## 2.5 *Environment of the nectobenthic habitat*

### 2.5.1 Oceanic environment near the bottom

In order to understand the habitat of demersal species, the distribution of water temperature and salinity at 1m above the bottom were taken into account Table 2.5 indicates the appearance of water temperature and salinity; Figure 2.15 shows the horizontal distribution of temperatures and salinity; and Figure 2.16 presents the T-S diagram according to the nineteen strata defined for the resources survey. (see Chapter 3, summarized in Figure 2.16).

#### (1) Coastal area (less than 20 m water depth)

Water temperature was within the 15.0–22.4 °C range in the cold season and the 15.7–29.1 °C range in the warm season (Table 2.5). Water temperature increased in the Banc d'Arguin in the cold season, and in the Southern area in the warm season (Figure 2.15). Season-wise, the difference in water temperature between the warm and cold seasons was significant in the Central and Southern areas (Figure 2.16).

Salinity was within the 35.6–39.2 range in the cold season and the 35.5–40.2 range in the warm season (Table 2.5). Regardless of season, salinity was high in the Banc d'Arguin and the Northern coastal area, having been affected no doubt by the highly saline Banc d'Arguin water mass mentioned above (Figure 2.15, 2.16). Salinity was also high in a portion of the Central area.

#### (2) Offshore area (over 20 m water depth)

Water temperature was within the 10.4–16.6°C range in the cold season and the 10.6–27.7°C range in the warm season (Table 2.5). At the 20–30 m stratum, temperature was higher in the Southern area and lower in the Northern area, but at the other strata no significant difference by area was observed (Figure 2.15). Season-wise, the difference in water temperature between warm and cold season tended to increase as depths went shallower, and was very small in the two strata deeper than 80 m water depth (Figure 2.16). Hatanaka (1979) reported water temperature at a bottom layer less than 100 m water depth in fishing grounds off the Cape Blanc was in the 15–19°C range the year round. Comparing those data with the present findings for the 20–30 m and 30–80 m strata in the Northern area, one notices a distribution of water temperatures of 16.9–25.4°C in the warm season (particularly, 17.3–25.4°C in Phase 2 warm season), higher values than the previously published figures.

Salinity was within the 35.3–36.1 range in the cold season and the 35.4–36.6 range in the warm season (Table 2.5). Salinity differences by area were very slight for a given stratum and no trend was observed (Figure 2.15). However, a more significant salinity than that in the Central and Southern areas was recorded in the Northern area, in the layer less than 80 m water depth. This was probably due to the effect of the Banc d'Arguin water mass. Salinity is overall higher in the warm season than in the cold season, a difference that tended to increase as depths become shallow (Figure 2.16). In a given area, salinity is lower in deep strata than in shallow ones, and the salinity difference by depth tended to increase more in the warm season than in the cold season.

## Table 2.5 Synopsis of water temperature and salinity at 1 m above the bottom.

a) Temperature (℃)

| | | Phase 1 | | | | | | Phase 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cold season | | | Warm season | | | Cold season | | | Warm season | | |
| Subarea | Stratum | mean | range | No. | mean | range | No. | mean | range | No. | mean | range | No. |
| North | Banc d'Arguin | 21.1 | (19.2 ~ 22.4) | 12 | 23.8 | (19.8 ~ 25.0) | 19 | 20.0 | (19.8 ~ 20.4) | 4 | 25.1 | (23.5 ~ 26.0) | 15 |
| | 3m – 20m | 19.0 | (17.6 ~ 21.5) | 10 | 20.2 | (15.7 ~ 23.7) | 9 | 17.1 | (15.3 ~ 19.9) | 11 | 21.2 | (18.8 ~ 23.5) | 12 |
| | 20m – 30m | 15.8 | (14.5 ~ 16.3) | 4 | 19.7 | (19.0 ~ 20.7) | 4 | 16.1 | (14.9 ~ 16.6) | 4 | 22.8 | (20.6 ~ 25.4) | 3 |
| | 30m – 80m | 15.4 | (14.6 ~ 16.1) | 8 | 17.6 | (16.9 ~ 18.1) | 5 | 15.3 | (14.0 ~ 16.0) | 8 | 20.5 | (17.3 ~ 23.4) | 9 |
| | 80m – 200m | 13.8 | (13.6 ~ 13.9) | 2 | 15.4 | (15.1 ~ 15.7) | 3 | 14.3 | (13.7 ~ 14.8) | 3 | 16.2 | (14.2 ~ 17.1) | 4 |
| | 200m – 400m | 12.7 | | 1 | 13.1 | (12.9 ~ 13.3) | 3 | | | | 12.5 | (12.1 ~ 12.9) | 2 |
| | 400m – 600m | 10.4 | | 1 | | | | | | | | | |
| Central | 3m – 20m | | | | 26.9 | (24.9 ~ 28.5) | 15 | 17.8 | (15.7 ~ 20.6) | 16 | 28.3 | (27.6 ~ 28.9) | 9 |
| | 20m – 30m | 14.7 | (14.2 ~ 15.4) | 4 | 24.7 | (24.3 ~ 25.2) | 4 | 15.5 | (15.4 ~ 15.6) | 4 | 26.6 | (26.2 ~ 27.1) | 4 |
| | 30m – 80m | 14.2 | (13.6 ~ 15.4) | 12 | 20.1 | (16.0 ~ 24.2) | 12 | 14.6 | (14.2 ~ 15.4) | 11 | 20.0 | (16.4 ~ 22.9) | 10 |
| | 80m – 200m | 13.6 | (12.8 ~ 14.3) | 10 | 15.0 | (14.3 ~ 16.1) | 11 | 14.1 | (13.1 ~ 15.2) | 10 | 14.5 | (14.1 ~ 14.9) | 6 |
| | 200m – 400m | 12.3 | (11.5 ~ 12.9) | 5 | 12.9 | (12.6 ~ 13.4) | 6 | 12.4 | (12.0 ~ 12.6) | 4 | 11.8 | (10.7 ~ 12.5) | 3 |
| | 400m – 600m | | | | 10.6 | | 1 | | | | | | |
| South | 3m – 20m | | | | 28.3 | (27.4 ~ 29.1) | 8 | 16.0 | (15.0 ~ 17.3) | 9 | 28.3 | (27.6 ~ 28.9) | 9 |
| | 20m – 30m | 15.8 | (15.6 ~ 15.9) | 3 | 26.0 | (25.1 ~ 26.8) | 2 | 15.7 | (15.0 ~ 16.4) | 4 | 26.6 | (26.2 ~ 27.1) | 4 |
| | 30m – 80m | 15.4 | (15.2 ~ 15.6) | 9 | 19.4 | (16.6 ~ 26.5) | 10 | 15.4 | (14.5 ~ 16.0) | 11 | 20.0 | (16.4 ~ 22.9) | 10 |
| | 80m – 200m | 14.8 | (13.7 ~ 15.5) | 7 | 14.7 | (14.2 ~ 15.4) | 9 | 14.4 | (13.5 ~ 15.2) | 9 | 14.5 | (14.1 ~ 14.9) | 6 |
| | 200m – 400m | 12.3 | (11.9 ~ 12.8) | 3 | 12.9 | (12.1 ~ 13.6) | 3 | 12.2 | (12.1 ~ 12.4) | 3 | 11.8 | (10.7 ~ 12.5) | 3 |
| | 400m – 600m | | | | | | | | | | | | |
| All | Banc d'Arguin | 21.1 | (19.2 ~ 22.4) | 12 | 23.8 | (19.8 ~ 25.0) | 19 | 20.0 | (19.8 ~ 20.4) | 4 | 25.1 | (23.5 ~ 26.0) | 15 |
| | 3m – 20m | 19.0 | (17.6 ~ 21.5) | 10 | 25.3 | (15.7 ~ 29.1) | 32 | 17.1 | (15.0 ~ 20.6) | 36 | 25.8 | (18.8 ~ 28.9) | 36 |
| | 20m – 30m | 15.4 | (14.2 ~ 16.3) | 11 | 22.9 | (19.0 ~ 26.8) | 10 | 15.8 | (14.9 ~ 16.6) | 12 | 25.4 | (20.6 ~ 27.7) | 11 |
| | 30m – 80m | 14.9 | (13.6 ~ 16.1) | 29 | 19.4 | (16.0 ~ 26.5) | 27 | 15.1 | (14.0 ~ 16.0) | 30 | 19.7 | (16.0 ~ 23.4) | 29 |
| | 80m – 200m | 14.1 | (12.8 ~ 15.5) | 19 | 15.0 | (14.2 ~ 16.1) | 23 | 14.2 | (13.1 ~ 15.2) | 22 | 15.1 | (14.1 ~ 17.1) | 17 |
| | 200m – 400m | 12.3 | (11.5 ~ 12.9) | 9 | 13.0 | (12.1 ~ 13.6) | 12 | 12.3 | (12.0 ~ 12.6) | 7 | 12.4 | (10.7 ~ 12.9) | 9 |
| | 400m – 600m | 10.4 | | 1 | 10.6 | | 1 | | | | | | |

b) Salinity (psu)

| | | Phase 1 | | | | | | Phase 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cold season | | | Warm season | | | Cold season | | | Warm season | | |
| Subarea | Stratum | mean | range | No. | mean | range | No. | mean | range | No. | mean | range | No. |
| North | Banc d'Arguin | 37.8 | (36.0 ~ 39.2) | 12 | 38.2 | (36.1 ~ 39.7) | 19 | 36.3 | (36.3 ~ 36.4) | 4 | 39.1 | (37.8 ~ 40.2) | 15 |
| | 3m – 20m | 36.3 | (35.9 ~ 37.6) | 10 | 36.2 | (35.7 ~ 37.2) | 9 | 36.0 | (35.7 ~ 36.3) | 11 | 36.0 | (35.5 ~ 36.7) | 12 |
| | 20m – 30m | 35.8 | (35.6 ~ 35.9) | 4 | 36.0 | (35.9 ~ 36.0) | 4 | 35.9 | (35.7 ~ 36.1) | 4 | 36.2 | (36.0 ~ 36.6) | 3 |
| | 30m – 80m | 35.8 | (35.6 ~ 35.9) | 8 | 35.9 | (35.8 ~ 35.9) | 5 | 35.8 | (35.7 ~ 36.0) | 8 | 36.0 | (35.9 ~ 36.1) | 9 |
| | 80m – 200m | 35.5 | (35.5 ~ 35.5) | 2 | 35.7 | (35.7 ~ 35.8) | 3 | 35.7 | (35.7 ~ 35.8) | 3 | 35.9 | (35.8 ~ 36.0) | 4 |
| | 200m – 400m | 35.5 | | 1 | 35.6 | (35.6 ~ 35.7) | 3 | | | | 35.7 | (35.7 ~ 35.8) | 2 |
| | 400m – 600m | 35.3 | | 1 | | | | | | | | | |
| Central | 3m – 20m | | | | 36.4 | (36.0 ~ 37.2) | 15 | 36.3 | (35.7 ~ 38.2) | 15 | 36.3 | (36.0 ~ 36.8) | 15 |
| | 20m – 30m | 35.6 | (35.6 ~ 35.6) | 4 | 36.1 | (36.0 ~ 36.1) | 4 | 35.6 | (35.6 ~ 35.7) | 4 | 36.2 | (36.1 ~ 36.2) | 4 |
| | 30m – 80m | 35.6 | (35.5 ~ 35.6) | 12 | 35.9 | (35.6 ~ 36.0) | 12 | 35.6 | (35.6 ~ 35.6) | 11 | 35.9 | (35.8 ~ 35.9) | 10 |
| | 80m – 200m | 35.5 | (35.5 ~ 35.6) | 10 | 35.7 | (35.6 ~ 35.8) | 11 | 35.6 | (35.6 ~ 35.6) | 10 | 35.7 | (35.7 ~ 35.9) | 7 |
| | 200m – 400m | 35.5 | (35.4 ~ 35.5) | 5 | 35.6 | (35.5 ~ 35.6) | 6 | 35.6 | (35.5 ~ 35.6) | 4 | 35.7 | (35.6 ~ 35.7) | 4 |
| | 400m – 600m | | | | 35.4 | | 1 | | | | | | |
| South | 3m – 20m | | | | 35.9 | (35.7 ~ 36.0) | 8 | 35.7 | (35.6 ~ 36.1) | 9 | 35.7 | (35.5 ~ 35.9) | 9 |
| | 20m – 30m | 35.6 | (35.6 ~ 35.6) | 3 | 36.0 | (36.0 ~ 36.0) | 2 | 35.6 | (35.6 ~ 35.7) | 4 | 35.9 | (35.8 ~ 36.0) | 4 |
| | 30m – 80m | 35.6 | (35.6 ~ 35.6) | 9 | 35.8 | (35.5 ~ 36.0) | 10 | 35.6 | (35.5 ~ 35.7) | 11 | 35.9 | (35.7 ~ 35.9) | 10 |
| | 80m – 200m | 35.6 | (35.5 ~ 35.6) | 7 | 35.6 | (35.6 ~ 35.7) | 9 | 35.6 | (35.5 ~ 35.6) | 9 | 35.7 | (35.7 ~ 35.7) | 6 |
| | 200m – 400m | 35.5 | (35.5 ~ 35.5) | 3 | 35.5 | (35.5 ~ 35.6) | 3 | 35.6 | (35.6 ~ 35.6) | 3 | 35.6 | (35.5 ~ 35.7) | 3 |
| | 400m – 600m | | | | | | | | | | | | |
| All | Banc d'Arguin | 37.8 | (36.0 ~ 39.2) | 12 | 38.2 | (36.1 ~ 39.7) | 19 | 36.3 | (36.3 ~ 36.4) | 4 | 39.1 | (37.8 ~ 40.2) | 15 |
| | 3m – 20m | 36.3 | (35.9 ~ 37.6) | 10 | 36.2 | (35.7 ~ 37.2) | 32 | 36.1 | (35.6 ~ 38.2) | 35 | 36.1 | (35.5 ~ 36.8) | 36 |
| | 20m – 30m | 35.7 | (35.6 ~ 35.9) | 11 | 36.0 | (35.9 ~ 36.1) | 10 | 35.7 | (35.6 ~ 36.1) | 12 | 36.1 | (35.8 ~ 36.6) | 11 |
| | 30m – 80m | 35.6 | (35.5 ~ 35.9) | 29 | 35.9 | (35.5 ~ 36.0) | 27 | 35.7 | (35.5 ~ 36.0) | 30 | 35.9 | (35.7 ~ 36.1) | 29 |
| | 80m – 200m | 35.6 | (35.5 ~ 35.6) | 19 | 35.7 | (35.6 ~ 35.8) | 23 | 35.6 | (35.5 ~ 35.8) | 22 | 35.8 | (35.7 ~ 36.0) | 17 |
| | 200m – 400m | 35.5 | (35.4 ~ 35.5) | 9 | 35.6 | (35.5 ~ 35.7) | 12 | 35.6 | (35.5 ~ 35.6) | 7 | 35.7 | (35.5 ~ 35.8) | 9 |
| | 400m – 600m | 35.3 | | 1 | 35.4 | | 1 | | | | | | |

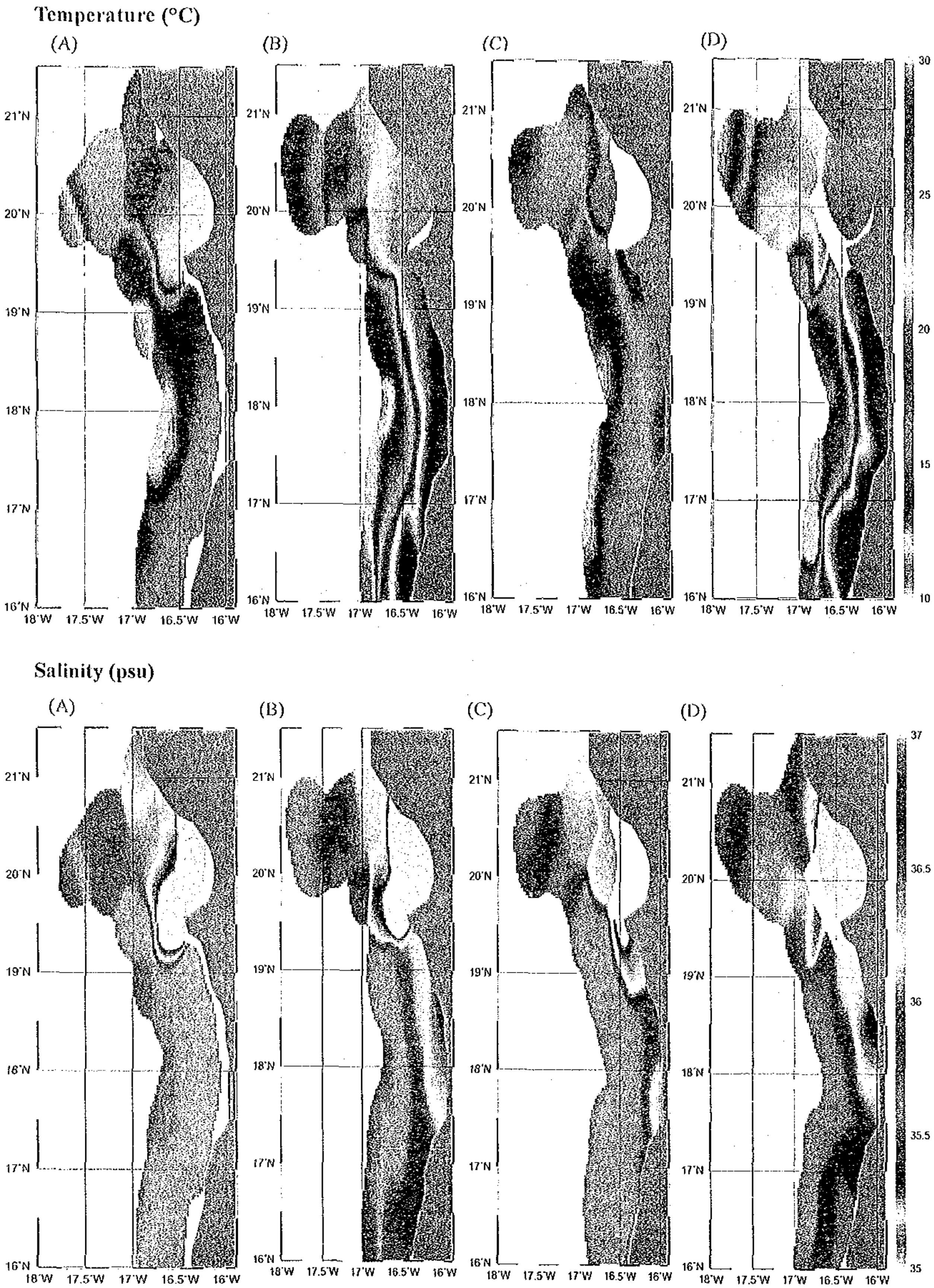



**Figure 2.15 Horizontal distribution of water temperature and salinity at 1 m above the bottom.**
(A) Phase 1 cold season; (B) Phase 1 warm season; (C) Phase 2 cold season; (D) Phase 2 warm season.

It is as follows when the bottom layer environment of the survey area is summarised from a view point of water temperature and salinity as a parameter. Overall, the deeper the waters the lower the water temperature. It is thought the situation changes outside the vertical boundary of 80 m and the horizontal limit of 19° N latitude. In other words, the seasonal variation of the environmenti is significant at the bottom layer less than 80 m water depth, as the water is affected by the Banc d'Arguin water mass and by upwellings. In deeper waters seasonal variations are not so important. Also, north of 19° N, seasonal variations are slight because the area is affected by the cold Canary Current the year round, while in the south, seasonal variations are significant as they are influenced by the Canary Current, by the Guinea Current and by the mixture of those two currents.

- **Summary of the nineteen strata defined for the resources survey**

| Division by latitude / Division by water depth | | North of 19°15' N | 19°15'–17°39' N | South of 17°39' N |
|---|---|---|---|---|
| | | Northern area | Central area | Southern area |
| 3- 20 m | Coastal area | Banc d'Arguin<br>3−20m stratum | 3−20m stratum | 3−20m stratum |
| 20−30m | Offshore area | 20−30m stratum | 20−30m stratum | 20−30m stratum |
| 30−80m | | 30−80m stratum | 30−80m stratum | 30−80m stratum |
| 80−200m | | 80−200m stratum | 80−200m stratum | 80−200m stratum |
| 200−400m | | 200−400m stratum | 200−400m stratum | 200−400m stratum |
| 400−600m | | 400−600m stratum | 400−600m stratum | 400−600m stratum |

1) Coastal area

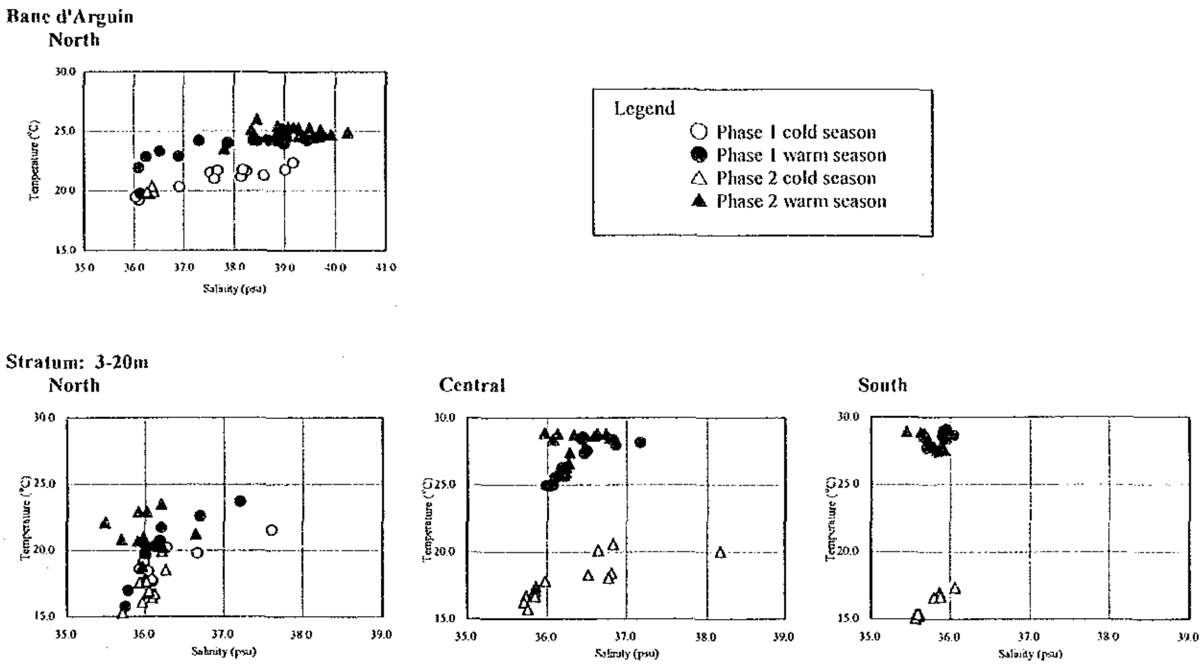


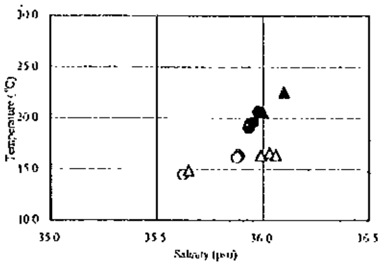

**Figure 2.16 T-S diagram by stratum at 1 m above the bottom.**

## Figure 2.16 continued

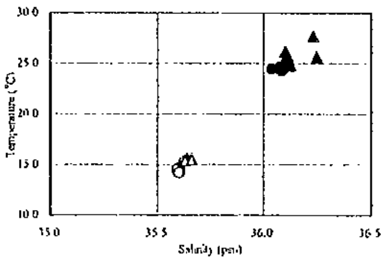
2) Offshore area

**Stratum: 20-30m**

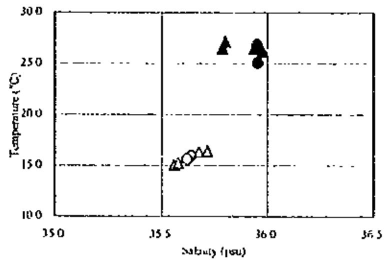
**North**




**Central**

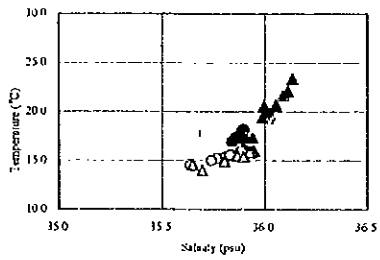



**South**

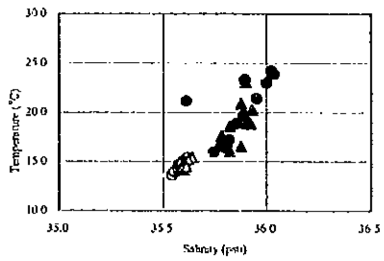



**Stratum: 30-80m**

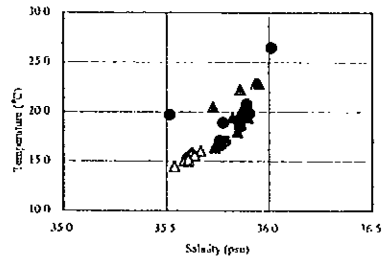
**North**




**Central**

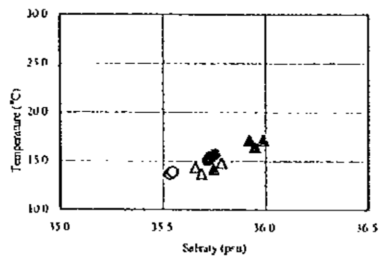



**South**

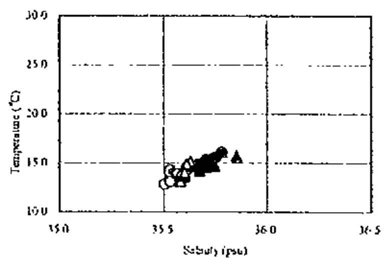



**Stratum: 80-200m**

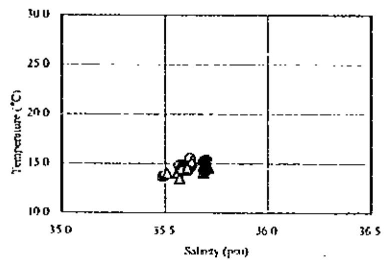
**North**




**Central**

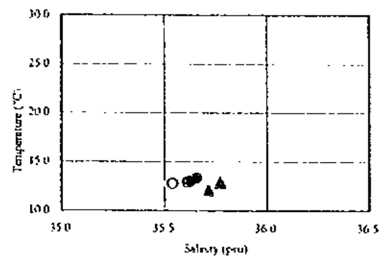



**South**

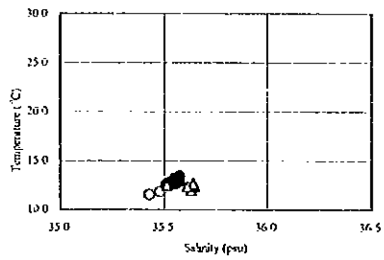



**Stratum: 200-400m**

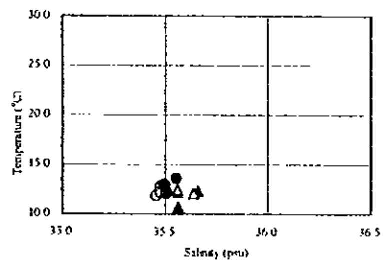
**North**




**Central**




**South**

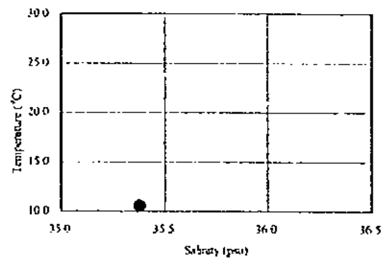



**Stratum: 400-600m**

**North**

No observation

**Central**




**South**

No observation

○ Phase 1 cold season
● Phase 1 warm season
△ Phase 2 cold season
▲ Phase 2 warm season

### 2.5.2 Oceanic environment and nectobenthos

The oceanic environment can be taken into account by the influence it exerts on nectobenthic resources -- that is, on their distribution and species structure, on the life history of their main species, etc. For instance, it is known that many species move along isobaths, or they cross the isobaths depending on seasonal environmental variations.

However, the results of the present observation correspond to only four seasons, which is insufficient for an overall analysis of their influence. Also, the environmental parameters observed this time were limited to a portion of the habitat environment. Other factors restrict the nectobenthic habitat, such as the biological environment (the existence or absence of seaweed, the feeding environment, etc.), the sedimentary environment, the undersea topography, etc., whose influence brings complexity to the situation.

This observation allowed to confirm the existence of significant seasonal differences for oceanic structure in water column less than 80 m water depth, particularly in the Central and Southern areas. Also, taking into consideration the nectobenthic fauna indicated in Chapter 3, some evident differences in the fauna between the cold and warm seasons were confirmed. As mentioned above, data are still insufficient to inform whether that is directly related to water temperature, and because of time constraints a proper analysis was not conducted. It is, however, a question to be studied in the future.

The oceanic environment, which includes not only the bottom layer but also the other layers up to the surface, does exert some influence on the nectobenthos living next to the bottom. In particular, the species with planktonic life at their larval stage are strongly affected. One of the characteristics of the oceanic environment in the survey area is the existence of upwellings. Nasu (1974) considers that the survival in early life of fishes that spawn in the upwelling area is subjected to the influence of annual variations of the upwelling phenomenon itself – a cause for the variation of recruitment of species that are targeted by fisheries. Faure *et al.* (2000) suggested the importance of retention process in upwelling areas for recruitment of octopus.

Upwellings bring abundant nutrient salts into the euphotic zone, allowing for the reproduction of great volumes of phytoplankton, which gradually shifted to the higher trophic level; as its productivity increases, so do the fish resources (Marumo, 1974). A factual report on the IRM areas (Hatanaka, 1979) indicates the area has a very high density of nutrient salts because of the upwellings, where the basic production capacity reaches 10 mg/ℓ for the density of chlorophyll-a. This value is considered the maximum density, except in case of an abnormal situation such as red tide. There is also a negative side to the upwelling area, which is the low reproductive rate of phytoplankton due to low temperature and the respiratory impediment due to hypoxia. In general, the number of animal species and their trophic level are low in coastal upwelling areas, where the food chain is relatively simple (Marumo, 1974).

The upwelling phenomenon was also confirmed in the present observation, but the analysis of the characteristics of the nectobenthos in the upwelling area was not done by lack of time. Nasu (1974) recognizes a clear correspondence between the upwelling area and the formation of fishing grounds, but also says a limited time survey does not allow to always identify such a correspondence. According to him, there is a slight lag between the upwelling phenomenon and the biological phenomena (formation of fishing grounds), the length of which doubtlessly varies according to the species habitat, trophic level and feed species, etc. The author suggests further the necessity of the ecological clarification of the target species.

## 2.6 Questions for future resolution

Many statistical case studies are needed to clarify the oceanic environment and its biological phenomena. For many years, there has been much discussion on the relationship between climactic variations and the variations in fishery resources over a 10-year scale (see, for instance, Marchhall & Yochanan, 1997; Cushing, 1982 ; etc.). The present observation, conducted twice in the cold season and twice in the warm season, allowed for the collection of data on the oceanographic structure, the oceanic environment and the nectobenthos living there at the moment of the Sea-borne survey. In the future, the collection and analysis of oceanographical observation data over longer periods will be useful for resource management. That is why monitoring of the oceanographic environment is necessary. Figure 2.17 presents a proposal for a system of oceanographical observation including long-term objectives, taking into account the current situation in Japan for example.

The objectives of oceanographical environment monitoring are: (1) to accumulate data on the oceanic environment continuously, to analyze oceanographical variations over medium-length and long periods, and to contribute for instance to clarify the environment of the habitat of aquatic life; and (2) to supply useful information for the fisheries sector.

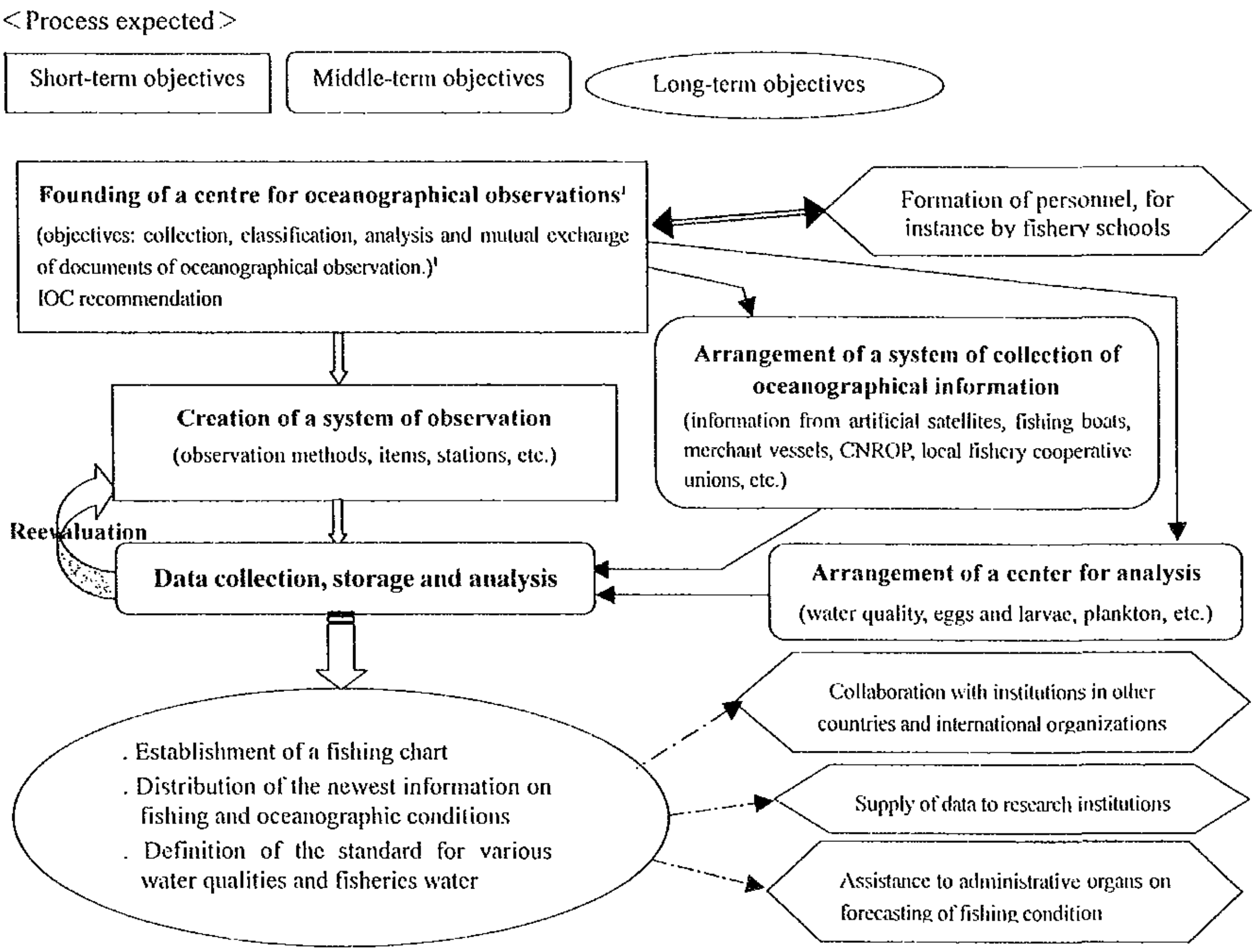



**Figure 2.17 Proposal for a system of oceanographic observation.**

In the current system in the IRM, continuous oceanographical observations of the Northern coastal area are being regularly conducted by the CNROP. However, for the dissemination of information to the fisheries sector, the installation of a communication network is indispensable, and given the situation of the country, a very long perspective for its realization should be adopted.

As an example of concrete orientation for the future, it is desirable to expand the present observation network of CNROP and to ensure the monitoring of oceanographical environment over the entire area of about 30 miles off the coast of the EEZ in the IRM. The initial observation system would consist in definite transects from east to west every 30' in latitude with a observation station every 10' in longitude, a deploying density of observation stations inferior to that utilized in the present observation. In addition to water temperature and salinity measuring with a water thermometer and a salinometer, water samples could be taken at several stations, and temperature and current of surface layer recorded during navigation. Of course, vessel navigation could be combined to other projects, at any rate a week-long navigation should be expected for this observation alone. Instead of increasing the number of observations per navigation, it would be more important to continue conducting observations four times a year on average. Also, CNROP researchers staying in the main villages or camps along the coast could routinely measure water temperature. At the same time, if that is done with taking account the relation between the oceanic environment and the demersal resources, it will be necessary to elucidate the ecology and life cycle of target species, particularly during their planktonic life stage.

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**Appendix Table 2.1 List of specifications of measuring instruments for oceanographic observation.**

(a) Water temperature and salinity

(*STD: Salinity, Temperature, Depth*)

| | |
|---|---|
| maker / name of instrument | Alec Electronics Co., Ltd. : AST-2016-P |
| Temperature measuring capacity (precision) | -5 to 40°C (±0.01°C) |
| Salinity measuring capacity (precision) | 0-40 (±0.01) |
| Measuring interval (precision) | 1 m (±0.1%) |

(Water quality checker)

| | |
|---|---|
| maker / name of instrument | Horiba, Ltd. : U-10 |
| Temperature measuring capacity (precision) | 0 to 50 °C (±0.1 °C) |
| Salinity measuring capacity (precision) | 0-40 (±0.1) |

Water temperature of surface layer (digital water thermometer, installed on the *Al-Awam*)

| | |
|---|---|
| maker / name of instrument | Murayama Denki, Ltd. : DT-3110 |
| Temperature measuring capacity (precision) | -6 to 36 °C |

(b) Current conditions (Color Doppler Current Profiler: *Al-Awam*)

| | |
|---|---|
| maker / name of instrument | Furuno Electric Co., Ltd. : CI-30 |
| Measuring depth | 75% of the water depth (70% corresponds to 80 m) and 2 to 200 m depth, but depth over 15 m |
| Current speed measuring capacity (precision) | 0.0-5.0 knots (±(2% of vessel speed + 0.2 knot)) |
| Current direction measuring capacity (precision) | 360° (±3.5°) |
| Frequency of emission | 130 kHz |

(c) pH-meter

| | |
|---|---|
| maker / name of instrument | TOA Denpa Kogyo Co., Ltd. (now TOA DKK) : WQC-20A |

(d) Wind vane and anemometer

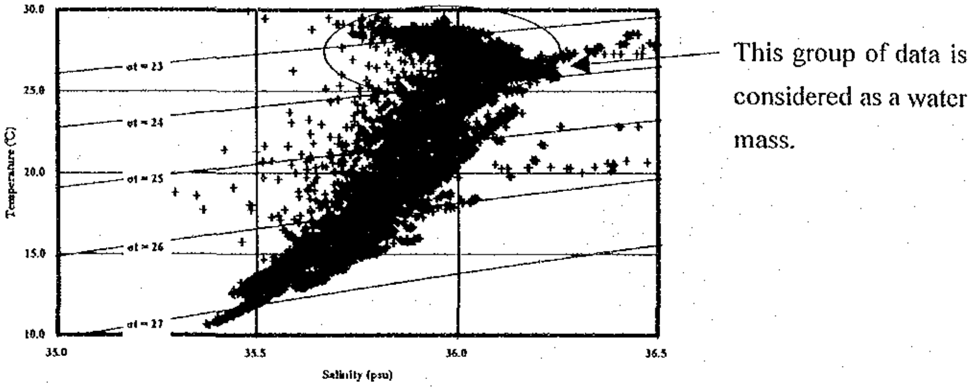
| | |
|---|---|
| maker / name of instrument | Koshin Denki Kogyo Co., Ltd. : FV-301 |
| Wind speed measuring capacity (precision) | 2–90 m/s (±0,5 m/s) for wind speed of less than 10 m, less than 5% for wind speed over 10 m) |
| Wind direction measuring capacity (precision) | 360° (±5°) |

(e) Global Positioning System (GPS)

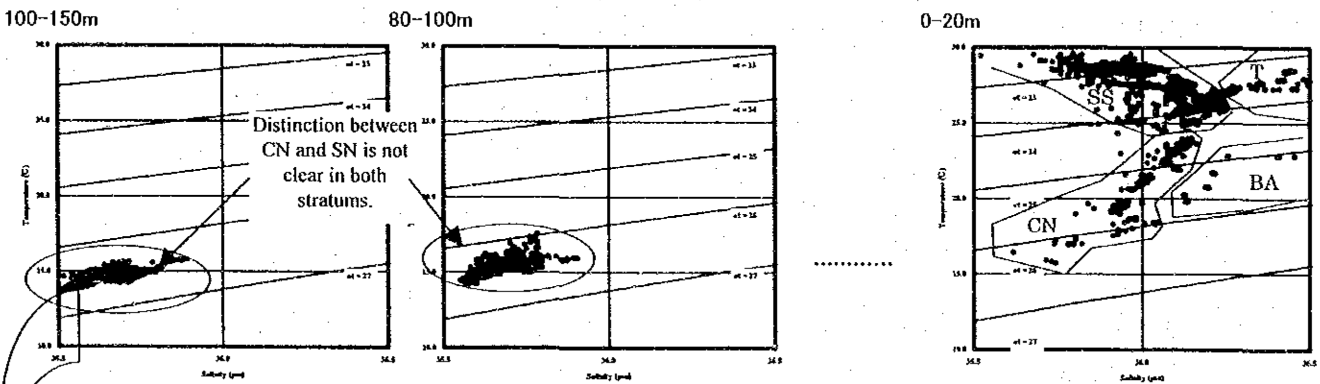
| | |
|---|---|
| maker / name of instrument | Japan Radio Co., Ltd.: JLU-128J |
| Measuring precision | Less than 15 m |

## ANNEX 2. METHOD OF WATER MASS IDENTIFICATION BASED ON T-S DIAGRAM.

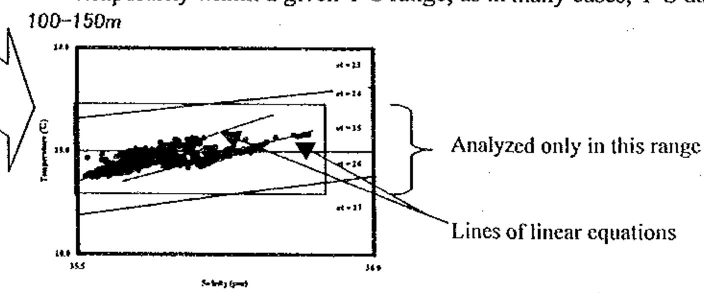
1. T-S diagram is drawn by using all the data of water tempetature and salinity observed from each survey. When a group of data is apparently distinguishable from other ones, it is considered as one water mass.




2. In the same manner, T-S diagram is drawn by specific stratum, and the data group, which seems T-S characters change continuously, is considered as one water mass.




If distinction between those data groups is not clear as below figure, two lines of linear equations are assumed temporarily within a given T-S range, as in many cases, T-S data within a same water mass is distributed linearly.




Each T-S data is divided between one linear group and another by its nearness to the lines of linear equations, and these two groups are considered as water masses respectively.

3. The geographical and horizontal distribution of those water masses identified by following abovementioned procedures is examined. When the distribution is questionable, e.g. a given water mass is separately distributed south and north or inshore and offshore, water mass identification is retouched by returning to the procedure of 2.

4. Identified water masses are compared and contrasted with those of existing reports, if possible, and a validity of its identification should be certified.

# 3. RESOURCES SURVEY BY BOTTOM TRAWL

## 3.1 Summary of the survey

### 3.1.1 Objectives

The first objective of this survey was to estimate the stock size[1] of demersal species occurring in the EEZ of the IRM. The second objective was to collect as much scientific and technical information possible concerning resources, including their interaction with the ecosystem.

Therefore, the present survey comprises two parts: a resources survey (including a comparative experiment of fishing efficiency between the two reseach vessels described below) and a biological survey.

### 3.1.2 Survey area

The survey area was defined on the continental shelf and the continental slope in water depths between 3 m and 600 m within the EEZ of the IRM, shown in Figure 3.1. That map was drawn based on the following marine charts:

- Defence Mapping Agency, 1996: 51460, Cape Blanc to Nouakchott.
- National Imagery and Mapping Agency, 1996: 51440, Punta Durnford to Cape Blanc.
- National Imagency and Mapping Agency, 1997: 51480, Coasts of Southern Mauritania and Northern Senegal.
- ORSTOM and CNROP, 1985: Carte sédimentologique du plateau continental mauritanien, à l'échelle de 1:200,000. Nouakchott.
- ORSTOM and CNROP, 1985: Carte sédimentologique du plateau continental mauritanien, à l'échelle 1:200,000. Nouadhibou.

The survey area covers about 40,000 km$^2$.

[1] Stock size of the target species means the total biomass in the entire area of its distribution. In the case of a given area, it is necessary to mention standing stock or migrating stock. This report makes no such distinction, and only the word "stock size" is employed. It should be understood that, for transboundary, straddling, or migratory species occurring within and outside the EEZ of the IRM, their total biomass obtained in this survey are in fact "standing stock".

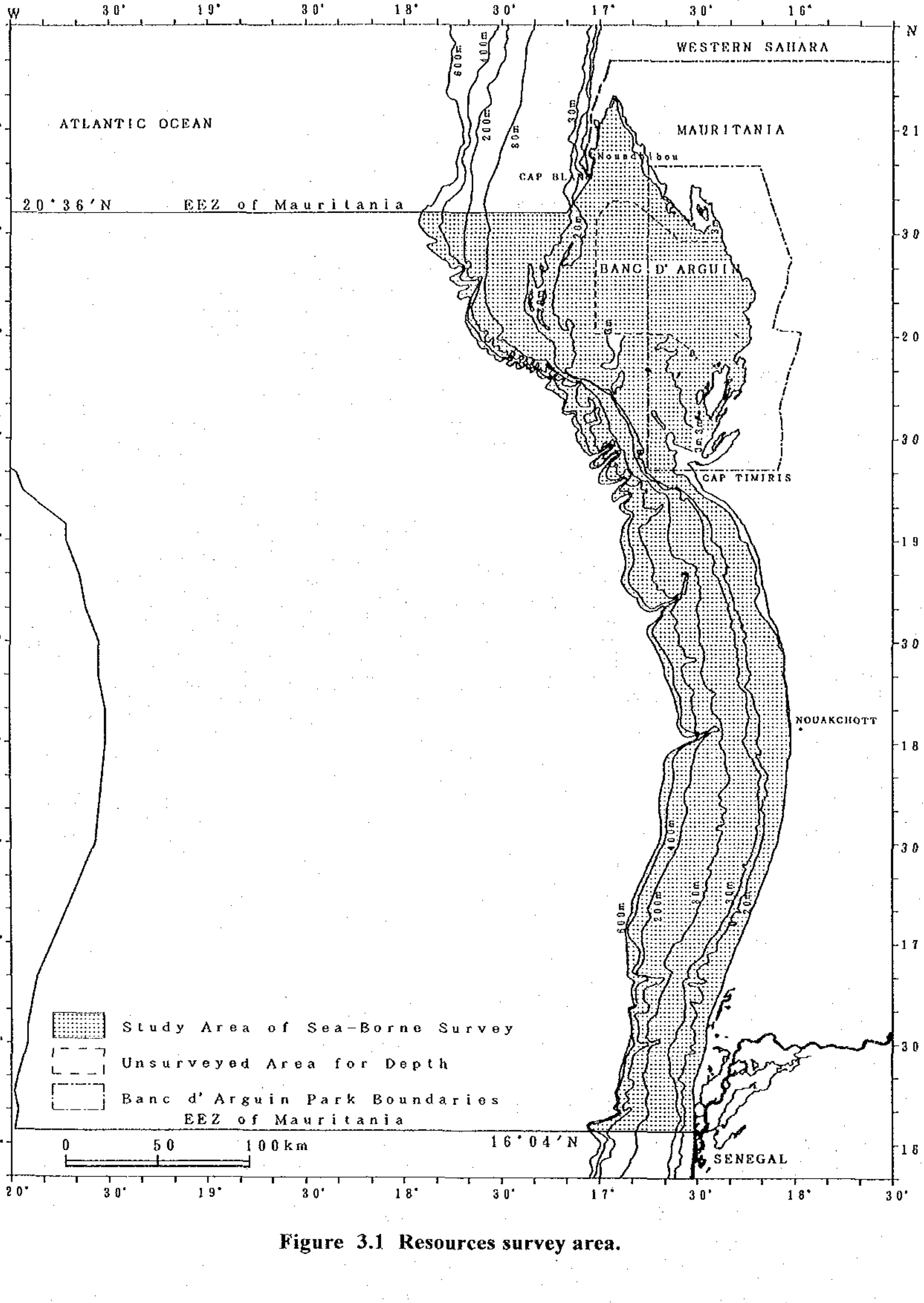



**Figure 3.1 Resources survey area.**

### 3.1.3 Period and duration of survey

The survey was conducted in two Phases, Phase 1 in 2000 and Phase 2 in 2001. In each Phase, two survey periods were defined, one in the cold season (March to May) and the other in the warm season (September and October). Table 3.1 shows the period of the two research vessels (see 3.1.4).

**Table 3.1 Period and duration of survey.**

| Survey season | Survey year | Research vessels | |
|---|---|---|---|
| | | *Al-Awam* | *Amrigue* |
| Phase 1 | | | |
| Cold season | 2000 | 1st leg: March 28-April 07<br>2nd leg: April 09-April 20<br>3rd leg: April 26-April 27<br>4th leg: May 04-May 06 | 1st leg: May 01-May 06<br>2nd leg: May 10-May 13 |
| | | (Comparative experiment of fishing efficiency between 2 vessels) May 08-May 09 | |
| Warm season | 2000 | 1st leg: Sept.05-Sept.13<br>2nd leg: Sept.15-Sept.26<br>3rd leg: Sept.29-Oct.09 | 1st leg: Oct.13-Oct .17<br>2nd leg: Oct.19-Oct .22 |
| Phase 2 | | | |
| Cold season | 2001 | 1st leg: April 05-April 15<br>2nd leg: April 17-April 28<br>3rd leg: April 30-May 09 | 1st leg: April 30-May 08<br>2nd leg: May 12-May 15 |
| Warm season | 2001 | 1st leg: Sept.05-Sept. 15<br>2nd leg: Sept. 17-Sept.26<br>3rd leg: Sept. 28-Oct. 08 | 1st leg: Oct. 11-Oct. 13<br>2nd leg: Oct. 21-Oct. 25 |

### 3.1.4 Research vessels

The two research vessels were the *Al-Awam* and the *Amrigue*, belonging to the CNROP, an organ under the MPEM. Their mooring port is NDB, where the CNROP is located. Table 3.2 presents main dimensions and specifications of those vessels.

**Table 3.2 Main dimensions and specifications of the research vessels.**

| Principal particulars | Research vessels | |
|---|---|---|
| | *Al-Awam* | *Amrigue* |
| Type | Steel-made research vessel for offshore area | Aluminum alloy catamaran research vessel for coastal area |
| Lpp[1] | 30.50m | 14.50m |
| Beam | 7.80m | 7.40m |
| Depth moulded | 3.30m | 2.90m |
| Designed l.l.[2] | 2.85m | 1.30m |
| International G.T.[3] | 301t | 62t |
| Main engine | 1,000ps×1,000rpm | (245ps×2,000rpm)×2 |
| Complement | 30 | 8 |

[1]Lpp: length between perpendiculars, [2]l.l.:load water line, [3]G.T.:gross tonnage.

### 3.1.5 Fishing gear used

The trawl gear utilized for the resources survey – otter trawl of the *Al-Awam* for operations over the continental shelf, and beam trawl of the *Amrigue* – were made in Japan in 1997 by JICA for the IRM simultaneously with those vessels.

The *Al-Awam* utilized a bottom trawl net with a 47 m-long ground rope and a 40 m-long head rope, with a cod end of mesh size 45 mm (see Appendix Figure 3.1.1). The *Amrigue* utilized a beam trawl net with a 5 m-long beam, a 15 m-long sinker line and a 12.45 m-long float line, with a cod end of mesh size 20 mm (see Appendix Figure 3.1.2). During the Phase 2 cold season, a 70 mm cod end was employed in all trawl stations. Also, in the warm season, 70 mm and 100 mm cod ends were used alternately according to circumstances.

The cod end of the bottom trawl net was covered with a covernet of mesh size 20 mm specially prepared for the present survey. Its goal was to standardize the catch data from both vessels and to allow for the estimation of quantities and sizes of juveniles and small individuals that pass through the cod end.

### 3.1.6 Target species

At first, the target species for the resources survey were all those captured by trawl net. However, only the 22 species presented in Table 3.3 were subjected to stock size estimation and biological survey. Also, commercially important species caught in great numbers outside these 22 species were also considered in the survey.

**Table 3.3 Target species.**

| Classification | Family | Species | English name |
|---|---|---|---|
| Fishes | Triakidae | *Mustelus mustelus* | Smooth-hound |
| | Merlucciidae | *Merluccius senegalensis* | Senegalese hake |
| | Zeidae | *Zeus faber* | John dory |
| | Serranidae | *Epinephelus aeneus* | White grouper |
| | Sciaenidae | *Argyrosomus regius* | Meagre |
| | Mullidae | *Pseudupeneus prayensis* | West African goatfish |
| | Sparidae | *Pagrus caeruleostictus* | Bluespotted seabream |
| | | *Dentex angolensis* | Angola dentex |
| | | *Dentex canariensis* | Canary dentex |
| | | *Pagellus bellottii* | Red pandora |
| | Mugilidae | *Mugil capurrii* | Narrowhead grey mullet |
| | | *Mugil cephalus* | Flathead mullet |
| | | *Liza aurata* | Golden grey mullet |
| | Soleidae | *Solea senegalensis* | Senegalese sole |
| Cephalopoda | Loliginidae | *Loligo vulgaris* | European squid |
| | Sepiidae | *Sepia officinalis* | Common cuttlefish |
| | Octopodidae | *Octopus vulgaris* | Common octopus |
| Crustacea | Penaeidae | *Penaeus notialis* | Southern pink shrimp |
| | | *Parapenaeus longirostris* | Deep-water pink shrimp |
| | Palinuridae | *Palinurus mauritanicus* | Pink spiny lobster |
| | | *Panulirus regius* | Green spiny lobster |
| | Geryonidae | *Chaceon (Geryon) maritae* | West African geryon |

The Cunene horse mackerel *Trachurus trecae* was captured in great quantities in the Phase 1 cold season survey and was added to the list of target species only for the biological survey in the following seasons.

### 3.1.7 On-board researchers and reseach vessel crews

On-board researchers and research vessel crews were the following:

**(1) *Al-Awam***

**1) Researchers**

CNROP: Cheikh Abdallahi Ould Inejih
Wague Abdoulaye
Ebaya Ould Sidina
Moustapha Ould Bouzouma
Moustapha Ould Telmidi
Bambaye Ould Hamady
Ahmedou Ould Moustapha
Diop Cheikh Tidjane
N'diaye Abdoulaye
Lam Mamadou
Harouna Tounkara
Sall Mamadou
Beyah Ould Meissa
M'bodj Oumar
Cheikh Baye Ould Isselmou
Ball Abou Cire
Diallo Ibra
Tall Oumar Samba

JICA: Osamu Arakawa (STM)
Tetsuro Fujino (STM)
Katsushi Yoshikawa (STM)
Kenji Okamura (OAFIC)

**2) Crews**

Capitain: Baba Ahmed Ould Cheikh
Seamen: 13-14 persons

**(2) *Amrigue***

**1)Researchers**

CNROP: Moustapha Ould Bouzouma
Diallo Ibra
Diop Cheikh Tidjane
Ball Abou Cire

JICA: Tetsuro Fujino (STM)
Kenji Okamura (OAFIC)
Osamu Arakawa (STM)
Katushi Yoshikawa (STM)

**2) Crews**

Capitain: Mohamed Abdallahi Ould Sidi El Had
Seamen: 5 personnes

## 3.2 Methodology

### 3.2.1 Resources survey

Trawl stations were determined by the stratified random sampling method. Stock size was estimated through the area-swept method.

The survey area was divided into 1,341 square blocks of 3 minutes in latitude and longitude. Those blocks were the sampling units to be selected as trawl stations (Figure 3.2).

The survey area was also divided in three subareas – Northern, Central and Southern. Each subarea was stratified into six strata through seven isobaths (3, 20, 30, 80, 200, 400 and 600 m). Also, the 3-20 m stratum of the Northern area was divided between the National Park of Banc d'Arguin area (hereafter referred to as the Banc d'Arguin) and the other. The survey area was thus stratified into a total of 19 strata. The 3–20 m strata (four in total, including the Banc d'Arguin) were called "coastal area", while the 20–600 m strata (fifteen in total) were designated "offshore area". The above-mentioned blocks were defined within those strata. However, there were some blocks, especially in the steep slope, which contained many isobaths within their own area. These blocks with a complex definition of stratification (eleven in the Northern area) were eliminated from the survey (Figure 3.3).

For each survey period, the planned number of trawl stations were 90 in the coastal area and 100 in the offshore area. At each of the four strata in the coastal area and fifteen in the offshore area, the number of trawl stations was allocated in proportion to the area of these 19 strata, ensuring anyway that there should be at least three trawl stations per stratum (Table 3.4).

The position of the trawl stations for each survey period was defined by the random sampling method (Figure 3.4). At first, plans were to operate the *Amrigue* in the coastal area and the *Al-Awam* in the offshore area. However, after Phase 1 cold season survey, a reconsideration of the navigational and fishing capabilities and the livability of the *Amrigue* was conducted. As a consequence, the *Amrigue* was thereafter confined to the Northern coastal area near the mooring site of NDB, while Central and Southern coastal areas were surveyed by the *Al-Awam*. In addition, after the Phase 2 cold season survey, in the interest of examining the possibility of estimating stock size of the entire survey area with the *Al-Awam*, this vessel was also operated in the Northern coastal area, within its capabilities. Both vessels were operated in daytime and trawled for thirty minutes at the speed of 3 knots.

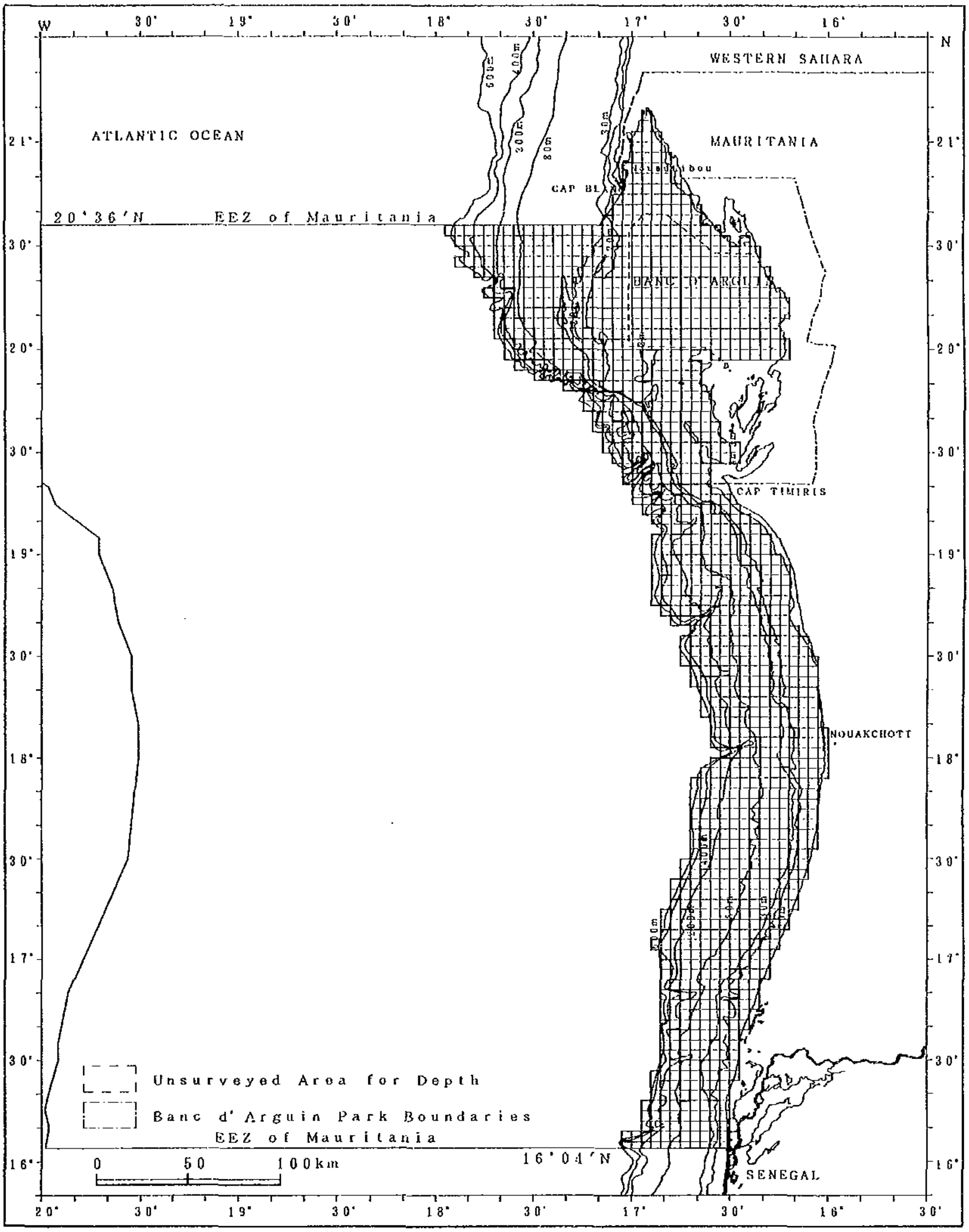



**Figure 3.2 Trawl blocks (sampling units).**

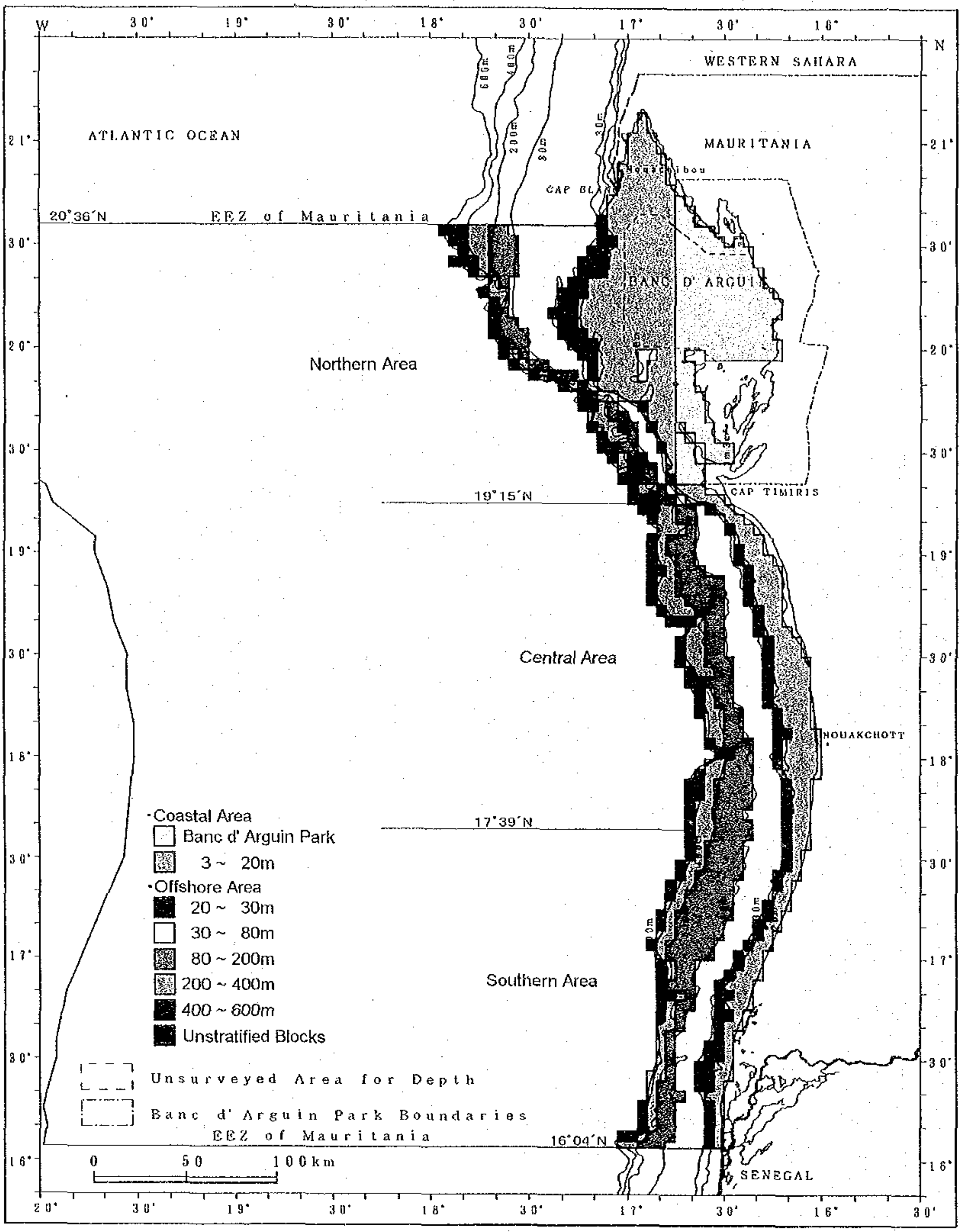



Figure 3.3 Stratification of the resources survey area.

For the estimation of stock size from the results of the trawl survey, the following equations were used :

$$dij = Xij/aij$$
$$Bi = Ai \cdot \overline{di}$$
$$SBi = Ai \frac{Sdi}{\sqrt{ni}}$$
$$B = \Sigma Bi$$
$$SB = \sqrt{\Sigma SBi^2}$$
$$CV = SB / B \times 100$$

where :

| | |
|---|---|
| $dij$ = | density (CPUA: Catch Per Unit Area) at the $j$-th station in the $i$-th stratum (kg/km$^2$) |
| $Xij$ = | catch at the $j$-th station in the $i$-th stratum (kg) |
| (*Al-Awam* : cod end + covernet catch) | |
| $aij$ = | area swept at the $j$-th station in the $i$-th stratum (km$^2$) |
| $Bi$ = | stock size in the $i$-th stratum (kg) |
| $Ai$ = | area of the $i$-th stratum (km$^2$) |
| $\overline{di}$ = | mean CPUA of the $i$-th stratum (kg/km$^2$) |
| $SBi$ = | standard error of stock size in the $i$-th stratum |
| $Sdi$ = | standard deviation of CPUA in the $i$-th stratum |
| $ni$ = | number of trawl stations in the $i$-th stratum |
| $B$ = | overall stock size (kg) |
| $SB$ = | standard error of overall stock size |
| $CV$ = | coefficient of variation (%) |

Area swept per haul ($a_{ij}$) was calculated as the product of the distance between wing-tips of net (or the beam length of 5 m in the case of the *Amrigue*) by the distance towed on the sea floor. On both vessels, the latter was calculated from the launching and hauling positions read by GPS (see Appendix Table 2.1). In the case of the *Al-Awam*, the distance between wing-tips was calculated by the method illustrated in Figure 3.5.

For stock size estimation, it was assumed that all the fish present within the area swept were captured, normally, that the efficiency of fishing was 1.0. Therefore, the estimated stock size will be the minimum value. The herding effect of the otter board, hand rope and bridle of the *Al-Awam* and the dispersion effect of the beam of the *Amrigue* were considered negligible. It was not possible to obtain information on the possible occurrence of fish above the head rope or the float line, and the exclusion of those individuals could have led to an underestimation of stock size.

The two vessels did not share the same size (see Table 3.2) or the same trawl gear (see Appendix Figures 3.1.1 and 3.1.2) and naturally had different catch capacities. For stock size estimation by species in the survey area, it was therefore necessary to adjust this difference in catchabilities. For obtain the data on the relative fishing efficiency between *Al-Awam* and *Amrigue*, at the Phase 1 cold season survey, a comparative experiment of the fishing efficiency was carried out (Table 3.1).

**Table 3.4 Area, number of blocks and number of trawl stations planned for each stratum.**

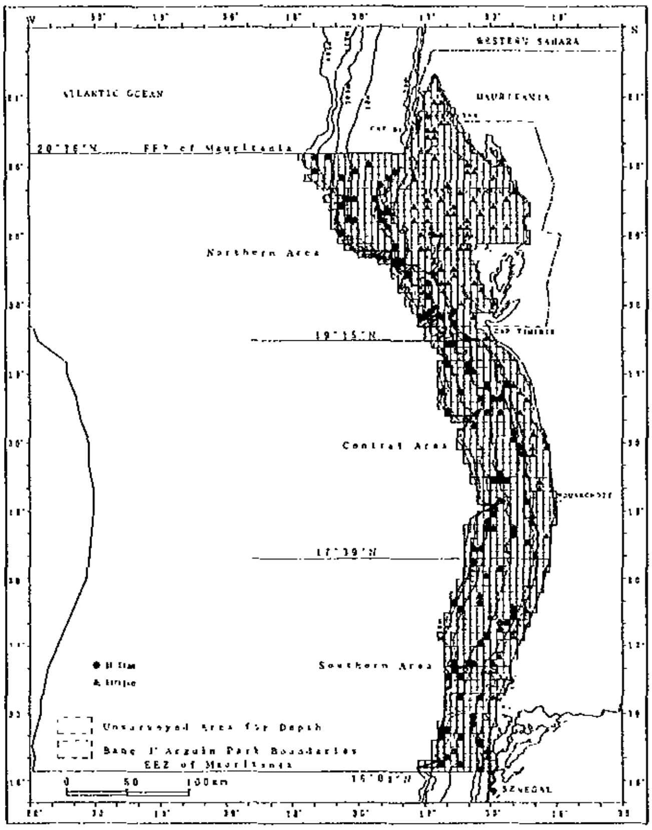
(A) Coastal area

| Stratum | Area in km² | | | | | Number of 3′ -square blocks | | | | | Planed number of stations | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Northern area | | Central area | Southern area | Total | Northern area | | Central area | Southern area | Total | Northern area | | Central area | Southern area | Total |
| | Banc d'Arguin | Other | | | | Banc d'Arguin | Other | | | | Banc d'Arguin | Other | | | |
| 3-20m | 11,540 | | | | | 360 | | | | | 65 | | | | |
| | 4,430 | 7,110 | 2,730 | 1,550 | 15,820 | 158 | 202 | 94 | 52 | 506 | 25 | 40 | 16 | 9 | 90 |

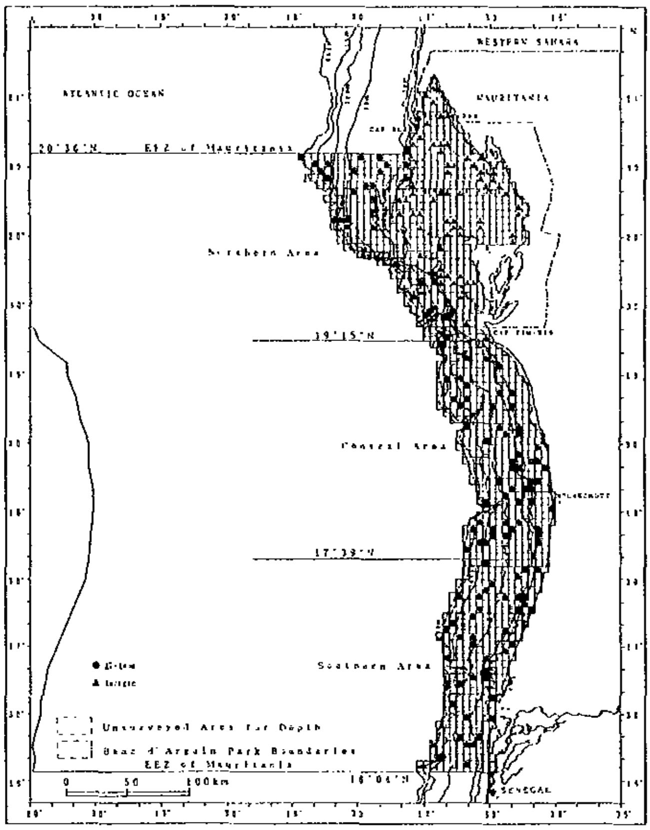
(B) Offshore area

| Stratum | Area in km² | | | | Number of 3′ -square blocks | | | | Planed number of stations | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Northern area | Central area | Southern area | Total | Northern area | Central area | Southern area | Total | Northern area | Central area | Southern area | Total |
| 20-30m | 1,210 | 870 | 960 | 3,040 | 37 | 30 | 37 | 104 | 5 | 4 | 4 | 13 |
| 30-80m | 2,830 | 2,980 | 2,910 | 8,720 | 95 | 95 | 98 | 288 | 12 | 12 | 12 | 36 |
| 80-200m | 1,300 | 2,560 | 2,730 | 6,590 | 45 | 89 | 93 | 227 | 5 | 11 | 11 | 27 |
| 200-400m | 980 | 1,720 | 1,060 | 3,760 | 27 | 54 | 39 | 120 | 4 | 7 | 4 | 15 |
| 400-600m | 730 | 710 | 440 | 1,880 | 28 | 35 | 22 | 85 | 3 | 3 | 3 | 9 |
| Unstratified | - | - | - | - | 11 | - | - | 11 | - | - | - | - |
| Total | 7,050 | 8,840 | 8,100 | 23,990 | 243 | 303 | 289 | 835 | 29 | 37 | 34 | 100 |

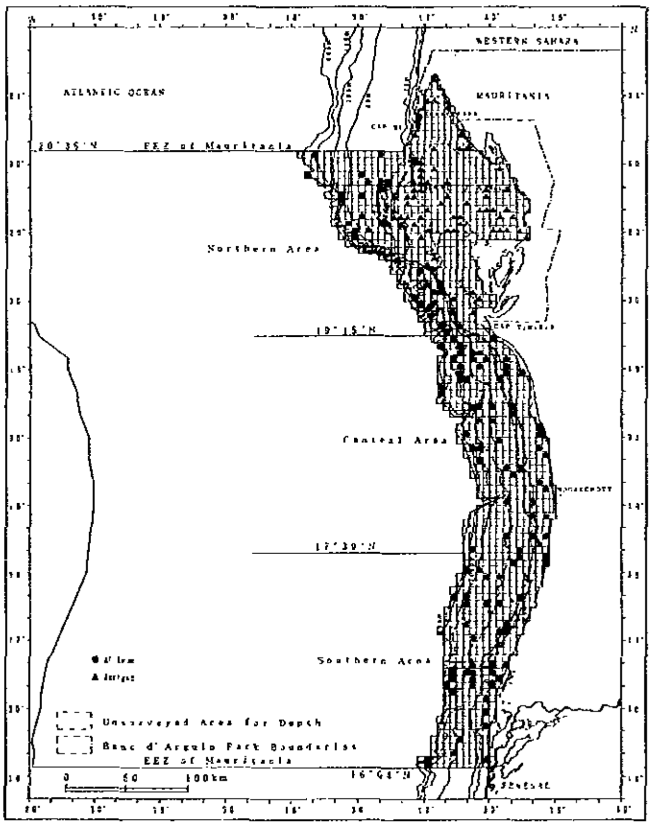
(A) Phase 1 cold season




(B) Phase 1 warm season




(C) Phase 2 cold season




(D) Phase 2 warm season

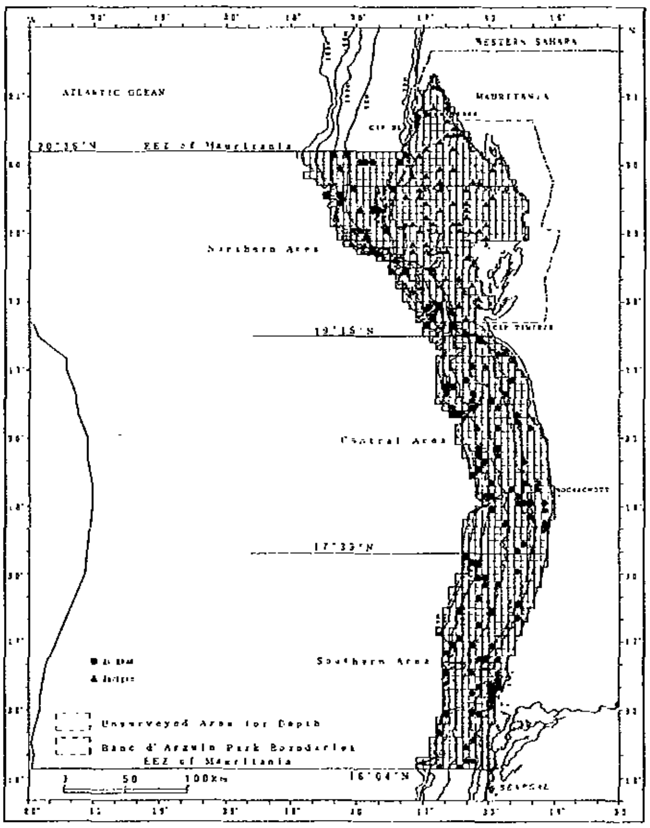



**Figure 3.4 Positions of the trawl stations planned by the random sampling method.**

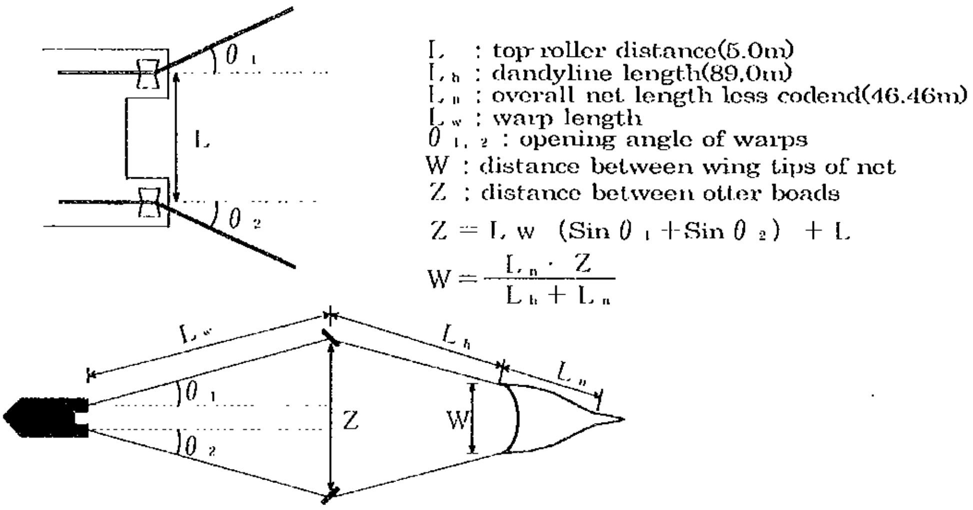



**Figure 3.5 Method for the calculation of the distance between wing-tips (W) for *Al-Awam*.**

The parallel haul method was adopted for this comparative experiment. The area for this experiment had to satisfy the following conditions: water depth between 8 and 20 m allowing for the haul of both vessels (over 8 m for the *Al-Awam* and less than 20 m for the *Amrigue*), sea floor suitable to bottom trawl, fish population abundant in quantity and number of species, distance from port allowing for a day trip, etc. The chosen area was off Cansado, south of the port of NDB, in the region of Lévrier Bay.

Trawl and swept area calculation methods were the same as those described above. Individuals caught were counted and weighed by species.

### 3.2.2 Biological survey

For the fishes, cephalopods and crustaceans captured at each trawl station, the following biological measurements were performed on board:

- Measurement of number of individuals and weight by species.
- Measurement of size composition of target species (Table 3.3); for each target species, the size of at most 100 individuals was recorded through the measuring-card punching method. On the *Al-Awam*, this measurement was done separately for the cod end and the covernet.
- Multi-item biological measurement of target species; for each target species, this measurement was performed at most 20 individuals randomly selected from the total of both cod end and covernet catches. This measurement comprised the measurement of body length and weight, gonad weight, the determination of sex and female maturity stage and the examination of stomach contents.
- Gathering of age characters of target species for age determination (see Chapter 7).

## 3.3 Data acquisition

All results obtained during the resources survey by bottom trawl were compiled into two files, one kept by JICA in Japan and the other by the CNROP of the IRM.

### 3.3.1 Resources survey

#### (1) Trawl operation

Table 3.5 shows the number of trawl stations actually carried out and Figure 3.6 defines their respective positions.

**Table 3.5 Number of actual trawl stations.**

(A) *Amrigue*

| Phase | Season | Stratum | North coastal area | | Total |
|---|---|---|---|---|---|
| | | | Banc d'Arguin | Other | |
| 1 | Cold | 3-20m | 9 | 9 | 18 |
| | Warm | 3-20m | 16 | 12 | 28 |
| 2 | Cold | 3-20m | 15 | 15 | 30 |
| | Warm | 3-20m | 15 | 7 | 22 |

(B) *Al-Awam*

| Phase | Season | Stratum | Subarea | | | Total |
|---|---|---|---|---|---|---|
| | | | North* | Central | South | |
| 1 | Cold | 3-20m | - | - | - | - |
| | | 20-30m | 5 | 4 | 3 | 12 |
| | | 30-80m | 8 | 12 | 9 | 29 |
| | | 80-200m | 3 | 10 | 7 | 20 |
| | | 200-400m | 3 | 4 | 2 | 9 |
| | | 400-600m | - | - | - | - |
| | | Total | 19 | 30 | 21 | 70 |
| | Warm | 3-20m | - | 15 | 8 | 23 |
| | | 20-30m | 4 | 4 | 3 | 11 |
| | | 30-80m | 6 | 12 | 10 | 28 |
| | | 80-200m | 3 | 11 | 9 | 23 |
| | | 200-400m | 3 | 6 | 3 | 12 |
| | | 400-600m | - | 1 | - | 1 |
| | | Total | 16 | 49 | 33 | 98 |
| 2 | Cold | 3-20m | 7 | 16 | 9 | 32 |
| | | 20-30m | 4 | 4 | 4 | 12 |
| | | 30-80m | 8 | 11 | 11 | 30 |
| | | 80-200m | 3 | 10 | 9 | 22 |
| | | 200-400m | - | 4 | 3 | 7 |
| | | 400-600m | - | - | - | - |
| | | Total | 22 | 45 | 36 | 103 |
| | Warm | 3-20m | 4 | 15 | 9 | 28 |
| | | 20-30m | 3 | 4 | 4 | 11 |
| | | 30-80m | 8 | 10 | 11 | 29 |
| | | 80-200m | 3 | 7 | 6 | 16 |
| | | 200-400m | 3 | 4 | 3 | 10 |
| | | 400-600m | - | - | - | - |
| | | Total | 21 | 40 | 33 | 94 |

Remarks. * Banc d'Arguin area is not included in 3-20m stratum. - : no trawl.

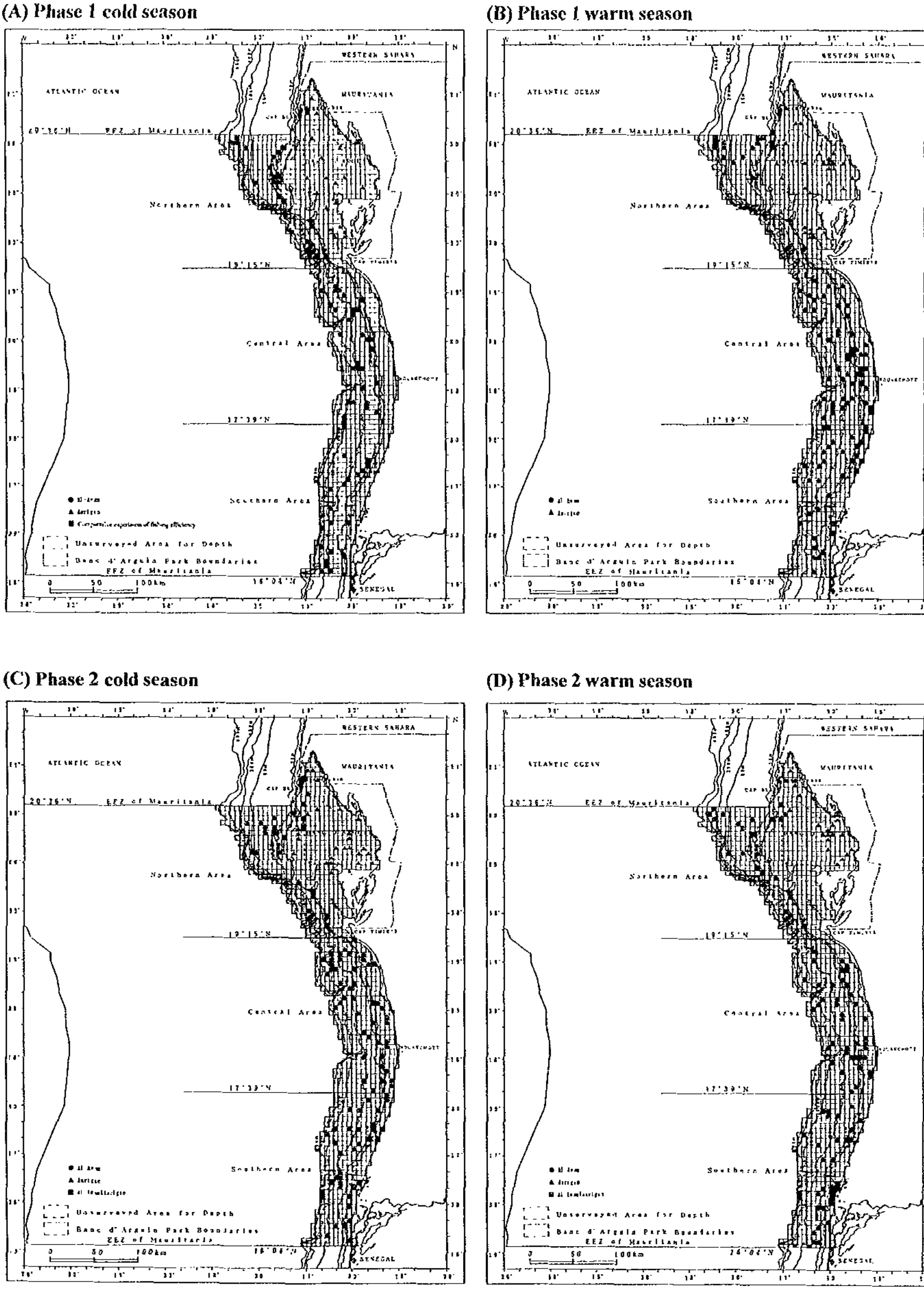



Figure 3.6 Positions of the trawl stations actually carried out.

Survey was actually conducted on most of the planned stations, although it was not possible to accomplish the planned number of stations both in the coastal and offshore areas. Any changes in trawl position were due to the fact the randomly sampled stations could sometimes correspond to a region unsuitable to trawl operations (e.g., with a rocky sea floor). In addition, the loss of fishing gear from the *Amrigue* following a unforeseen event that occurred in the course of a trawl in the Phase 1 cold season survey was the main reason for the absence of results on the Central and Southern coastal areas. As mentioned before, those areas were surveyed by the *Al-Awam* from the Phase 1 warm season onward.

Distances towed were recorded for all trawl stations for both vessels. For the *Amrigue*, the distance between wing-tips was fixed at 5 m (beam length). For the *Al-Awam*, it was calculated according to the method shown in Figure 3.5, but many unreliable data (particularly, measuring the opening angle of warp several times in rough sea would make the deference between each data very large and the wing-tips distances calculated from the data would be unreliable) were detected in all data calculated. Therefore, to delete those unreliable data, and to estimate the distance between the wing-tips (W) where the opening angle of warps was not recorded, the relationship between W and water depth (D) was thus established:

***Data treatment for obtaining the W-D equation***

First, according to the trawl net design and the results of hydraulic model experiment (obtained from the fishnet maker), the maximum distance between the wing-tips was 20 m (50% of head rope length), and 44 data above this figure were discarded among 342 data obtained from four surveys. 191 data outside the confidence interval of 95% in the figure for the W-D relationship determined from 298 data remained were also eliminated. After this double-filtering process, 107 effective data finally allowed to establish the following W-D equations:

$$W = 5.5068 + 2.4628 \ln D$$
$$R^2 = 0.7833$$
$$n = 107$$

Table 3.6 shows the area swept per haul was calculated from the distance between the wing-tips and the distance towed (including the results obtained by the comparative experiment of fishing efficiency mentioned below).

**Table 3.6 Area swept by trawl net (km$^2$).**

| Phase | Season | Beam trawl net of *Amrigue* | | | Bottom trawl net of *Al-Awam* | | |
|---|---|---|---|---|---|---|---|
| | | Mean | S. D.* | Range | Mean | S. D.* | Range |
| 1 | Cold | 0.00988 | 0.00146 | 0.00565 - 0.01180 | 0.04266 | 0.00993 | 0.01546 - 0.06459 |
| | Warm | 0.00734 | 0.00184 | 0.00565 - 0.01190 | 0.04035 | 0.00949 | 0.00981 - 0.05766 |
| 2 | Cold | 0.00827 | 0.00156 | 0.00350 - 0.01010 | 0.04100 | 0.01077 | 0.00802 - 0.06240 |
| | Warm | 0.00771 | 0.00181 | 0.00220 - 0.00900 | 0.04351 | 0.00777 | 0.02846 - 0.06073 |

Remark. *: Standard deviation.

Moreover, the relationship expression between warp length (Lw ; m) and water depth at trawl position and the met-mouth height acquired from the net-recorder (CN-10 model, FURUNO ELECTRIC) attached near the head rope center are shown below respectively.

- Lw - D equation

| | | |
|---|---|---|
| Lw | = | 60.887 + 2.133D |
| $R^2$ | = | 0.9748 |
| n | = | 365 |

- Net-mouth height (m)

| | | |
|---|---|---|
| Mean | = | 1.97 |
| S. D. | = | 0.57 |
| Range | = | 1.00 - 3.50 |
| n | = | 240 |

Figure 3.6 illustrates the area where the comparative experiment of fishing efficiency of both vessels was conducted. Eight parallel hauls were conducted in two days, but the data available on the analysis could be obtained from five hauls.

### (2) Soundings

Data from soundings for all navigations by the two research vessels (Table 3.7) were compared to the water depths indicated in existing marine charts, and data lacking in the latter were completed. Appendix *Figures 3.2 and 3.3 show the revised isobath chart and the new stratification of the survey area based on it* respectively. Table 3.8 indicates the revised area of each stratum.

**Table 3.7 Number of soundings data.**

| Area | North | | Central | South | Total |
|---|---|---|---|---|---|
| | Banc d'Arguin | Other | | | |
| Coastal (3-20m) | 1,399 | | 257 | 143 | 1,799 |
| | 586 | 813 | | | |
| Off-shore (20-600m) | 888 | | 1,284 | 958 | 3,130 |
| Total | 2,287 | | 1,541 | 1,101 | 4,929 |

Some important remarks: (i) the isobaths of the survey area referred to in this report are those that were known during the planning phase of this study; (ii) the revised areas indicated in Table 3.8 were used only for the estimation of stock size.

**Table 3.8 Revised surface areas of each stratum ($km^2$).**

| Subarea | Stratum | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | 3-20m | | 20-30m | 30-80m | 80-200m | 200-400m | 400-600m | |
| | Banc d'Arguin | Others | | | | | | |
| North | 10,653 (11,540) | | 1,290 (1,210) | 2,924 (2,830) | 1,147 (1,300) | 936 (980) | 738 (730) | 17,688 (18,590) |
| | 4,741 (4,430) | 5,912 (7,110) | | | | | | |
| Central | 2,783 (2,730) | | 835 (870) | 2,870 (2,980) | 2,767 (2,560) | 1,453 (1,720) | 848 (710) | 11,555 (11,570) |
| South | 1,485 (1,550) | | 805 (960) | 2,640 (2,910) | 3,025 (2,730) | 994 (1,060) | 583 (440) | 9,533 (9,650) |
| Total | 14,921 (15,820) | | 2,930 (3,040) | 8,434 (8,720) | 6,939 (6,590) | 3,383 (3,760) | 2,169 (1,880) | 38,776 (39,810) |

Remark: Figures in brackets give the areas of the strata in the planning stage (cf. Table 3.4).

### 3.3.2 Biological survey

Table 3.9 shows the number of individuals of each target species subjected to size composition, and biological measurement.

**Table 3.9 Number of individuals subjected to biological survey.**

| Species | Phase 1 | | | | Phase 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cold season | | Warm season | | Cold season | | Warm season | |
| | BLC | BI | BLC | BI | BLC | BI | BLC | BI |
| *Mustelus mustelus* | 4 | 4 | 90 | 56 | 127 | 71 | 621 | 200 |
| *Merluccius senegalensis* [*1] | 1,805 | 551 | 1,974 | 497 | 824 | 279 | 639 | 241 |
| (*Merluccius polli*) | | | | | 1,202 | 263 | 2,824 | 300 |
| *Zeus faber* | 552 | 380 | 286 | 231 | 580 | 544 | 355 | 260 |
| *Epinephelus aeneus* | 22 | 22 | 26 | 26 | 20 | 20 | 49 | 52 |
| *Trachurus trecae* | - | - | 2,522 | 392 | 5,389 | 593 | 2,402 | 174 |
| *Argyrosomus regius* | 2 | 2 | 105 | 105 | 166 | 122 | 143 | 130 |
| *Pseudupeneus prayensis* | 553 | 141 | 2,615 | 646 | 2,012 | 527 | 3,227 | 659 |
| *Pagrus caeruleostictus* | 63 | 63 | 617 | 402 | 925 | 405 | 2,084 | 481 |
| *Dentex angolensis* [*2] | 247 | 113 | 207 | 47 | 0 | 0 | 1 | 1 |
| *Dentex canariensis* | 222 | 155 | 660 | 248 | 569 | 252 | 274 | 157 |
| *Pagellus bellottii* | 2,049 | 418 | 3,879 | 677 | 3,695 | 546 | 5,826 | 645 |
| *Mugil capurrii* | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| *Mugil cephalus* | 0 | 0 | 0 | 0 | 14 | 14 | 1 | 1 |
| *Liza aurata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Solea senegalensis* | 3 | 3 | 18 | 18 | 40 | 40 | 19 | 19 |
| *Loligo vulgaris* | 261 | 261 | 2,363 | 560 | 688 | 406 | 1,469 | 322 |
| *Sepia officinalis* | 20 | 20 | 233 | 233 | 111 | 111 | 237 | 237 |
| *Octopus vulgaris* | 986 | 1,022 | 638 | 638 | 472 | 472 | 415 | 415 |
| *Penaeus notialis* | 50 | 50 | 536 | 260 | 247 | 247 | 1,460 | 464 |
| *Parapenaeus longirostris* | 385 | 230 | 310 | 310 | 355 | 355 | 336 | 336 |
| *Palinurus mauritanicus* | 0 | 0 | 13 | 13 | 2 | 2 | 26 | 26 |
| *Panulirus regius* | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 4 |
| *Chaceon maritae* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Remarks. BLC: Body Length Composition, BI: Biological Investivation, -: no investigation.

*1: The specimen of *Merluccius senegalensis* and *M. polli* in Phase 1 are not separated.

*2: Difference in the numbers of specimen between Phase 1 and Phase 2 is possibly caused by misidentification.

### 3.4 Study results

#### 3.4.1 Comparative experiment of fishing efficiency

Table 3.10 shows the comparison and similarity index between catches of the *Al-Awam* and the *Amrigue* at each trawl station. Similarity indexes Cπ (Kimoto, 1967)[2] obtained from the five parallel trawls by both vessels were all high, with a mean value of 0.994. This suggests the experiment was conducted on the same demersal zoobenthos (the dominant species for the number of catches of both vessels was Senegal seabream *Diplodus bellottii* - see Appendix Table 3.1 for a list of species captured). Nevertheless, there was a significant difference in the number of individuals (mean value *Amrigue* / *Al-Awam* = about 0.04) and the number of species between catches of both vessels.

**Table 3.10 Comparison and similarity index between catches of *Al-Awam* and *Amrigue*.**

| Test No. | Captures per km² | | Number of species | | Number of common species | Rate of dominance of Senegal sea bream *Diplodus bellottii* (%) | | Cπ |
|---|---|---|---|---|---|---|---|---|
| | *Al-Awam* | *Amrigue* | *Al-Awam* | *Amrigue* | | *Al-Awam* | *Amrigue* | |
| 1 | 1,060,752 | 21,422 | 29 (7) | 11 (1) | 7 (1) | 76 | 78 | 0.995 |
| 2 | 1,764,232 | 130,455 | 25 (6) | 19 (4) | 12 (3) | 86 | 85 | 0.999 |
| 3 | 1,694,915 | 62,176 | 29 (6) | 15 (4) | 11 (3) | 79 | 76 | 0.998 |
| 4 | 1,792,289 | 47,778 | 22 (6) | 17 (4) | 9 (3) | 57 | 61 | 0.998 |
| 5 | 850,106 | 24,537 | 27 (6) | 17 (4) | 8 (2) | 82 | 71 | 0.991 |
| Mean | 1,432,459 | 57,274 | 26 (6) | 16 (3) | 9 (2) | 75 | 77 | 0.994 |
| | | | 57 (11) | | | | | |
| Total | 7,162,294 | 286,368 | 47 (10) | 36 (7) | 26 (6) | - | - | - |

Remark. Figures in parentheses indicate numbers of target species.

Table 3.11 shows the ratio of CPUA (Catch Per Unit Area, in kg/km²) related to the total catch in both vessels, *Amrigue* and *Al-Awam* at each trawl station. It also indicated the results of a Student t-test (test of significance of population mean) on the difference between the population mean value (mean of CPUA ratios for five trawls) and reference value (1.0). CPUA ratio between the two vessels at each trawl station (relative fishing efficiency) varied between 0.0128 and 0.0470 (mean, 0.0250), that is, a significant fluctuation. Also, as $|t_0| > t\ (4,\ 0.05)$, the difference in catch capacity between the two vessels was considered significant.

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[2] Similarity index Cπ according to Kimoto (1967)

$$C\pi = \frac{2\sum_{i=1}^{s} n_{ai} n_{bi}}{\left(\sum \Pi a^2 + \sum \Pi b^2\right) Na \cdot Nb} \quad , 0 \leqq C\pi \leqq 1$$

$$\sum \Pi a^2 = \frac{\sum_{i=1}^{S} n_{ai}^2}{Na^2}, \quad \sum \Pi b^2 = \frac{\sum_{i=1}^{S} n_{bi}^2}{Nb^2}$$

where, $Na$, $Nb$ : total number of individuals captured at both trawl stations.

$n_{ai}$, $n_{bi}$ : number of individuals of species $i$ captured at both trawl stations.

$s$ : number of species common to both trawl stations.

**Table 3.11 Relative fishing efficiency between *Al-Awam* and *Amrigue* for total catch in weight.**

| Test No. | CPUA ($kg/km^2$) | | Ratio of CPUA | $t_0$*[1] , $t(f,\alpha)$ |
|---|---|---|---|---|
| | *Al-Awam* | *Amrigue* | *Amrigue/Al-Awam* | Student t-test *[2] of significance of population mean |
| 1 | 132,343 | 1,775 | 0.0134 | f : degree of freedom 4 |
| 2 | 164,631 | 7,746 | 0.0470 | $\alpha$ : level of significance 0.05 |
| 3 | 197,061 | 5,337 | 0.0271 | $t(4, 0.05) = 2.776451$ |
| 4 | 281,355 | 3,607 | 0.0128 | $t_0 = -5.30495$ |
| 5 | 91,350 | 2,234 | 0.0245 | |
| Mean | 173,348 | 4,140 | 0.0250*[3] | $\|t_0\| > t(4, 0.05)$ |

*[1] Student's t-factor calculated from observe values

*[2] MS-Excel analysis software (study of mean of pairs of samples)

*[3] Mean ratio of CPUA in each test

Table 3.12 presents mean ratios of CPUA for target species caught by the two vessels in the course of the same test trawl. Of the 22 target species, four have supplied valuable data allowing for comparisons. The CPUA ratios (relative fishing efficiency) of those four species varied from 0.0167 to 0.6778. Nevertheless, one could argue that the fact of correcting CPUA and stock size estimates by utilizing each relative fishing efficiency of those four species would involve a significant error when the number of those data (that is, the number of times a given target species was simultaneously captured by both vessels) is insufficient.

**Table 3.12 Relative fishing efficiency between *Al-Awam* and *Amrigue* for target species.**

| Target species of the experiment | Number of stations at which species were caught | | | Mean CPUA | | Ratio of CPUA (*Amrigue/Al-Awam*) |
|---|---|---|---|---|---|---|
| | *Al-Awam* | *Amrigue* | both vessels | *Al-Awam* | *Amrigue* | |
| *Mustelus mustelus* | 5 | 3 | 3 | 6,306 | 245 | 0.0389 |
| *Argyrosomus regius* | 4 | 2 | 1 | 90 | 61 | 0.6778 |
| *Dentex canariensis* | 5 | 5 | 5 | 5,494 | 220 | 0.0400 |
| *Sepia officinalis* | 5 | 2 | 2 | 897 | 15 | 0.0167 |

*Based on those results, one cannot say a increase in the number of experiments would allow for obtaining data that could be used on relative fishing efficiency for all target species. The main reasons are the following:*

- The difference in catch capacity betwen the two vessels (including the fishing efficiency of trawl gear) is quite significant: mean ratio of CPUA: 0.0250 (see Table 3.11); mean ratio of numbers of captured individuals: 0.0400 (see Table 3.10); mean weight of individuals: 121 g for *Al-Awam* and 72 g for *Amrigue* (see Tables 3.10 and 3.11); mean number of species found: 26 for *Al-Awam* and 16 for *Amrigue* (see Table 3.10).

In conclusion, from the significant difference in catch capacity between the two vessels, it is difficult to calculate the relative fishing efficiency for all 22 target species. In the analyses described below, the survey areas of each vessel are presented separately. Of course, it is conceivable that the biological data (species composition, size composition, etc.) obtained from the results of the *Amrigue* surveys do not correctly reflect the natural state *in situ*, and that density and stock estimates were underevaluated.

### 3.4.2 Nectobenthos fauna centered on demersal fish species

In order to grasp the current situation of the diversity of species in the nectobenthos living in the survey area, the population structure and aquatic ecosystems[3], and also to establish the foundations necessary to their conservation, protection and/or repopulation, and to allow for the future comparative studies, the results of analyses on the nectobenthos fauna were mentioned below.

Appendix Table 3.2 lists the species captured by the *Amrigue*, while Appendix Tables 3.3 (fishes) and 3.4 (non-fish species) also account for the species captured by the *Al-Awam*. Habitat information on those species was taken from the «Fish Base» database (http://www.fishbase.org - habitat definition in Appendix Table 3.5). Not all species caught by both vessels were strictly demersal: there were also species labelled as benthopelagic, pelagic, bathydemersal, bathypelagic or reef-associated. Species captured by the *Al-Awam* had a more diversified habitat. Classification in orders and families here adopted is that of Nelson (1994). Species are referred to by their scientific names as they appear in FishBase.

#### (1) Fish fauna in the entire survey area

Table 3.13 lists the names of the fish species, classified by order and family, caught by the *Amrigue* and the *Al-Awam*. It should be noted that many captured fishes were not strictly demersal as already indicated.

##### 1) *Amrigue* survey area

A total of 95 species belonging to 47 families of 11 orders were identified, among them 8 target species. Fifty-five of those species were demersal, 18 benthopelagic, 9 pelagic and 7 reef-associated (Appendix Table 3.2). Captured species were more numerous in the warm season (61 and 67) than in the cold season (50 and 55). In both seasons, the order Perciformes was the richest in species composition, representing 40-50% of all species caught. Species from the orders Rajiformes, Pleuronectiformes and Tetraodontiformes were also quite numerous.

##### 2) *Al-Awam* survey area

A total of 294 species belonging to 113 families of 25 orders were registered, of which 14 were target species. As for the number of species per habitat, 131 of those species were demersal, 54 benthopelagic, 23 pelagic, 22 bathydemersal, 9 bathypelagic and 15 reef-associated (Appendix Table 3.3). The number of families in different seasons varied between 76 and 98, and that of species, between 186 and 235. Again, the order Perciformes was the richest in species composition in all seasons, with about 40% of the total number of species. Species of the orders Pleuronectiformes, Scorpaeniformes, Rajiformes, Gadiformes and Anguilliformes were also very numerous.

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[3] According to the Code of Conduct for Responsible Fisheries (FAO, 1995), concern for maintenance of biological diversity and conservation of the population structure and aquatic ecosystems is essential.

## Table 3.13 Fishe fauna in the entire survey area.

(A) *Amrigue* survey area

| Order | Phase 1 | | | | Phase 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cold Season | | Warm Season | | Cold Season | | Warm Season | |
| | Families | Species | Families | Species | Families | Species | Families | Species |
| Carcharhiniformes | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 2 |
| Rajaformes | 5 | 8 | 5 | 6 | 5 | 6 | 5 | 5 |
| Clupeiformes | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 3 |
| Siluriformes | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Aulopiformes | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Batrachoidiformes | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Gasterosteiformes | 0 | 0 | 2 | 3 | 0 | 0 | 2 | 3 |
| Scorpaeniformes | 2 | 2 | 3 | 3 | 4 | 4 | 1 | 1 |
| Perciformes | 13 | 26 | 19 | 34 | 11 | 22 | 13 | 27 |
| Pleuronectiformes | 4 | 9 | 5 | 10 | 5 | 10 | 4 | 12 |
| Tetraodontiformes | 3 | 5 | 3 | 7 | 3 | 4 | 3 | 6 |
| Total | 32 | 55 | 40 | 67 | 32 | 50 | 33 | 61 |

(B) *Al-Awam* survey area

| Order | Phase 1 | | | | Phase 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Cold Season | | Warm Season | | Cold Season | | Warm Season | |
| | Families | Species | Families | Species | Families | Species | Families | Species |
| Carcharhiniformes | 2 | 3 | 4 | 7 | 4 | 6 | 5 | 7 |
| Hexanchiformes | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Squaliformes | 0 | 0 | 2 | 2 | 1 | 1 | 1 | 1 |
| Rajaformes | 3 | 8 | 6 | 17 | 6 | 16 | 6 | 15 |
| Elopiformes | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| Albuliformes | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| Anguilliformes | 5 | 7 | 7 | 13 | 5 | 11 | 5 | 7 |
| Clupeiformes | 2 | 4 | 3 | 5 | 3 | 5 | 3 | 5 |
| Siluriformes | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Osmeriformes | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| Stomiiformes | 3 | 4 | 2 | 4 | 3 | 3 | 0 | 0 |
| Aulopiformes | 3 | 6 | 3 | 6 | 3 | 4 | 3 | 5 |
| Myctophiformes | 1 | 3 | 1 | 2 | 1 | 2 | 1 | 1 |
| Ophidiiformes | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 |
| Gadiformes | 3 | 12 | 3 | 10 | 3 | 10 | 3 | 9 |
| Batrachoidiformes | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lophiiformes | 2 | 4 | 3 | 6 | 3 | 4 | 2 | 3 |
| Mugiliformes | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 |
| Beryciformes | 1 | 3 | 1 | 3 | 2 | 4 | 2 | 3 |
| Zeiformes | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 |
| Gasterosteiformes | 2 | 2 | 2 | 5 | 2 | 3 | 3 | 4 |
| Scorpaeniformes | 3 | 14 | 4 | 14 | 4 | 15 | 4 | 13 |
| Perciformes | 31 | 83 | 38 | 96 | 35 | 93 | 35 | 90 |
| Pleuronectiformes | 5 | 19 | 6 | 22 | 6 | 24 | 6 | 21 |
| Tetraodontiformes | 3 | 5 | 4 | 11 | 4 | 10 | 4 | 11 |
| Total | 76 | 186 | 98 | 235 | 93 | 223 | 91 | 208 |

## (2) Species other than fishes

### 1) Target species (8 species: 3 cephalopods and 5 crustaceans)

#### a) *Amrigue* survey area

A total of four species was recorded (3 cephalopods and 1 crustacean) (see Appendix Table 3.2, page 2).

#### b) *Al-Awam* survey area

Seven species were confirmed in total (3 cephalopods and 4 crustaceans) (see Appendix Table 3.3, pages 14 and 15).

### 2) Other species

About the mollusks, crustaceans, etc. captured in the area surveyed by the *Al-Awam*, families and species recorded opportunely were the following (see Appendix Table 3.4):

- Mollusks – gastropods: 13 families, 18 species; bivalves: 4 families, 6 species; cephalopods: 8 families, 23 species.
- Crustaceans – stomatopods: 1 family, 1 species; shrimps: 8 families, 18 species; lobsters: 1 family, 1 species; anomurans: 1 family, 1 species; crabs: 7 families, 14 species.
- Echinoderms – 1 family, 1 species (except for starfishes).

## (3) Nectobenthos fauna

The nectobenthos described here comprises fishes, target cephalopods and crustaceans. Table 3.14 lists the numbers of families and species caught in each stratum. It was not easy to compare the numbers of species between strata as the number of trawl stations – that is, sampling area – are not identical. For that comparison, the mean number of species captured per trawl was used as an indicator of the species richness at each stratum (hereinafter referred to simply as species richness).

As indicated in Section 3.2.1, the survey area comprised 19 strata. This stratification was associated to a geographical division in three subareas (Northern, Central and Southern areas) and to a vertical division (six water depth ranges in three subareas: 3-20 m, 20-30 m, 30-80 m, 80-200 m, 200-400 m and 400-600 m). This vertical division includes two large area, the coastal area (water depth of 3-20 m; in Northern area, there is another geographical subdivision with the Banc d'Arguin considered apart from the others) and the offshore area (20-600 m).

Given this stratification, the nectobenthos fauna was characterized by the geographical representative species (defined as the species that appear throughout the survey in Northern, Central and Southern areas respectively : hereinafter referred to as GRS), and by the dominant occurrence stratum (defined as the stratum were those GRS occur throughout the survey : hereinafter referred to as DOS). GRS and DOS were obtained from Appendix Tables 3.2 and 3.3 according to their definitions and integrated into Table 3.15.

### 1) *Amrigue* survey area (Northern coastal area)

No significant difference in species richness between the Banc d'Arguin and other areas was recognized in any season. In the Banc d'Arguin, the number of species captured in each season varied between 32 and 54, with a higher value in the warm season. In other area, on the contrary, there was no significant seasonal variation, with the number of species captured in the 42–49 range (Table 3.14). The total number of species caught throughout the survey in the Banc d'Arguin and in other area was, respectively, 76 and 82 (Appendix Table 3.2).

The number of GRS in the Banc d'Arguin and other area was 18 and 16 (9 species overlap), respectively.

### 2) *Al-Awam* survey area

In the Northern, Central and Southern areas, no significant variation in species richness was recognized in any season. In the Northern area, species richness was slightly higher in the warm season. At strata of less than 80 m water depth in three subareas, species richness tended to increase in the warm season, while in deeper strata it showed a increase tendency in the cold season (see Table 3.14).

Area-wise, the number of species were, from north to south, 211, 262 and 255. Stratum-wise, the number of species varied as follows: 162 at 3-20 m, 154 at 20-30 m, 191 at 30-80 m, 156 at 80-200 m, 117 at 200-400 m and 24 at 400-600 m (a single trawl) (see Appendix Table 3.3).

The number of GRS by subarea, Northern, Central and Southern areas, was 57, 72 and 65 respectively. The total number of GRS in the entire area was 96 (39 species overlap in three subareas).

The GRS caught only in the Northern area were 9 : *Mustelus mustelus* (DOS: 3-20m and 30-80m), *Dasyatis pastinaca* (no DOS), *Engraulis encrasicolus* (no DOS), *Halobatrachus didactylus* (DOS: 3-20m and 20-30m), *Branchiostegus semifasciatus* (DOS: 80-200m), *Campogramma glaycos* (DOS: 3-20m), *Diplodus sargus cadenati* (DOS: 3-20m), *Diplodus bellottii* (DOS: 3-20m and 20-30m) and *Galeoides decadactylus* (DOS: 3-20m).

The GRS caought only in the Central area were 14 : *Aulopus filamentosus* (DOS: 80-200m), *Hoplostethus mediterraneus* (DOS: 200-400m), *Chelidonicthhys gabonensis* (DOS: 30-80m and 80-200m), *Peristedion cataphractum* (DOS: 200-400m), *Epinephelus costae* (DOS: 3-20m), *Parapristipoma octolineatum* (DOS: 30-80m), *Pagrus auriga* (DOS: 3-20m), *Pagrus pagrus* (no DOS), *Diplodus vulgaris* (DOS: 3-20m), *Chaetodon hoefleri* (DOS: 3-20m), *Chromis chromis* (DOS: 30-80m), *Xyrichtys novacula* (DOS: 3-20m and 20-30m), *Nicholsina usta collettei* (DOS: 3-20m) and *Monolene microstoma* (DOS: 80-200m and 200-400m).

The GRS caought only in the Southern area were 12 : *Dasyatis chrysonota marmorata* (DOS: 3-20m), *Malacocephalus occidentalis* (no DOS), *Serranus africanus* (no DOS), *Rypticus saponaceus* (no DOS), *Chloroscombrus chrysurus* (DOS: 3-20m and 20-30m), *Pomadasys rogerii* (DOS: 3-20m and 20-30m), *Argyrosomus regius* (DOS: 3-20m), *Pseudotolithus senegalensis* (DOS: 3-20m and 20-30m), *Stromateus fiatola* (DOS: 3-20m), *Microchirus frechkopi* (DOS: 30-80m), *Cynoglossus canariensis* (DOS: 3-20m) and *Chilomycterus spinosus mauretanicus* (DOS: 3-20m).

## Table 3.14 Nectobenthos fauna by stratum.

### (A) *Amrigue* survey area

| Subarea | Stratum | No. of trawl sts. | | | | No. of families | | | | No. of species | | | | No. of species per haul | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1C | 1W | 2C | 2W | 1C | 1W | 2C | 2W | 1C | 1W | 2C | 2W | 1C | 1W | 2C | 2W |
| North | Banc d'Arguin | 9 | 16 | 15 | 15 | 26 | 32 | 22 | 32 | 39 | 52 | 32 | 54 | 10 | 13 | 8 | 18 |
| | Other | 9 | 12 | 15 | 7 | 29 | 33 | 30 | 29 | 46 | 49 | 42 | 43 | 12 | 9 | 7 | 16 |
| | Total | 18 | 28 | 30 | 22 | 35 | 42 | 35 | 37 | 58 | 69 | 53 | 65 | 11 | 11 | 7 | 17 |

### (B) *Al-Awam* survey area

| Subarea | Stratum | No. of trawl sts. | | | | No. of families | | | | No. of species | | | | No. of species per haul | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1C | 1W | 2C | 2W | 1C | 1W | 2C | 2W | 1C | 1W | 2C | 2W | 1C | 1W | 2C | 2W |
| North | 3-20m | - | - | 7 | 4 | - | - | 39 | 39 | - | - | 67 | 65 | - | - | 27 | 33 |
| | 20-30m | 5 | 4 | 4 | 3 | 29 | 32 | 29 | 35 | 43 | 53 | 45 | 51 | 18 | 27 | 20 | 28 |
| | 30-80m | 8 | 6 | 8 | 8 | 38 | 38 | 34 | 48 | 67 | 64 | 51 | 81 | 26 | 28 | 19 | 30 |
| | 80-200m | 3 | 3 | 3 | 3 | 30 | 26 | 30 | 35 | 50 | 36 | 48 | 47 | 29 | 25 | 30 | 28 |
| | 200-400m | 3 | 3 | - | 3 | 30 | 27 | - | -25 | 49 | 37 | - | 36 | 29 | 25 | - | 22 |
| | 400-600m | - | - | - | - | - | - | - | - | | | | - | | | | - |
| | Total | 19 | 16 | 22 | 21 | 64 | 65 | 62 | 76 | 129 | 123 | 122 | 146 | 25 | 27 | 23 | 29 |
| Central | 3-20m | - | 15 | 16 | 15 | - | 47 | 57 | 46 | - | 95 | 108 | 83 | - | 36 | 30 | 30 |
| | 20-30m | 4 | 4 | 4 | 4 | 29 | 38 | 33 | 36 | 48 | 58 | 49 | 62 | 23 | 31 | 23 | 28 |
| | 30-80m | 12 | 12 | 11 | 10 | 39 | 53 | 43 | 42 | 73 | 85 | 71 | 76 | 24 | 24 | 23 | 22 |
| | 80-200m | 10 | 11 | 10 | 7 | 47 | 50 | 43 | 41 | 82 | 74 | 77 | 60 | 27 | 26 | 30 | 25 |
| | 200-400m | 4 | 6 | 4 | 4 | 33 | 32 | 37 | 30 | 46 | 50 | 56 | 44 | 24 | 20 | 29 | 23 |
| | 400-600m | - | 1 | - | - | - | 19 | - | - | - | 24 | - | - | - | 24 | - | - |
| | Total | 30 | 49 | 45 | 40 | 65 | 96 | 87 | 88 | 132 | 192 | 194 | 173 | 24 | 28 | 28 | 27 |
| South | 3-20m | - | 8 | 9 | 9 | - | 47 | 48 | 39 | - | 89 | 85 | 72 | - | 36 | 32 | 34 |
| | 20-30m | 3 | 3 | 4 | 4 | 34 | 33 | 37 | 36 | 52 | 51 | 54 | 59 | 27 | 35 | 24 | 29 |
| | 30-80m | 9 | 10 | 11 | 11 | 46 | 46 | 44 | 45 | 74 | 78 | 86 | 88 | 26 | 31 | 27 | 29 |
| | 80-200m | 7 | 9 | 9 | 6 | 41 | 38 | 48 | 38 | 75 | 64 | 75 | 55 | 34 | 24 | 31 | 24 |
| | 200-400m | 2 | 3 | 3 | 3 | 26 | 23 | 35 | 19 | 34 | 32 | 57 | 27 | 22 | 16 | 33 | 16 |
| | 400-600m | - | - | - | - | - | - | - | - | | | | - | | | | - |
| | Total | 21 | 33 | 36 | 33 | 66 | 77 | 88 | 75 | 133 | 164 | 185 | 163 | 28 | 29 | 29 | 28 |

Remarks. 1C: Phase 1 cold season; 1W: Phase 1 warm season; 2C: Phase 2 cold season; 2W: Phase 2 warm season.
-: no trawl.

**Table 3.15 Geographic representative species and their dominamt occurrence stratum.**

**(A) *Amrigue* survey area**

| Family | Species | Northern coast | |
|---|---|---|---|
| | | Banc d'Arguin | Others |
| Dasyatidae | *Dasyatis chrysonota marmorata* | x | |
| Gymnuridae | *Gymnura altavela* | x | |
| Clupeidae | *Sardinella maderensis* | x | |
| Ariidae | *Arius heudelotii* | x | x |
| Batrachoididae | *Halobatrachus didactylus* | | x |
| Serranidae | *Serranus scriba* | | x |
| Carangidae | *Chloroscombrus chrysurus* | x | |
| Haemulidae | *Pomadasys incisus* | x | x |
| Sparidae | *Pagrus caeruleostictus* * | x | |
| | *Dentex canariensis* * | | x |
| | *Diplodus bellottii* | x | x |
| Polynemidae | *Galeoides decadactylus* | x | x |
| Sciaenidae | *Pseudotolithus senegalensis* | x | |
| Mullidae | *Pseudupeneus prayensis* * | | x |
| Labridae | *Symphodus roissali* | | x |
| Psettodidae | *Psettodes belcheri* | x | x |
| Paralichthyidae | *Syacium micrurum* | x | x |
| Soleidae | *Pegusa triophthalma* | | x |
| | *Solea senegalensis* * | x | |
| | *Dicologoglossa cuneata* | | x |
| Monacanthidae | *Stephanolepis hispidus* | x | x |
| Tetraodontidae | *Ephippion guttifer* | x | |
| | *Sphoeroides spengleri* | x | x |
| Diodontidae | *Chilomycterus spinosus mauretanicus* | x | |
| Penaeidae | *Penaeus notialis* * | x | x |

*: Target species.

Table 3.15 continued.

**(B) *Al-Awam* survey area (1/3)**

| Family | Species | Geographical representative species | | | Dominant occurrence stratum | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | N | | | | | C | | | | | S | | | | |
| | | N | C | S | I | II | III | IV | V | I | II | III | IV | V | I | II | III | IV | V |
| Scyliorhinidae | *Scyliorhinus stellaris* | x | x | | | | | | x | | | | x | | | | | | |
| Triakidae | *Mustelus mustelus* * | x | | | x | | x | | | | | | | | | | | | |
| Torpedinidae | *Torpedo torpedo* | | x | x | | | | | | | | x | | | | x | x | x | |
| Rajidae | ***Raja miraletus*** | x | x | x | x | x | | | | | | | | | x | | x | x | |
| | ***Raja straeleni*** | x | x | x | | | | | x | | | | x | | | | | x | |
| Dasyatidae | *Dasyatis chrysonota marmorata* | | | x | | | | | | | | | | | x | | | | |
| | *Dasyatis pastinaca* | x | | | | | | | | | | | | | | | | | |
| Albulidae | *Pterothrissus belloci* | | x | x | | | | | | | | | x | x | | | x | x | x |
| Engraulidae | *Engraulis encrasicolus* | x | | | | | | | | | | | | | | | | | |
| Clupeidae | ***Sardinella aurita*** | x | x | x | x | x | x | | | x | x | | | | x | x | | | |
| | *Sardinella maderensis* | x | | x | x | | x | | | | | | | | x | x | | | |
| Aulopidae | *Aulopus filamentosus* | | x | | | | | | | | | | x | | | | | | |
| Chlorophthalmidae | ***Chlorophthalmus agassizi*** | x | x | x | | | | | x | | | | x | x | | | | x | x |
| Synodontidae | ***Saurida brasiliensis*** | x | x | x | | | x | | | | | x | x | | | | x | x | |
| Ophidiidae | ***Brotula barbata*** | x | x | x | | | | x | | | | | x | x | | | x | x | |
| Macrouridae | *Malacocephalus occidentalis* | | | x | | | | | | | | | | | | | | | |
| | *Caelorinchus caelorhincus caelorhincus* | | x | x | | | | | | | | | | x | | | | | x |
| Merlucciidae | ***Merluccius senegalensis**** | x | x | x | | | | x | x | | | | x | x | | | | x | x |
| Batrachoididae | *Halobatrachus didactylus* | x | | | x | x | | | | | | | | | | | | | |
| Trachichthyidae | *Hoplostethus mediterraneus* | | x | | | | | | | | | | | x | | | | | |
| Zeidae | ***Zeus faber**** | x | x | x | | | x | x | | | | x | x | | | | x | x | |
| | ***Zenopsis conchifer*** | x | x | x | | | | x | x | | | | x | x | | | | x | x |
| Caproidae | *Antigonia capros* | | x | x | | | | | | | | | x | | | | | x | |
| | ***Capros aper*** | x | x | x | | | | x | x | | | | x | x | | | | x | |
| Scorpaenidae | ***Helicolenus dactylopterus dactylopterus*** | x | x | x | | | | | x | | | | x | x | | | | x | x |
| | *Scorpaena elongata* | | x | x | | | | | | | | | x | x | | | | | |
| | *Scorpaena normani* | | x | x | | | | | | | | | x | x | | | | x | |
| | *Scorpaena stephanica* | x | x | | | | | x | | | | x | x | | | | | | |
| | ***Pontinus kuhlii*** | x | x | x | | | | x | | | | | x | x | | | | x | x |
| Triglidae | *Chelidonichthys gabonensis* | | x | | | | | | | | | x | x | | | | | | |
| | *Peristedion cataphractum* | | x | | | | | | | | | | | x | | | | | |
| Platycephalidae | *Solitas gruveli* | | x | x | | | | | | | | x | | | | | x | | |
| Acropomatidae | ***Synagrops microlepis*** | x | x | x | | | | x | x | | | | x | x | | | | x | x |

Remarks. N: North area, C: Central area, S: South area. I: 3-20m, II: 20-30m, III: 30-80m, IV: 80-200m, V: 200-400m. *: Target species.
(shaded) : Common species in entire survey area.

Table 3.15 continued.

**(B) *Al-Awam* survey area (2/3)**

| Family | Species | Geographical representative species N | C | S | Dominant occurrence stratum N I | N II | N III | N IV | N V | C I | C II | C III | C IV | C V | S I | S II | S III | S IV | S V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Serranidae | *Serranus africanus* | | | x | | | | | | | | | | | | | | | |
| | *Serranus cabrilla* | x | x | x | | | | x | | | | x | x | | | | x | x | |
| | *Serranus scriba* | x | x | | x | | | | | x | | | | | | | | | |
| | *Epinephelus aeneus** | x | x | x | x | x | | | | x | | | | | x | | | | |
| | *Epinephelus costae* | | x | | | | | | | x | | | | | | | | | |
| | *Rypticus saponaceus* | | | x | | | | | | | | | | | | | | | |
| Malacanthidae | *Branchiostegus semifasciatus* | x | | | | | | x | | | | | | | | | | | |
| Carangidae | *Caranx rhonchus* | x | x | x | x | x | x | | | x | x | x | | | x | x | x | | |
| | *Campogramma glaycos* | x | | | x | | | | | | | | | | | | | | |
| | *Trachurus trachurus* | x | x | | | | | x | x | | | | x | x | | | | | |
| | *Trachurus trecae* | x | x | x | | x | x | x | | | | x | x | | | | x | x | |
| | *Chloroscombrus chrysurus* | | | x | | | | | | | | | | | x | x | | | |
| Haemulidae | *Pomadasys incisus* | x | x | | x | | | | | x | | | | | | | | | |
| | *Pomadasys rogerii* | | | x | | | | | | | | | | | x | x | | | |
| | *Brachydeuterus auritus* | x | x | x | x | | | | | x | | | | | x | x | x | | |
| | *Parapristipoma octolineatum* | | x | | | | | | | | | x | | | | | | | |
| | *Plectorhinchus mediterraneus* | x | x | x | x | | | | | x | x | x | | | x | x | | | |
| Sparidae | *Pagrus auriga* | | x | | | | | | | x | | | | | | | | | |
| | *Pagrus caeruleostictus** | | x | x | | | | | | x | x | | | | x | x | | | |
| | *Pagrus pagrus* | | x | | | | | | | | | | | | | | | | |
| | *Boops boops* | x | x | x | x | | x | | | | | x | x | | | | x | | |
| | *Dentex canariensis** | x | x | x | x | x | x | | | x | x | x | | | x | | x | | |
| | *Dentex macrophthalmus* | x | x | x | | | | x | | | | | x | x | | | | x | |
| | *Dentex maroccanus* | x | x | x | | | x | x | | | | x | x | | | | x | x | |
| | *Diplodus sargus cadenati* | x | | | x | | | | | | | | | | | | | | |
| | *Diplodus vulgaris* | | x | | | | | | | x | | | | | | | | | |
| | *Diplodus bellottii* | x | | | x | x | | | | | | | | | | | | | |
| | *Pagellus bellottii** | x | x | x | x | x | x | | | x | x | x | | | x | x | x | | |
| | *Spondyliosoma cantharus* | x | x | x | x | x | x | | | x | x | | | | | | | | |
| Centracanthidae | *Spicara alta* | | x | x | | | | | | | | | | | | | | x | |
| Polynemidae | *Galeoides decadactylus* | x | | | x | | | | | | | | | | | | | | |
| Sciaenidae | *Argyrosomus regius** | | | x | | | | | | | | | | | x | | | | |
| | *Pseudotolithus senegalensis* | | | x | | | | | | | | | | | x | x | | | |
| | *Umbrina canariensis* | x | x | x | | | | | | | | x | x | | x | | x | x | |

Remarks. N: North area, C: Central area, S: South area. I: 3-20m, II: 20-30m, III: 30-80m, IV: 80-200m, V: 200-400m. *: Target species.
(shaded): Common species in entire survey area.

Table 3.15 continued.

**(B) *Al-Awam* survey area (3/3)**

| Family | Species | Geographical representative species | | | Dominant occurrence stratum | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | N | | | | | C | | | | | S | | | | |
| | | N | C | S | I | II | III | IV | V | I | II | III | IV | V | I | II | III | IV | V |
| Mullidae | *Pseudupeneus prayensis** | x | x | x | x | x | x | | | x | x | x | | | x | x | x | | |
| Chaetodontidae | *Chaetodon hoefleri* | | x | | | | | | | x | | | | | | | | | |
| Cepolidae | *Cepola pauciradiata* | x | x | | | | | x | | | | | x | | | | | | |
| Pomacentridae | *Chromis chromis* | | x | | | | | | | | | x | | | | | | | |
| Labridae | *Xyrichthys novacula* | | x | | | | | | | x | x | | | | | | | | |
| Scaridae | *Nicholsina usta collettei* | | x | | | | | | | x | | | | | | | | | |
| Percophidae | *Bembrops heterurus* | | x | x | | | | | | | | | x | x | | | | x | |
| Trachinidae | *Trachinus draco* | x | x | | | x | x | | | | | | | | | | | | |
| Uranoscopidae | *Uranoscopus polli* | | x | x | | | | | | | | | | | | | | | |
| Trichiuridae | [illegible] | x | x | x | x | | | | | x | | x | x | x | x | x | x | x | x |
| Stromateidae | *Stromateus fiatola* | | | x | | | | | | | | | | | x | | | | |
| Citharidae | [illegible] | x | x | x | | | x | x | | | | x | x | | | | x | x | |
| Bothidae | [illegible] | x | x | x | | x | x | | | x | x | | | | | x | | | |
| | [illegible] | x | x | x | | | x | x | | | | x | x | | | | x | x | |
| | *Monolene microstoma* | | x | | | | | | | | | | x | x | | | | | |
| Paralichthyidae | [illegible] | x | x | x | | x | | | | x | x | x | | | | x | x | | |
| Soleidae | [illegible] | x | x | x | x | | | | | | | | | | | | | | |
| | *Dicologoglossa hexophthalma* | | x | x | | | | | | | | | | | | | | | |
| | [illegible] | x | x | x | | | x | x | | | | x | x | | | | | x | |
| | *Microchirus frechkopi* | | | x | | | | | | | | | | | | | x | | |
| Cynoglossidae | *Cynoglossus canariensis* | | | x | | | | | | | | | | | x | | | | |
| Tetraodontidae | [illegible] | x | x | x | | | x | | | x | x | x | | | | | x | | |
| Diodontidae | *Chilomycterus spinosus mauretanicus* | | | x | x | | | | | x | | | | | x | | | | |
| Loliginidae | [illegible] | x | x | x | x | x | x | | | | | x | x | | | | x | | |
| Sepiidae | *Sepia officinalis** | x | | x | x | x | | | | | | | | | x | x | | | |
| Octopodidae | [illegible] | x | x | x | x | x | x | x | x | x | x | x | x | | | | x | x | |
| Penaeidae | [illegible] | x | x | x | | | | | | x | x | | | | x | | x | | |
| | [illegible] | x | x | x | | | | x | x | | | | x | x | | | x | x | x |

Remarks. N: North area, C: Central area, S: South area. I: 3-20m, II: 20-30m, III: 30-80m, IV: 80-200m, V: 200-400m. *: Target species.
(shaded) : Common species in entire survey area.

### (4) Diversity of the nectobenthos

To study the biodiversity of the nectobenthos (fishes, target cephalopods and crustaceans) caught at each trawl station, diversity index *H'* (indicator of species diversity synthesized richness in number of species and evenness in number of individuals of each species) was employed according to the Shannon-Weavere (1949) equation:

$$H' \cong -\sum_{i=1}^{S} pi \ln pi$$

where: S = number of species in sample
pi = proportion of the number of individuals of the *i*-th species.

A high *H'* indicates a complex community structure, and a low *H'* a simple one. Nevertheless, it should be noted that a diversity index based on the numbers of individuals does not reflect necessarily well the structural features of nectobenthos containing simultaneously large-size species (sharks, rays, etc.) and small-size ones (bogies, shrimps, etc.) Also, one should be aware that, in taking account of biodiversity, it is difficult to estimate correctly the spatial extent of the data to consider. Finally, the *H'* index does not presume any particular model.

#### 1) Distribution of the diversity index *H'*

Appendix Figure 3.4 shows the horizontal distribution of diversity indexes *H'* obtained at each trawl station.

#### a) *Amrigue* survey area (Northern coastal area)

*H'* obtained for the *Amrigue*, whose catch capacity was inferior to that of the *Al-Awam*, in general was low. It was presumably higher in the warm season, and in the Banc d'Arguin.

#### b) *Al-Awam* survey area

*H'* obtained for the *Al-Awam* was higher in the warm season than in the cold season, in the Central and Southern areas than in the Northern area, and in the coastal area than offshore.

#### 2) Diversity index *H'* by stratum

Table 3.16 presents diversity index *H'* by stratum.

#### a) *Amrigue* survey area

For whatever season, the overall *H'* obtained for the *Amrigue* was lower than that for the *Al-Awam*. It increased between Phase 1 and Phase 2. *H'* in the Banc d'Arguin is higher in the cold season and lower in the warm season. In other areas, it is the other way round.

#### b) *Al-Awam* survey area

Overall *H'* increased in the chronological order of the seasons surveyed. Except for the Phase 1 cold season, in all other periods overall *H'* increased from the Northern area to the Southern area. Analyzing the vertical distribution of *H'* in the seasons when the 3-20 m stratum data were obtained, one can see that, in the Central and Southern area (and in the latter, *H'* values in the Phase 2 cold season at the 3-20 m and 30-80 m strata are practically identical), the maximum value occurs mainly at strata of less than 30 m water depth, while in the Northern area, it appears at the 30-80 m stratum.

**Table 3.16 Diversity index *H'* by stratum.**

**(A) *Amrigue* survey area**

| Subarea | Stratum | Phase1 | | Phase2 | |
|---|---|---|---|---|---|
| | | Cold season | Warm season | Cold season | Warm season |
| Banc d'Arguin | 3-20m | 1.706 | 1.618 | 1.931 | 1.699 |
| Other | | 1.041 | 2.724 | 1.334 | 2.211 |
| All area | | 1.254 | 1.752 | 1.965 | 1.892 |

**(B) *Al-Awam* survey area**

| Subarea | Stratum | Phase1 | | Phase2 | |
|---|---|---|---|---|---|
| | | Cold season | Warm season | Cold season | Warm season |
| North | 3-20m | - | - | 1.706 | 1.096 |
| | 20-30m | 1.314 | 1.847 | 1.760 | 1.753 |
| | 30-80m | 1.597 | 1.519 | 2.018 | 1.830 |
| | 80-200m | 1.752 | 1.215 | 1.773 | 1.306 |
| | 200-400m | 1.381 | 1.809 | - | 1.182 |
| | 400-600m | - | - | - | - |
| | 20-600m | 2.582 | 2.622 | 2.558 | 2.549 |
| Central | 3-20m | - | 2.968 | 3.086 | 2.307 |
| | 20-30m | 1.722 | 2.289 | 1.324 | 2.375 |
| | 30-80m | 1.169 | 1.885 | 1.754 | 1.358 |
| | 80-200m | 1.890 | 1.408 | 1.576 | 1.505 |
| | 200-400m | 1.876 | 1.601 | 1.305 | 1.975 |
| | 400-600m | - | 2.285 | - | - |
| | 3-600m | 2.070 | 2.641 | 2.724 | 2.892 |
| South | 3-20m | - | 2.796 | 2.567 | 2.500 |
| | 20-30m | 1.516 | 2.354 | 1.505 | 2.676 |
| | 30-80m | 1.943 | 2.359 | 2.569 | 2.580 |
| | 80-200m | 2.542 | 1.950 | 2.134 | 2.166 |
| | 200-400m | 2.143 | 1.774 | 2.127 | 1.860 |
| | 400-600m | - | - | - | - |
| | 3-600m | 2.530 | 3.280 | 3.233 | 3.228 |
| All area | 3-20m | - | 3.094 | 2.971 | 2.483 |
| | 20-30m | 2.091 | 2.603 | 2.605 | 2.660 |
| | 30-80m | 2.035 | 2.290 | 2.268 | 2.103 |
| | 80-200m | 2.138 | 1.546 | 2.011 | 1.990 |
| | 200-400m | 2.246 | 1.914 | 1.883 | 2.278 |
| | 400-600m | - | 2.285 | - | - |
| | 3-600m | 2.649 | 3.009 | 3.211 | 3.312 |

Remark. -: no trawl.

**(5) Cluster analysis of nectobenthos by similarity between trawl stations**

The nectobenthos caught at each trawl station was clustered by the method of Mountford (1962) based on the similarity index $C\pi$ defined by Kimoto (see Table 3.10).

Results of cluster analysis following Mountford's method are shown in the dendrogram of Figure 3.7. Table 3.17 illustrates the composition of the various clusters comprising at least five trawl stations with $C\pi$ fixed at 0.5 (Roman numerals in Figure 3.7 correspond to the *Amrigue* and letters to the *Al-Awam*), as well as the main species in those clusters – the first three species in terms of the ratio of mean number of individuals. Also, the covering area of trawl stations in each cluster is shown in Figure 3.8, for each survey season, with the main group of species representing that cluster. (Not all the main species groups mentioned in Table 3.17 necessarily appear in the figure). Hereinafter the cluster is referred to by the name of its dominant species (the species with the highest mean number of individuals) -- for instance, Cunene horse mackerel group.

### 1) *Amrigue* survey area

Except in the Phase 1 warm season, only one group appeared in each period: the Senegal seabream *Diplodus bellottii* group in the Phase 1 cold season (82% in number of individuals); the planehead filefish *Stephanolepis hispidus* group in the Phase 2 cold season (82%); and the lesser African threadfin *Galeoides decadactylus* group in the Phase 2 warm season (48%). Distribution of those groups was not wide, but the lesser African threadfin group was relatively broad. In the Phase 1 warm season, there were three groups: (1) the planehead filefish (25%) group, (2) the Atlantic bumper *Chloroscombrus chrysurus* (53%) group, (3) the lesser African threadfin (43%) group.

### 2) *Al-Awam* survey area

Number of groups were 3–5 in the cold season and 6–7 in the warm season. The following groups were recognized in all seasons: (1) shortnose greeneye *Chlorophthamus agassizi*, (2) blackbelly rosefish *Helicolenus dactylopterus*, (3) thinlip splitfin *Synagrops microlepis*, (4) false scad *Caranx rhonchus*, (5) Cunene horse mackerel *Trachurus trecae*, (6) bigeye grunt *Brachydeuteus auritus*, (7) Senegal seabream *Diplodus bellottii*, (8) red pandora *Pagellus bellottii*, (9) lesser African threadfin *Galeoides decadactylus*. Among those nine groups, the only one observed throughout the survey was that of the Cunene horse mackerel. Bigeye grunt, red pandora and lesser African threadfin groups occurred only in the warm season.

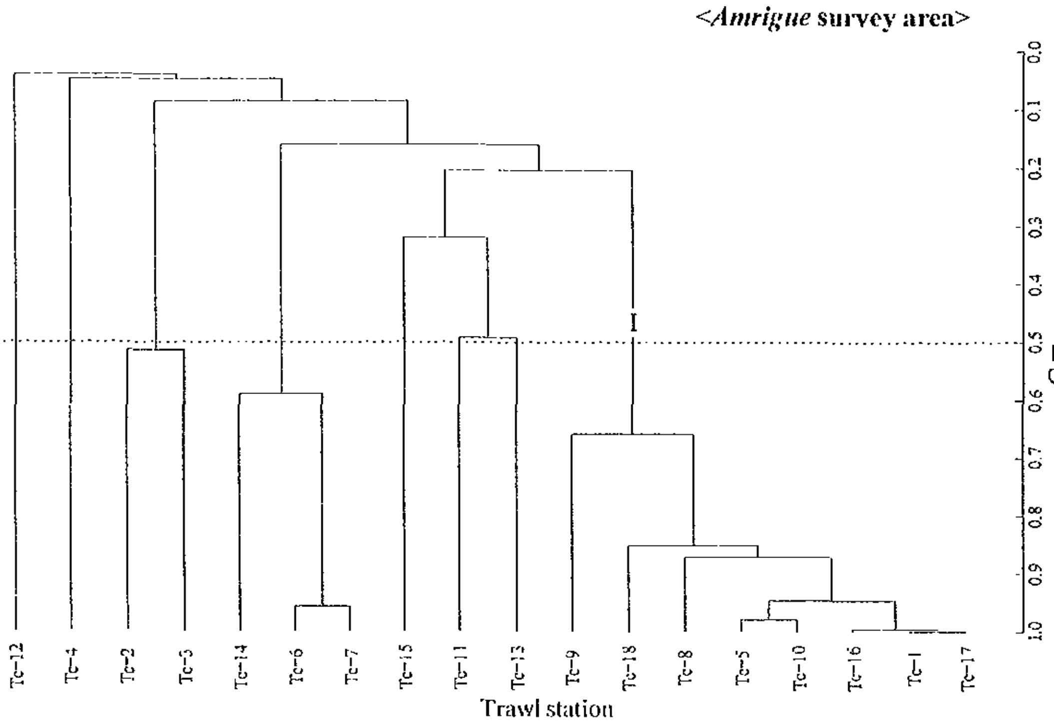
By water depth range, the groups were distributed more or less in the following manner:

| | |
|---|---|
| 3-30m | : 3 groups of false scad, bigeye grunt and lesser African threadfin |
| 30-80m | : red pandora group |
| 80-200m | : 2 groups of Senegal seabream and thinlip splitfin |
| 30-200m | : Cunene horse mackerel group |
| 200-400m | : 2 groups of shortnose greeneye and blackbelly rosefish (warm season). |

Geographical distribution and presumed shoal patterns are the following:

| | |
|---|---|
| Shortnose greeneye group | : Central and Southern areas; in patches or trans-area strips. |
| Blackbelly rosefish group | : Central and Southern areas in the cold season, Northern and Central areas in the warm season; in patches or strips. |
| Thinlip splitfin group | : Entire area, but Central and Southern areas in the Phase 1 cold season; in patches or trans-area strips. |
| False scad group | : Northern and Central areas, or Central and Southern areas; in patches or strips. |
| Cunene horse mackerel group | : Entire area, but Central and Southern areas in the Phase 2 warm season; in patches or long, broken strips. |
| Bigeye grunt group | : Central and Southern areas; in patches for Central aea; in strips for Southern area. |
| Senegal seabream group | : Northern and Central areas; in patches or localized. |
| Red pandora group | : Entire area, or Central and Southern areas; in strips from Central to South, in an ameboid patch in Northern area. |
| Lesser Arican threadfin group | : Central and Southern areas; in patches or trans-area strips. |

(A) Phase 1 cold season



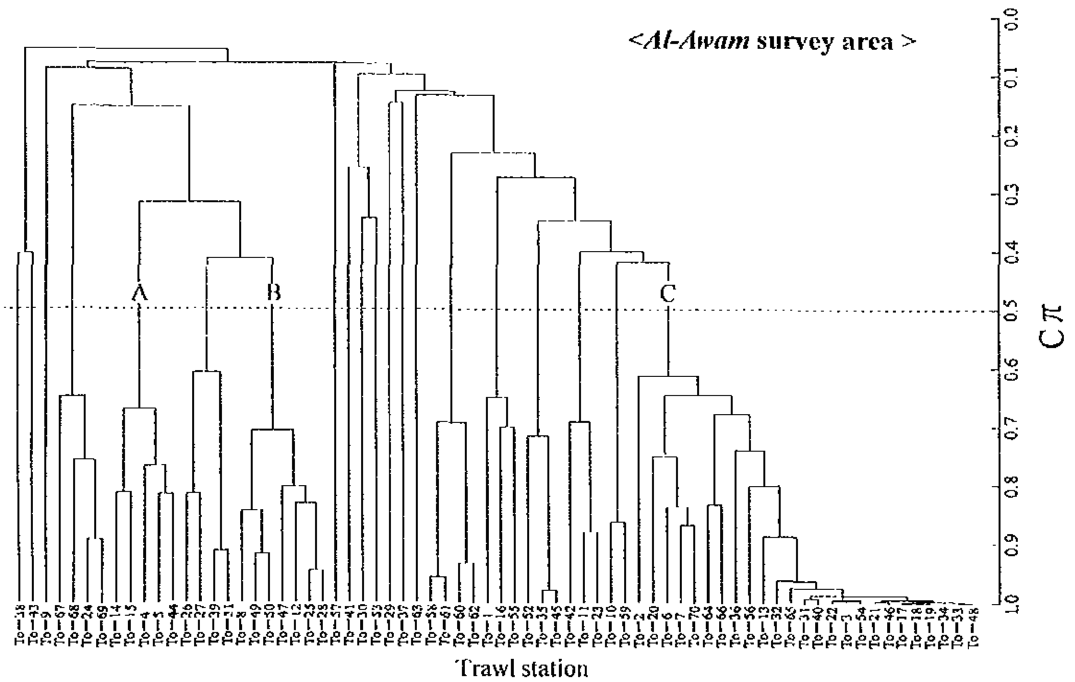



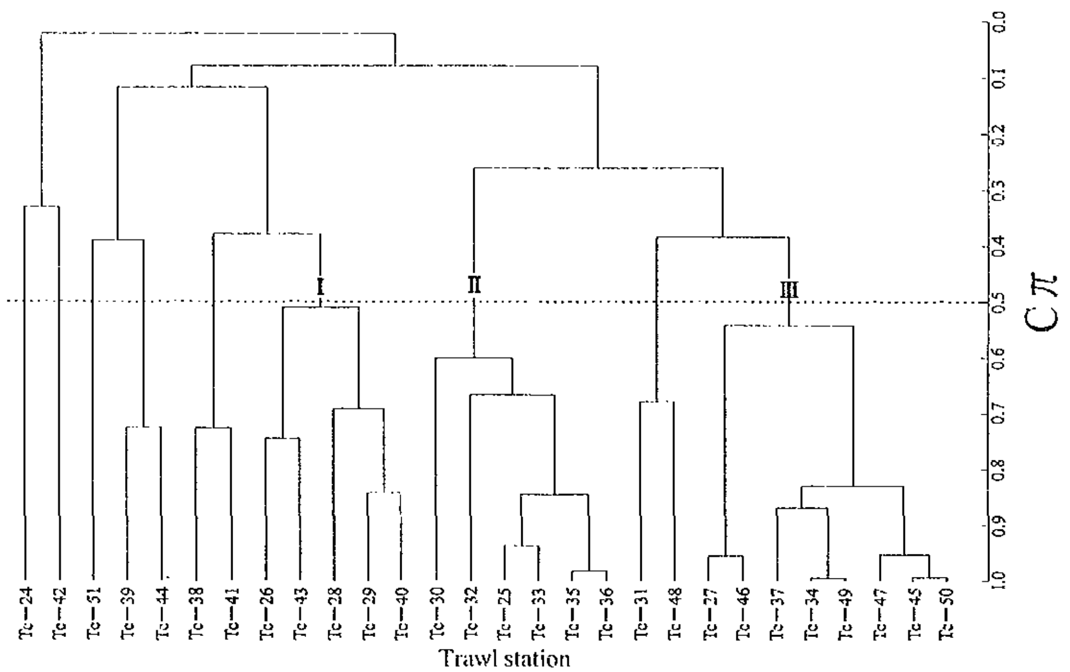

**Figure 3.7 Results of cluster analysis by the Mountford's method.**

For the positions of the trawl stations in each seasonal survey, refer to the FIELD REPORT ON THE SEA-BORNE SURVEY, May 2000, Oct. 2000, May 2001 and Oct. 2001.

**Fig. 3.7 continued**

**(B) Phase 1 warm season**

**<*Amrigue* survey area >**




**<*Al-Awam* survey area >**

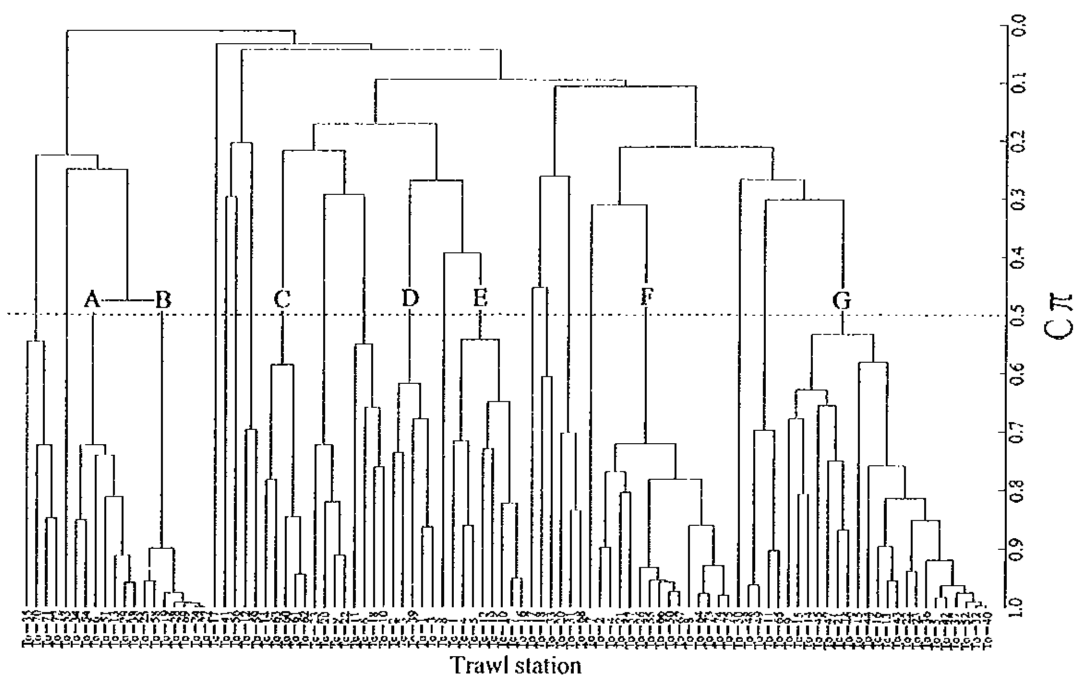
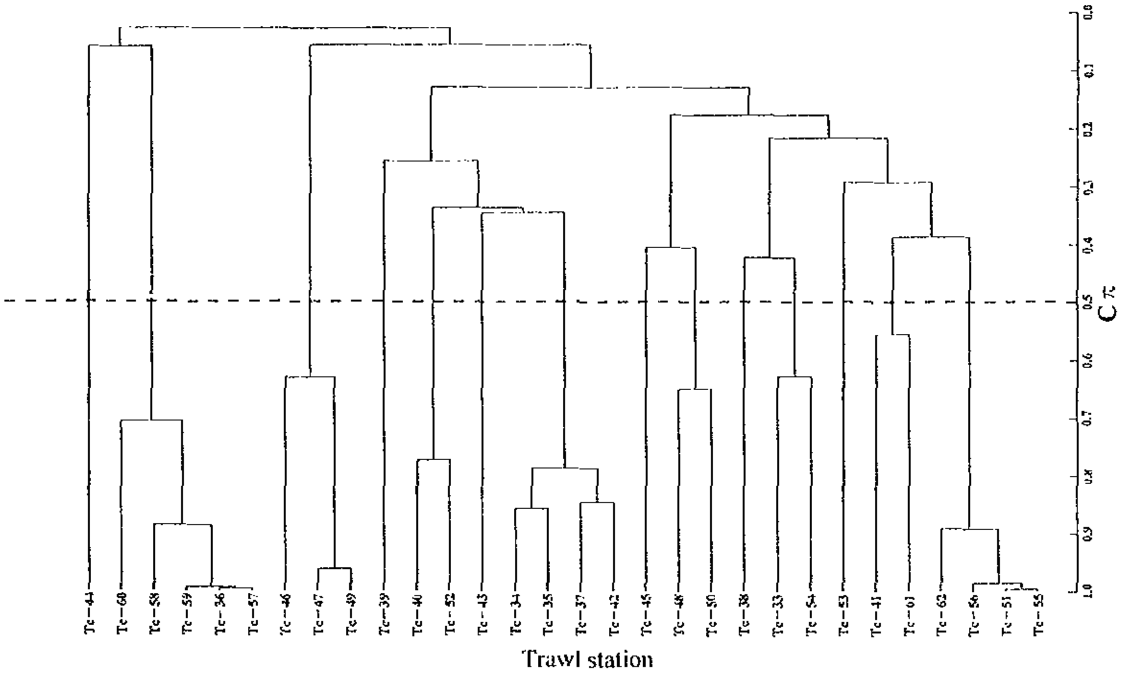


**Fig. 3.7 continued**

**(C) Phase 2 cold season**

<*Amrigue* survey area>




<*Al-Awam* survey area >

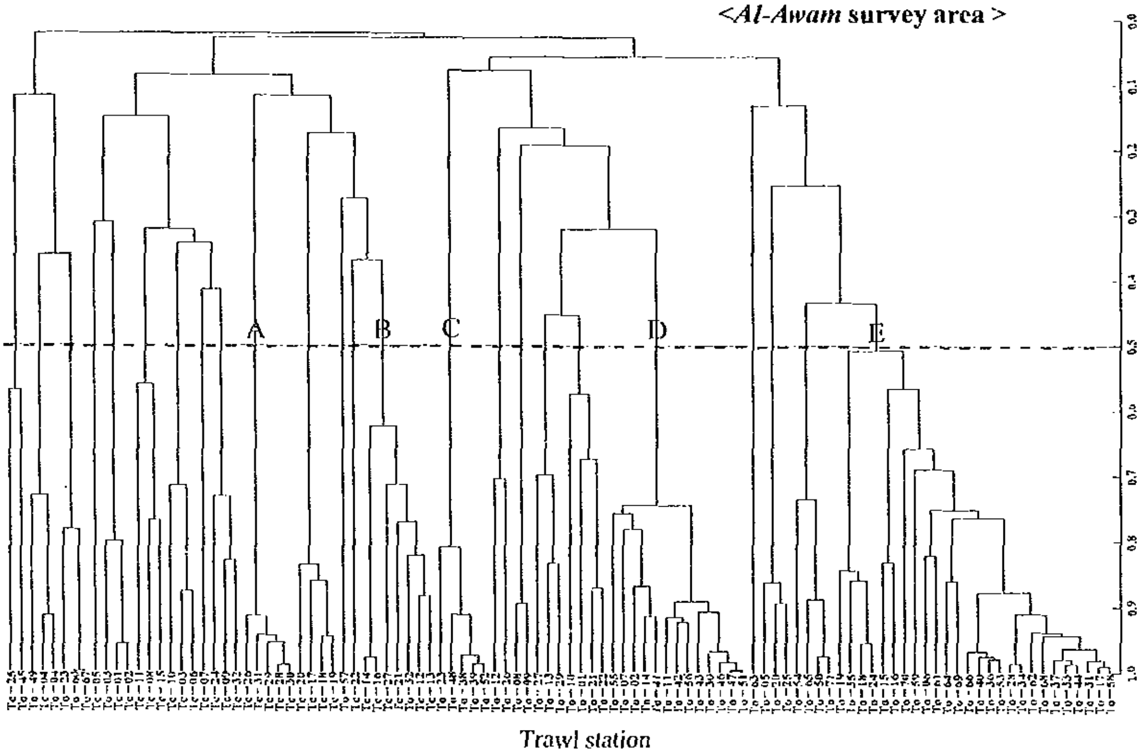


**Fig. 3.7 continued**

**(D) Phase 2 warm season**

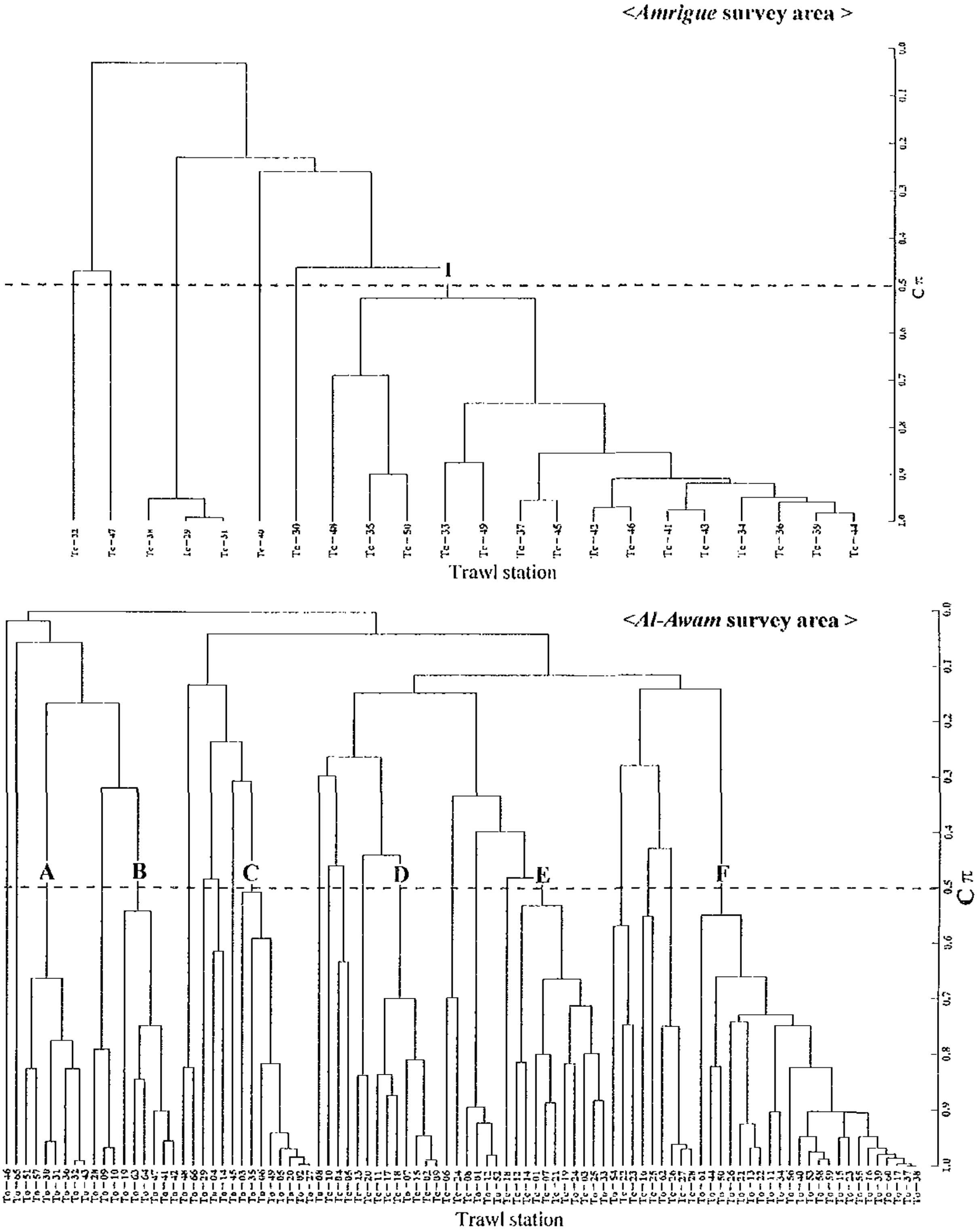


**Table 3.17 Results of cluster analysis by the Mountford's method.**
Clusters comprising at least five trawl stations with $C\pi$ =0.5, and main species.

**(A) Phase 1 cold season**

| Subarea | Clusters | Trawl stations in clusters | Main species in clusters (%: the ratio of mean number of individuals) | |
|---|---|---|---|---|
| Northern coast | I | Tc-1,5,8,9,10,16,17,18 | *Diplodus bellottii* | (82%) |
| | | | *Stephanolepis hispidus* | ( 4%) |
| | | | *Serranus scriba* | ( 2%) |
| North, Central and South | A | To-4,5, 14,15,44 | *Synagrops microlepis* | (43%) |
| | | | *Pontinus kuhlii* | (11%) |
| | | | *Dentex maroccanus* | (11%) |
| | B | To-8,12,25,28,47,49,50 | *Chlorophthalmus agassigi* | (46%) |
| | | | *Trachurus trecae** | (17%) |
| | | | *Microchirus boscanion* | (13%) |
| | C | To-2,3,6,7,13,17,18,19,20,21, 22,31,32,33,34,36,40,46,48, 54,56,64,65,66,70 | *Trachurus trecae** | (76%) |
| | | | *Microchirus boscanion* | ( 4%) |
| | | | *Synagrops microlepis* | ( 4%) |

**(B) Phase 1 warm season**

| Subarea | Clusters | Trawl stations in clusters | Main species in clusters (%: the ratio of mean number of individuals) | |
|---|---|---|---|---|
| Northern coast | I | Tc-26,28,29,40,43 | *Stephanolepis hispidus* | (25%) |
| | | | *Pseudupeneus prayensis** | (24%) |
| | | | *Serranus scriba* | (21%) |
| | II | Tc-25,30,32,33,35,36 | *Chloroscombrus chrysurus* | (53%) |
| | | | *Galeoides decadactylus* | (16%) |
| | | | *Penaeus notialis** | (12%) |
| | III | Tc-27,34,37,45,46,47,49,50 | *Galeoides decadactylus* | (43%) |
| | | | *Diplodus bellottii* | (37%) |
| | | | *Chloroscombrus chrysurus* | ( 5%) |
| North, Central and South | A | To-6,13,29,34,38,51,54 | *Chlorophthalmus agassigi* | (31%) |
| | | | *Synagrops microlepis* | (24%) |
| | | | *Helicolenus dactylopterus dactylopterus* | (19%) |
| | B | To-19,24,25,27,28,58,69 | *Synagrops microlepis* | (81%) |
| | | | *Helicolenus dactylopterus dactylopterus* | ( 6%) |
| | | | *Chlorophthalmus agassigi* | ( 4%) |
| | C | Tc-14 | *Caranx rhonchus* | (35%) |
| | | To-60,61,62,63 | *Diplodus bellottii* | (31%) |
| | | | *Pomadasys incisus* | ( 7%) |
| | D | Tc-2,3 | *Brachydenterus auritus* | (42%) |
| | | To-1,3,39 | *Saurida brasiliensis* | (10%) |
| | | | *Pagellus bellottii** | ( 8%) |
| | E | Tc-1,4,5,7,10,12,19 | *Galeoides decadactylus* | (24%) |
| | | To-16 | *Selene dorsalis* | (16%) |
| | | | *Chloroscombrus chrysurus* | ( 9%) |
| | F | To-2,4,8,21,26,50,55,57,64, 66,67,73,74,75 | *Trachurus trecae** | (67%) |
| | | | *Pagellus bellottii** | ( 9%) |
| | | | *Loligo vulgaris** | ( 4%) |
| | G | Tc-13,15,16,21 | *Pagellus bellottii** | (50%) |
| | | To-5,9,14,15,22,23,32,36,37, 40,42,43,44,45,46,47,52 | *Pseudupeneus prayensis** | ( 9%) |
| | | | *Trachurus trecae** | ( 6%) |

Remarks. :*Trawl stations in the coastal area (depth:3-20m) and the offshore area(depth: >20m) are indicated with "Tc-" and "To-", respectively.* For the positions of the trawl stations in each seasonal survey, refer to the FIELD REPORT ON THE SEA-BORNE SURVEY, May 2000, Oct. 2000, May 2001 and Oct. 2001. *:target species.

Table 3.17 continued.

**(C) Phase 2 cold season**

| Subarea | Clusters | Trawl stations in clusters | Main species in clusters (%: the ratio of mean number of individuals) | |
|---|---|---|---|---|
| Northern coast | I | Tc-36,57,58,59,60 | *Stephanolepis hispidus* | (82%) |
| | | | *Sphoeroides spengleri* | ( 6%) |
| | | | *Ephippion guttifer* | ( 3%) |
| North, Central and South | A | Tc-26,28,29,30,31 | *Diplodus bellottii* | (70%) |
| | | | *Caranx rhonchus* | (15%) |
| | | | *Pomadasys incisus* | ( 7%) |
| | B | Tc-12,13,14,16,21,27 To-32 | *Caranx rhonchus* | (50%) |
| | | | *Pagellus bellottii* * | (21%) |
| | | | *Galeoides decadactylus* | ( 8%) |
| | C | To-23,38,39,48,52 | *Helicolenus dactylopterus dactylopterus* | (75%) |
| | | | *Chlorophthalmus agassizi* | ( 6%) |
| | | | *Capros aper* | ( 5%) |
| | D | To-2,7,11,14,30,41,42,43,46, 47,51,55,56 | *Chlorophthalmus agassizi* | (74%) |
| | | | *Synagrops microlepis* | ( 7%) |
| | | | *Pontinus kuhlii* | ( 4%) |
| | E | To-6,15,16,17,18,19,24,28,31, 33,34,35,36,37,40,44,53,58, 59,61,62,64,66,68,69,70 | *Trachurus trecae* * | (57%) |
| | | | *Trachurus trachurus* | (19%) |
| | | | *Gobiidae* | (11%) |

**(D) Phase 2 warm season**

| Subarea | Clusters | Trawl stations in clusters | Main species in clusters (%: the ratio of mean number of individuals) | |
|---|---|---|---|---|
| Northern coast | I | Tc-33,34,35,36,37,39,41,42,43, 44,45,46,48,49,50 | *Galeoides decadactylus* | (48%) |
| | | | *Chloroscombrus chrysurus* | (19%) |
| | | | *Penaeus notialis* | (16%) |
| North, Central and South | A | To-30,31,32,36,43,51,57 | *Synagrops microlepis* | (68%) |
| | | | *Pterothrissus belloci* | ( 8%) |
| | | | *Chlorophthalmus agassizi* | ( 8%) |
| | B | To-19,41,42,47,63,64, | *Helicolenus dactylopterus dactylopterus* | (44%) |
| | | | *Chlorophthalmus agassizi* | (20%) |
| | | | *Merluccius polli* | (17%) |
| | C | To-2,3,5,6,20,27,35,49 | *Trachurus trecae** | (82%) |
| | | | *Umbrina canariensis* | ( 3%) |
| | | | *Brachydeuterus auritus* | ( 3%) |
| | D | Tc-2,9,11,15,17,18 To-7 | *Caranx rhonchus* | (75%) |
| | | | *Brachydeuterus auritus* | ( 6%) |
| | | | *Diplodus sargus cadenati* | ( 4%) |
| | E | Tc-1,3,7,12,14,19,21 To-24,25,33 | *Galeoides decadactylus* | (40%) |
| | | | *Pomadasys incisus* | (15%) |
| | | | *Brachydeuterus auritus* | (14%) |
| | F | To-11,13,15,16,17,21,22,23,26, 34,37,38,39,40,44,50,53,55, 56,58,59,60,61 | *Pagellus bellottii** | (70%) |
| | | | *Trachurus trecae** | (10%) |
| | | | *Caranx rhonchus* | ( 6%) |

Remarks. :Trawl stations in the coastal area (depth:3-20m) and the offshore area(depth: >20m) are indicated with "Tc-" and "To-", respectively. For the positions of the trawl stations in each seasonal survey, refer to the FIELD REPORT ON THE SEA-BORNE SURVEY, May 2000, Oct. 2000, May 2001 and Oct. 2001. *:target species.

(A) Phase 1 cold season

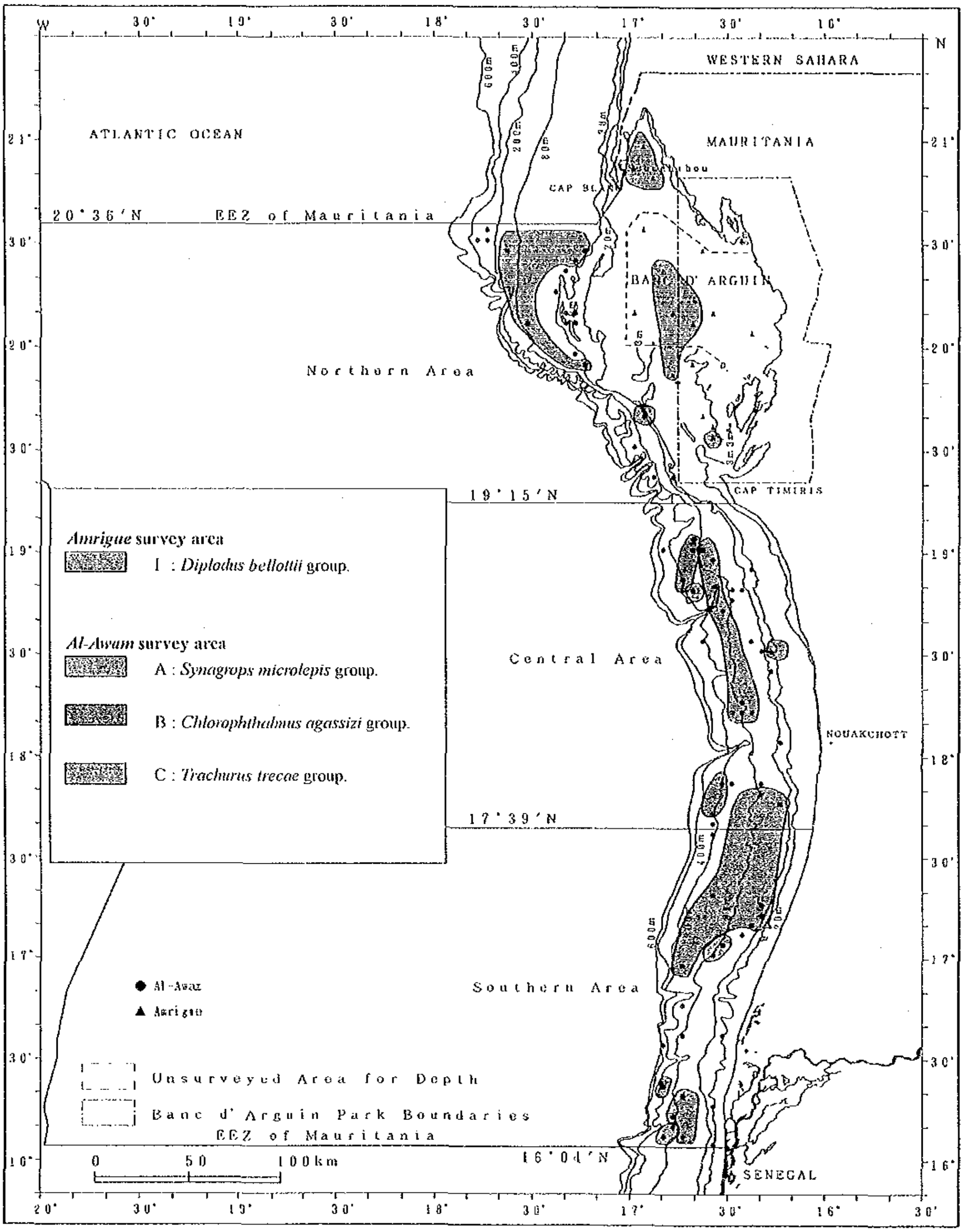



Figure 3.8 Distribution of main clusters in the survey area.

Figure 3.8 continued

**(B) Phase 1 warm season**

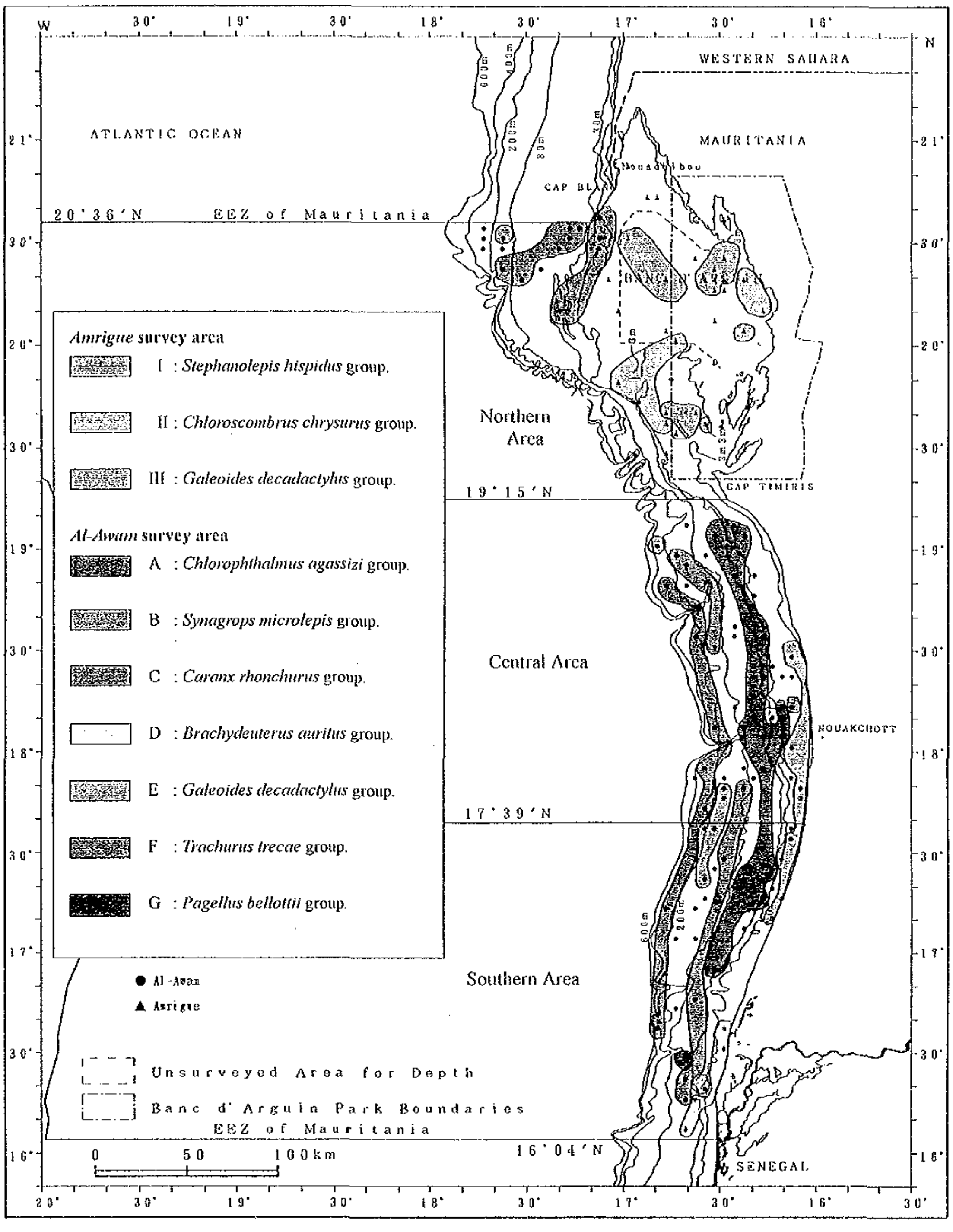


Figure 3.8 continued

**(C) Phase 2 cold season**

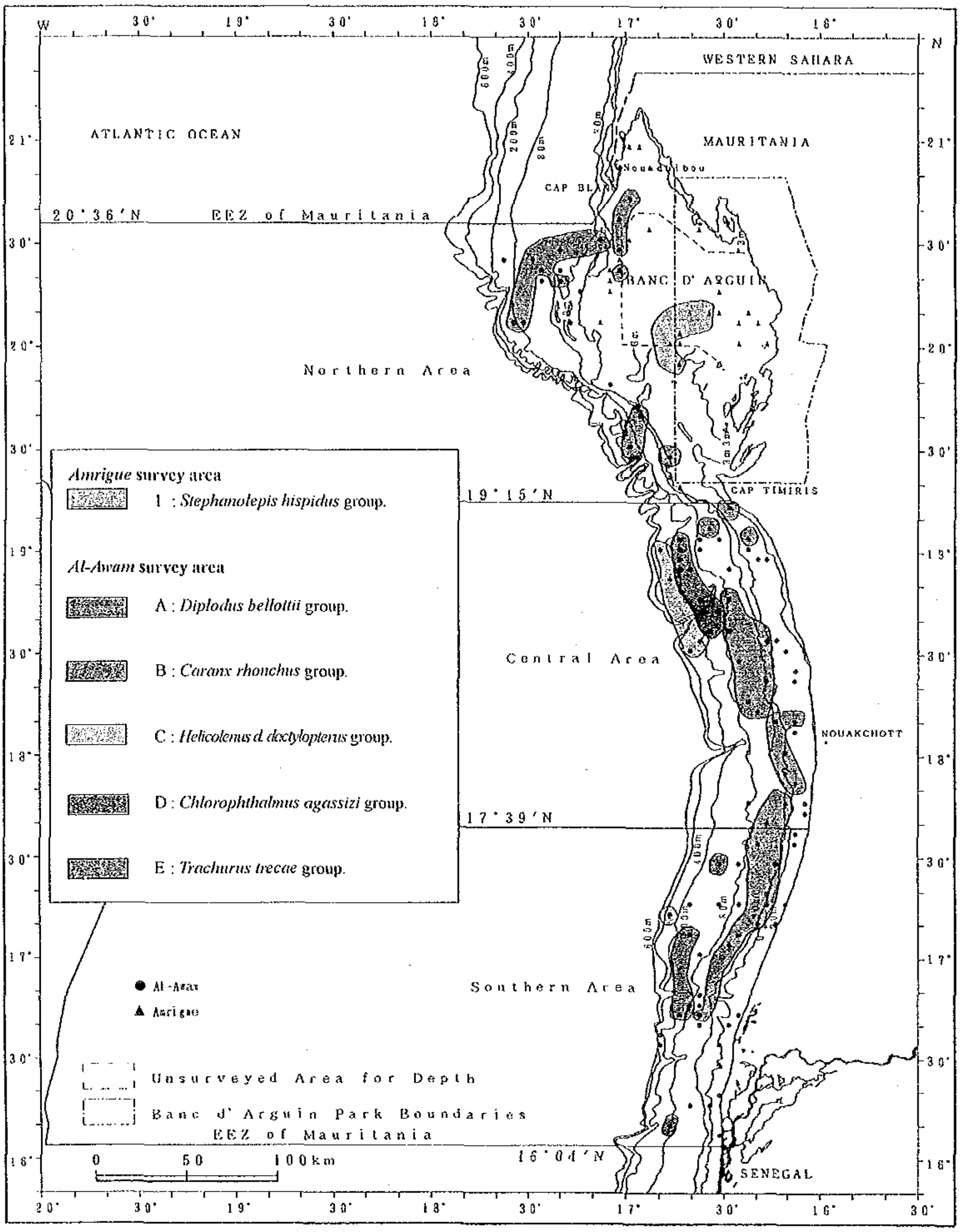


Figure 3.8 Continued

**(D) Phase 2 warm season**