1673**	**2396**	**2791**	**2967**	**3355**	**3288**	**4095**	**1805**	**2866**
	Total	40206	40555	43894	37271	41091	47369	45044	49598	33091	40441

boldface: evaluation target *>> : combined species related*

Table 5-1-7-2 Monthly average catch of the target species in Ghana

Species＼Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Decapterus rhonchus	286	414	253	71	198	274	90	654	527	148	2	34	2950
Brachydeuterus auritus	1486	1130	892	532	1043	377	217	421	1106	2280	3462	750	13695
Pomadasys incisus	7	11	20	9	2	9	8	4	11	2	5	24	112
Dentex canariensis	36	84	130	50	35	128	54	33	30	26	51	20	676
Sparus caeruleostictus	57	134	207	79	56	203	87	53	47	41	80	32	1076
Pagellus bellottii	599	891	400	759	694	389	947	368	238	412	803	887	7387
Galeoides decadactylus	161	170	96	67	168	170	53	53	62	232	187	115	1534
Pseudotolithus senegalensis	180	116	92	56	303	56	14	20	19	28	141	115	1140
Pseudupeneus prayensis	4	14	67	2	185	1	0	14	7	7	5	43	348
Sepia officinalis	259	488	437	170	83	70	242	95	222	314	240	413	3033

Table 5-1-7-3(1) Annual catch by species group and country (compiled by FAO)

Flounders, halibuts, soles

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	1	6	5	2	10	18	8	6
Ghana	223	247	231	407	295	339	347	284
Cote d'Ivoire	316	255	211	208	177	139	217	217

Cods, hakes, haddocks

	1992	1993	1994	1995	1996	1997	1998	1999
Togo								
Ghana	0	0	0	0	1	0	34	3
Cote d'Ivoire								

Redfishes, basses, congers

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	341	434	362	501	459	282	1,379	2,252
Ghana	26,881	27,718	28,744	25,283	28,620	35,230	30,882	36,969
Cote d'Ivoire	7,799	5,991	6,709	6,568	6,141	6,029	4,043	6,451

Jacks, mullets, sauries

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	393	672	1,121	668	818	796	1,234	2,940
Ghana	19,590	21,485	22,848	26,025	26,857	32,403	34,507	29,309
Cote d'Ivoire	3,573	3,488	2,881	2,184	1,999	3,093	3,150	2,857

Herrings, sardines, anchovies

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	4,057	8,850	5,772	5,653	7,977	6,490	7,778	9,213
Ghana	230,894	194,160	151,311	161,926	252,112	193,108	149,661	121,944
Cote d'Ivoire	37,770	26,856	26,331	24,391	30,034	22,932	26,001	25,416

Tunas, bonitos, billfishes

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	114	405	291	165	294	389	323	639
Ghana	44,340	39,096	38,101	34,967	38,546	54,070	66,479	83,660
Cote d'Ivoire	273	498	474	465	476	353	289	411

Mackerels, snoeks, cutlassfishes

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	83	140	99	158	112	253	183	460
Ghana	16,323	5,731	10,909	14,296	18,133	22,749	32,207	16,749
Cote d'Ivoire	528	451	237	910	493	1,620	1,832	3,012

Sharks, rays, chimaeras

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	11	44	13	20	213	59	67	232
Ghana	1,145	2,253	1,467	1,453	1,367	894	1,936	4,867
Cote d'Ivoire	379	335	256	258	288	501	407	265

Miscellaneous marine fishes

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	209	341	226	0	176	823	594	2,059
Ghana	18,840	23,620	19,552	19,946	25,128	27,896	43,399	116,883
Cote d'Ivoire	18,405	16,954	20,297	23,386	19,901	19,552	22,232	23,558

Sea-spiders, crabs

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	0	0	0	0	0	0	1	3
Ghana	75	195	462	218	399	576	271	145
Cote d'Ivoire	0	0	0	0	0	0	0	1

Table 5-1-7-3 (2) Annual catch by species group and country (compiled by FAO)

Lobsters, spiny-rock lobsters

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	1	1	1	0	0	0	0	2
Ghana	218	369	510	230	134	203	65	0
Cote d'Ivoire	2	0	0	0	2	4	5	6

Shrimps, prawns

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	0	1	1	1	12	2	2	0
Ghana	2,236	1,148	1,507	2,228	1,554	1,602	1,448	87
Cote d'Ivoire	171	168	176	196	195	394	400	411

Miscellaneous marine crustaceans

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	1	2	0	1	0	0	0	0
Ghana								
Cote d'Ivoire	0	0	0	0	0	0	0	0

Squids, cuttlefish, octopuses

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	0	32	9	1	12	77	51	5
Ghana	1,875	1,716	2,469	2,946	3,104	3,422	3,391	4,114
Cote d'Ivoire	0	0	0	0	0	0	0	81

Miscellaneous marine molluscs

	1992	1993	1994	1995	1996	1997	1998	1999
Togo	0	0	0	1	0	0	0	0
Ghana								
Cote d'Ivoire								

5-2. Stock Survey Results

5-2-1. Oceanographic Observations

In Ghanaian waters, the months of July through September are an upwelling period while the months of April through June and the months of October to November represent stable periods. Oceanographic structure is considered to be vastly different between the upwelling period and the stable periods. The second and fourth field surveys were conducted during the stable periods (in October of 2000 and October to November of 2001) while the third and fifth field surveys were carried out during the upwelling period (July to August of 2001 and July to August of 2002).

The horizontal distributions of temperature, salinity and density are shown in Figs. 5-2-1-1 through 5-2-1-3 (in layers at depths of 0.5, 10, 20 and 30 meters). The horizontal distribution of chlorophyll (in layer at a depths of 0.5 meters) is shown in Fig. 5-2-1-4. However, during the fifth field survey, no chlorophyll measurement could be conducted on account of fluorescence sensor trouble.

Furthermore, to study the vertical oceanographic structure of upwelling currents, vertical cross-sections of temperature, salinity and density at survey stations in the neighborhood of longitude 00° 20' W where upwelling currents occurred at remarkable rates during the third field survey are shown in Fig. 5-2-1-5.

In addition, vertical profiles of temperature, salinity and chlorophyll at the individual survey stations are shown in Figs. 5-2-1-7 through 5-2-1-10.

(1) Temperature

Studies were made of temperature distribution in each survey period. (Fig. 5-2-1-1)

In the second field survey, the surface temperature measured 22.4 to 26.9°C. Horizontally, the surface temperature tended to be lower on the western side of the line extending off-shore from the neighborhood of Cape Coast (hereafter referred to as the

Cape Coast line) whereas it tended to be higher on the eastern side. Between these two waters, a difference of approximately 2 to 3°C was observed. This tendency was more of the same at depths of 10 meters and beyond. However, it becomes less conspicuous with increasing depth. Also vertically, differences were observed between the eastern side and the western side of the above-mentioned line. Thermoclines were observed at depths of approx. 10 meters in waters west of the Cape Coast line whereas at depths of approx. 20 meters in waters east of the line.

In course of the third field survey, the surface temperature measured 20.8 to 25.0°C. Horizontally, there existed higher-temperature marine waters along and away from the shore extending from Cape Three Point to the neighborhood of Cape Coast. And, the temperature was observed to decrease on the eastern and western sides of the said waters. In particular, the temperature was at its lowest in waters east of Accra and Tema. This tendency held more of the same also in layers at a depth of 10 meters. However, the tendency became less manifest at depths of 20 meters and beyond from one sea area to another. Also vertically, although thermoclines were observed at depths of approx. 10 to 20 meters in higher-temperature waters (at St. 20 through 31, 46 and 47) off the coast between Cape Three Point and Cape Coast, no variations large enough to be regarded as thermoclines were detected in low-temperature waters (at St. 4 through 9, 42 and 43) east of Tema.

During the fourth field survey, the surface temperature measured 27.3 to 28.3°C, showing very small variations. However, horizontally, waters characterized by somewhat higher temperatures were found at surface-layer in waters west of Cape Three Point, waters in the neighborhood of Cape Coast, and waters off the coast between Accra and Tema. This tendency was more of the same at depths of 10 meters and beyond. However, waters characterized by somewhat lower temperatures were observed with increasing depth in waters off the coast from Keta Lagoon to Tema. Vertically, thermoclines were observed at depths of approx. 10 to 15 meters in the outer perimeters of waters (St. 19 through 30) in the neighborhood of Cape Coast, whose surface temperatures were in the upper reaches of the above-mentioned temperature range. Furthermore, at off-shore survey stations (St. 46 through 50), thermoclines were observed at depths of approx. 40 to 50 meters.

In the fifth field survey, the surface temperature measured 21.3 to 24.9°C. Horizontally, lower-temperature waters were observed in the following three sea areas; waters west of Accra, waters off the coast from Tema to Angaw Lagoon, and waters east of Keta Lagoon. This tendency was more of the same at depths of 10 meters and beyond for the most part. However, sea areas with relatively high temperatures were observed off Cape Coast in layers at a depth of 10 meters. In addition, survey stations marked with relatively high temperatures were spotted sporadically. Furthermore, with increasing depth, temperature differentials became smaller; in layers at a depth of 30 meters, sea areas with relatively lower temperatures were found in waters off the coast from Accra to Cape Coast and waters off the coast from Angaw Lagoon to Keta Lagoon. Also vertically, thermoclines were found at depths of approx. 10 to 15 meters at most survey stations. However, their temperature differentials were small east of Accra.

(2) Salinity

Studies were made of the distribution of salinity during each survey period. (Fig. 5-2-1-2)

In course of the second field survey, the surface-layer salinity measured 33.3 to 35.7. Horizontally, as was the case with temperature in the surface layer, it tended to be higher on the western side of the Cape Coast line and tended to be lower on the eastern side of the line. The same tendency was observed in 10-meter-deep layers. Moreover, the salinity in 20-meter-deep and 30-meter-deep layers was virtually uniform. Vertically, survey stations characterized by extremely low salinity readings were spotted at depths of up to approx. 5 meters in low-salinity waters on the eastern side. (These included St. 2, 3, 41, 42. 11, 13, 38, 39, and 40.) Of these, the survey stations (St. 2, 3, 41 and 42) in waters off the coast between Angaw Lagoon and Keta Lagoon were considered to have been possibly impacted by freshwater released from those lagoons -- considering the fact that the direction of the currents during the survey was easterly. At survey stations other than those, although a tendency to increase in salinity with increasing depth from surface to bottom layers was observed, there were no variations large enough to be regarded as haloclines.

In the third field survey, the surface-layer salinity measured 34.1 to 35.9. Horizontally, a tendency was observed, in which the salinity was lower in surface layers on the western side of a line tending southeast from the neighborhood of Cape Coast while the salinity was higher on the eastern side of the said line. High-salinity sea areas were spotted also in waters off the coast from Takoradi to Cape Coast. However, in 10-meter-deep layers, low-salinity waters were observed off the coast between Cape Three Point and Cape Coast. And, the salinity in waters east of the above waters was virtually uniform. Furthermore, 20-meter-deep and 30-meter-deep layers were virtually uniform in salinity. Vertically, at survey stations in waters whose surface layers were marked with low salinity (e.g. St. 38 through 40), haloclines were observed at depths of approx. 5 to 10 meters. At other survey stations, no variations were observed that were significant enough to be construed as haloclines.

During the fourth field survey, the surface-layer salinity stood at 32.0 to 35.6. Horizontally, vastly differing from temperature, the salinity in surface layers stood at very low readings of 33.0 or less at survey stations (St. 1 through 3, and 41) in waters off Keta Lagoon. At other survey stations, a sea area with relatively high salinity was spotted at survey station (St. 32) in waters off Sekondi while areas with relatively low salinity were found west of Cape Three Point and in waters off Cape Coast. And, sea areas marked with high salinity came to be found with increasing depth in waters off the coast between Cape Three Point and Cape Coast. Vertically, there were wild variations in salinity at depths from surface down to approx. 10 meters at survey stations (St. 1 through 3, and 41) in waters off Keta Lagoon. Furthermore, haloclines were observed at depths of approx. 10 to 15 meters just as was the case with thermoclines in the outer perimeters (at St. 19 through 30) of waters marked with high-temperature surface layers in the neighborhood of Cape Cost. At survey stations other than these, no variations were detected that were large enough to be regarded as haloclines.

In the fifth field survey, surface layers measured 32.6 to 35.4 in salinity. Horizontally, a tendency was observed, in which the salinity was lower in surface layers on the western side of a line tending southwest from the neighborhood of Cape Coast while the salinity was higher on the eastern side of the line. Low-salinity sea areas were spotted around Cape Three Point (in the neighborhoods of Cape Coast to Half Assini). In addition, low-salinity sea areas were also found in waters off Keta Lagoon. Although the salinity was almost uniform in 10-meter-deep layers, low-salinity sea areas were observed on the western side of Cape Three Point and in waters off Cape Coast. And, the salinity in 20-meter-deep and 30-meter-deep layers was virtually uniform. Vertically, haloclines were observed at a depth of approx. 10 meters at survey stations (e.g. St. 3, 26, 27, and 33 through 36) in waters with low-salinity surface layers. However, at survey stations other than these, no variations were detected that were large enough to be interpreted as haloclines.

(3) Studies of Water-Mass Structures

Studies were made of the vertical distribution of temperature, salinity and density of upwelling currents. (Fig. 5-2-1-5)

In the third field survey, low-temperature high-density seawater existed at depths of approx. 10 meters up to the surface in places near the coast, suggesting that lower-layer water was distributed all the way up to the surface by upwellings. Furthermore, also in the fifth field survey, seawater marked with somewhat lower temperature existed from a depth of approx.

10 meters up to the surface in places some distance from the coast. And, the occurrence of upwellings was observed even though they were not so strong. On the other hand, in the second and fourth field surveys, despite the fact that extremely low salinity seawater existed in surface layers (observed during the second field survey) and somewhat higher-temperature, low-density seawater was present along and off the coast (observed during the fourth field survey), a tendency to drop in temperature and rise in density with increasing depth was observed, suggesting the existence of stability vertically.

Studies were conducted of the structures of water masses in each survey period. (Fig. 5-2-1-6) For information, since the names of the water masses have been derived from the classification of sea areas, water masses having similar names do not necessarily share similar characteristics.

1. Water Masses Studied In The Second Field Survey

(1) West Coast Water Mass

An inspection of temperatures reveals that a front is formed on the Cape Coast line in a surface-to-30-meter-deep layer. With this front as a boundary, temperature is obviously low on the western side. Although no significant salinity variations were observed at depths of 20 meters and beyond, the salinity was higher on the western side of the front and lower on the eastern side at depths of 10 meters and shallower. Furthermore, an inspection of vertical distribution has shown surface to bottom layer temperature and density of the western side of the front pictures that were completely different from their counterparts derived from the eastern side of the front. From the above, the west coast water mass can be characterized as being "extremely low temperature and high salinity." Furthermore, in waters off Takoradi, low-temperature seawater existed all the way up to the surface in the vicinity of the thermocline, leading us to think that it may be an upwelling current.

(2) Central West Water Mass

Although no significant differences are observed in salinity between the eastern and western sides of the Accra-Tema line, an inspection of temperatures shows that a front is formed at depth of 30 meters in the vicinity of the Accra-Tema line. Not so conspicuous in surface layers though, the temperature on the western side of the line was approx. 1°C higher than that on the eastern side even in surface layers. From the above, the central west water mass can be characterized as being "high temperature and low salinity." Also by taking a look at vertical density distribution, a tendency has been recognized in which density rises with a descent from upper to lower layers in this water mass, pointing to the presence of stability vertically.

(3) Central East Water Mass

Although no significant salinity differentials were observed between the southern and northern sides of the Keta line (extending eastward from Keta Lagoon), an inspection of temperatures reveals *that a clear-cut front is formed in the* vicinity of the Keta line. The temperature on the northern (Togolese) side of the Keta line is lower by as large as approx. 3 °C than that on the southern (Ghanaian) side.

Within this water mass, a high-temperature water mass is recognized to be flowing into waters off the estuary of the Volta river. An inspection of the vertical distribution of temperatures at St. 42 shows that the temperature is high up to depths of approx. 50 meters and the temperature at St. 42 remains high all the way down to bottom layers when compared with neighboring St. 41 and 43. Although all this leads us to think that this high-temperature water mass may be of great thickness in terms of depth as well as of great volume, no particular classification has been made here due to our inability to determine its horizontal expanse. An inspection of the vertical density distribution of this water mass suggests the intrusion of a different (high-density) water mass at a depth of 30 meters. Although the structure is thus complex, the central east water mass can be characterized as being "low temperature and low salinity."

(4) East Coast Water Mass

When compared with the neighboring central east water mass, the east coast water mass is by approx. 3°C lower in temperature, indicating that it is obviously a different water mass. For lack of survey stations close to the eastern side border, its expanse and shape are unknown.

2. Water Masses Studied In The Third Field Survey

(1) Western Surface Water Mass

This water mass measures 23°C or lower in temperature and 35.0 or smaller in salinity and is, therefore, characterized as being "high temperature and low salinity." Taking a look at vertical distribution, thermocline was recognized at depths of 5 to 10 meters. In layers lower than those depths, a high-density water mass marked with low temperature and high salinity existed, leading us to surmise that low-density coastal water may be riding on top of high-density offshore water.

(2) Offshore Surface Water Mass

As is the case with the western surface water mass, this offshore surface water mass can be characterized as being "high temperature and low salinity." However, its temperature stood at 23°C or higher and its salinity measured 35.0 to 35.5, meaning it was higher than the western surface water mass in terms of both temperature and salinity. Taking a look at vertical distribution, a thermocline was recognized at depths of approx. 5 to 10 meters as in the case of the western surface water mass. In layers lower than these depths, a high-density mass was present. Considering that the seawater of the offshore surface water mass is high in temperature but low in salinity, the low-density coastal water is surmised to be riding on top of the high-density offshore water. However, the origin of the coastal water is considered to be unrelated to the western surface water mass.

(3) Eastern Coastal Water Mass

Measuring 21 to 23°C in temperature and 35.5 and greater in salinity, this water mass can be characterized as being "low temperature and high salinity." Taking a look at vertical distribution, although the temperature dropped with increasing depth, no apparent thermoclines were recognized. All this leads us to think that the eastern coastal water mass is a water mass originating from an upwelling water mass (which is discussed later on) in the form of upwelling lower layers that spread while being warmed up during ascent.

(4) Upwelling Water Mass

As is the case with the eastern coastal water mass, the surface layer of this water mass can be characterized as being "low temperature and high salinity." Measuring 21°C or less, its temperature is, however, lower than that of the eastern coastal water mass. Taking a look at vertical distribution, since variations in both temperature and salinity in the perpendicular direction are small, upwelling currents are considered to be occurring here from lower layers.

3. Water Masses Studied In The Fourth Field Survey

(1) Western Surface Water Mass

Ranging from 34.5 to 35.0 in salinity, this water mass can be characterized as being "low salinity." An inspection of vertical salinity distribution revealed that salinity rose with increasing depth. In light of the fact that the low-salinity seawater of this water mass existed only as far as to certain depths from the surface layer, this western surface-layer water mass is considered to be a water mass which is impacted by freshwater coming from lagoons of Côte d'Ivoire. Taking a look at the vertical distribution of density, the difference in density between the surface and lower layers is large, suggesting that low-density surface water may be riding on top of high-density lower-layer water.

(2) Central Water Mass

During the fourth field survey, the horizontal distribution of temperature was very small in variation. Although waters with somewhat higher temperature were observed west of Cape Three Point, in the neighborhood of Cape Coast and off the coast from Accra to Tema, variations in temperature were too small to impact density. Furthermore, although low salinity was encountered at one survey station and high salinity was detected at another survey station in waters off Cape Coast, these survey stations were not treated as separate water masses but were included into this central water mass because their relationships with surroundings were not known.

Despite its characterization as being "high temperature and high salinity," this central water mass appears to include a number of small water masses. Also an inspection of vertical density distribution reveals that density increases with a descent from the surface down to lower layers, suggesting the absence of upwelling currents.

(3) East Coast Surface Water Mass

Measuring 33.0 or smaller in salinity, this water mass is characterized as being "extremely low salinity." An inspection of vertical distribution, salinity varies widely at a depth of approx. 10 meters and extremely low salinity water masses are considered to be present only in surface layers. With this being the situation, as for the structure of the seawater of this water mass, seawater which is heavily impacted by freshwater coming from Keta Lagoon as well as lagoons in Togo is riding atop high-salinity lower-layer seawater. Also taking a look at the vertical distribution of density, the difference in density between the surface and lower layers is large, indicating a structure in which low-density surface water is riding on top of high-density lower-layer water.

4. Water Masses Found In The Fifth Field Survey

(1) Central West Water Mass

Taking a look at the temperature of surface layers, lower-temperature sea areas were found in the following three waters; waters west of Accra, waters off the coast from Tema to Angaw Lagoon, and waters east of Keta Lagoon. Other than these, no significant variations were observed. However, a tendency was observed that surface-layer salinity was lower on the western side of the line extending southwest from the neighborhood of Cape Coast and was higher on the eastern side of the line. Although this central west water mass can be characterized as being "low salinity," the difference in density between this water mass and the central east water mass (discussed later) is small. An inspection of the vertical distribution of salinity reveals that somewhat low-salinity seawater exists up to depths of approx. 10 meters. With this being the situation, this central west water mass is considered to be a water mass which derives from the low-salinity seawater of the Cape Three Point water mass discussed below and spreads while mixing with high-salinity offshore water.

(2) Cape Three Point Water Mass

As is the case with the central west water mass, this water mass can be characterized as being "low salinity." Measuring 34.0 or smaller in salinity, the salinity of this water mass was even lower than that of the central west water mass. Also in terms of density, this water mass was lower than its surroundings. Taking a look at the vertical distribution of salinity, considering the fact that a halocline was recognized at depths of approx. 10 meters, low-salinity coastal water impacted by freshwater is surmised to be riding on top of high-salinity offshore water in this water mass. However, the origin of the coastal water is unknown.

(3) Central East Water Mass

This water mass is located on the eastern side of the line which extends southeast from the neighborhood of Cape Coast. Since this sea area represents somewhat high-salinity waters, it can be characterized as being "high salinity." However, there were also low-temperature survey stations within this water mass, suggesting the existence of some small-sized water masses. The reason for this is considered as follows: the water mass is adjacent to the likes of low-temperature upwelling masses and the east coast water mass, and these water masses mix with one another inside the central east water mass, thereby giving rise to complexity. Taking a look at the vertical distribution of salinity, no significant halocline was recognized. For this reason, this water mass is considered to be a protrusion of high-salinity offshore water.

(4) Upwelling Water Mass

Unlike the third field survey, although no typical upwelling phenomenon in which high-density lower-layer water upwells was not recognized in course of the fifth field survey, low-temperature water masses were found in waters west of Accra. Since an inspection of the vertical temperature distribution revealed that the temperature was uniform up to depths of approx. 10 meters, this water mass is considered to be an upwelling current that can be characterized as being "low temperature." However, surveys of the upwelling water mass were carried out one or two days before the completion of the survey cruise. Although the neighboring surroundings of the water mass were investigated one week prior to those surveys, no water mass appearing to be upwelling current was recognized. In other words, it was highly probable that the upwelling water mass happened to have recognized on that particular investigation day, leading us to think that the detected upwelling may portend the occurrence of full-fledged upwelling current.

(5) East Coast Water Mass

Measuring 35.0 or smaller, this water mass can be characterized as being "low salinity." Since an inspection of the vertical distribution of salinity showed the presence of a halocline at depths of approx. 10 meters, low-salinity coastal water impacted by freshwater coming from surrounding lagoons is surmised to be riding on top of high-salinity offshore water within this water mass.

For information, the existence of a somewhat high salinity water mass was also suggested. However, due to lack of survey stations (in the vicinity of Togo's border) on the eastern side of this east coast water mass, the expanse and shape of the east coast water mass are unknown.

Through the performance of the four surveys, the occurrence of upwelling current and the way how it spread while being warmed up by its surroundings were observed during the third field survey. During the forth field survey, it has been found out that warm offshore water was spreading out all across the waters off Ghana's coast with near uniformity horizontally. Furthermore, the density of seawater rose with increasing depth, indicating vertical stability. On the other hand, during the second field survey, high-temperature seawater of considerable thickness appeared to be making an entry into the vicinity of the coast by thrusting aside low-temperature seawater of the upwelling period, leading us to think that it was the time for transition from the upwelling period to the stable period. This was also confirmed by inspection of salinity; a water mass whose surface layer was marked with extremely low salinity was found in the waters off Keta Lagoon, indicating a situation similar to that encountered during the fourth field survey that took place in the stable period. Although not so clear signs of upwelling current were recognized as those observed during the third field survey, the fifth field survey was considered to coincide with a period preceding the occurrence of full-fledged upwelling current.

The second field survey was considered to coincide with a period of transition from the upwelling period to the stable period. The third and fourth field surveys were believed to coincide with the upwelling period and the stable period, respectively. And, the fifth field survey was deemed to be in the early days of the upwelling period. The second field survey was launched in early October, by 25 days earlier than the starting date of the fourth field survey, leading us to think that the occurrence of upwelling current may have lasted until late. However, the fifth field survey and the third field survey started at nearly the same time, with the former by only 5 days earlier than the latter. It appears that the time of occurrence of upwelling current varies from year to year.

The atmospheric pressure distribution of over the African continent basically consists of one equatorial depression and two extra-tropical high-pressure belts. This pressure distribution seasonally moves northward and southward, thereby controlling wind systems. As discussed in Chapter 5-1-1, Harmattan is one of such wind systems. In particular, Atlantic southeast trade winds (or southeast winds in the northern hemisphere) have a profound effect on the climate of West Africa by blowing into the deep recesses of the continent because the tropical depression travels northward during the summer season of the Northern hemisphere (Oda, 1962). Upwelling current in the Guinea Current extending from Côte d'Ivoire to Ghana has a bearing on those trade winds that blow during the summer season (Uda, 1974). The migration of depression belts varies from year to year, and so does the behaviour of trade winds. These factors are considered to vary the time of occurrence of upwelling current.

(4) Chlorophyll

During the second field survey, the amount of chlorophyll in the surface layer stood at 0.11 to 32.00 ppb. Taking a look at horizontal distribution in the surface layer, high readings occurred in the waters off the coast between Accra and Sekondi (in particular, at St. 16 and 19 and their surroundings). Readings tended to be lower on both sides of the said waters.

Vertically, high readings were obtained at St. 16, 19, 20, 23, 25, 29, 32 and 45 at depths of 0.5 to 1 meter whereas stable low readings were produced at depths of 2 meters and beyond. At other survey stations, low uniform readings were obtained from the surface down to bottom layers.

In the third field survey, the amount of chlorophyll in the surface layer measured 0.22 to 5.34 ppb. An inspection of horizontal distribution in the surface layer indicated a tendency which was the reversal of the tendency of temperature. The amount of chlorophyll in high-temperature offshore water masses was small whereas that in low-temperature upwelling water masses was large. Vertically, high readings were recorded at depths of 10 meters and shallower at St. 4. 7, 8, M-3 and M-4. At other survey stations, nearly uniform low readings were obtained from the surface down to bottom layers.

During the fourth field survey, the amount of chlorophyll in the surface layer stood at 0.00 to 2.62 ppb. Taking a look at horizontal distribution in the surface layer, the highest chlorophyll reading was obtained at a survey station (St. 27) in low-salinity waters off Cape Coast. In addition, slightly higher chlorophyll amounts were recorded in waters off Keta Lagoon (at St. 1 through 3) as well as in waters off the coast between Tema and Songaw Lagoon. At some other survey stations, a little greater chlorophyll amounts were observed. Vertically, St. 27 produced high readings at depths of 0.5 to 1 meter and stable low readings at depths of 2 meters and beyond. At other survey stations, uniform low values were obtained from the surface down to bottom layers.

The amount of chlorophyll increases as phytoplankton proliferation gains momentum. Phytoplankton thrives well under conditions of high nutrients and high temperature. In the chlorophyll-rich upwelling water mass encountered in the third field survey which fell on the upwelling period, the proliferation of phytoplankton was considered to be promoted by highly nutrients supplied by the upwelling current. However, since high chlorophyll amounts tended to be recorded at low-salinity survey stations during the second field survey, the impact of freshwater was also considered to be significant.

In the fourth field survey, the amount of chlorophyll was the lowest of the three surveys as a whole. The reason for this can be explained as follows: The second field survey was surmised to have coincided with the time for transition from the upwelling period to the stable period. The third field survey fell on the upwelling period. On the other hand, the amount of nutrients was considered to be small on the whole during the forth field survey.

For information, taking a look at vertical data representing the amount of chlorophyll, spike-like high values are sporadically shown. Almost all the time, these are errors contained in electrical signals and are not indicating the amount of chlorophyll.

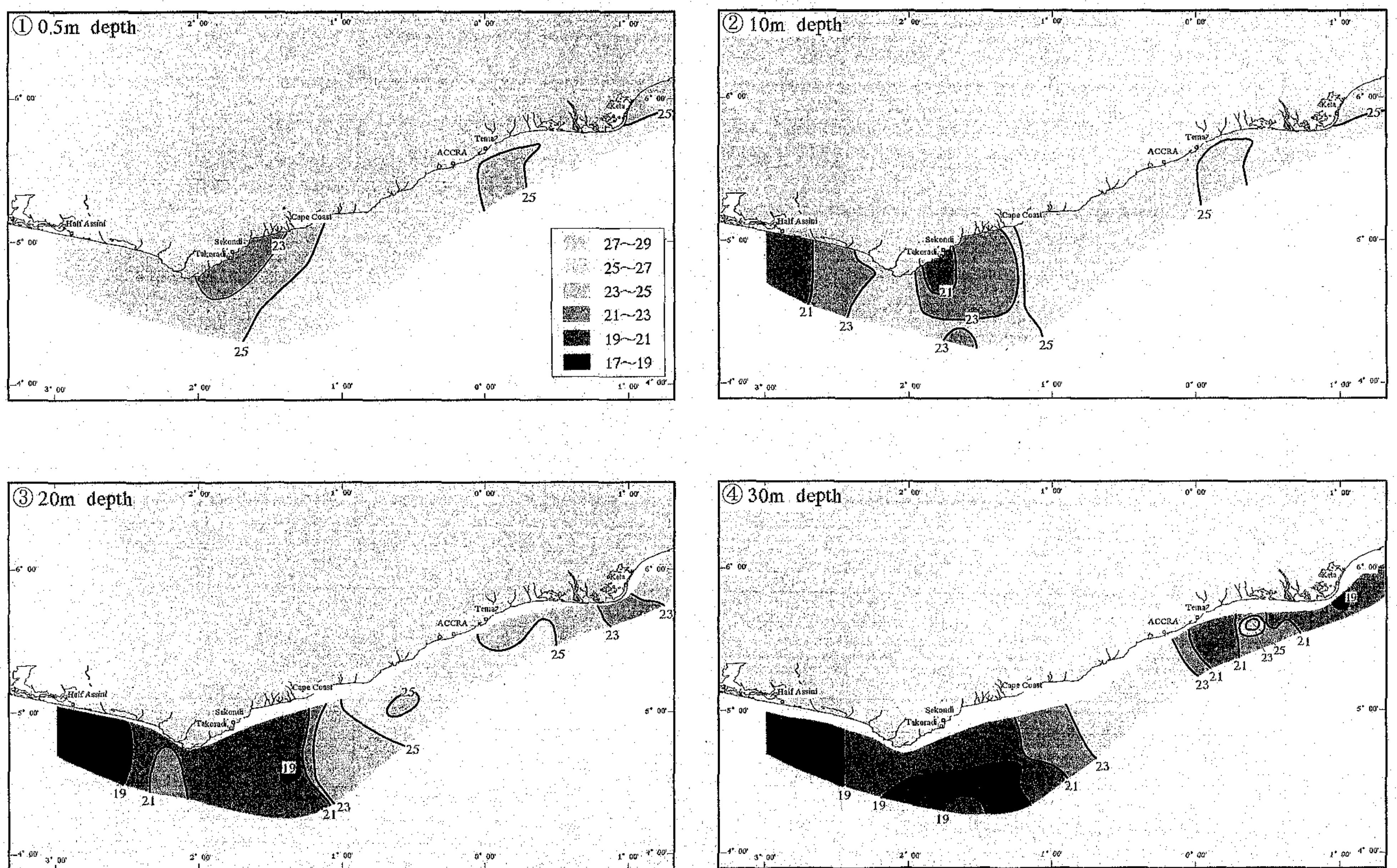


Figure 5-2-1-1 (1) Horizontal distribution of water temperature in the 2nd survey

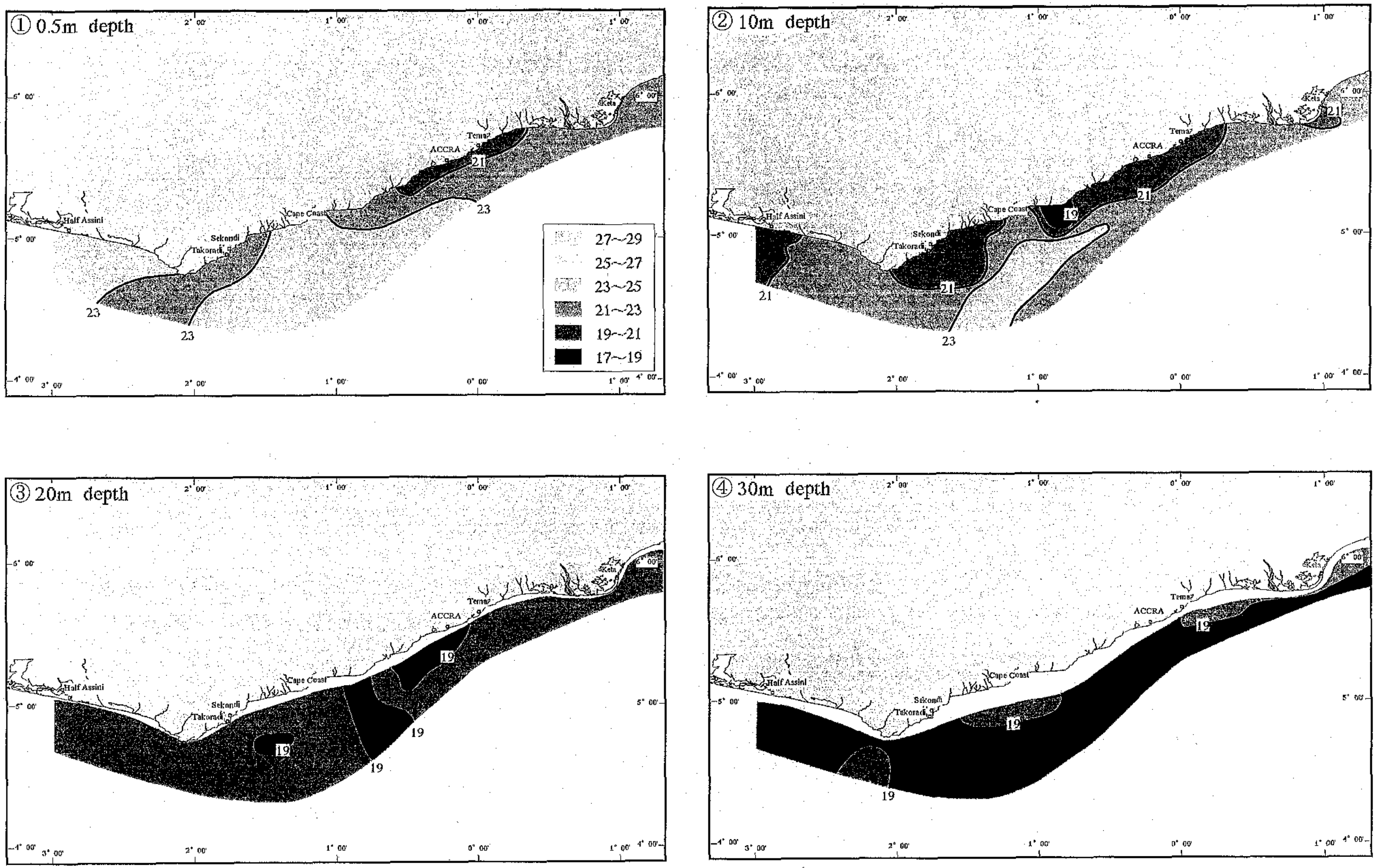


Figure 5-2-1-1 (2) Horizontal distribution of water temperature in the 3rd survey

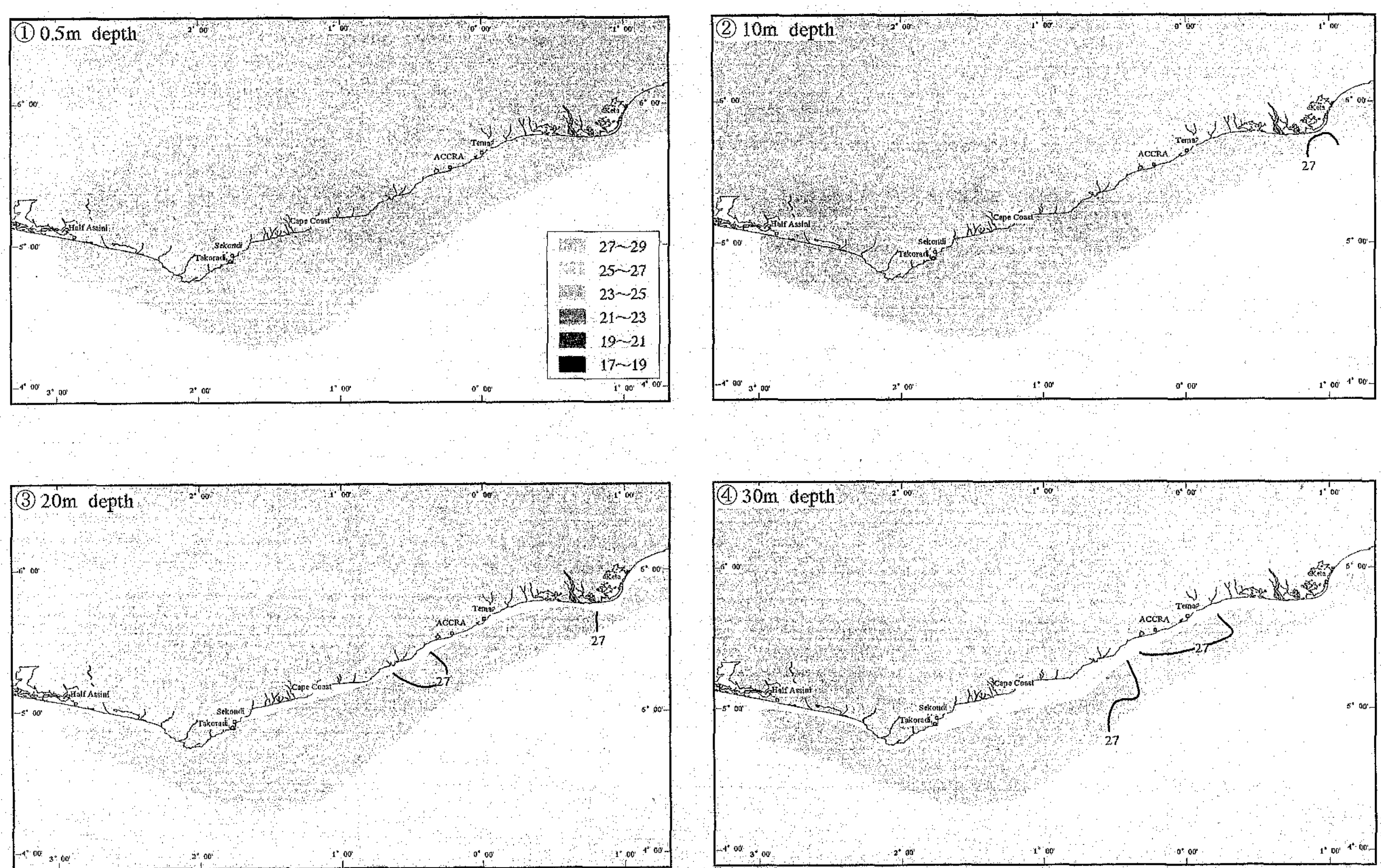


Figure 5-2-1-1 (3) Horizontal distribution of water temperature in the 4th survey

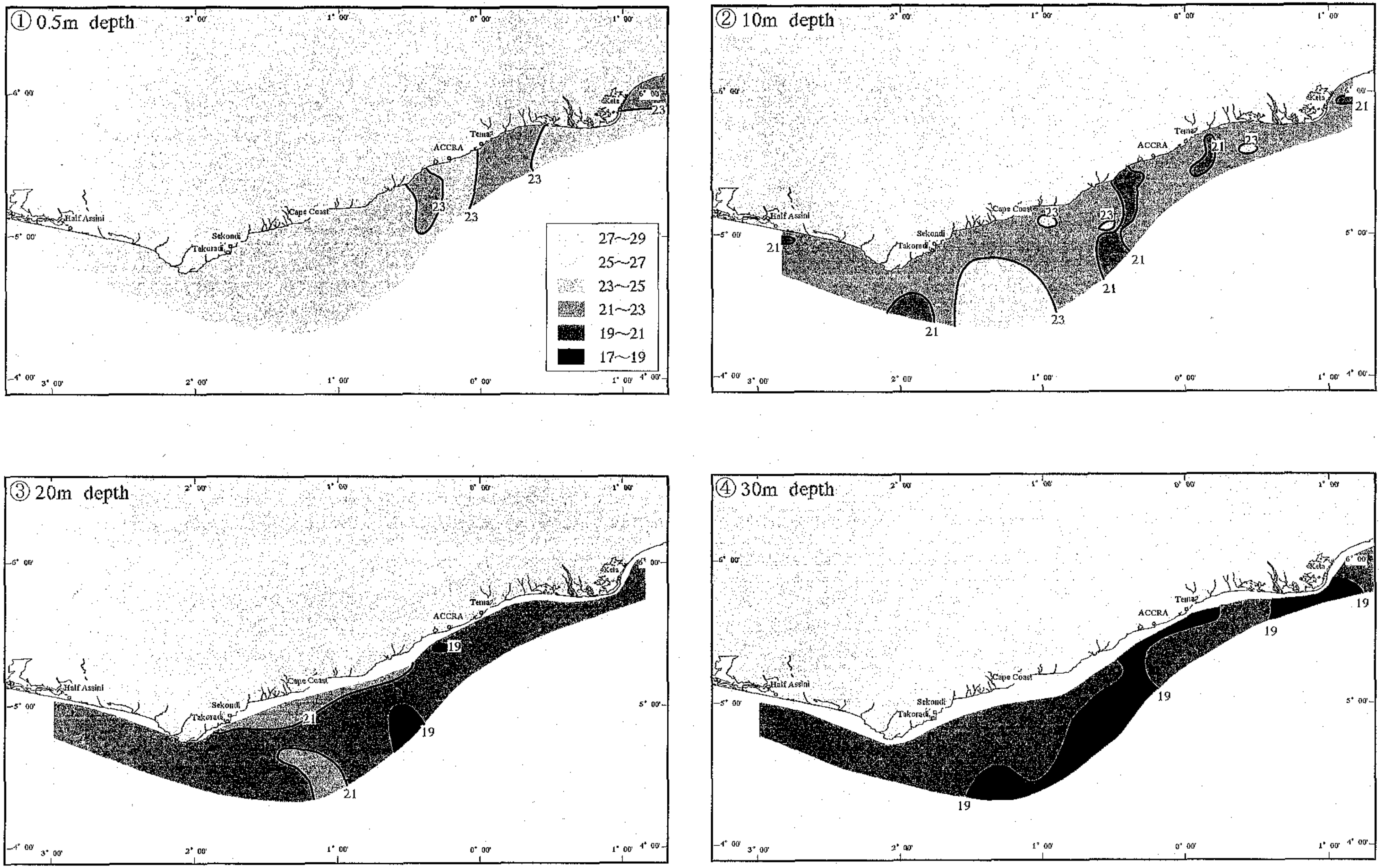


Figure 5-2-1-1 (4) Horizontal distribution of water temperature in the 5th survey