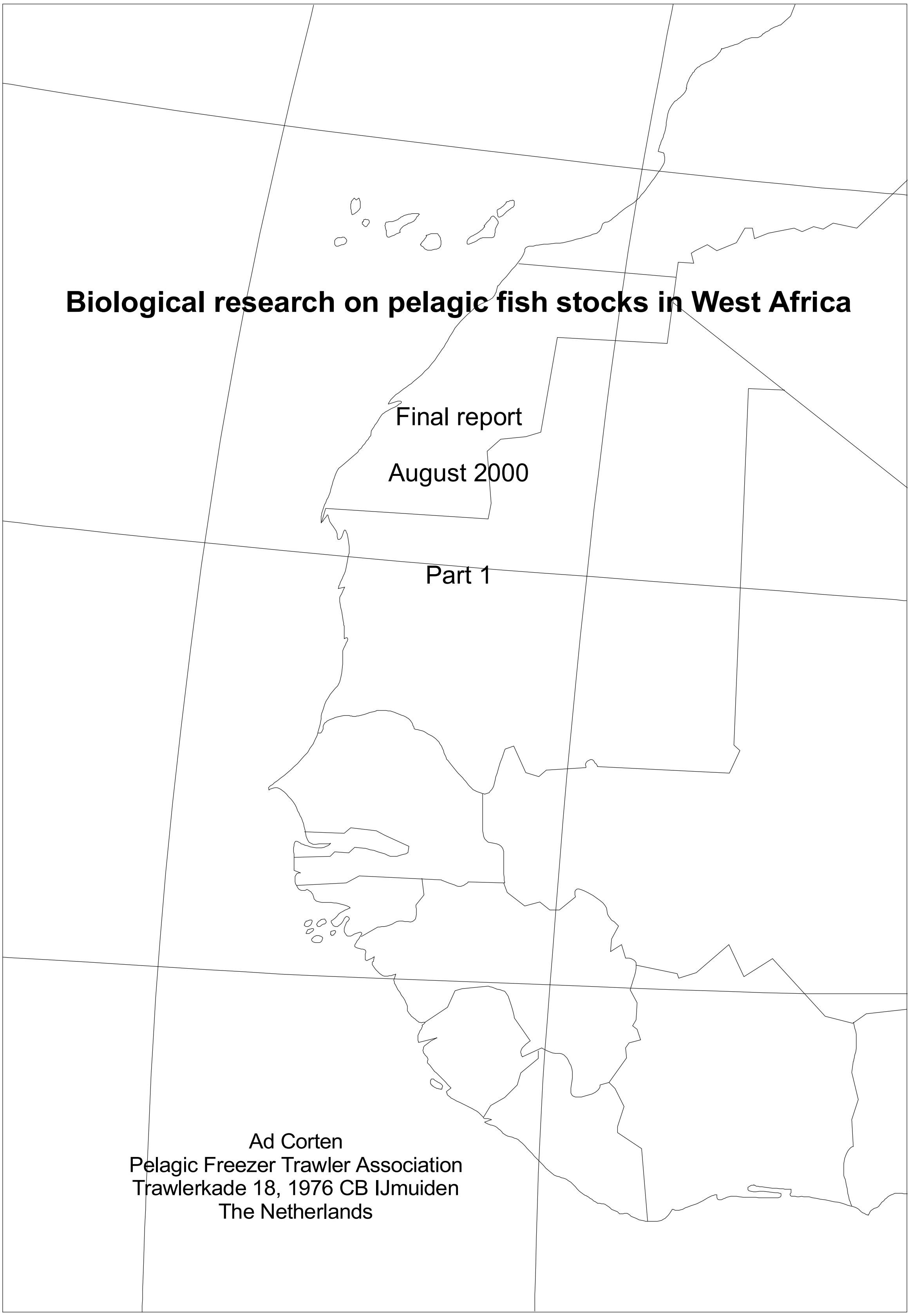

Biological research on pelagic fish stocks in West Africa

Final report

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Part 1

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Annex 7. Inejih, C.A. and A. Corten : "Analysis of length frequency distributions of the catches by Dutch pelagic vessels" (in French).

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1. Introduction

1.1. Background and history of the project

Small pelagic fish are abundant in the waters of Mauritania and its neighbouring countries. The meteorological conditions along the coast of the Sahara cause upwelling of nutrient-rich water, which is the basis for a high plankton production. Part of this plankton production is converted into pelagic fish such as sardinella, horse mackerel, mackerel, bonito, and sardines. These species are generally referred to as “small pelagics”, to distinguish them from the tunas which are the large pelagics. The populations of small pelagics migrate up and down along the West-African coast, thereby visiting the economic zones of Morocco, Mauritania and Senegal. The total harvest of small pelagics in these three countries has been around 1.5 million tonnes per year during the last decades, but large year-to year variations have occurred as a result of natural changes in the stocks and changes in exploitation.

In the 1980s and early 1990s the bulk of the catch was taken by long-distance fleets from the Soviet-Union and other Eastern European nations. Since 1994, however, the activities of these fleets have declined, due to the economic reforms in Eastern Europe. This caused a reduction in the revenues from fishing licenses for the coastal states, in particular Mauritania. In order to compensate the reduced fishing effort by East-European countries, the Mauritania government invited companies from other European countries to buy licenses for small pelagics in Mauritanian waters. A group of ship owners from countries in the European Union (Netherlands, Germany, U.K. and France) responded to this invitation, and started fishing for small pelagics in Mauritania in 1996. The main interests in this fishery were held by four Dutch companies that jointly operated under the name “Dutch Freezer Trawler Association” (DFTA). Catches of the EU pelagic fleet rose from 60,000 tonnes in 1996 to 120,000 tonnes in 1997, and to 150,000 tonnes in 1998. The fishery was directed mainly at sardinella, which constituted about 85-90% of the total landings. Secondary species were horse mackerel, mackerel, sardine, hairtail and bonito.

Two years after the start of the fishery in Mauritania, the DFTA felt the need for more information on the state of the fish stocks and the catch potential for small pelagics in West-Africa. In the years prior to 1990, a considerable amount of biological research on small pelagics had been conducted by scientists from the USSR and other East-European countries. The USSR had built a fisheries research institute in Nouadhibou, and many scientists from the USSR had been working for some years in Mauritania. However, as a consequence of the economic reforms in Eastern Europe around 1990, all foreign scientists were withdrawn from Mauritania. Since then, very little new information had been collected. The Mauritanian fisheries research institute CNROP (Centre National de Recherches Océanographiques et des Pêches) had not been able to continue the research on small pelagics, mainly because all the catches by EU vessels were landed in Las Palmas, and the CNROP was unable to sample these catches.

In order to obtain more up-to-date information, the DFTA in June 1998 decided to start a pilot study on the state of the pelagic resources in the area and their long-term catch potential. The necessary financial means were advanced by the DFTA. The main components of the study were:

- assembling and evaluating existing information on pelagic fish stocks in West Africa;
- investigating the possible use of satellite data in predicting the distribution of pelagic fish;
- collecting biological information on catches and discards of the EU fleet in Mauritania;
- providing technical support to the Mauritanian fisheries research institute CNROP;
- establishing joint research programmes with other research institutes in the region;
- investigating the possibility of obtaining acoustic abundance estimates from commercial vessels;
- investigating the incidental by-catches of dolphins and other large species;
- formulating a research proposal for a larger project in the period 2000-2004.

The pilot study was commissioned by the VOF Voorwaarts, a working company of the DFTA. A project manager was contracted from the Netherlands Institute for Fisheries Research RIVO-DLO, for the duration of the project. He was based at the office of The Group, a subsidiary of the DFTA in IJmuiden, but he had to spent part of his time on board the trawlers, and also at the CNROP in Mauritania.

The co-operation with the CNROP was formalised in an agreement signed in June 1998 during a visit of a CNROP delegation to the Netherlands (Annex 1). The agreement comprised technical and financial support for a number of research activities, in particular the development of national acoustic surveys in Mauritania. A large proportion of the budget was allocated to the recovery of historic data from institutes in Eastern Europe. These data had been collected by East-European scientists in Mauritania during the 1980s, but they had been taken to institutes in Europe, and were no longer available at the CNROP. The CNROP considered the repatriation of this material as a matter of high priority. Other aspects of the DFTA/CNROP agreement were the provision of material, in particular computers and software, and the training of CNROP scientists.

For the study of remote sensing (the application of satellite data), a contract was signed between DFTA and the University of Las Palmas Gran Canaria (ULPGC). Under the terms of this contract, the university was to provide infra-red satellite images from the Mauritanian zone, showing the temperature distribution at the sea surface. The DFTA would provide catch positions and catch compositions of their vessels in West-Africa. A comparison of these two data sets would provide information on the relationship between sea surface temperature and fish distribution. In order to encourage fishing vessels to investigate areas with strong temperature gradients, a series of experiments was planned in which vessels received real-time temperature charts from the ULPGC. If vessels decided to search in areas with interesting temperature distributions, they would be compensated in case the value of their catches remained below a certain level.

The project commenced on the 1st of June 1998, and lasted until the 30th of June 2000. The progress of the work was described in interim reports dated July 1999 and January 2000. The present report covers the entire project until the closing date of 30 June 2000.

1.2. Project proposal to the Dutch Ministry of Agriculture, Conservation and Fisheries

The Dutch Ministry of Agriculture, Conservation and Fisheries was asked to provide financial support to the project. For this purpose, a project proposal was submitted, the details of which are outlined in Annex 2.

During the course of the project, some adjustments were made to the original plan, due to unforeseen developments or newly acquired information. The two main amendments to the original plan and their justification are given below. All other components of the project plan were completed according to schedule.

Development GIS data base for biological and hydrographic information (Item B.4)

This item was suggested by the CNROP delegation during their visit to Holland in June 1998. However, during his first visits to Mauritania, the project manager found that the CNROP already possessed a first version of a GIS data base, developed in co-operation with experts from France and from FAO. It was concluded that the existing technical support in this area was adequate, and that no extra support was needed in the framework of the Dutch project.

Instead of investing in the further development of the GIS data base, it was decided to honour a request from the CNROP for the expansion and upgrading of other computing facilities. Within the framework of the project, the institute was allowed to purchase 4 IBM desk-top PCs, and 7 lab-tops, including software.

Acoustic abundance estimates obtained from commercial vessels (Item B.8)

The initial idea had been to use echo sounders and sonars on board EU pelagic trawlers to collect information on stock abundance, particularly of sardinella. During a number of sea trips on board these vessels, the project manager investigated this possibility. In the end it was concluded that this was not a promising line of future research. The main problems in using acoustic information from commercial trawlers were:

- The vessels use a variety of commercial echo sounders and sonars, none of which are calibrated for measuring absolute densities of fish;

- Most of the time the fleet is concentrated in a very small area, and the vessels continuously pass over the same concentration of schools. It is impossible to extrapolate the acoustic observations within this limited area to the rest of the Mauritanian zone.

It was decided, therefore, to abandon the idea of using acoustic information from commercial vessels for stock estimation. Instead, all acoustic work was focussed on surveys with the Mauritanian research vessel.

2. Assessment of small pelagics in West Africa

2.1. Biological basis of the fishery

Upwelling

The coastal waters of Mauritania are characterised by a high fish production. This high productivity, which is also found further north in the adjacent waters of Western Sahara, is caused by a natural phenomenon called "upwelling". The strong north-east trade winds along the coast of the Sahara blow the surface waters offshore, and thereby create a vertical transport of colder, nutrient-rich water from the deeper layers towards the surface. Once this nutrient-rich water mixes with warm surface water, a dense production of plankton is generated. The upwelling along the coast of Mauritania and Morocco is comparable to similar processes along the coast of Ecuador and Peru, and along the coast of Namibia. As wind is the driving force of the upwelling, the process is strongest in the area where the trade-winds are strongest, i.e. the southern border of the Sahara. In this region (around Nouadhibou) , the trade winds blow throughout the year, and hence the upwelling is also a continuous process. Further south (near Nouakchott), strong winds blow only in the winter, and here the upwelling is limited to the winter season.

Pelagic fish species

A large proportion of the plankton production is consumed by fish that occur in schools near the surface or in mid-water, the so-called "pelagic" species. This group includes sardinella, sardine, mackerel, and horse mackerel. As these species feed directly on the plankton, they have a tendency to concentrate in areas of high plankton production.

The group of pelagic species also includes some larger species such as hairtail and tuna like species (bonito). These are predators that feed on juvenile fish (small anchovies, sardinellas and horse mackerel). However, as the juvenile fish are mainly found in areas of high plankton production, the larger predators are also found in these areas.

A list of the various pelagic species with their names in Latin, French and English is presented in the table below. In the rest of this report the English names are used throughout.

Latin name	English name	French name
Sardinella aurita	Round sardinella	Sardinelle ronde
Sardinella maderensis	Flat sardinella	Sardinelle plat
Trachurus trachurus	Atlantic horse mackerel	Chinchard
Trachurus trecae	Southern horse mackerel	Chinchard jaune
Scomber colias	Mackerel	Maquereau espanol
Sardina pilchardus	Pilchard	Sardine
Engraulis encrassicolus	Anchovy	Anchois
Triciurus lepturus	Hairtail	Sabre
Sarda sarda	Bonito	Bonite

The pelagic fish normally have a lower value per kg than the bottom-living "demersal" species. For this reason, the pelagic resources in West-Africa have been less intensively exploited so far than the demersal stocks.

Migrations

Pelagic fish are well-know for their extensive migrations. The fish cover large distances, either to find food, or to spawn in places that are suitable as nursery areas for small fish. In West-Africa both sardinellas and horse mackerels migrate north in summer and south in winter.

During summer, the highest plankton production is found off Nouadhibou and further north; the only areas where significant upwelling occurs at this time of the year. Consequently, a large proportion of the stocks is found north of Nouadhibou in Moroccan waters. During winter the upwelling spreads south towards Senegalese waters, which increases food production in this area. Another factor that stimulates food production is the increased input of nutrients by river outflow at the end of the rainy season. Both sardinella and horse mackerel migrate to the area south of Dakar during winter, in order to take advantage of the high food production in this area. This is the time of the year when the catches of (large) sardinella by Senegalese fishermen reach their annual peak.

Natural variability

Because of their dependence on water currents, pelagic species tend to react strongly to changes in oceanic conditions. This probably explains their strong variations in abundance and distribution from year to year. In addition to this inter-annual variability, the species sometimes also exhibit multi-annual trends, apparently in response to climatic variations.

The best-know example of short-time variations of pelagic fish in other regions are the changes in the anchoveta stock off Peru, due to the so-called "El Niño" phenomenon. In West-Africa, such extreme variations have not been recorded so far. Still, the species composition of the pelagic landings has shown long-term changes during recent decades. Since 1990, the catches of sardinella in Mauritania and Morocco have increased, whereas the catches of horse mackerel have shown a decline. Presumably, these changes were not only caused by fishing, but also by long-term natural changes in the pelagic ecosystem. These long-term changes are further discussed in section 2.10.

2.2. Historical development of the pelagic fishery

The first industrial fishery for small pelagics in the waters off Mauritania started in 1968. This fishery was conducted by foreign purse seiners that delivered their catches to factory vessels, operating under the flag of Norway or Curaçao. On board the factory vessels, the catches were transformed into fish meal and oil. In the period 1968 - 1973 fishing outside the 3-mile zone was free and the fleets of factory ships and catching vessels could fish unrestricted along the whole West-African coast. In the years 1970-1973 total annual catches reported from Mauritanian waters were in the order of 800 000 tonnes (section 2.3). It is likely that a significant part of this catch was taken inside the 12 mile zone, and also in the area north of 21°N (Western Sahara) which was claimed by Mauritania in those years.

After 1975 the West-African countries extended their jurisdiction over the coastal waters. Foreign vessels were no longer allowed to fish within the 12-mile limit, and after 1981 they were no longer free to fish in the waters of Western Sahara either. The fleet of factory vessels and purse seiners gradually declined, and the last fishmeal factory vessel left Mauritanian waters in 1981. At the same time, there was an increase in the number of pelagic trawlers. These vessels came from the Soviet Union and other East-European countries, and also from Ghana and Iraq. The pelagic trawlers preserved their catches for human consumption, either as frozen fish or as canned products. All foreign vessels holding licenses for Mauritanian waters were obliged to land their catches in Mauritania.

After the extension of fishing limits and the disappearance of the fishmeal factory vessels, the catch of small pelagics reported from Mauritanian waters dropped to a level around 400 000 tonnes/year (section 2.3).

With the economic reforms in Eastern Europe after 1990, state subsidies to the long-distance fleets were reduced. This resulted in major problems for the East-European fleet in Mauritania. The number of fishing days by foreign trawlers declined sharply, as did the catches of this fleet. In an attempt to compensate for the decline of East-European fishing effort, the Mauritanian government invited ship owners from West-European countries to buy licenses for Mauritanian waters. In 1995 a group of EU ship owners concluded an agreement with the Mauritanian government that allowed them to operate a maximum of 22 vessels to fish in Mauritanian waters. These were free licenses, i.e. the vessels were not obliged to land their catches in a Mauritanian port. In 1996 the private agreement between the EU ship owners and the Mauritanian government was incorporated into the fisheries agreement between the EU and Mauritania.

2.3. Catch statistics

For an evaluation of the production potential of West-African pelagics stocks, it is useful to know the size of the catches that were achieved during earlier periods. For this reason, existing catch and effort data will be reviewed here in some detail.

Four sources of catch statistics for West-African waters were available for this study: FAO data, national catch data for the coastal states, catch and effort statistics for Mauritania, and logbook data from EU vessels. Each of these data sets will be considered below.

FAO data

FAO data are the only statistics that cover the entire West-African region since the start of the industrial fishery. The FAO data do not refer to national exclusive economic zones (EEZs), but to wider statistical areas that encompass the waters of several coastal states. These areas have been defined by the Committee on East Central Atlantic Fisheries (CECAF), and are therefore called CECAF-areas. The borders of these CECAF areas do not coincide with the borders of national EEZs, and it is impossible, therefore, to convert CECAF data into national catch data or vice versa. The main CECAF areas off West-Africa are the areas 34.1.3 (Sahara) and 34.3.1 (Cape Verde). Their boundaries are shown in Figure 1. The Mauritanian EEZ contains part of area 34.1.3 and part of area 34.3.1.

The FAO data are the main source of information for the period prior to 1995. In these years, most of the industrial catches of small pelagics in the area were taken by East European countries. It is assumed that the national statistical agencies of these countries correctly reported the catches of their fleets to FAO. There may have been a limited number of countries that did not report their catches. For instance, vessels from Iraq and Ghana are known to have worked in the area, but there are no catch data for these countries in the FAO statistics. It is assumed, however, that the underreporting of catches was limited, and that the FAO figures provide a realistic estimate of the catches in this period.

The accuracy of the FAO statistics probably declined after 1995 when the fleet composition in the area changed because of the reforms in Eastern Europe. Many vessels of the former East-European fleet were sold to companies in other countries, and some of these vessels continued to operate in Mauritania under a different flag. It is doubtful whether the new flag states have all been equally diligent in providing the required statistics to FAO. Also the catch statistics from Eastern Europe have probably become less accurate since 1995, because the vessels were now operated by private companies instead of by state companies.

The FAO catch data for CECAF areas 34.3.1. and 34.1.3 for the period 1972-1995 are summarised in Figures 2 and 3. The first of these figures shows the catch of each major species in each of the two areas. It is seen that some species are taken almost exclusively in the northern area (Sahara), and others in the southern area (Cap Verde). Examples of northern species are anchovy, pilchard, mackerel and Atlantic horse mackerel. Examples of southern species are flat sardinella, and southern horse mackerel. The round sardinella and hairtail occupy an intermediate position, and occur in both CECAF areas.

Many species exhibited strong multi-annual variations during the period considered. These changes were most pronounced in the northern species (anchovy, pilchard, and to a lesser extent mackerel). The changes presumably reflect natural variations in stock size. The round sardinella showed a long-term increase, whereas the Atlantic horse mackerel declined steadily over the period.

The development of the combined catch in both CECAF areas over the period 1972 - 1995 is presented in Figure 3. In this figure the catches of anchovy and pilchard have been omitted, as these species are of little importance for the fishery in Mauritania and Senegal. The combined catch of the remaining species varied between 400,000 and 900,000 tonnes per year. Catches reached a peak during the years 1988 - 1991, and declined to a minimum in 1994. This minimum probably reflects the economic problems of the East-European fleet. The species composition shows the gradual decrease of Atlantic horse mackerel, and the increased importance of the sardinellas after 1985.

The average annual catch of all species combined (except pilchard and anchovy) during the period 1972 – 1995 was 630 000 tonnes. As noted before, this is probably an underestimate since not all fleets in the area have reported their catches to FAO. It is seen that the catch for the whole region showed strong fluctuations from one year to another. This was partly caused by changes in fishing effort, but probably also by natural changes in fish abundance.

National catch statistics

In view of the declining quality of FAO catch statistics in recent years, more emphasis is now being placed on catch statistics collected by the coastal states. All foreign vessels operating in West-African waters are obliged to complete logbooks, and to provide detailed information on their catches to the coastal state. Therefore, the coastal states are in a position to estimate precisely the catch of the various species in their waters.

Until recently, the national catch statistics were not readily available. Each coastal state kept its own records, but there was no system by which information between the countries was exchanged. In order to remedy this situation, FAO in February 2000 organised a workshop in Casablanca, aimed at assembling national catch statistics for the main fishing nations in the northern CECAF area. The meeting was attended by representatives from Morocco, Mauritania, Senegal and The Gambia. During this meeting, new catch data were provided by all countries for the period 1990-1998 (Figure 4).

The summed national data for each of the main species are compared with the FAO data in Figure 5. It should be noticed that the two data sets are not directly comparable. As mentioned earlier, the CECAF areas do not coincide with national zones. Catches taken in Moroccan waters north of 26°N will not be included in CECAF area 34.1.3. Conversely, CECAF area 34.3.1. includes catches taken in Guinea Bissau and Guinea Conakry (Figure 1), which are not included in the national data reported at the Casablanca meeting in February 2000. However, the differences in catches, caused by the mismatch in geographical coverage, are supposed to be small.

The comparison of the two data sets in Figure 5 shows considerable discrepancies for some species in some of the years. Especially for the first years of the national data series (1990-1992), the sum of the national catch figures is generally lower than the FAO estimate. One may assume that in these years, the national statistics were still incomplete, and that the FAO data are the most reliable. Starting from 1994, the sum of the national data is generally equal or higher than the FAO data (with the exception of Atlantic horse mackerel). It is assumed, therefore, that from this year onwards the data series based on national statistics is the most reliable.

Catch and effort statistics for Mauritania

Catch statistics for Mauritania were available in much more detail than for the other coastal states. For this reason, the Mauritanian statistics are presented here separately.

Mauritanian statistics are based on data that have been reported directly by fishing vessels to the Mauritanian authorities. Data files are kept by the Mauritanian inspection service, various ministries, and the national research institute CNROP. In this report, two sets of data have been considered. The first one is derived from a study by the Ministry of Planning (Ministere du Plan, 1996). This data series can be used to study the long-term development of the pelagic fishery in Mauritania. The second data set is a series of catch statistics, derived from the CNROP. These catch data have been screened and corrected for inconsistencies by CNROP scientists.

Figure 6, based on data from the Ministry of Planning, illustrates the development of the pelagic fishery in Mauritania since 1968. There are some obvious data gaps in the years prior to 1980, but still the data provide an interesting account of the long-term development of the fishery. During the 1970s, both pelagic trawlers and purse seiners (in combination with factory vessels) operated in Mauritania. In some years, the reported catches exceeded 800,000 tonnes. The data on fishing effort for these earlier years are very scanty. No effort data are available for the fleets of factory vessels and purse seiners. Estimates of fishing effort for the pelagic trawlers are also virtually absent in the years in the years prior to 1980.

In the post-1980 period, the purse seiners disappeared, and only the pelagic trawlers remained. The effort data for the trawlers show a high initial level (number of vessels, total tonnage, and number of fishing days), and a gradual decrease in later years. The number of trawlers and their tonnage also includes vessels that have fished only part of the year in Mauritania. Therefore, these numbers are not very accurate estimates of fishing effort. The best estimate of total fishing effort is probably the number of fishing days. Even these data, however, are not very precise since they have not been corrected for horse power, efficiency, or target species.

Another series of catch data for the Mauritanian zone was provided by the CNROP. This series covers the period 1979 – 1997, and provides a breakdown by species (Figure 7). For the period 1979-1986, the data were taken from the report of the Working Group meeting in Nouadhibou in November 1993 (CECAF report 95/60), while data for 1987-1997 were provided by the CNROP. For the first 3 years (1979-1981), the total catch of small pelagics estimated by the CNROP data is much lower than the total figure given by the Ministry of Planning (Figure 8a). On average, the CNROP data are about half of those given by the Ministry of Planning. This is due presumably to the inclusion of catches in the waters of Western Sahara in the data from the Ministry of Planning. Up till 1981, Western Sahara was claimed by Mauritania, and the catches taken in this area were probably added to the catches taken in Mauritanian waters. Therefore, these figures probably represent almost the entire industrial catch for the northern CECAF area. A comparison between the data from the Mauritanian Ministry of Planning, and FAO data for the whole northern CECAF region (Figure 8b) shows that this is indeed the case. During the period 1972 – 1981, the catch reported by Mauritania alone was at about the same level as the catch reported by FAO for the entire northern CECAF area. The fact that the Mauritanian estimates are sometimes even higher than the FAO figures may be due to the fact that pilchard and anchovy have been excluded from the FAO data. In some years, the catch reported by Mauritania (from Western Sahara) may have contained a substantial amount of pilchards. From the comparison between CNROP data and the figures from the Ministry of Planning (Figure 8a), it appears that the catches taken in Western Sahara have been removed from the CNROP data. The CNROP data, therefore, provide a more accurate picture of the catches taken in Mauritanian waters than the figures from the Ministry of Planning.

The steady decline in catches of horse mackerel seen in the CNROP data (Figure 7), corresponds to the trend in the data for the whole CECAF sub-region (figure 3). However, the steady increase in sardinella catches since 1986, shown by data for the whole CECAF sub-region, is not seen in the Mauritanian data. In Mauritania, catches of sardinella started to rise only in 1996. Either the abundance of sardinella in Mauritanian waters before 1996 was still low, or the pelagic trawlers were not interested in this species.

Logbook data from EU pelagic trawlers

In 1996 a fleet of pelagic trawlers from EU countries started to work in Mauritanian waters. Most of these vessels were Dutch, or partly owned by Dutch companies. Although some of the vessels operated under flags of other countries (Germany, United Kingdom, France, United States), it is commonly referred as the Dutch pelagic fleet.

All vessels were obliged to keep records of their catches in logbooks. Copies of these logbook sheets for the years 1996-1998 were available from the Dutch Freezer Trawler Association. The data in these logbooks specify the composition of the EU catches during this period, and the geographical distribution of the catches.

Figure 9 illustrates the catch composition of the EU fleet in 1996-1998. It is seen that the sardinellas made up the bulk of the catch, contributing as much as 85-87% to the total catch in weight. The EU vessels were obviously targeting on sardinellas. The reason for this was that the vessels have a large processing capacity (up to 250 tonnes per 24 hours), which made it more profitable to take large quantities of low-valued sardinella, than small quantities of higher priced horse mackerel. However, if sardinellas were absent, the vessels would fish for other species that occurred in less dense concentrations.

The geographical distribution of the sardinella catches in each of the three years is shown in Figure 10. It is seen that the largest quantities of sardinella were taken in the northern half of the Mauritanian zone. Since the other species were taken mainly as a by-catch in the sardinella fishery, the distribution of these catches tended to coincide with that of sardinella.

2.4. Acoustic surveys

The only fishery-independent source of information on the development of the fish stocks in Mauritanian waters were the results of acoustic surveys conducted by the Norwegian research vessel "Dr. Fridtjof Nansen". This vessel operates in West-Africa in the framework of a technical assistance project, run by Norway and the FAO. Surveys were conducted at irregular intervals in the 1980s and early 1990s, but since 1995 the Mauritanian zone has been covered each year in November/December.

The survey results are probably most accurate for sardinella. This species is easily recognised on the echogram. Other species such as horse mackerel and mackerel are more difficult to identify, and the results for these species are considered to be less reliable.

When interpreting the survey results, one should keep in mind that the surveys in the period 1995-1999 were always conducted in November/December. At this time of the year, the sardinellas have their most southern distribution, and a substantial part of the stock has migrated out of the Mauritanian zone into Senegalese waters.

The results of all surveys conducted in 1981 - 1998 in the waters of Morocco, Mauritania, Senegal and The Gambia are presented below. The figures represent standing stocks in thousands of tonnes.

survey	sardinellas	Atlantic horse mackerel	southern horse mackerel
April-May 81	230		
Sept 81	435		
Feb-Mar 82	90		
Nov-Dec 86	630		
Feb-Mar 92	3510	190	530
Nov-Dec 95	3495	260	180
Nov-Dec 96	3160	450	662
Nov-Dec 97	1826	540	655
Nov-Dec 98	1828	180	799

It is seen that the abundance of sardinella increased sharply between 1986 and 1992, but then declined from 1995 to 1998.

Results from the survey in November/December 1999 have not yet been officially released by the Nansen Programme (the Norwegian organisation responsible for the surveys). Preliminary results reported at the Casablanca workshop in February 2000, however, indicated a substantial increase in the stock of sardinella. The stock was now estimated to be at about the same level as in 1995. The growth in stock size appeared to be due to a good recruitment throughout the West-African region.

2.5. Previous assessments

The most recent assessments of small pelagics in West Africa were made by the following workshops or working groups:

- Evaluation des stocks et des pêcheries mauritaniens; voies de développement et d'aménagement. Rapport du troisième Groupe de travail CNROP. Nouadhibou, Mauritania, 20-26 novembre 1993 (CECAF 1995)
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- Goupe de travail ad hoc sur les sardinelles et autres especes de petits pelagiques cotieres de la zone nord du COPACE. Centre de Recherche Océanographique de Dakar Thiaroye (Sénégal), 29 novembre - 3 décembre 1993 (CECAF 1994)

- Groupe de Travail *ad hoc* sur la sardine. Casablanca, Maroc, 24-28 février 1997 (CECAF 1997)

- Évaluation des Stocks et Aménagement des Pêcheries de la ZEE Mauritanienne. Rapport du 4ème Groupe de travail CNROP, Nouadhibou, Mauritanie, 7-13 décembre1998 (CECAF 1999)

The most important meeting for sardinella and horse mackerel was the working group meeting in Nouadhibou in November 1993. This working group applied a variety of analytical models to the stocks of sardinella and horse mackerel, and also to the combined stocks of small pelagics. The models gave rather variable results, as is shown in the table below:

species	Potential catch in whole region (per year)	Optimum fishing effort in relation to 1990 level	Remarks
Horse mackerel (both species combined); global model	400 000	- 70%	The stock appears to have been over-exploited since 1980. However, an analysis based only on Russian data suggests that the stocks are not yet over-exploited.
Horse mackerel (both species); ADAPT model	610 000 – 640 000	+ 100%	
Sardinella (both species combined); global model	750 000	+ 400%	The model estimates that the maximum catch is attained at a fishing effort of four times the 1990 level.
All species except pilchard; global model	1 100 000	+ 20%	

The two assessments for horse mackerel arrived at opposite conclusions: the first model estimated that the stocks were severely over-exploited, and that the maximum potential catch (400 000 t) could be reached already with 35% of the current fishing effort. The second model estimated that the maximum potential catch was more than 600 000 t, and that this catch was reached by a doubling of current fishing effort. The working group stated that the second (more optimistic) model was probably the most accurate

The conclusion of the working group was that in general the stocks of small pelagics appeared to be moderately exploited. The maximum catch in the whole region (excluding pilchard) would be in the order of 1.1 million tonnes. It was only in 1990 that fishing effort approached the level that corresponded to the maximum potential catch. If fishing effort had declined since 1990, due to the problems in Eastern Europe, the fish stocks at the time of the meeting (1993) would be only moderately exploited. For the horse mackerel, the ADAPT-model was more precise than the global model, which meant that this group of species was also still in a healthy situation.

The CECAF meeting in Dakar from 29 November to 3 December, a few days (!) after the meeting in Nouadhibou, did not attempt to make a new assessment of the stocks. Instead, this meeting was devoted mainly to a description of the fisheries, and the biological characteristics of the various species.

The meeting in Casablanca in February 1997 only dealt with pilchards in the Moroccan region. Since the present study focuses on sardinella and horse mackerel (the species that are most relevant for the fishery in Mauritania), the results of the 1997 Casablanca meeting will not be further discussed here.

During the meeting in Nouadhibou in December 1998, a new assessment was made of the two stocks of horse mackerel (Atlantic and southern horse mackerel). Developments in both stocks were investigated by Virtual Population Analysis. However, due to a lack of data for tuning the VPA, the results were considered reliable only up until 1995. The conclusion of the analysis was that both the Atlantic and southern horse mackerel were under-exploited, with the fishery taking less than 10% of the total stock in each year. The results showed an increase of the stock of Atlantic horse mackerel from 1990 to 1995. However, it was noted that the results of the VPA were inconsistent with the results from acoustic surveys. No new assessment was made for sardinella, due to a lack of catch and effort data for recent years.

The 1998 Nouadhibou meeting did not make new estimates of the long-term potential catch (maximum sustainable yield or MSY) of sardinella and horse mackerel. Instead, the figures calculated in 1993 for the northern CECAF area (750,000 tonnes/year for sardinella and 400 - 600,000 tonnes/year for both species of horse mackerel combined) were repeated in the report of the 1998 meeting. It was recommended that fishing effort for horse mackerel could be maintained at the current level or even increased by 20%. Unfortunately, the figures in the 1998 report are presented in table that gives an overview of fish resources in Mauritania. This suggests, therefore, that the MSY-estimates apply to the Mauritanian zone, instead of to the whole of the northern CECAF area.

2.6. Estimates of current stock size

There have been no recent analytical assessments by working groups that provide reliable estimates of the current stock size of sardinella and horse mackerel. In the absence of effort data for the international fishery, such an assessment can not be made by the present author either.

The only source of information on the latest developments of the stocks are the results of acoustic surveys by the Norwegian research vessel “Dr. Fridtjof Nansen” (see section 2.4 above). These surveys cover the whole West-African region, and the survey estimates can be considered as fairly accurate indices of the total stock of each species in the area.

The results presented in section 2.4 showed pronounced changes in the stock of sardinella (round and flat sardinella combined) in the last two decades. From a level of some hundred thousand tonnes in the 1980s, the stock increased in the early 1990s and reached a level of 3.5 million tonnes in 1995. Since then the stock gradually declined to 1.8 million tonnes in 1998. In the latest year (1999), however, the stock showed an increase again to 3.5 million tonnes. This increase was due mainly to the presence of large numbers of juvenile sardinella all over the area, particularly in Senegal.

Survey estimates for the two species of horse mackerel are considered reliable only since 1992. The present time series (1992-1998) is too short to detect long-term trends. Results fluctuate strongly from one year to another, presumably also due to problems in identifying the species on the echogram. In recent years, the southern horse mackerel has been more abundant in the surveys than the Atlantic one. This corresponds to the results of the (national) catch statistics, that also show a predominance of southern horse mackerel over the Atlantic one.

In using the results of acoustic surveys, one should not attribute too much value to the absolute values of the stock estimates. These estimates depend very much on the values for target strength (TS) used in the calculations, and these TS values are rather uncertain. Instead, the survey estimates should be used as relative indices of stock size, that indicate changes in stock from one year to another. For this purpose, the survey results are most valuable.

On the basis of the results obtained during the last years, one may conclude that the stock of sardinella appears to be in a healthy condition. The strong recruitment in 1999 will probably maintain the stock at a high level for at least 2-3 years (depending on the level of fishing effort). The results for horse mackerels are more variable and do not allow precise conclusions as to the current state of these stocks. The results seem to confirm the declining trend in Atlantic horse mackerel, seen in catch statistics, and the steady state (or possibly even increase) of the southern horse mackerel.

2.7. Maximum sustainable yield for northern CECAF area estimated by analytical methods

Definition of assessment area

Estimates of potential yield must refer to the total distribution area of a particular species or group of species. Since the stocks of small pelagics in West-Africa migrate back and forth between the economic zones of several countries, the potential yield can only be estimated for the entire area that is inhabited by the stocks. Although it is impossible to draw sharp boundaries for the distribution areas of individual species, previous assessment working groups have considered the northern part of the CECAF area (sub-areas 34.1.3 and 34.3.1, see Figure 1) as a practical unit for stock assessment purposes. This area includes all or part of the economic zones of Morocco, Mauritania, Senegal, The Gambia, Portuguese Guinea and Guinea. Presumably, there is little exchange of pelagic fish between this area and the neighbouring regions. Exceptions are the stocks of mackerel and (Atlantic) horse mackerel, that probably migrate across the northern boundary.

Principle of analytical methods

Analytical methods estimate the potential catch of a fish population on the basis of a mathematical model. The model simulates the development of the population under different levels of fishing pressure, and it gives the long-term average catch for each scenario. For these calculations, the model has to be fed with realistic estimates of the growth rate of individual fish, the natural mortality, and the amount of new fish (“recruits”) that will join the population each year. Normally, it is assumed that recruitment will vary within certain limits around a long-term average. In other words, recruitment is not expected to show long-term trends.

Problems with analytical methods in West Africa

For the small pelagics in West-Africa, it is difficult to apply the analytical approach. The basic parameters needed for mathematical models are lacking for most of the fish species. Despite the large amount of biological work that has already been done in the past, accurate estimates of growth and natural mortality are still not available. The main reason for this deficiency is the problem in age determination. Unlike fish in temperate regions, tropical fish do not form clear growth marks on their scales or otoliths (bony structures in the ear). In northern Europe, the growth of the fish is interrupted during the winter season, and this interruption can be detected in the form of annual rings on their scales or bones. By counting these rings, the age of the fish can be determined. In tropical seas, however, the growth of the fish continues throughout the year, and no annual growth marks are formed. This makes it very difficult to determine the age of the fish, and hence the growth rate, and the rate at which fish disappear from the population (total mortality).

A second problem in West-Africa is that one can not assume recruitment to fluctuate around a steady long-term mean. Catch statistics over the last decades have shown long-term trends in the recruitment of some of the major species (sardine, sardinella, horse mackerel), the cause of which will be discussed in section 2.10. It is likely that similar long-term variations will also occur in future. This invalidates predictions that are based on the assumption of steady recruitment.

In the absence of accurate biological parameters, the models can be fed with arbitrary assumption about growth rate, natural mortality, and future recruitment. This has been the approach by the earlier working groups mentioned in section 2.5. It should be realised, however, that the results of these exercises depend entirely on the arbitrary value of the input parameters. This leads to rather variable results, as was shown by the review presented in section 2.5. The best estimate for the maximum sustainable yield (MSY) for the northern CECAF area, based on the analytical method, was 1.1 million tons/year for sardinella, horse mackerel and mackerel combined.

2.8. Maximum sustainable yield for northern CECAF area estimated by empirical methods

Principle of empirical method

The second method is to estimate the potential catch of a particular species on the basis of past experience, that is on the relationship between fishing effort and total catches in earlier years. The principle of this approach is that each level of fishing effort must correspond to a certain equilibrium catch. If we know the equilibrium catch in a few periods with different levels of fishing effort, an empirical curve can be constructed that represents the relationship between fishing effort and equilibrium catch. The total catch will reach a ceiling at a certain level of fishing effort. This level of fishing effort provides the “maximum sustainable yield”. If effort increased beyond this point, there are two possibilities. Either recruitment is independent of the stock of adult fish, in which case the total catch will continue to fluctuate around the long-term maximum. If, on the other hand, recruitment depends on the number of adult fish, the recruitment will decline, and so will the catches. This is the classical situation of overfishing.

A consideration of time series of total catch and fishing effort may thus provide an estimate of the maximum sustainable catch, and also of the corresponding level of fishing effort. However, this remains a crude method. It does not take into account the effects of transition from one effort level to another: a rise in effort is always accompanied by a temporary increase in catches, and a decrease in effort results in a temporary decrease of catches. Moreover, when applied in a mixed fishery, the method does not take into account differences in development between the various stocks, or changes in fishing strategy of the fleet. Still, in the absence of adequate biological data, this method will provide a more robust estimate (less subject to variation) of potential yield than the analytical approach.

Effort data

The only effort data available for the West-African region refer to the Mauritanian EEZ (Fig. 6). Since a major part of the total West-African catch of small pelagics in the past originated from the Mauritanian zone, it is assumed that the effort series for this area is representative for the total region. The statistics show that the effort by pelagic trawlers in the Mauritanian zone was at a maximum in the years 1980-1988 (80 trawlers on average), and declined in later years.

Estimated potential catch for horse mackerel

Catches of Atlantic horse mackerel in the northern CECAF area were at a high level during the 1970s (around 300,000 tonnes/year), but stabilised at a level of 190,000 tonnes/year during the 1980s. The high catches during the 1970s were probably due to the harvesting of an accumulated stock of older fish. This is a normal phenomenon when a fishery starts exploiting a new resource. After the old fish have been removed (and the stock has been reduced from its initial level), an equilibrium situation is established in which the fishery only harvests the annual increase of the stock, and the stock remains at a steady level. The catch level of 190,000 tonnes/year, maintained throughout the 1980s, probably represented this equilibrium situation. We may thus assume that this figure corresponds to the long-term sustainable yield of the species.

After 1988 the catches of Atlantic horse mackerel showed a decline, despite the fact that fishing effort remained relatively high, at least until 1993. This means that the stock itself must have declined during these years. There are two possible explanations for this decline in stock size. The first explanation is that the fishery during the 1980s was not in an equilibrium situation, but that the stock was gradually further depleted by the fishery. This implies that the stock was overfished during the 1980s, and that the catches during this period were still above the MSY level. In this case, the actual MSY level would be lower than 190,000 tonnes/year. The second possibility is that the decline in stock size after 1988 was due to natural changes in the ecosystem. Towards the end of the 1980s, there was a strong expansion of sardinellas, which may have been a symptom of a change towards a more southern species composition (see also section 2.10). Such a change in ecosystem may have adversely affected the (northern) Atlantic horse mackerel. Either recruitment of the species may have declined, or the distribution of the adult stock may have shifted north, across the northern boundary of the assessment area. If this situation continues in future, the maximum sustainable yield will be less than the 190,000 tonnes/year achieved in the 1980s.

Catches of southern horse mackerel continued to fluctuate around a level of 100,000 t, irrespective of variations in fishing effort. The fact that this species did not show a decline after 1988 supports the theory that the reduction in Atlantic horse mackerel was due to a change in ecosystem. This change might have had opposite effects on both species of horse mackerel: a negative effect on the (northern) Atlantic horse mackerel, and a positive effect on the southern horse mackerel. If the change in ecosystem is maintained in future years, the MSY for southern horse mackerel might be higher than the average catch level (about 100,000 tonnes/year) in former years.

In order to estimate the future potential catch of both species of horse mackerel combined, one may arbitrarily assume that (climatically induced) changes in both species will compensate each other. Thus, a reduction in Atlantic horse mackerel, due to a temperature increase (or other factor favouring southern species) would be compensated by an increase in southern horse mackerel. In this case, the MSY for the two species combined would remain constant. If the fishery in the period 1980-1988 was in a steady state, the MSY for the combined stocks in that period was 190,000 + 100,000 = 290,000 tonnes/year. Assuming that a change in ecosystem composition would not alter the MSY for the two species combined, the potential catch of both species of horse mackerel in the northern CECAF area in future years is thus estimated at about 290,000 tonnes/year. This figure is considerably lower than the outcome of the analytical models (section 2.6).

Estimated potential catch for sardinella

For sardinella it is more difficult to draw conclusions about the MSY from historic catch and effort data. The increase in catches after 1987 must have been due at least partly to an increase in stock size, rather than to an increased exploitation. This is evident from the results of the acoustic surveys, which show a marked increase in stock size after 1990. For some reason, recruitment to the stock seems to have increased substantially towards the end of the 1980s. The possible causes of this change in recruitment will be discussed in the next section (2.10).

Following the recruitment increase of the late 1980s, the total catch of both sardinella species combined increased to nearly 350,000 t in 1990, but declined again in subsequent years (Figure 3). With the advent of the EU trawlers in 1996, the catches of sardinella increased again, and the average catch for the most recent years (1996 – 1998) is now above 400,000 tonnes/year (Figure 4). Whether this catch level is sustainable or not depends on the recruitment in the next years. The latest acoustic survey in 1999 found evidence for a strong recruitment in that year (section 2.4). The resulting increase in stock size may help to maintain catches at 400 - 500,000 tonnes/year at least for the next 2-3 years. It would be very dangerous, however, to assume that the current high level of recruitment will remain the normal situation in future. Unless the ecosystem has permanently changed, recruitment is expected to drop back sometime in future to the level it had in the 1980s.

The uncertainty about sardinella recruitment in future years makes it difficult to provide an indication of the long-term sustainable yield for this species. A high level of recruitment, such as seen during the 1990s, may sustain annual catches in the order of 400,000 tons. However, in a period when recruitment is low, the sustainable yield may not be higher than 200,000 tonnes/year (comparable to the catches in the period 1975-85). Assuming that periods of strong recruitment occur as frequently as periods of poor recruitment, the mean catch potential could be around 300,000 tonnes/year. It should be noted, however, that such a long-term mean has no practical significance in an actual situation, where the annual catch may either be much higher or much lower than the long-term average. The MSY of 300,000 tonnes/year, estimated on the basis of historic catch data, is again lower than the result obtained from the analytical models (750,000 tonnes/year, see section 2.7).

Estimated potential catch in the northern CECAF area for all small pelagics combined

In order to arrive at an estimate for the potential catch for all species combined, we have to include figures for mackerel and hairtail as well. The catch of mackerel has been rather variable during the past decades (Figure 2), with peaks of more than 250,000 tonnes in 1989 and 1990, and minima of 25,000 tons in some other years. Using the same reference period of assumed equilibrium fishing (1980-1988) as for horse mackerel, the long-term MSY level for this species is estimated at 100,000 tonnes/year.

Catches of hairtail have generally been low, and they exceeded 50,000 tonnes/year only in the period 1986-1991. It is possible that this species has been underexploited so far, due to problems in processing and marketing of the fish. The fish can not be kept in storage tanks on board for more than 1-2 hours since it quickly loses quality after capture. Another problem seems to exist in respect to internal parasites. According to Mauritanian sources, Russian scientists in the 1980s found parasites in the flesh of the fish that could create a health risk for consumers. Because of this discovery, the Russians apparently used the species only for preparation of fish meal. The mean catch level during the period 1980-1988 (40,000 tonnes/year) may therefore be a conservative estimate of the actual catch potential for this species. However, there is as yet no evidence of what the real potential could be. For the time being, an arbitrary rounded figure of 100,000 tonnes/year may be used for the MSY of this species.

If we sum the above estimates for the MSY of the individual species, we arrive at the following total for all small pelagics in the northern CECAF area (excluding pilchards and anchovy which are of little relevance for the Mauritanian area):

Atlantic horse mackerel	190,000
southern horse mackerel	100,000
sardinella	300,000
mackerel	100,000
hairtail	100,000
Total	790,000 t/year

Considering the large uncertainty in the estimated MSY for the individual species, this figure should be rounded to 800,000 tonnes/year. From the discussion above, it is obvious that the actual catches in a given period may deviate considerably from the long-term average estimated here.

As mentioned earlier, this estimate does not include pilchards. In the Mauritanian zone, this species has yield an average catch of 35,000 tonnes/year during the period 1987-97 (data CNROP).

The estimated MSY of 800,000 tonnes/year for the northern CECAF area seems low in comparison to the catches of nearly 900,000 tonnes per year reported for Mauritania alone during some years in the period 1970-1980 (Figure 6). This would suggest that the catch potential for the whole northern CECAF area would be far above 1 million tonnes/year. However, there are several reasons why the catch figures for Mauritania in 1970-1980 probably give an over-optimistic impression of the sustainable yield in this area:

- Catch statistics reported by the Mauritanian Ministry of Planning for the period 1968-1981 also comprised catches taken in the waters of Western Sahara (which at that time was claimed by Mauritania; see section 2.3).
- The catches were taken during the initial phase of the industrial fishery in West Africa. It may be assumed that the fishery in this period was harvesting an accumulated stock of older fish, and that the annual catches during this initial phase were higher than the sustainable catch in an equilibrium situation.

- A large part of the catch was taken within the 12 miles limit, an area which at present is no longer accessible for trawlers and purse seiners. The above calculations of maximum sustainable yield only refer to the proportion of the stocks that can be harvested outside the 12 mile zone.

2.9. Maximum sustainable yield for the Mauritanian zone

As mentioned earlier, the small pelagics in the Mauritanian zone constitute part of larger stocks that occur also the waters of the neighbouring countries, and that perform seasonal migrations from one national zone to another. Thus, the potential yield in the Mauritanian zone is only a fraction of the potential yield estimated for the entire northern CECAF region.

So far, there is no international agreement about the division of the future catches among the coastal states. However, such an agreement will be needed shortly in order to avoid overexploitation of the stocks. If each country tries to harvest the maximum share of the common resource while the fish are in its national zone, the end result will be a depletion of the resource. Therefore, rational exploitation of pelagic resources in the West-African region can only be based on political agreements that allocate a fair share of the potential yield to each of the coastal states. How the potential catch will eventually be divided among the coastal states can not be foreseen at this moment. The political agreement will probably be based partly on "zonal attachment", partly on historical rights, and partly on socio-economic considerations (dependence on small pelagics by a large population in Senegal). It is expected, however, that the share allocated to Mauritania will probably not exceed 50% of the total yield of the shared stocks. This corresponds to an annual average of 400,000 tonnes/year (see section 2.7).

Another way of estimating the potential for the Mauritanian zone is to use the period 1980-1988 as a reference period, assuming that the exploitation of small pelagics in Mauritania at that time was in a state of equilibrium. Using the CNROP data set (which also includes pilchard, anchovy, bonito and "others", we arrive at a mean catch level of 405,000 tonnes a year.

The species composition of the catches in Mauritania will vary, depending upon the climatic regime in the area. During periods of southern influence (like the 1990s), the bulk of the catch will consist of sardinella and southern horse mackerel. Conversely, during periods of northern influence (like the

1970s and 1980s) catches will be dominated by Atlantic horse mackerel and other northern species such as pilchard. It is assumed, however, that the combined catch of all species will remain in the order of 400,000 tonnes/year.

2.10. Ecosystem changes

The potential catch of small pelagics in West-Africa is strongly affected by changes in the ecosystem. Earlier we saw that the stock of Atlantic horse mackerel declined starting from the late 1980s, whereas the stock of sardinellas increased during the same period. It is not known what caused these changes, and whether they will be reversed again in future. Neither do we know the effect of these changes on the production potential of the combined stocks of small pelagics. In this section, some theories will be presented concerning the cause of the observed changes in ecosystem, and the implications of each theory for the potential yield of the total pelagic system.

(a) *The climate theory*.

It is tempting to speculate that the opposite changes in Atlantic horse mackerel and sardinella are related to climatic fluctuations. Sardinellas are warm-water fish, whereas the Atlantic horse mackerel is a species of cooler water. A change of temperature regime would affect both species in opposite ways. The observed decline of Atlantic horse mackerel and the increase of sardinella could thus be explained by an increase of water temperature, or another environmental parameter that would favour southern species at the expense of northern ones (e.g. ocean currents). This theory is supported by the observation that the southern horse mackerel, in contrast to the Atlantic one, did not show a decline after 1987 (Figure 2). Also the fact that sardinellas in recent years were recorded in very northern positions along the Moroccan coast supports the theory of a climatic change. However, there is no hydrographic evidence for a sustained increase in temperature along the West-African coast. The more northern occurrence of sardinella along the Moroccan coast might be simply a function of the large stock size at present.

(b) *The overfishing theory*

A more pessimistic theory is that the fishery first depleted the stock of Atlantic horse mackerel, and then turned to a lower valued species (sardinella) that was earlier ignored. When the East-European trawlers first arrived in West-African waters, they found a large, unexploited stock of older Atlantic horse mackerel. This accumulated stock provided high catches for a number of years, but as the stock declined, the catches became increasingly dependent upon the annual recruitment. In section 2.7 it was assumed that during the period 1980-1988 an equilibrium situation was established, in which the removals from the stock were compensated by the natural growth of the stock. It is possible, however, that in reality the stock was over-exploited, and that the stock continued to decline throughout the 1980s.

Although the stock of Atlantic horse mackerel was probably reduced during the 1970s as a result of fishing, it is unlikely that this was the only reason why the trawlers turned to sardinella. The increase of the sardinella catch started already in 1986, well before the decline of the horse mackerel catch. The acoustic surveys by the "Dr. Fridtjof Nansen" showed that there was a large expansion of the sardinella stock between 1986 and 1992. This increase in stock size must have been the primary cause of the expansion of sardinella catches, rather than the depletion of the Atlantic horse mackerel.

(c) *The species-interaction theory*

The last - and most optimistic - theory is that the increase in stock size of sardinella was caused by a reduced predation, particularly by horse mackerels. It is known that adult horse mackerel feed on small fish, including juvenile sardinella. The reduction in stock size of Atlantic horse mackerel, presumably caused by fishing, could thus have resulted in a reduced predation on juvenile sardinella, and thereby in an increased recruitment of this species. If this theory is correct, the recruitment of sardinella will continue to be high as long as the stock of horse mackerel is kept low.

Sardinellas feed primarily on plankton, partly even on phytoplankton. Compared to the carnivorous horse mackerels, they are more efficient converters of primary production (plankton) into fish. Therefore, an ecosystem dominated by sardinella might produce more fish biomass than an ecosystem in which horse mackerel constitute the main component. A permanent switch from horse mackerel to sardinella might thus increase the potential yield of the pelagic species assembly above the level that existed in earlier years.

2.11. Conclusions

The potential catch of small pelagics in Mauritania is part of the total potential for the region (the northern CECAF area). The actual share that Mauritania will receive (or take) from the regional potential depends on political decisions. A scientific analysis can only provide estimates for the regional potential, not for the Mauritanian share.

Estimates of the long-term potential of small pelagics in the northern CECAF area are based either on analytical or empirical methods. The analytical methods give variable results, with an average of about 1.1 million tonnes per year for all stocks combined (excluding pilchard and anchovy). The empirical method arrives at an estimate of 800,000 tonnes/year, also excluding pilchard and anchovy.

At this moment, the empirical estimate (800,000 tonnes/year) is considered more reliable than the estimate based on analytical methods. The analytical methods used arbitrary assumptions about biological parameters, which results in large variations of the results produced. The potential yields calculated by these methods have never been achieved for any length of time, even with a high fishing effort.

The potential yield estimated by the empirical methods has proven to be sustainable (at least for one decade) in the past. One may be confident, therefore, that such yields will also be attainable in future. The reliability of the empirical estimate depends on the accuracy of historic catch data, and on the assumption that the ecosystem in future will remain the same as in the past. If historic catch data underestimate the real catches that have been taken in the past, the estimated future potential will also be an underestimate. Also, if the species composition of the ecosystem shifts permanently to species that are lower in the food chain (sardinella), the potential yield may be higher than in earlier periods when horse mackerel dominated the ecosystem.

The estimated potential for the Mauritanian zone depends on the assumption which proportion of the regional potential will be taken in the Mauritanian zone. A share of 50% for instance would give Mauritania in future an annual catch of 400,000 tonnes per year. This figure corresponds also to the average annual catch in Mauritania in 1980-1988, a period when the stocks in the northern CECAF region were assumed to be exploited at their MSY level.

The actual catches in the coming years may show strong fluctuations due to natural variations in recruitment to the various species. The estimate of the long-term potential is not an adequate basis to set TACs for individual years; these TACs will have to be based upon the actual developments in each of the stocks, estimated on the basis of annual acoustic surveys.

At this moment (August 2000), there are no indications for overfishing of the stocks of small pelagics in the northern CECAF area. The sardinella stock appears to be in healthy condition, judging from the strong recruitment in 1999. The decline of the Atlantic horse mackerel during the last decade was probably related to a climatic variation; a variation that did not affect the southern horse mackerel to the same extent.

However, despite the apparent healthy situation at this moment, there are some reasons for concern. The EU fishery in Mauritania depends at this moment heavily on sardinella, and thereby on a continuation of the current high level of recruitment. It is uncertain how long this period of exceptionally high recruitment will continue. A return to the (lower) recruitment level of the 1980s would lead to problems for the EU fleet, unless the decline in sardinella catches would be compensated by increased catches of other small pelagics.

A second reason for concern is the absence of international agreements on catch or effort limitation in the West African region. This situation will probably lead to a further expansion of the foreign fleets in the area as long as the fishery remains profitable, and serious problems at the moment when recruitment declines due to natural causes. A sustainable fishery in the region can only be attained if the coastal states jointly decide to adopt a common fisheries policy, and to manage the stocks on the basis of scientific advice.

3. Development of Mauritanian acoustic surveys

As mentioned in the introduction, the initial idea had been to use to echo sounders on board the EU trawlers to collect information on stock abundance, particularly of sardinella. However, because the trawlers always concentrate in areas of high fish abundance, it was impossible to extrapolate the observations on board the trawlers to the total distribution area of the stock. For this reason, the idea of using acoustic information from commercial vessels was abandoned, and it was decided to concentrate the efforts on the developments of acoustic surveys by the Mauritanian research vessel.

3.1. Acoustic surveys by RV "Al Awam"

The Mauritanian research institute CNROP possesses a modern 37 m research vessel, the "Al Awam", which was donated by Japan in 1997. The vessel is equipped with state of the art acoustic instrumentation, including a Simrad EK 500 scientific sounder and a Simrad EP-500 post-processing system. In addition, the instrument came with a set of calibration equipment for the hull-mounted transducer.

Before the start of the project, no acoustic surveys had been made with the "Al Awam". Within the framework of the joint project, the DFTA financed a number of experimental surveys, designed to test the acoustic equipment and to train Mauritanian scientists and crew in carrying out acoustic surveys. The results of these surveys will be summarised below.

The first cruise took place during 10 days in December 1998. The objective of the cruise was to test and calibrate the acoustic equipment on board, and to make a pilot survey in a restricted area. Technical assistance was provided by an electronic engineer from the Russian research institute ATLANTniro in Kaliningrad. This expert had been hired for a 3-week period to check all electronic instruments on board. The Dutch project manager participated in the survey as an advisor on acoustic methods. The results of the cruise demonstrated that the EK-500 echo sounder was functioning properly, and that the noise level of the vessel was sufficiently low for acoustic surveys. In fact, the EK-500 appeared to produce good echograms even under bad weather conditions. The main problem experienced during the survey was the inability to fish with a pelagic trawl. The headline transducer on this gear was not working, and could not be repaired during the cruise. This meant that echo traces could not be identified by fishing.

A second acoustic survey was conducted during 10 days in May 1999. Again the Russian electronic engineer was hired for technical support. This time the headline transducer could be repaired, but the crew still had major problems in handling the pelagic trawl. Obviously, the crew needed to be trained by an experienced master fisherman in the handling of this gear.

In September 1999, the "Al Awam" made its third acoustic survey, sponsored by the joint programme. At this time, very few fish schools were recorded during the survey, apparently due to a scarcity of fish in Mauritanian waters. As during the second survey, the handling the pelagic trawl still presented major problems. Sardinellas were taken only in a few trawl sets. The lack of reliable trawl data prevented an adequate identification of echo traces. Therefore, it was not possible to convert the acoustic measurements into quantities of fish, and to estimate the standing stock of the different species in the Mauritanian area.

The problems in handling the pelagic trawl on board the “Al Awam” were investigated during the 4th survey, that took place in May 2000. During this trip, the DFTA had provided an expert skipper, Mr. Steven Kilvinton, to investigate the performance of the net. The expert concluded that the existing pelagic trawl was in fact unsuitable to sample small pelagics. The net was too short, which allowed the fish to escape at the moment when the ship slowed down to start the hauling operation. Other problems were experienced with the headline transducer. This instrument, which is a small echo sounder at the top of the net, is meant to provide information on the depth of the trawl and the position of the fish relative to the net. The system on board the “Al Awam” uses an acoustic link between net and vessel, instead of a cable. This acoustic system did not function properly, especially when the net was close to the surface (which is essential to catch sardinella). It was concluded, therefore, that the current system has to be replaced by a headline transducer (net recorder) that uses a fixed cable between ship and net. This requires the installation of a fixed netsonde winch on board the vessel. The expert made a number of recommendations for the acquisition of new pelagic trawls and a new netsonde winch. His report is presented in Annex 3.

3.2. Training of Mauritanian scientists in acoustic methods

The DFTA financed a working visit of three Mauritanian scientists to the Netherlands Institute for Fisheries Research (RIVO) in June-August 1999. All three of them participated in a 3-week herring acoustic survey with the Dutch RV "Tridens" in the North Sea. One of the Mauritanian scientists stayed for two more months to participate in the data analysis.

The DFTA also financed the participation of two Mauritanian scientists in an FAO workshop in Casablanca from 18-22 October 1999. The objective of this workshop was to standardise acoustic methods throughout the West-African region. The project manager also participated in this workshop. The workshop produced the first draft of a survey manual that should be used by all countries involved, or planning to be involved, in acoustic surveys in the region (Morocco, Mauritania, Senegal, and Norway).

An important possibility of training in acoustic methods is provided by the Norwegian “Nansen Programme”. The Norwegians each year conduct an acoustic survey along the entire coast of West Africa, and they invite scientists from each coastal state to participate in this survey. The project manager participated in such a cruise in December 1998 as part of the Mauritanian team on board the “Dr. Fridtjof Nansen”. During this trip, possibilities were discussed for a Dutch/Norwegian co-operation with respect to training of Mauritanian scientists. Such a co-operation seems highly desirable in view of the fact that Norway is the only country that conducts echo surveys in West-Africa at present.

3.3. Planning of future acoustic work in Mauritania

The continuation of Mauritanian acoustic surveys is considered as one of the highest priorities for the research on small pelagics in this area. The Norwegians will continue their acoustics surveys probably for another 3 years, but at the end of this period the coastal states are supposed to take over this work. The neighbouring countries of Morocco and Senegal will shortly receive new research vessels from Japan, similar to the “Al Awam” in Mauritania, and they are also planning to develop their own acoustic surveys. This will provide the possibility for organising co-ordinated, synoptic surveys throughout the regions in a few years from now.

The main bottleneck in Mauritania is the pelagic fishing by “Al Awam”. In order to improve the performance of this ship, investments are required in fishing gear and electronics. These expenditures are given high priority in the proposal for the follow-up of the present project.

4. Application of remote sensing in predicting fish distribution

4.1. Potential use of remote sensing in forecasting fish distribution

During earlier years, some captains of EU trawlers in Mauritanian waters had the impression that the distribution of sardinella was related to the sea surface temperature (SST). This temperature sometimes changes over short distances, and the sardinella were often found in areas with such strong temperature gradients.

In other pelagic fisheries such as for instance for tuna, it has been known for a long time that the fish tend to accumulate in the border area between water masses of different temperature. These are often the areas where food is produced or accumulated. In many tuna fisheries, the position of such hydrographic fronts is determined from infra-red satellite pictures, and the vessels choose their fishing positions on the basis of this satellite information.

4.2. Co-operation with the University of Las Palmas

In view of the successful application of satellite photographs in the tuna fishery, Dutch ship owners assumed that this type of information might also be useful in the fishery for sardinella. To investigate this possibility, an agreement for co-operation was signed with the University of Las Palmas Gran Canaria (ULPGC) in 1998. The biological department of this university has a ground receiving station for meteorological satellites, and they also have the expertise to process the received signals into sea surface temperature (SST) maps for the whole West-African area. Under the agreement between DFTA and ULPGC, the University was to produce daily SST charts for the Mauritanian zone for the period 1 September 1998 until 31 October 1999. These charts were based on infra-red images, received from a number of American NOAA meteorological satellites. In the same period, the DFTA was to collect information on exact fishing positions of the EU trawlers in Mauritanian waters. The captains were asked to complete special record forms that contained position, time, duration, and catch composition for each trawl haul. Most captains complied with this request, and a large amount of data was received concerning the exact fishing locations and catch composition of the EU fleet.

4.3. Use of real-time SST information by EU trawlers

In order to obtain more information from areas with strong temperature gradients, captains were requested to search particularly in these areas. These experiment were restricted to a number of periods during which the vessels received daily real-time SST charts. These periods were:

15 October - 1 December 1998
8 April - 8 May 1999
15 August -15 September 1999
23 February – 3 March 2000
5 – 13 June 2000

From the SST charts, the captains could see in which positions the hydrographic fronts occurred at that moment, and they could direct their ships to these positions.

The experiment in February/March 1999 was hampered by the fact that surface temperatures in the whole Mauritanian zone were unusually low, and that hardly any sardinella occurred in the entire area. In such a situation, the availability of SST charts can not help the captains to locate the fish. Also in other situations, the existence of a hydrographic front appeared to be no guarantee for the occurrence of sardinella. In order to stimulate captains to take the risk of exploring new areas instead of staying together with the rest of the fleet, ships were offered a compensation in case the value of their catches during the "research days" remained below a certain level.

4.4. Relationship between sardinella and surface temperature

The position of sardinella catches by EU trawlers was compared with the temperature distribution for each week for which data were available. In some periods (notably May and June 1999) no temperature charts could be prepared due to the occurrence of clouds and dust-storms in the Mauritanian zone. For all weeks in which a temperature distribution was available, charts were prepared showing the distribution of surface temperature, and the position of sardinella catches superimposed on them. An example of these charts is presented in Figures 10a-e. A full set of all charts produced is available on request from the project manager.

The results showed that in some months the distribution of sardinella catches was indeed related to the distribution of temperature. This was particularly the case in the summer 1998 (September), when the upwelling of cold water was restricted to the northern part of the Mauritanian area (figure 10a). The fish were found on the border between cold and warm water, presumably because of a high food abundance in these areas.

In autumn 1998 (October-November), the area with upwelling extended southward, and the fishery shifted south as well. The sardinella was still found at the border between warm and cold water (Figure 10b). Because the shelf in the southern region is very narrow, the upwelling took place close to the coast, and the sardinellas were found close inshore as well.

In the winter of 1998/99 (December-April), the temperature in the whole Mauritanian zone was uniformly low, and there were no temperature gradients that might attract the sardinellas. Besides, sardinellas appeared to be very scarce in the waters outside the 12-mile fishing limit. This may have been due partly to emigration of sardinella during the winter to Senegal, and partly to a concentration of the remaining fish inside the 12 mile fishing limit. It is within this fishing limit that the fish concentrate for spawning during the cold season. The sardinella catches were low, and there was no connection between fishing positions and water temperatures (Figure 10c).

The situation in summer 1999 (June - August) resembled the situation of the previous September. Good catches of sardinella were taken in the northern part of the area, on the border between cold and warm water (Figure 10d). In late August the upwelling in Mauritania temporarily ceased, and the surface temperature throughout the whole area increased to values above 29°C. During this episode of high surface temperatures, which lasted at least until mid-October (for which we have the last pictures), the sardinella largely disappeared from the Mauritanian area, presumably due to a scarcity of food. In the adjacent waters of Morocco, the catches of sardinella increased at this time, which suggested an emigration of some of the sardinella out of the Mauritanian zone. In Mauritania, the only catches were taken relatively south and close inshore. This suggested that, like in 1988, some sardinella at this time were already moving into the direction of Senegal. These fish seem to migrate south irrespective of the temperature at the surface (figure 10e).

4.5. Conclusions

During the summer months (May - September), the distribution of sardinella appears to be related to surface temperature. These months are the main feeding season for sardinella and the fish appear to concentrate on the border between cold and warm water, presumably because of a high food abundance in these areas. At this time of the year, the upwelling is restricted to the Cap Blanc area, and this is where most of the sardinellas are caught.

At other times of the year, a relationship could not be established. This was particularly the case in winter and spring 1998/99 when the whole Mauritanian area was very cold , and in August/September 1999 when the whole area was very warm. In both situations, sardinellas appeared to be scarce in Mauritanian waters. The distribution of the remaining sardinella did not seem to be related to the small variations in SST within the total area.

In general, most fishing skippers had the impression that real-time temperature charts could help them to locate the fish. Some of them have asked already whether they could receive such charts on a routine basis.

5. Biological sampling of EU-catches in Mauritania

5.1. The need for data collection on board the pelagic trawlers

During the first years of the EU pelagic fishery in Mauritania (1996-1998), the only information on the catches by this fleet was derived from the logbooks that the vessels were obliged to keep. No data were collected on the precise species composition (for instance no distinction was made between the two species of sardinella or the three species of horse mackerel) nor on the length composition of the various species. This meant that the existing data were inadequate for stock assessment purposes. Another deficiency was the lack of data on discards of commercial species and the accidental by-catch of larger, non-commercial species.

The lack of scientific sampling was due to logistic problems. Since all catches were landed in Las Palmas, it was difficult for scientists both in Mauritania and in Europe to collect samples for biological studies. In Mauritania, an EU-funded programme of fishery inspectors had been set up in the early 1990s, but this programme had not resulted in the collection of biological data from catches of the freezer trawlers. One of the reasons was that the Mauritanian inspectors had no experience in fisheries research. The material collected by them, therefore, was not considered to meet the quality requirements for scientific research. Another problem was that the inspectors, for a variety of reasons, had actually made very few trips on board the EU pelagic trawlers.

The only way to solve the problem of biological data collection was to set up a new sampling programme, in which the catches and discards would be sampled by trained technicians from the CNROP.

5.2. Organisation of the scientific observer programme

In co-operation with the CNROP, a programme of scientific observers on board the EU freezer trawlers was initiated in February 1999. The CNROP provided the observers from its own scientific staff. This meant that the observers were all qualified technicians, most of which had previous experience in sampling catches on board (Russian) pelagic trawlers. They operated in teams of two persons, which stayed on board the same vessel for two consecutive trips. Each team made two trips with the same trawler. The fishing trips varied between 3 – 5 weeks. This meant that each team would spend 6 – 10 weeks at sea. Two teams were deployed at the same time, giving an average coverage of the fleet of about 25%. During the 1999 season, all EU freezer trawlers that worked in the Mauritanian zone were visited at least once by a team of observers.

The observers joined the vessels in Las Palmas, which was the home base for the vessels. It was more economical to fly the observers from Nouadhibou to Las Palmas, than to have them picked up by the trawlers in the port of Nouadhibou. Between two sea trips, the observers would stay on board the vessel in the port of Las Palmas.

After the completion of the two trips, the team would fly home to Nouadhibou. Every time a team was changed, a new trawler was selected as well. This was done in order to cover as many different vessels as possible. The alternation of teams between different vessels provided an opportunity to observe differences in fishing strategy and discard practice between the various ships. The frequent changes of vessels and teams, however, also created logistic problems. The equipment for the observers had to be moved constantly from one vessel to another, which sometimes resulted in a loss of material. Also, each team of new observers had to get used to the work on board a new vessel. In general, however, the observers appeared to adapt themselves quickly to the circumstances on board.

The project manager joined the first trips in which observers worked on board the EU trawlers, in order to assist them in establishing routine sampling procedures. The objectives and procedures of the programme also had to be explained to the captains and crews of the trawlers. Because of the language barrier (the observers did not speak English or Dutch), communication problems frequently arose between crews and observers during the first months of the programme. In order to help both sides in solving these problems, a bilingual manual for the working arrangements on board was prepared. With increasing routine on both sides, most communication problems between observers and crews were solved after the first months, and the observers generally established a good working relationship with the crews

The salary costs of the observers plus an extra sea allowance was paid by the CNROP. The flight tickets to Las Palmas were paid by the Mauritanian inspection service (Surveillande de Pêche) from funds provided by the EU. The observers received free food on board, and an additional allowance for small expenditures, both at sea and in the port of Las Palmas. Finally, the equipment for the work of the observers on board (scales, measuring boards etc.) was provided by the DFTA.

During the first trips, some confusion arose about the precise task of the observers. Some of them were of the opinion that they also had an inspection task, and that they had to alert the fishery inspection vessel in case they noticed an infraction of the regulations. However, it was pointed out to them that scientific research can not be combined with fisheries inspection. For their scientific work, the observers depend on the full co-operation of the crew, for instance to alert them if there are large fish in the net which are not taken down to the factory deck. If the observers also have an inspection task, they can not expect the same kind of voluntary help from the crew. The CNROP agreed that it was impossible to combine the two tasks, and it was decided to limit the task of the observers strictly to scientific sampling of catches and discards.

In co-operation with CNROP scientists, a protocol for the sampling of catches and discards on board the freezer trawlers was developed. This protocol is given in Annex 4. The main task of the observers was to estimate for each haul the species composition (in weight) of the part of the catch preserved on board, and also the species composition of the fraction that was discarded. Length frequency distributions were measured for all species in the catch, and additional biological measurements (weight, sex, maturity, fat content, stomach fullness) were taken for sardinella and horse mackerel. The data were entered on log sheets, and after the trip entered in a computer data base at the CNROP. An extra copy of all data sheets was mailed to the Dutch co-ordinator of the programme.

A list of all trips made by CNROP observers on board EU pelagic trawlers is given in Annex 5 . In 1999 a total of 13 trips was made by 7 different teams of observers. In 2000, the programme was continued at the same level of sampling effort as in 1999. During the first 7 months of this year, 9 trips were made by 5 teams of observers.

5.3. Results of the observer programme

Example of results from an individual fishing trip

As an example of the results obtained by the observer programme, the data for an individual trip ("Frank Bonefaas", 18 October – 14 November 1999) have been summarised in Figures 12 and 13. During this trip (which was representative for most of the fishery in 1999) the catches consisted mainly of round sardinella, with smaller quantities of flat sardinella and southern horse mackerel. The discards comprised 4.7% of the catch in weight, and included a large variety of species with no commercial value (Figure 12).

The length distribution of the main species (Figure 13) shows that round sardinella had a modal length at 30 cm (fork length), and flat sardinella a modal length of 27 cm. Very few fish of both species were discarded. This situation was different for mackerel and hairtail, where an important fraction of the catch was discarded. In mackerel, the discards consisted mainly of small individuals, but in hairtail the discarding was apparently not based on length. It is assumed that in this case the discarding was based mainly on the quality of the fish, which in turn depends on the duration of the haul.

Data analysis by the CNROP

Most of the analysis of the material collected by the observers was done at the CNROP, and the preliminary results, covering all trips made in 1999, were presented at a meeting in Nouadhibou in December 1999. Three documents presented at this meeting dealt with the results of the observer programme. These documents (in French) have been included as annexes to the present report, and their contents are summarised below.

> Document #1. Diop, M and C.A. Inejih: Species composition of the catches by the Dutch pelagic fishery in the Mauritanian zone and discards (Annex 6). This document showed that the catches by the EU fleet consisted of more than 99% (in weight) of pelagic species. The most common species in the catch, Sardinella aurita, made up almost 84% of the total catch. Other important species were Sardina pilchardus, Trachurus trecae, and Scomber japonicus. About 60 different species were identified in the catches. Out of these, 34 species were completely discarded. Total discards amounted to 7% (in weight) of the catch. Most of the discarded fish consisted of pelagic species that were either of a small size, or of bad quality (damaged in the net).

Document # 2. Inejih, C.A. and A. Corten : Analysis of length frequency distributions of the catches by Dutch pelagic vessels (Annex 7). Length frequency distributions are presented for the fraction of the catches that was preserved on board, and for the fraction that was discarded. For round sardinella (*Sardinella aurita*), the length distribution of both fractions had a mode at 30 cm (fork length). It was concluded, therefore, that discarding occurred mainly because the fish were of low quality, and not because of their size. The same conclusion applied to the flat sardinella (*Sardinella maderensis*). For pilchards (*Sardina pilchardus*), there was a clear difference in length between the fraction preserved (modal length at 21 cm) and the fraction discarded (modal length 17 cm). For this species, discarding appeared to be based mainly on length. For the southern horse mackerel (*Trachurus trecae*) and the mackerel (*Scomber japonicus*), the discarded fraction consisted of larger individuals that the preserved fraction (Note that for mackerel these results differed from the results obtained from the single trip with the "Frank Bonefaas" presented earlier). The discarding of large fish is presumably an effect of the relative abundance of the different length groups in the catch. Large mackerel and horse mackerel normally occur only in small percentages in the catch. In this case, it may be decided to discard these species, because the quantities are not enough to fill one freezer. If smaller size categories are taken in the catch, they often come in larger quantities, in which case they are processed in the normal way.

Document # 3. Wagué, A. and M. Oumar: First results on the biology of *Sardinella aurita* and other small pelagics of the Mauritanian coast (Annex 8). This study presented data on sex ratio, length at first maturity, and length/weight relationship for the main pelagic species in the catch of the EU fleet. The data showed a relative low condition for *Sardinella aurita*, compared with results from previous studies. It is not clear whether this low condition occurred throughout 1999, or whether it was restricted to the summer. In august 1999, food was apparently scarce in the Mauritanian zone (due to the high water temperature?). Dutch exporters received complaints from their buyers about the low quality (weight for length) of *S. aurita* caught in this period. The analysis of maturity data for *S. aurita* showed that the catches of the EU fleet consisted mainly of adult fish. The data showed a difference in length at first maturity for the two sexes, with the males reaching first maturity at smaller length (29 cm) than the females (30 cm). This could be due to a difference in growth rate between the two sexes.

The observer data for 1999 and 2000 will further be used to estimate the total quantities (in numbers by length group) of all species caught by the EU-pelagic fleet in 1999 and 2000. For this purpose, the data for hauls sampled by observers will be raised to the total landings, first of the vessel, and then of the fleet. The estimates of total catches by length group, obtained in this way, will be used as input data for stock assessment.

The observer data on by-catches of dolphins and other large species will be discussed in section 7.

6. Promoting joint research activities within the West-African region

The project concentrated on two activities that were considered essential for the future management of small pelagics within the West-African region: internationally co-ordinated acoustic surveys, and the establishment of an international stock assessment working group on small pelagics. Both activities are described below.

6.1. Co-ordination of acoustic surveys

The future management of small pelagics in the West-African region will depend primarily on accurate, real-time stock estimates of the various species. The best way to obtain these estimates is through acoustic surveys. Development of such surveys was therefore given high priority within the Mauritanian/Dutch co-operation (section 3). However, in order to utilise the results of the Mauritanian surveys, they have to be combined with the results of similar surveys in neighbouring countries. Therefore, the project also supported activities that were aimed at promoting co-operation between the various West-African countries in the field of acoustic surveys.

Fortunately, a large technical assistance programme for acoustic surveys exists already in the area. This is the Norwegian "Nansen Programme", which organises acoustic surveys by the RV "Dr. Fridtjof Nansen" throughout the West African region (section 3). The best way to use the resources of the Dutch project, therefore, was to co-operate with the Norwegians, and support activities that were organised in the context of the Nansen Programme. Since the budget of the Nansen Programme was an order of magnitude higher than the budget of the entire Dutch project, the contribution of the Dutch project was relatively modest.

From 17-23 October 1999, a meeting was organised in Casablanca by the FAO and Nansen Programme. The main objective of this meeting was to discuss methodology of acoustic surveys, and to co-ordinate future international surveys. The Dutch project financed the participation of two Mauritanian scientists in this meeting. In addition, the project manager attended the meeting. One of the products of the meeting was a draft manual for standard acoustic methods, to be used during all surveys in West-Africa.

6.2. Establishment of an international stock assessment working group on small pelagics

In recent years, international assessments of the stocks of small pelagics in West-Africa were done by ad-hoc working groups on an irregular basis and with long intervals. Even at the time of writing this report (August 2000), the most recent analytical assessment of sardinella dates from November 1993 (section 2). During a later meeting in Nouadhibou in December 1998, participants were unable to update the 1993 assessment because of a lack of new data.

The lack of new data was partly due to the lack of regular meetings by scientists from the whole region. Without such meetings, it is very difficult to build up a common data base, check the quality of the data, and develop a common methodology for stock assessment. During the meeting in Nouadhibou in December 1998, therefore, the participants agreed that there was a need for more intensive co-operation between scientists of the different countries in West Africa. The meeting adopted a recommendation to establish a permanent working group on small pelagics in the region. This working group, which would meet each year in one of the countries within the region, would operate under the umbrella of CECAF (Committee on East Central Atlantic Fisheries). After the meeting, the project manager drafted a detailed proposal for such a working group. The terms of reference for the group would be:

- to assemble catch statistics and set up and maintain a data base on small pelagics for the whole region;
- to co-ordinate international research projects, in particular acoustic surveys;
- to evaluate the state of the stocks and to advise appropriate conservation measures to the governments of member states.

The draft proposal for the CECAF working group was discussed with Mauritanian colleagues at the CNROP, FAO experts in Rome, EU administrators in Brussels, and Dutch administrators at the Ministry of Agriculture, Conservation and Fisheries. The FAO headquarters offered to take on the organisation of the meetings. The DFTA offered to provide 25% of the cost, and the EU was asked to provide the balance. At a later stage, FAO also offered to contribute to the cost of the meeting (25%).

The first meeting of this group was organised by FAO from 22-27 February in Casablanca. Scientists participated from Senegal, Mauritania, Morocco, The Gambia, Russia, Spain (Canary Islands), and The Netherlands. Because the EU-funding of the working Group had not yet been approved, the meeting was financed on an ad-hoc basis by Norway, FAO, Morocco, and the DFTA (the DFTA paid flight tickets and per diem for the Mauritanian participants). The objective of the meeting was to assemble data on catches, fishing effort, and biological characteristics of the species during the last 10 years, and to established standard formats for the exchange of data between countries. In general, the meeting was quite successful. A large amount of data was presented by the various participants, and for the first time in recent years, a good picture of the international catches in the whole region was obtained (see section 2). The meeting was also useful in promoting a spirit of co-operation between the various national scientists.

From 27 June to 1 July, a workshop on stock assessment methods was organised in Santa Cruz (Tenerife) for all participants of the CECAF working group. The objective of this workshop was to provide all participants with a common expertise of basic methods in stock assessments. FAO organised and financed the meeting, with contributions also from Spain and the DFTA (travel and per diem for one Mauritanian participant). The workshop concentrated on so-called "global" methods of stock assessments. These methods, which do not required data on age composition of the catch and population, are particularly suitable in the West-African situation.

7. Monitoring by-catches of dolphins and other large species

A monitoring programme to record by-catches of dolphins and other large animals was carried out in conjunction with the observer programme. Information was collected on the types of animals that were taken as by-catch, the frequency of incidents, and the circumstances under which the by-catches were taken (position, water temperature, season, time of day). Such data will be used in a next phase of the project when methods will be developed to reduce the number of incidents by adapting gear and fishing methods.

The data collected by observers in 1999 and 2000 are still being processed by the CNROP, and final results will become available later this year. At this stage, a preliminary inspection of the data show that by-catches consist predominantly of common dolphins (*Delphinus delphis*), moonfish (*Mola mola*), hammerhead sharks (*Sphyrna* spp.), unidentified sharks, and marlins (*Tetrapturus* spp.).

In general, by-catches of large specimen seemed to occur most frequently in warm waters with temperatures > 22°C. Most of the larger species, therefore seem to be associated with the tropical waters of the Guinea Current that spread north in summer, and replace the colder waters of the Canary Current at this time of the year. The common dolphin, however, was also taken in the earlier months of the year when water temperature is still below 22°C.

The by-catches occurred very irregularly. Most catches did not contain any larger specimen, but sometimes several individuals would be found in a single catch. Dolphins are probably caught because they are attracted to the net by their curiosity. Theoretically, they could easily avoid the net since their maximum swimming speed is at least twice the towing speed of the net. However, in some cases, the animals seem to get disorientated when they find themselves in the front part of the net, and swim towards the cod end instead of towards the opening. The distress signals of the animals trapped in the cod end may attract other individuals, which results in the occasional catch of several dolphins in one haul.

All dolphins found in the net were dead by the time the net was hauled. The total quantity of dolphins (mainly common dolphins) taken by the whole EU-fleet in one year can not be estimated accurately, but it will be in the order of some hundreds.

Since no estimates are available for the total stock size in the area, it is impossible to express the by-catches as a percentage of the total population, and thus to calculate fishing mortality. Sightings of large numbers of dolphins in the vicinity of the vessels (up to 500 individuals at one moment; N. Korving, pers. comm.) suggest that the standing stock of common dolphins is large in relation to the numbers taken in the fishery. However, quantitative estimates of total population size have to be made in order to evaluate the effect of the by-catches in the pelagic fishery.

8. Financial support to CNROP for data retrieval and computers

Within the framework of the agreement between CNROP and DFTA, technical and financial support to the CNROP was given in order to solve existing problems in data retrieval and processing. These problems concerned particularly the recovery of historic data from institutes in Europe, and the acquisition of computer hardware and software for the CNROP. Both aspects will be considered below.

8.1. Recovery of historic data from institutes in Europe

After the termination of the Russian and Romanian research activities in Mauritania (1991), the scientists from these countries took most of their data home. No copies were left at the CNROP. The data concerned biological characteristics of Russian and Romanian catches (mainly horse mackerel) in Mauritanian waters during the 1980s and hydrographic data. These data are important for the study of long-term variations in ecosystem and horse mackerel stocks, and the CNROP considered the recovery of the data as a matter of high priority.

Within the CNROP/DFTA agreement of June 1988 (Annex 1), funds were allocated for the recovery of these data from institutes in Russia and Romania. Because the data in most cases existed only on paper, extra work was required (by the East-European scientists) to prepare electronic versions of the data.

In May 1999 a CNROP delegation visited the ATLANTniro institute in Kaliningrad (Russia), and concluded a formal agreement with this institute for the preparation and repatriation of Mauritanian data. Because the Russians already had a general agreement for co-operation with Mauritania, they offered to do the required labour at a reduced cost. Since the ATLANTniro data covered most of the data requirements of the CNROP, no attempts were made to recover additional data from institutes in Romania.

The main part of the ATLANTniro data had arrived in Mauritania by August 2000.

8.2. Financial support for the acquisition of computer hardware and software

It was originally envisaged that the DFTA would provide funds for the acquisition by the CNROP of GIS software (Geographical Information Systems). However, shortly after the agreement was signed, the CNROP could already obtain this software through a co-operation project with France and the FAO. As an alternative, the CNROP proposed to use the DFTA funds to purchase more personal computers for the institute. In view of the obvious need for this material, the DFTA agreed with this proposal, and the institute got permission to purchase 4 IBM desk-tops and 7 lab-tops, including software.

9. Plans for a follow-up project

9.1. Identification of research priorities

One of the terms of reference of the current project was to identify research priorities and to draft a proposal for a follow-up project.

In consultation with scientists from the CNROP, a number of research priorities for the next years was identified. It was decided that the main research effort in the period 2000-2004 should be dedicated to the following topics:

- further development of Mauritanian acoustic surveys
- age and growth of sardinella
- reproductive cycle of sardinella
- stock identity of sardinella
- interactions between different pelagic species
- environmental effects
- preventing by-catches of protected species

The necessity for the further development of Mauritania's capacity for acoustic surveys is evident. These surveys are the only source of information on recent developments in the stocks, and future assessment working groups will depend heavily on their results. The current surveys by the Norwegian Nansen Programme will not be continued forever, and it is the intention of the Norwegians that Mauritania within a few years from now will be capable to take over the responsibility for these surveys. There is a great need, therefore, for training and further development of standard methods within the next few years.

Further studies on the biology of pelagic species, notably sardinella, are required to provide input data for analytical stock assessment models. So far there are no accurate estimates of growth rate and natural mortality in sardinella, which prevents the application of age-structured models. Without such models, it is not possible to predict the development of the stocks one or two years ahead, and to adjust the fishing effort to variations in stock size that arise from variations in year-class strength.

The stock identity of sardinella is an important topic in view of the possible interaction of fisheries in different countries. At present it is not known whether all sardinella in the northern CECAF region belong to one homogeneous unit stock, or whether there are several individual populations, each with its own spawning ground and migration pattern. More knowledge on this topic will allow an evaluation of the interaction between the artisanal fishery for sardinella in Senegal, and the industrial one in Mauritania and Morocco.

In order to interpret recent changes in ecosystem composition, we need more knowledge of the interaction between the different components of the pelagic ecosystem. How large is the predation of horse mackerel on juvenile sardinella, and does a reduction in stock size of horse mackerel lead to a reduced predation (and thereby a stronger recruitment) of sardinella? The answer to this question may possibly allow a better understanding of the changes in ecosystem in recent years (replacement of horse mackerel by sardinella), and a prognosis of future trends.

Strong year-to-year variations in the recruitment of the various species are probably related to environmental conditions during spawning time or shortly thereafter. The use of remote sensing offers great potential in Mauritania and Morocco for monitoring environmental conditions (because of the absence of clouds). If a relationship between environmental conditions (temperature, currents, wind stress) and recruitment could be established, the strength of newly born year-classes could be predicted already at a very early age. It would also be possible to identify long-term trends in recruitment that are due to environmental (climatic) variation.

Finally the by-catch of protected species in the pelagic trawl fishery is a problem that needs further attention. Even if these by-catches do not present a direct threat to the survival of these species, they constitute an unnecessary damage to the ecosystem. A study should be made to identify the conditions under which protected species are taken most frequently, and recommendations should formulated for measures that will reduce these by-catches to a minimum.

9.2. Proposal for a new project

The research activities described above can only be undertaken within the framework of a project that is considerably larger than the current pilot project. Therefore, a proposal was drafted for a follow-up project that would last for 5 years, with a total budget of US $ 5.0 million. This proposal was submitted for financial support to the European Commission and the Dutch government in the autumn of 1999 (via the Mauritanian Ministry for Fisheries). During a meeting between the CNROP director and representatives of the Commission in May 2000, the Commission indicated that the proposal was to big and that it needed to be scaled down. A similar response was received from the Dutch Ministry for Agriculture, Conservation and Fisheries.

On the basis of the comments received from the EU Commission, a new proposal was formulated in July 2000. This proposal entailed a 3-year project, with a total budget of ? 2.3 million. The proposal was submitted to the EU Commission and the Dutch government, and a discussion of the proposal with these potential donors is scheduled for September this year.

After the current project expired in June 2000, the DFTA decided to continue financing a minimum research programme, until the project has been accepted by the EU Commission and other donors. This minimum programme comprises the work of the scientific observers on board the EU vessels, and a limited contribution to the Mauritanian acoustic surveys. It does not have provisions, however, for biological and environmental studies. These can only be continued after a new project has been approved.

10. References

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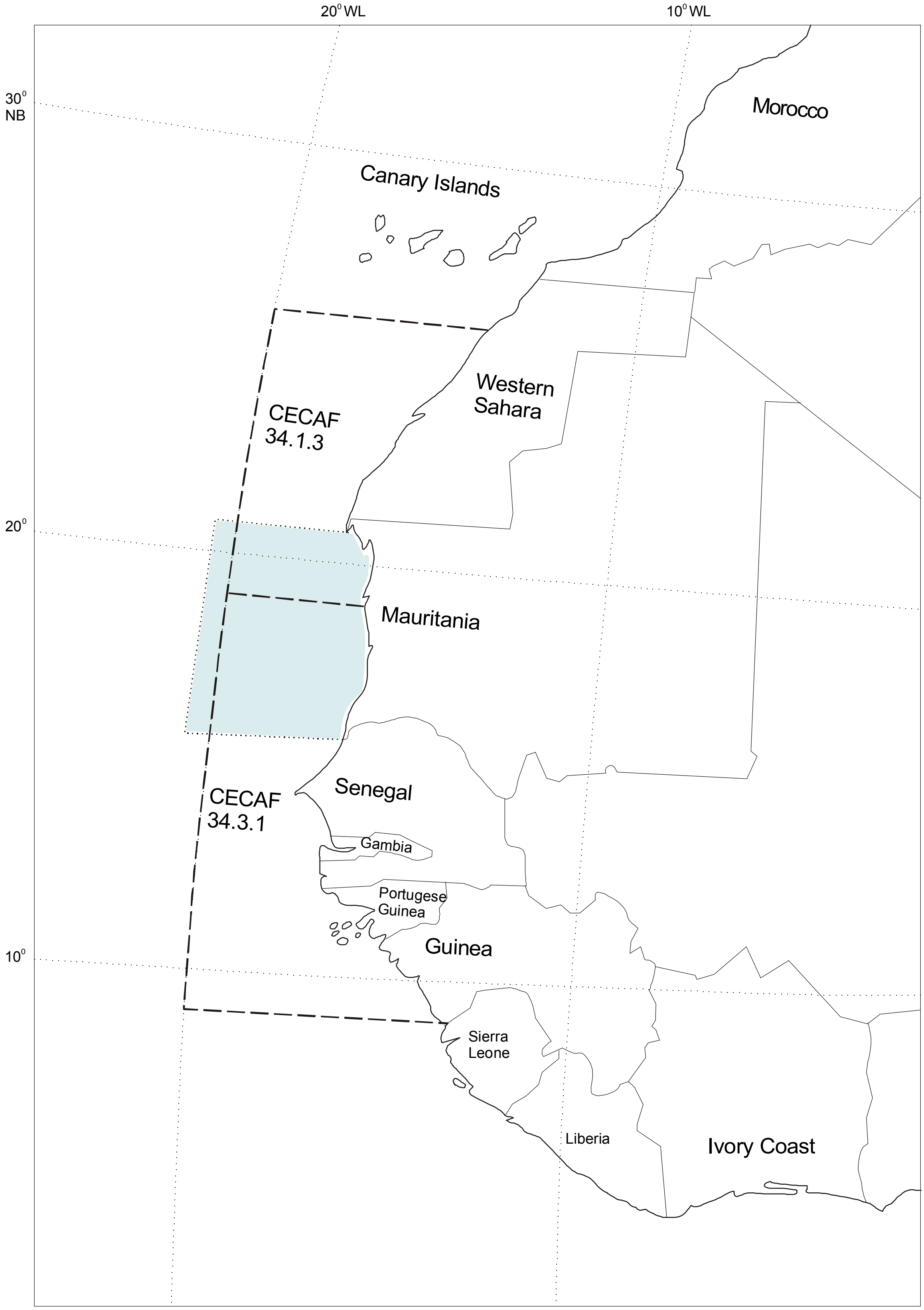
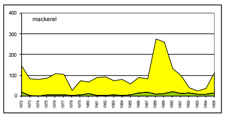
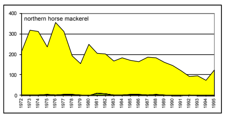
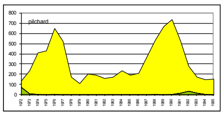
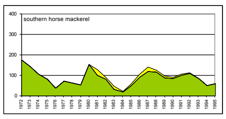


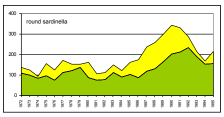
Figure 1. CECAF statistical areas 34.1.3 and 34.3.1 compared to national economic zone Mauritania

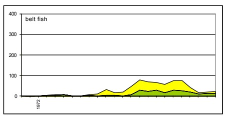


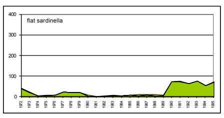












CECAF area 34.1.3 Sahara

CECAF area 34.3.1 Cap Verde

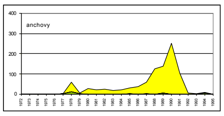


Figure 2. Catches of different species by CECAF area

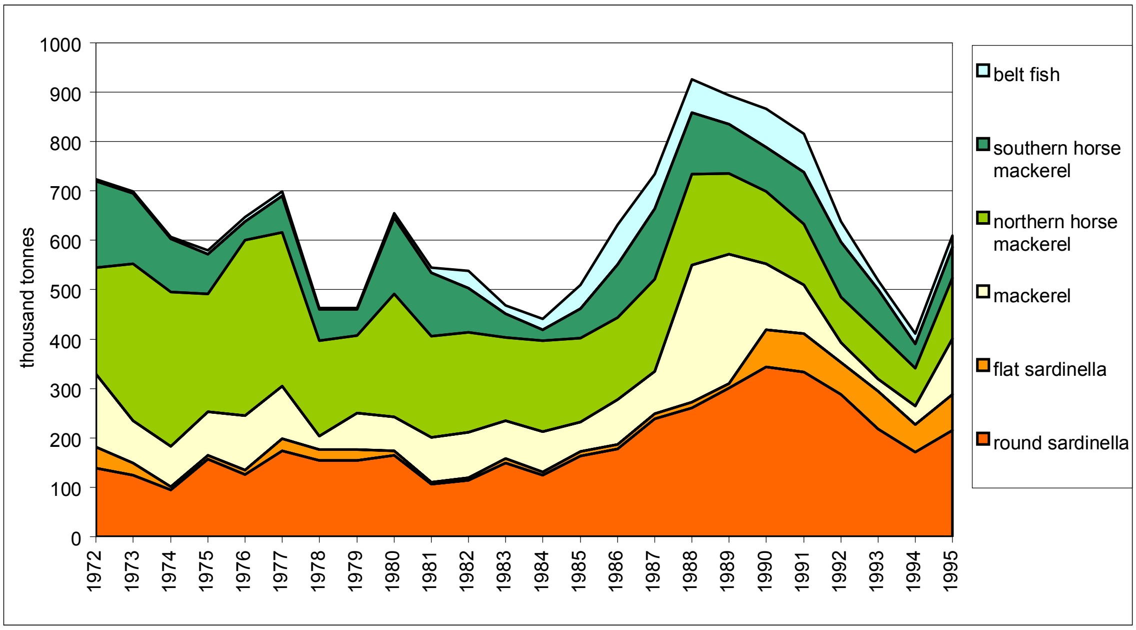
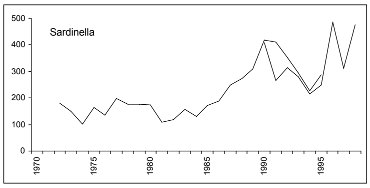
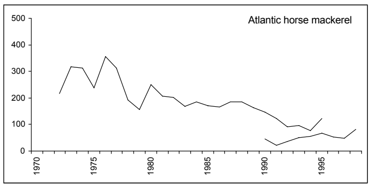
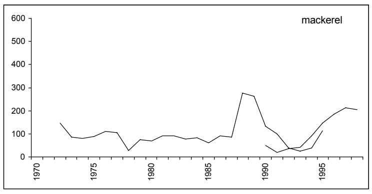


Figure 3. Catches of small pelagics for CECAF areas 34.3.1 and 34.1.3. combined

Figure 4. Annual catches by species and country, reported to FAO meeting in Casablanca, February 2000.


Sardinella
500
400
300
200
100
0
1970
1975
1980
1985
1990
1995


Atlantic horse mackerel
500
400
300
200
100
0
1970
1975
1980
1985
1990
1995


mackerel
600
500
400
300
200
100
0
1970
1975
1980
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1990
1995

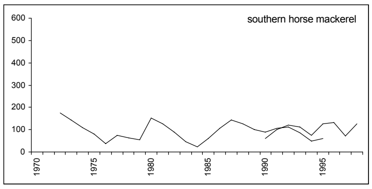

Figure 5. Comparison between FAO data for CECAF areas 34.1.3 + 34.3.1 (thin line) and the sum of national data for Morocco, Mauritania, Senegal and The Gambia (heavy line). All figures in thousands of tonnes.

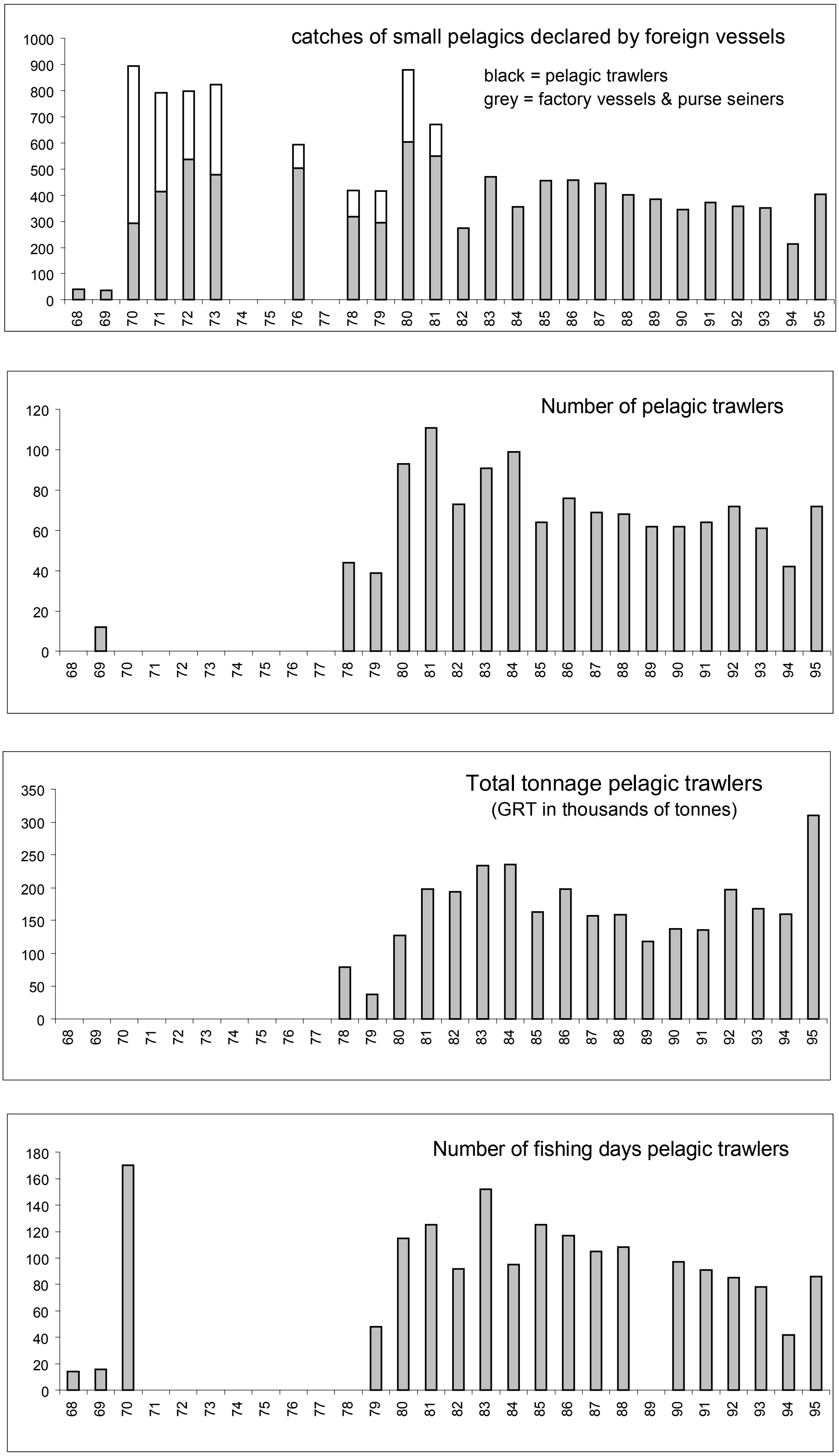

Figure 6. Development of the industrial fishery for small pelagics in Mauritania since 1968

Data from Ministry of Planning Mauritania

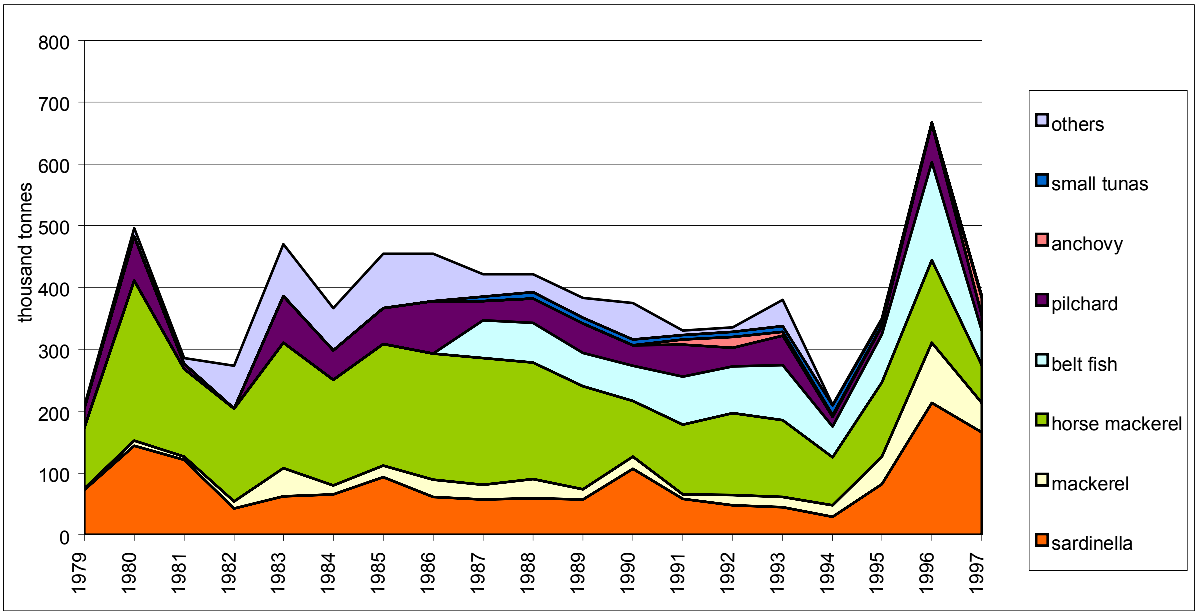

Figure 7. Catches of small pelagics in Mauritanian waters, CNROP data

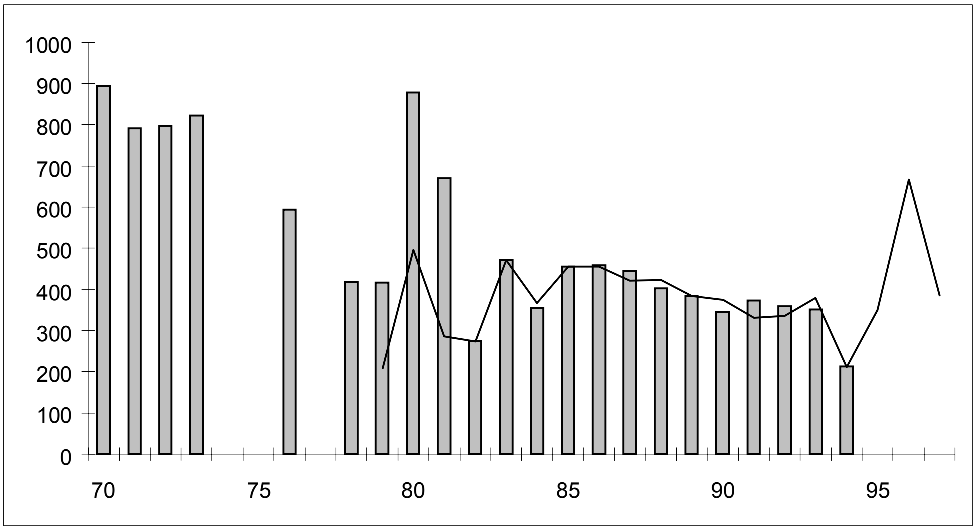

Figure 8a Catches of small pelagics in Mauritania estimated by Ministry of Planning (bars) and CNROP (line)

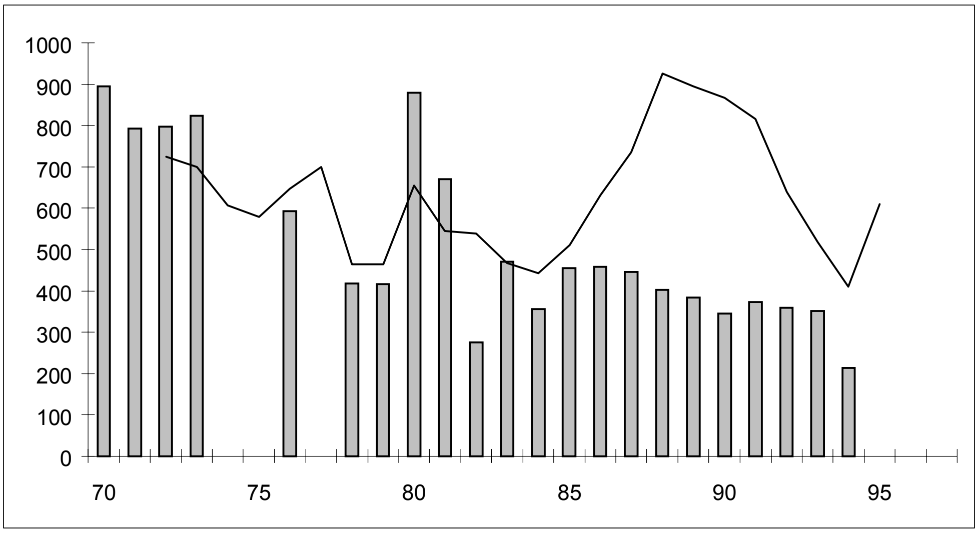

Figure 8b Catches of small pelagics in Mauritania estimated by Ministry of Planning (bars) compared with FAO estimates for CECAF areas 34.3.1 + 34.1.3 (line). FAO estimates do not include pilchard and anchovy

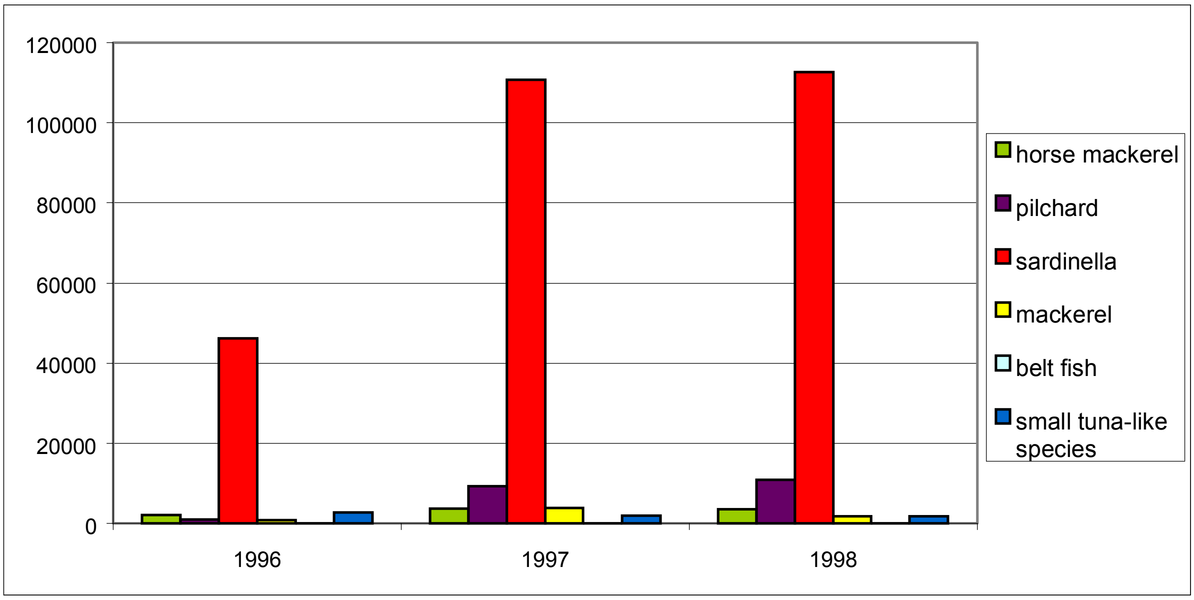

Figure 9. Species composition of Dutch catches in Mauritanian waters

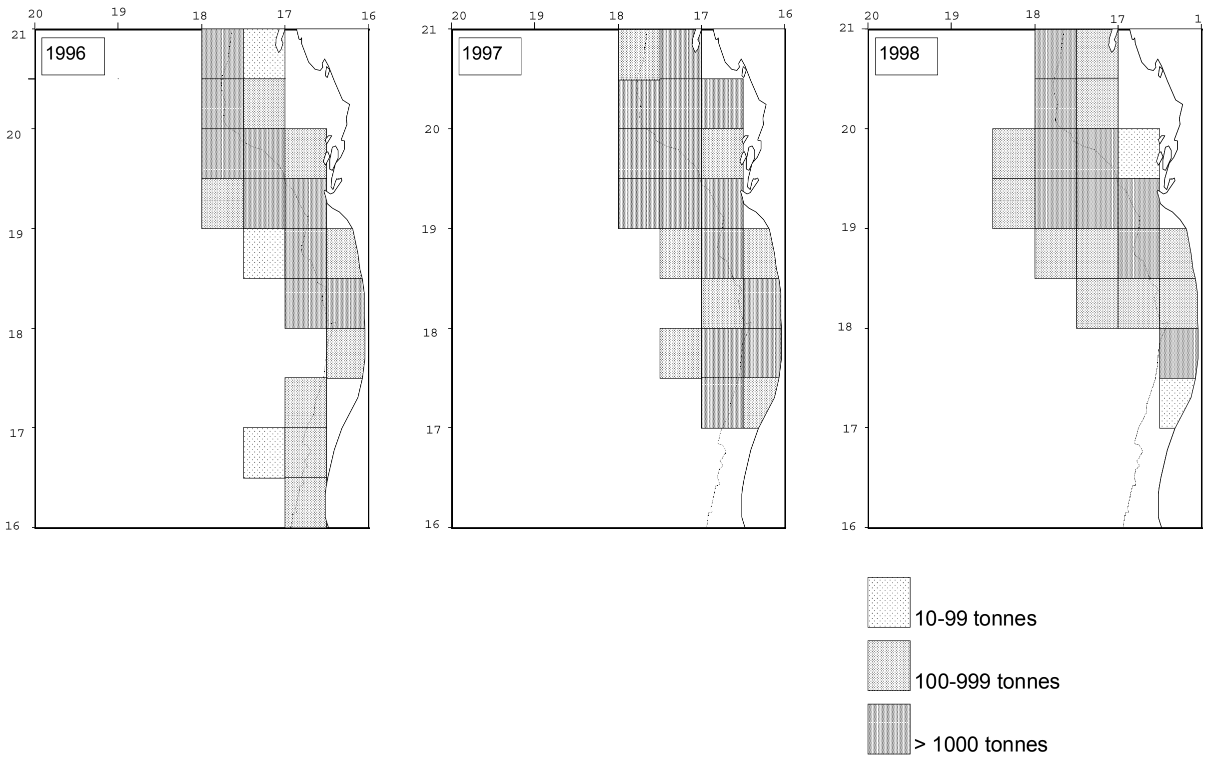

Figure 10. Geographical distribution of sardinella catches by the Dutch fleet

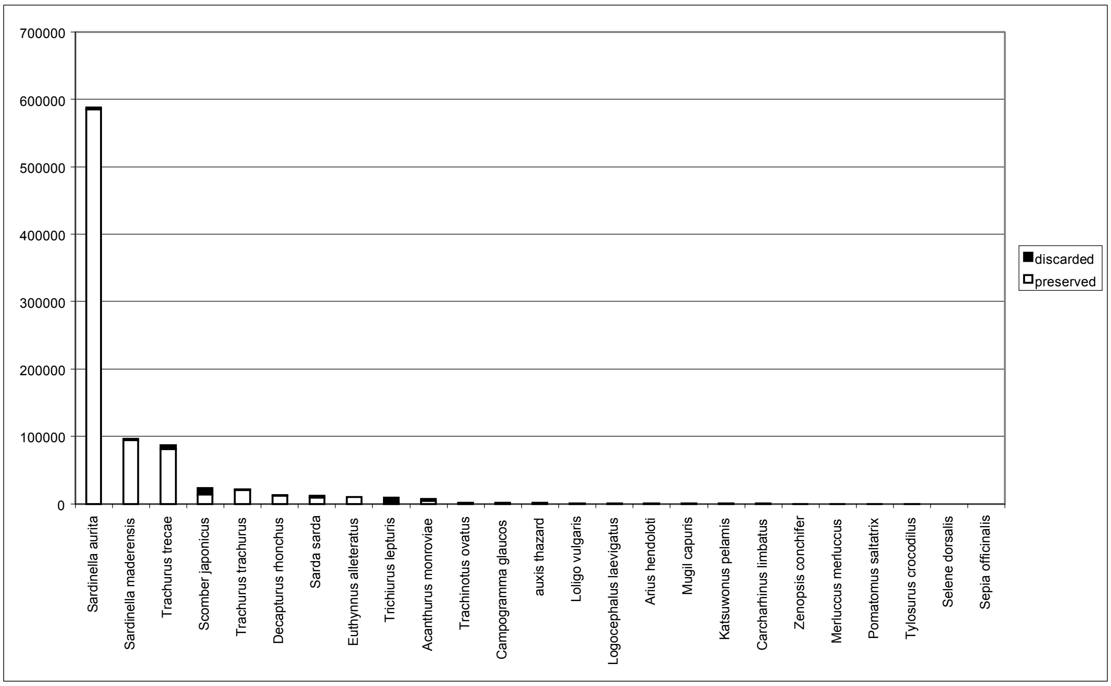

Figure 12. Catch composition (in kg) "Frank Bonefaas" 18 October - 14 November 1999.
Data refer to hauls that have been sampled, which comprised 67% of the total catch during the trip

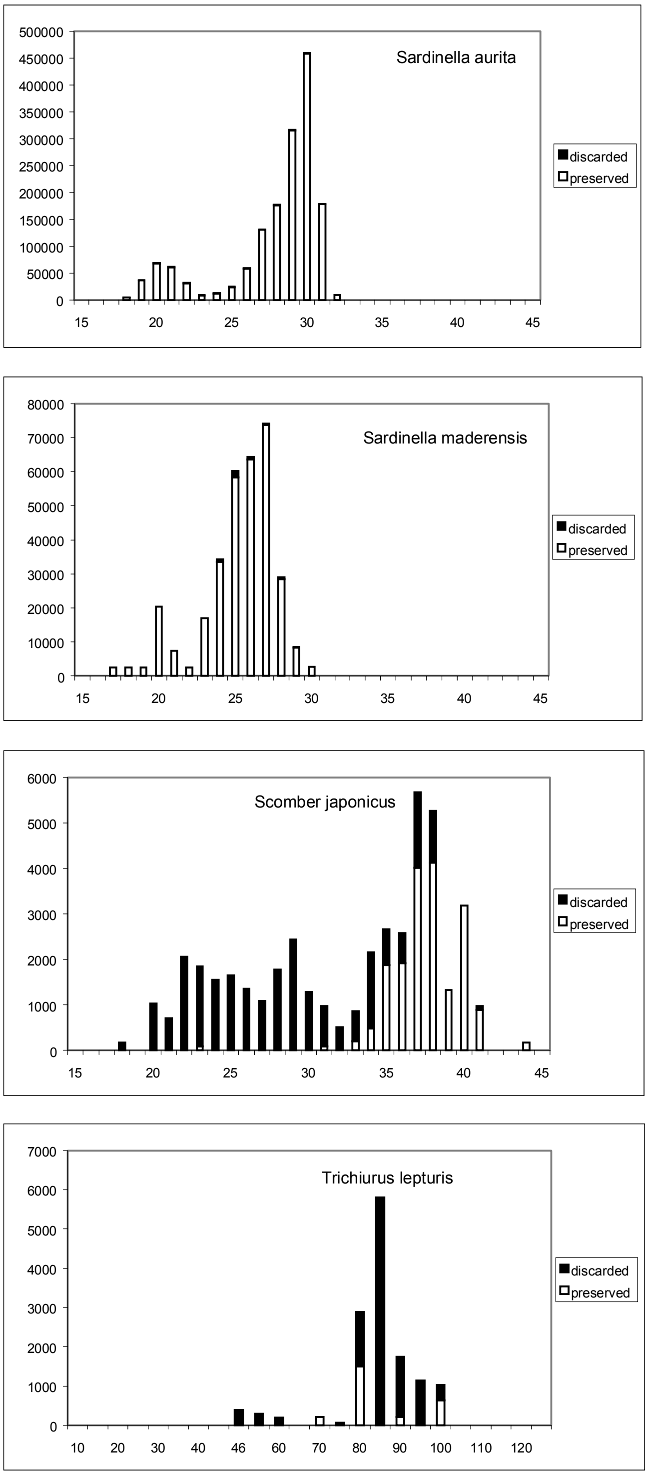

Figure 13. Length composition (in numbers of fish) of the fractions preserved and discarded for the main species taken during the trip of the "Frank Bonefaas" 18 October - 14 November 1999.