RIVO-Netherlands Institute for Fisheries Research

P.O. Box 68
NL 1970 AB Ymuiden
The Netherlands
Phone: +31 255 564646
Fax: +31 255 564644

P.O. Box 77
NL 4400 AB Yerseke
The Netherlands
Phone: +31 113 672300
Fax: +31 113 573477

Internet:postmaster@rivo.wag-ur.nl

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The reproductive cycle of *Sardinella aurita* in the Eastern Atlantic Ocean off Northwest Africa.

Progress Report 2002

Mw. ir. I.T. Mantingh

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T.a.v. de directeur Visserij
De heer drs. R.J.T. van Lint
Postbus 20401
2500 EK DEN HAAG

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Head Department Biology & Ecology

Signature: _____

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Summary

This progress report describes the reproduction patterns of *Sardinella aurita* in the Eastern Atlantic Ocean off Northwest Africa. Data have been obtained by biological sampling of the catches of the industrial and artisanal fleet.

Sardinella in maturity stage 5 (spawning) can be found throughout the whole year, but clear peak-spawning periods can be found though they differ from year to year. There are years in which the data suggested that main spawning periods occurred in January-February (1999, 2001), July-September (2000 and lab data 2002) and September-October (observer data 2002), but mainly in the northern part of the Mauritanian zone, north of 19°N.

GSI has a positive relation with the maturity stages. Mean GSI values of the industrial fisheries were higher than those of the artisanal fisheries though mean fork length in both fisheries was the same for each month except May.

No clear relationship between the spawning period and the fat content or stomach filling has been proved.

1. Introduction

This report describes the first results of a study on the reproductive cycle of round sardinella (*Sardinella aurita*, Valenciennes 1847). This study is part of a joint project between the Mauritanian Fisheries Research Institute (IMROP) and the Netherlands Fisheries Research Institute (RIVO). The project is aimed at stock assessment of small pelagics in northwest African waters, in particular the Mauritanian zone.

Sardinella is found in a large area from Senegal to Morocco and it is one of the commercial species of small pelagics that are heavily exploited by both the (international) industrial fishery and the artisanal fisheries. The need for stock assessment arises from the continuous increase of fishing effort in the region and a lack of information on how much fishing effort can be supported by the ecosystem. Stock assessment is complicated by the high recruitment variability to which particularly clupeoid stocks in upwelling regions are subject. Part of the variability is caused by natural fluctuations, but over-fishing, when present, could increase the susceptibility to recruitment variability even more (Cole & McGlade 1998).

A number of essential parameters for stock assessment are still lacking, such as data on stock identity (are all the fish in this area part of one and the same spawning population or not), growth rate (what is the age of sardinella at a certain length), and information on spawning season and area.

The present study is aimed at identifying the current spawning season(s) and area(s) of *Sardinella aurita* in Mauritanian waters. Research on spawning season and area is important for a number of reasons:

(1) It can show if there are one or more spawning season(s) and/or area(s), and if there are possibly also more spawning populations.

(2) Data on variations of spawning intensity during the year can demonstrate if there is a peak in spawning activity during a certain season. Such a peak will correspond to the birth of a cohort, which later can be observed in the fisheries. In this way, information can be obtained about the growth rate of the fish.

(3) At birth, fish probably is most vulnerable to environmental influences. Information about spawning season and area is therefore important to study the effect of hydrographical circumstances on the recruitment.

Several authors have described the spawning areas and seasons of round sardinella in West Africa in the past (Boely *et al.* in FAO 1979, Boely 1980, Boely *et al.* 1982, Shotton 1984 and Fréon 1986). For specifically the Mauritania area Sedletskaia (2001), Ould Taleb Ould Sidi (2000) and FAO (2001) have described the patterns of the reproductive cycle. The distribution of sardinella larvae was described by Conand (1976).

Since the time these observations were made, the abundance of *S. aurita* in Mauritania has increased considerably, and the distribution of the population has extended north (FAO 2001). It is not certain whether spawning areas and seasons at present are similar to those in the 1970s and 1980s. The present research is therefore executed to gain a better understanding of the reproduction patterns of round sardinella in Mauritania in recent years.

The spawning intensity of sardinella in Mauritania is determined by: (a) the amount of fish present in the area, and (b) the percentage of these fish, which are ready to spawn. In this study, information of

type (a) is obtained from commercial catch statistics, whereas information of type (b) is obtained from a biological sampling scheme. By combining the two types of information, variations in spawning activity during the year can be followed.

In order to examine whether spawning activity may be influenced by the food conditions in a given period, relationships have been analysed between maturity stage on one hand, and fat content and stomach filling on the other hand.

2. Material and Methods

2.1 Catch statistics industrial fishery

Detailed information on catches in the industrial pelagic fleet was available for the years 1999-2001. The data were provided directly by vessel captains in the framework of a study on the applicability of remote sensing data (Zeeberg *et al.* 2002). These data comprised total catch in weight; catch position, sea surface temperature (SST), water depth, and species composition in the catch. Whereas the catch is here the amount of fish that is caught in one haul. The duration of the hauls is variable.

In order to study monthly changes in abundance of sardinella in Mauritanian waters, the total catch per month was taken as an index of abundance in that particular month. This total catch is also dependent on fishing effort and the catchability of the fish, but as a first approximation it was assumed that these parameters were constant throughout the year. For each year, the catch in each month was expressed as a percentage of the total annual catch, and then the values for each month were averaged over the period 1999-2001. This provided an impression of the mean annual pattern of the abundance of sardinella in the Mauritanian zone.

The variations in the spatial distribution of sardinella were analysed in detail for the year 1999. The stations were grouped by two-monthly periods and plotted in charts. To indicate the size of the catch at a certain station, a distinction was made between 4 categories: 0-1 ton, 1-10 ton, 10-100 ton and more than 100 ton. The sardinella caught by the industrial fleet, has been caught outside the 13-miles zone. Although sardinella may also have occurred inside the 13-miles zone, the distribution of industrial catches is assumed to provide a good approximation of the actual distribution of the fish.

2.2 Maturity stage

Material for the analysis of maturity stages was collected in three different ways:

(1) Samples taken from catches of Dutch trawlers were analysed at sea by Mauritanian observers on board the vessels. The time between bringing in the catch and the analysing of the samples varies from 1-10 hours.

(2) Other samples from Dutch trawlers were brought ashore in Nouadhibou and analysed in the laboratory of IMROP. Samples were landed frozen and defrosted in the laboratory one night before analysing.

(3) Samples from landings of the artisanal fishery in Nouakchott were collected by a representative of IMROP and analysed in a small laboratory at the landing site. Fish were stored on ice directly after the catch and analysed the same day.

Samples collected and analysed by observers at sea in 1999, 2000 and 2001 consisted of 15-60 fish. The samples collected in 2002 all contained 25 fish (table 1).

From each individual fish the following parameters were collected: weight, empty weight*, fork length, sex, maturity stage, gonad weight**, stomach filling, fat content, and otoliths***.

* Empty weight is the weight of the fish after removing the intestines and fat.

** Gonad weight was only taken in 2002, when samples were treated on land. On board of the trawlers accurate weight measurements could not be taken due to the movement of the vessels.

*** Otoliths were collected only in 2002.

In this study two methods of determining the maturity stage were used. The first classification method was based on the macroscopic appearance of the gonads, following the key of Fontana (1969) (Table 2). This method was used at sea when there were no possibilities to weigh the gonads accurately.

The second method to describe maturity was based on the weight of the gonads in relation to total body weight. This relation is described by the gonado-somatic index (GSI), which is calculated as follows:

[1] GSI = Gonad weight / Empty weight * 100

Gonad weight and empty weight are both expressed in grams. Empty weight is used to avoid the influence of the varying weight of the intestine on the GSI. In 2002 the weight of the gonads of sardinella was taken from both the artisanal and the industrial catches.

The macroscopic classification of gonads appeared to be more difficult for male fish than for females. The criteria for distinguishing between stages 3, 4 and 6 were not very sharp, and it was suspected that classifications made by observers at sea were to some degree subjective. Therefore it was decided to leave out the male fish, and to concentrate on the females. Fish smaller than 21 cm were also excluded to avoid the influence of immature individuals.

For the study of the spatial variation of spawning, data obtained from Dutch trawlers were grouped in two monthly periods. Female fish were classified as spawning (stage 5) or non-spawning (stages 2,3,4,6 and 7). For each sample the position was taken and the percentage of female fish in stage 5 determined. Catches were divided into 5 categories according to the percentage females in stage 5 (0%, 1-10%, 11-20%, 21-30%; and > 30 %. The positions were then plotted on a map of Mauritania by using the ArcView GIS programme.

2.3 Fat content and stomach filling

Data on fat content and stomach filling were collected from the same material as described in paragraph 2.2. Fat content is here defined as the amount of fat in the abdominal cavity of the fish. It is classified in four categories from 0 to 3. Category 0 indicates no fat and category 3 indicates that all the intestines are completely covered with fat (table 3).

Stomach filling was defined as the volume of food present in the stomach. For stomach filling there are five categories from 0 to 4, of which 0 is completely empty and 4 is completely full (table 3). The classification of both fat content and stomach filling is done macroscopically.

For both fat content and stomach filling, the percentage in each category was calculated by month.

2.4 Anecdotic information from skippers

The author and several of her colleagues regularly joined Dutch trawlers in Mauritanian waters for trips of 1-2 weeks. During these trips, a large amount of anecdotic information was collected from captains and crewmembers. Although it is difficult to quantify or even verify this information, some of it is presented here because it is assumed to provide additional insight in the spawning biology of sardinella.

3. Results

3.1 Seasonal changes in abundance of S. aurita in Mauritanian waters

Figure 1 shows the temporal variation of sardinella catches by the Dutch fleet over the year. Catches have been expressed as the percentage contribution to the annual total, and the figure presents the mean values over the years 1999-2001. Catches were small at the beginning of the year and they gradually increased to a maximum in June. From then on the catches decreased till the end of the year. It should be mentioned that fishing effort was generally low in the beginning of the year and in the end, so the low catches for these periods may not accurately reflect sardinella abundance.

Variations in the spatial distribution of sardinella catches by the Dutch fleet in the year 1999 are presented in Figure 2. This distribution of the catches showed that a majority of the catches occurred in the southern part of the Mauritanian zone during the first two months of the year. In May-June the catches shifted north to the Cap Blanc region, and in July-August this northward shift continued. By September, catches started to concentrate in the coastal region. Figure 2 also shows that fishing effort was lower during the first and last two months of the year.

The results shown in Figure 1 and 2 indicate a weak presence of sardinella in the Mauritanian waters at the beginning of the year. The fact that most catches occurred in the south suggests that the sardinella population is mainly distributed in Senegal by this time of the year. The fish started to migrate north in March-April and this migration went rather fast. The abundance of sardinella reached a maximum in the Mauritanian zone from May till August. In the last quarter of the year the abundance in the Mauritanian zone declined, probably due to a migration of sardinella into the Moroccan zone. At the same time sardinella was found close to the coast where they were not accessible for the industrial fishery.

3.2 Seasonal changes in spatial distribution of mature fish

1) Samples collected by observers on board Dutch trawlers in 1999-2002
For the samples collected by the observers on board of the Dutch trawlers in 1999-2002, the mean monthly percentage of female sardinella in the different maturity stages is presented in Figure 3. Great variations in peak spawning periods are found between the years. In 1999, the main spawning occurred from February till May; in 2000 from July till September; in 2001 in January-February and June-July, and in 2002 in September-October.

2) Samples from Dutch trawlers in 2002, analysed in the laboratory
The samples analysed at the laboratory of the IMROP showed an increased spawning activity in June-July (Fig. 4a) for females. Striking is that almost all the fish were close to, or in the spawning period during these four month.

3) Samples from the artisanal fishery in 2002
Fish sampled from the artisanal fisheries in 2002 showed peak spawning in January-February, May-June and October when more than 20% of the individuals were in stage 5 (Fig. 4b). April was characterised by the absence of mature fish. The great majority (almost 90%) of the fish were in stage 2 or 3 during this month. When comparing the samples from the industrial and the artisanal fisheries, the results differ greatly in the period May-August, especially for group 4 + 6.

Figure 5 shows the spatial distribution of maturity stages by 2-monthly periods for March till October 2002. The size of the circle corresponds to the relative amount of females in maturity stage 5. It is shown that the highest percentage of spawning females was found in September-October in the northern part of the Mauritanian zone and that during the other months (March-

August) most of the samples contained less than 10% females in stage 5. Also in these other months, spawning activity was concentrated north of 19°N.

3.3 Gonado-somatic index (GSI)

Sardinellas caught by the industrial fleet (Fig. 6a) had higher GSI values than sardinellas caught by the artisanal fleet (Fig. 6b). The difference is large and cannot be caused due to sampling errors, since the weight of the fish and its gonads is measured precisely. GSI values in catches of the industrial fleet were highest in June, whereas catches by the artisanal fleet did not show a seasonal peak in GSI.
The mean GSI per month of both artisanal and industrial fisheries were plotted against the maturity stages that were determined by macroscopic inspection (Fig. 7a+b). These plots show a relation between GSI and the maturity stage determined by macroscopic inspection. After stage 5 the weight of the gonads decreased and as a result also the GSI. The standard deviations in both graphs show that the variation is big for stage 4 for the trawler data.

3.4 Fat content

The monthly distribution of fat categories in the artisanal fishery in 2002 is presented in Figure 8a. A difference is noted between the period January-April and the period May-August. The first period is characterised by the absence of fish in fat stage 0 and an increase of stage 3 from 23% in January to 52% in April. This suggests that the fish were building up a fat reserve. From May till August the presence of fat stage 0 increased to 12%, whereas fat stage 3 stayed at around 20%.

The data of the industrial fisheries, available only for May–August 2002, show no big variation in the monthly composition of the fat stages (Fig. 8b). The results for the industrial fleet did hardly differ from the data of the artisanal fleet during these months.

3.5 Stomach filling

In the samples from the industrial fisheries, the percentage of fish with a full stomach decreased from May till August (Fig. 9a). Stomach filling stage 4 was not found at all in the data set. Both full stomachs (stage 3) and completely empty stomachs (stage 0) were hardly found. Stage 1 was most common in all the months. Data on stomach filling from the artisanal fleet did not differ from the trawler data of May till August. But a clear increase of empty and almost empty stomachs (stage 0 and 1) can be noted from January till August (Fig. 9b).

3.6 Anecdotic information

During trips by the author and her colleagues on board of Dutch trawlers, the captains and crew made a number of remarks that may be pertinent to the subject of the present study. Some of these remarks are presented here. Also some observations are presented that were made by project staff during research cruises of the Mauritanian research vessel “Al Awam”.

- Spawning sardinella was caught in large numbers by the Dutch trawler ‘Carolien’ in August and September 2001 in the northern part of Mauritania. The fish was migrating further north at that time (around 7 miles per day). In October, after spawning, the fish migrated to the west.
- Captains of Dutch trawlers mentioned the occurrence of big sardinella schools in the Moroccan zone on their way from Nouadhibou to Las Palmas in the period of November 2002 till February 2003.
- No migrating schools were seen in the northern part of Mauritania by Dutch vessels from November till December 2002.

- The Mauritanian research vessel 'Al Awam' caught only small sardinella's (20-25 cm total length) in immature condition in the region of Cap Blanc (northern Mauritania) on a mission in November 2002.
- The Dutch trawlers caught mainly sardine and only a few small sardinellas in the same period, also mainly in the northern region.
- Large adult sardinellas were hardly found in both Mauritania and Senegal by the end of 2002.
- In Senegal the artisanal fisheries caught big quantities of sardine in November 2002 till March 2003, which is unusual in this region (Sylla 2003 *pers. comm.*). This was probably due to low water temperatures during this period.

In general catches of round sardinella have decreased in the Mauritanian zone from 1998 to 2002, although fishing effort (expressed in fishing days) has slightly increased (Ter Hofstede 2003).

4. Discussion

4.1 Spawning season and area

Sardinella in maturity stage 5 can be found throughout the whole year, but clear peak-spawning periods can be found though they differ from year to year. There are years in which the data suggested that main spawning periods occurred in January-February (1999, 2001), July-September (2000 and lab data 2002) and September-October (observer data 2002).
Besides the differences between the years there are also differences within the years due to the use of data from both industrial and artisanal fisheries targeting the same species, but in different areas. In the data collected from the trawlers maturity stage 4 dominated from May till August, while the artisanal data showed not even 50% of stage 4 and 5 together in these months.
The differences between these results from the industrial and artisanal fisheries may be affected by different catch positions; the industrial fisheries occur outside the 13-miles limit and mainly north of 19°N and the artisanal data are only collected inside this limit around the 18°N; A second reason may be that the two types of fisheries aim two different sardinella population, a southern and a northern population, and that these populations do not spawn synchronously.

Based on the data so far it can be assumed that the main spawning area is in the north of the Mauritanian zone. As the high mobility of the EU trawlers permits them to search the whole zone in a short time we may assume that the fleet fish normally there where the majority of the population stays. In general the fishery on sardinella by EU trawlers hardly takes place south of the 18°N. The major quantity of spawning sardinella is fished in the north and this suggests that the major spawning areas are there.
Above-mentioned does not correspond with the findings of Conand (1977). He has described the migration and spawning cycle of *S. aurita* in 1974. He found that after a period of sexual inactivity the spawning cycle started with the warming of the water in Senegal by the end of May. From this moment on *S. aurita* migrates up north. In June the maximum concentration of spawning sardinella was found in the Dakar region ('Petite Côte') and big concentrations of larvae were present very close to the coast between 16°N-18°N in the last week of June. In the beginning of August hardly any mature fish were found south of 19°N and little spawning was observed in the Arguin Banc. But the time of spawning has been variable during the last few years (1999-2002). The spawning season for *S. aurita* did not only occur in the months June-September as described by Conand and others (e.g. Sedletskaia, 1979; Ould Taleb Ould Sidi, 2000), but also in the months January, February and May the percentage mature females (stage 5) exceeded the 20%. The high occurrence of stage four in the months August and September 2001 (not shown) and in May till August in 2002 confirms the observations of the FAO (1979) that peak spawning occurs in August and September (assuming that spawning (stage 5) will follow shortly after stage 4). It is not understood why stage 5 did not show up in high numbers in Mauritania. Possibly the fish has migrated to Morocco and spawned there.

According to the present study, Sardinellas spawn in both deep and shallow waters as female fish in stage 5 were found between 16°30'W and 17°45'W. Conand (1977) also suggested that sardinella spawns close to the shore, or that the eggs are disposed in deep water and are subsequently distributed towards the coast by the currents.
Further research should be executed to clarify the mechanisms of egg deposition, and larval transport.

Remarkable is the difference between the spawning data obtained from the samples collected by observers on board of the trawlers and the fish samples treated in the laboratory, although both type of samples were collected in the same area and period. This could be the result of the way the maturity stages are determined. The presence of sometimes inexperienced observers, determining the maturity stages on board of the trawlers, could have caused some error in the sampled data.

Another explanation could be that the development of the gonads is synchronically within schools and differs greatly between schools. No literature has been found on this.

The differences between the results found in the present study and those from other studies in the 1970s and 1980s could also be caused by small changes in the climatologically situation. The Brazilian sardine, *Sardinella brasiliensis*[1] (Steindachner 1879), searches for areas with favourable spawning conditions. Main spawning areas may therefore change from year to year, depending on oceanographic conditions (Matsuura (1979); Isaac-Nahum *et al.* (1987)). In their study on *S. brasiliensis,* they showed that spawning occurred at several different places and with varying intensity throughout the Brazilian area studied and did not form a specific geographical pattern. They also concluded that *S. brasiliensis* is a batch spawner with a gonadal cycle that differed slightly from the Fontana cycle.

Parrish *et al.* (1983) and Bakun & Parrish (1990) identified a pattern of simultaneous avoidance of strong offshore-directed transport and of wind-induced turbulent mixing in the spawning habits of the anchovies and sardines[2] inhabiting the temperate eastern ocean boundary upwelling systems. This could indicate that *S. aurita* is not strictly tied to fixed spawning areas, but changes the spawning area and season depending on the environmental circumstances.

The main limitation of the analysis of spawning season and area in this report arises probably from the fact that long biological data series are not available to get a good insight in the spawning and migration patterns of *S. aurita*.

4.2 Relation GSI - maturity stage

A big difference between the GSI values of the industrial and artisanal fishery was found. This can possibly be explained by the difference in mean fish length and therefore in different gonad weight. An exact look at the length-frequency data of both the artisanal and industrial fishery confirms this hypothesis for the months June, July and August, but the mean fork length in May was the same for both fisheries as well as the total mean of 2002. The incomplete data set prevents further comparison of other months.
Another explanation may be found in the allocation of the maturity stage to a gonad. In the field we have seen many gonads that were hardly macroscopically classifiable on the basis of the key of Fontana. Problems of stage determination arose between maturity stage 4 and 6. Sardinella is a batch spawner. The first spawning period in a spawning season is preceded by a clear stage 4 as described by Fontana, but a second (or maybe even a third) spawning period is preceded by a state of the gonads that has features of both stage 4 and 6 and the ovaries are smaller. Often the anterior side of the gonad has the features of a gonad in stage 4 (orange and granulous) and at the same time the posterior side is vascular and dark red.

A positive relationship between the GSI and the maturity stages has been found, but the different stages could not clearly be distinguished by the GSI-values. Fontana (1969) based his key for maturity stages on the histology of the gonads. Each stage is characterised by a certain length range of the oocytes. This is an accurate method to distinguish the different stages, but is due to labour intensity not feasible. The disadvantage of the GSI is that it is just a rough standard; it cannot show the small nuances between the maturity stages as the key of Fontana does.

GSI has been used as an indicator for spawning periods of *S.* aurita (Cury & Fontana 1988; Quaatey & Maravelias 1998) and still can be a good parameter in addition to the visual determination of maturity stages.

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1 *Sardinella brasiliensis* is probably similar to *S. aurita* (Whitehead 1985).

2 *Sardinella aurita* is the warmer water counterpart to the sardine species of the genera *Sardinops* and *Sardina* (Parrish *et al.* 1989).

4.3 Relation fat content – maturity stage

The fat content is a constant index, which is not changing from day to day. In fish gonad maturation requires a large amount of energy and therefore usually occurs during or after a period of intense feeding (Wootton 1992 in: Fréon *et al.*, 1997). Nevertheless no clear relation has been proved between high fat content and subsequent high GSI values.

There are also other factors that could influence the start of spawning. Other studies showed contrasting results for the reproductive 'drive' of *S. aurita*. As described in paragraph 4.1 sardinella species also tend to avoid areas with high turbulence and offshore transport for reproduction. Fréon *et al.* (1997) described for Brazilian sardine in Venezuela the opposite. The reproductive strategy of this population apparently is to give priority to optimal food availability for the offspring and not to prevent eggs and larvae being transported offshore.

4.4 Relationship stomach filling – maturity stage

The stomach filling varied from month to month, but declined approximately from January till September and did not show a clear relation with the fat content or the spawning patterns. This is possibly caused by the variable food intake of sardinella. The feeding behaviour of sardinella depends on the occurrence of upwelling, but has also a day and night rhythm. *S. aurita* migrates to the surface of the water during the night and is then no longer concentrated in schools as during daytime. Than the fish can be found deeper in the water column (Cury & Fontana, 1988). Therefore the occurrence of a full stomach probably strongly depends on the moment the sardinella is caught and the mean stomach filling is therefore not a clear indicator for the real feed intake in a certain month.
Also the duration of the sardinellas in the provision tanks on board of the trawlers may influence the stomach content, because the digestion in the stomach is continuous stimulated by the gastric juices, till the fish is frozen.

5. Recommendations for future research

Changes in migration and reproduction patterns may have taken place compared to earlier investigations, but due to incomplete data sets further research with more data in complete data sets of whole year round sampling is recommended.

The main focus in 2002 was on the Mauritanian zone, but for a better understanding of the behaviour of *S. aurita* sampling methods of Senegal, Morocco and Mauritania should be standardised so that results can be compared.

In general the key of Fontana for the determination of the maturity stages for *S. aurita* has proved to be a good one for the Mauritanian region. Nevertheless a key, illustrated with both macroscopic and microscopic photos of the different stages, would help to standardise the observations in the future.

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Tables

Table 1. Numbers of *S. aurita* collected for maturity studies in 1999-2002.

Year	Samples collected from industrial catches and analysed by observers at sea	Samples collected from industrial catches and analysed ashore in Nouadhibou	Samples collected from artisanal catches in Nouakchott
1999	6297	0	0
2000	3090	0	0
2001	3094	0	0
2002	4099	821	699

Table 2. Key for the macroscopic determination of the maturity stages of Sardinella aurita by Fontana (1969).

Stage	Female	Male
1	Immature (virgin) Ovaries small and firm, pink clear or transparent – oocytes invisible	Immature (virgin) Testes white or slightly translucent. Very small and knife blade shaped.
2	Sexual resting period Identical characteristics as stage one, but ovaries are bigger, transparent and tube-shaped - oocytes invisible	Sexual resting period Identical characteristics as stage one, but testes are bigger.
3	Late developing Ovaries firm. Colour varies from pink to clear orange. Some of the oocytes may be visible through the membrane of the ovary. Ovaries occupy circa 1/3 of the abdominal cavity.	Late developing Testis firm and whitish. No liquid is running out after making an incision.
4	Ripe Ovaries big and less firm clear deep orange. Surface of the ovary granulous. Oocytes visible through the membrane.	Ripe Testis white and very soft/weak. White liquid runs out after the slightest incision.
5	Spawning Gonads are very big and occupy almost the whole abdominal cavity. The ovarian membrane is very thin. Hyaline oocytes are perfectly visible and run out after the slightest pressure on the abdomen.	Spawning Emission of spermatozoids Testes big and soft. Sperm runs out after slightest pressure on the abdomen.
6	Spent Ovaries are flabby and vascular. Color generally salmon-pink. Oocytes of 450 microns and numerous hyaline spaces can be seen through the ovarian membrane	Spent Testes are flaccid/flabby and show a very fine vascularisation on the posterior part.
7	Recovering spent Ovaries are empty	Recovering Spent Testis very flaccid and strongly vascular

Table 3. Classification of fat content (stages 0-3) and stomach filling (stages 0-4).

Stage	Fat content	Stomach filling
0	No fat at all.	Stomach completely empty.
1	Small chains of fat along the intestines.	After incision at the end of the stomach a very small amount of food particles will emerge.
2	Chains of fat cover half of the intestines.	After incision about 2 cm of food particles will emerge.
3	Intestines completely covered with fat. Fat structure is firm and lobe shaped.	Stomach is almost full. Also the two lobes of the stomach are partly filled.
4		Stomach completely full.

Figures

Figure 1. Monthly variation of sardinella catches by the EU fleet (mainly Dutch trawlers) in the Mauritanian ZONE in 1999-2001.

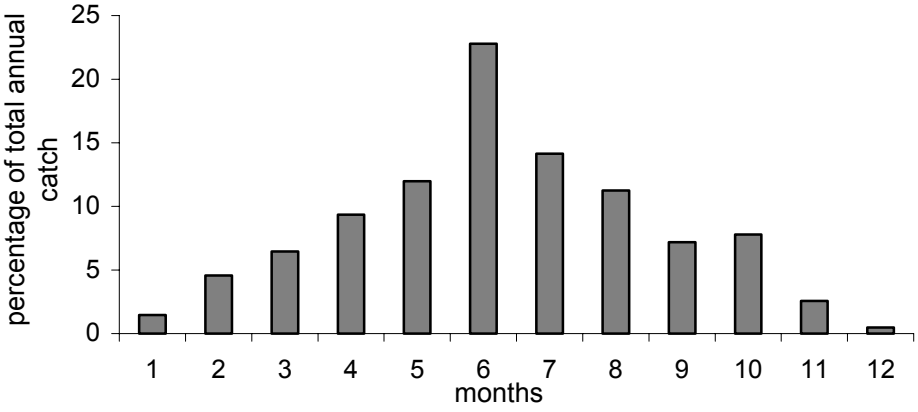

Figure 2. Distribution of sardinella catches by the Dutch fleet in 1999 (Ter Hofstede 2002 *unpublished*).

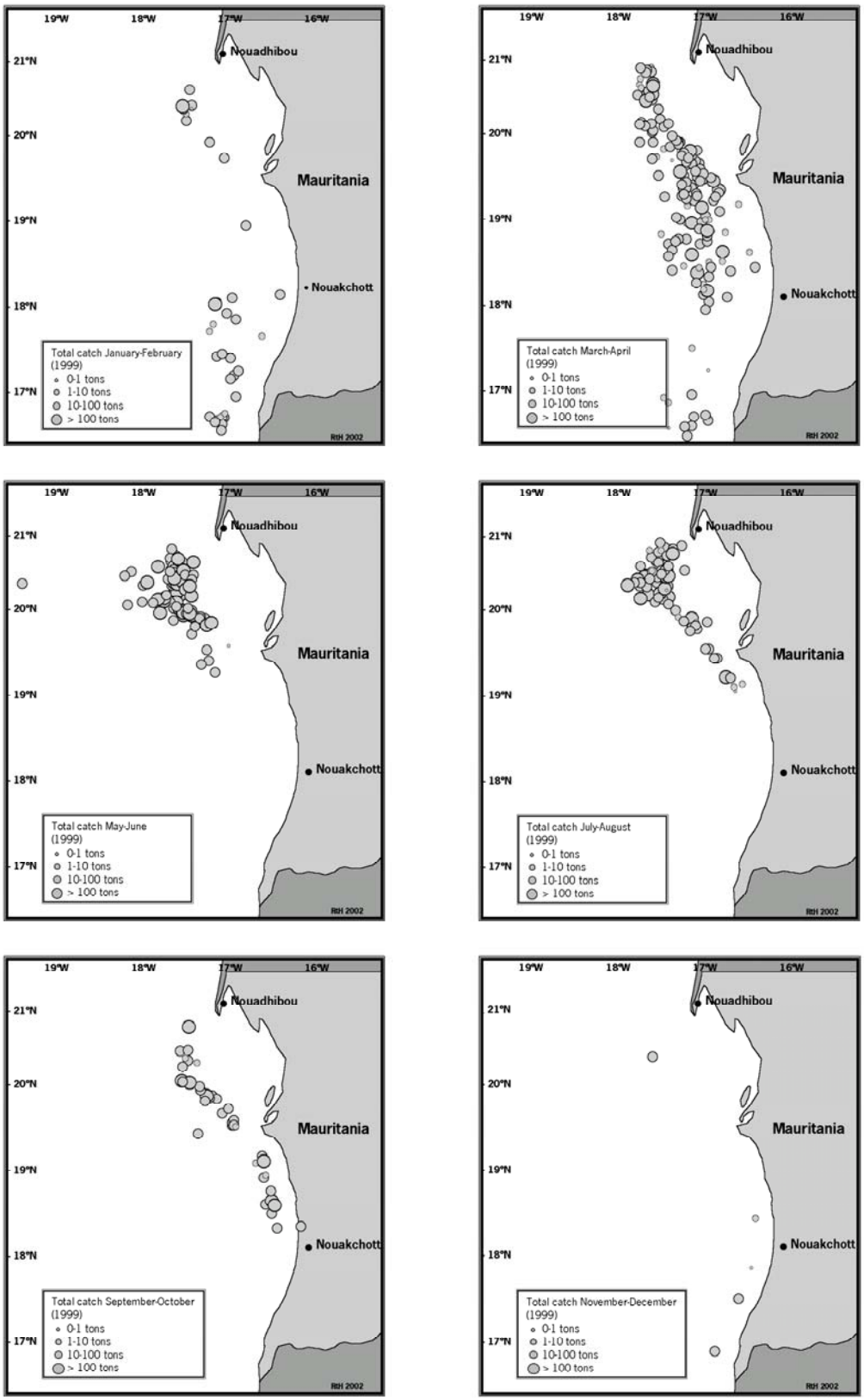

Figure 3. Mean monthly percentage of female fish in maturity stage 5 from 1999 to 2002 (samples collected on board of Dutch trawlers).

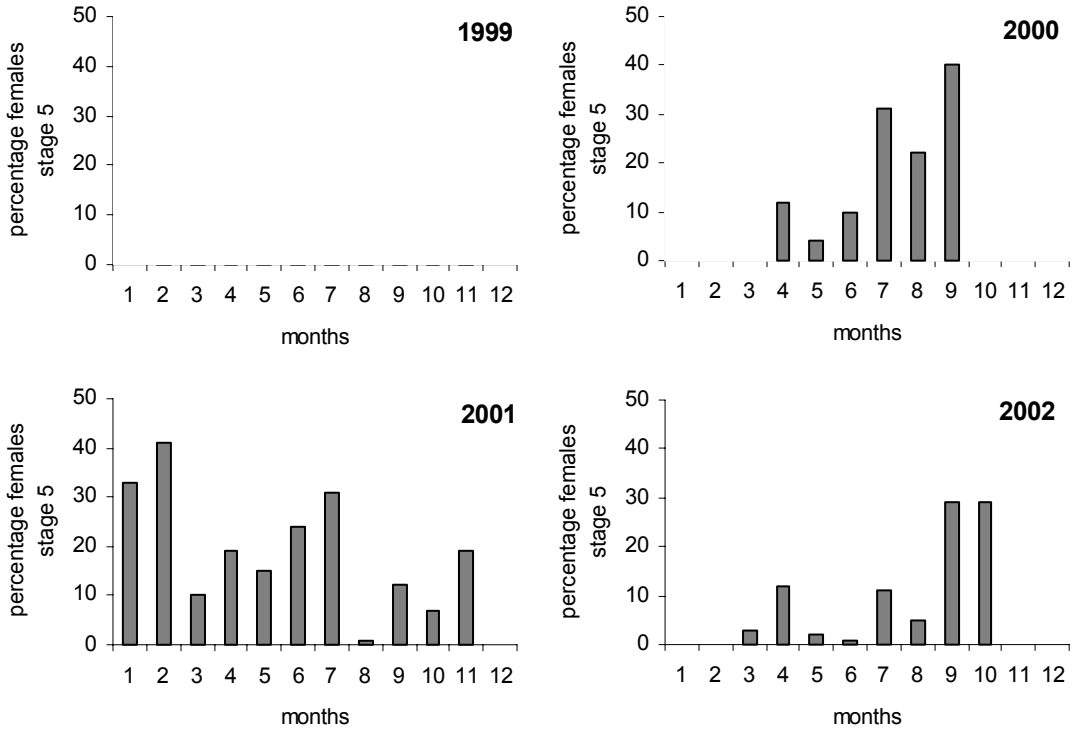

Figure 4. Mean monthly percentages of maturity stages, grouped in three categories; stage 5, stages 6+4, and stages 2+3+7 from a) Dutch trawlers and from b) artisanal fisheries in 2002.

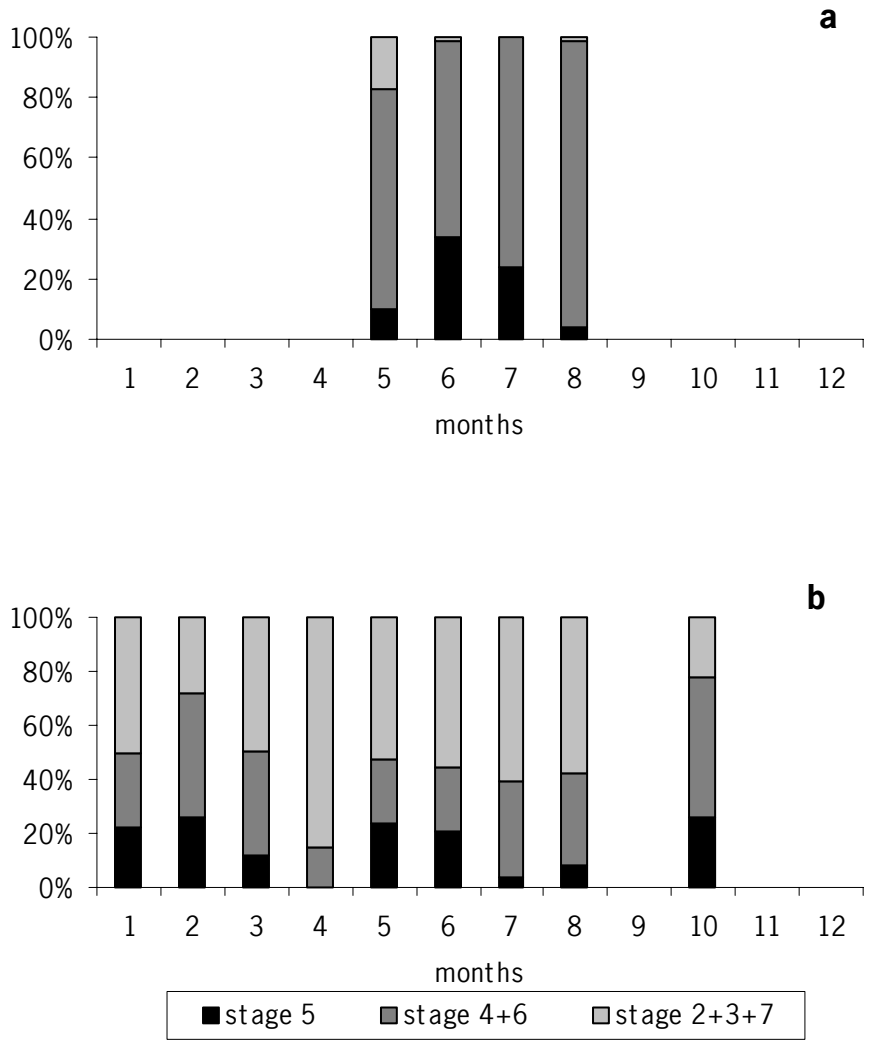

Figure 5. Catch positions of samples from Dutch trawlers with the relative amount of female sardinella in maturity stage 5 in 2002.

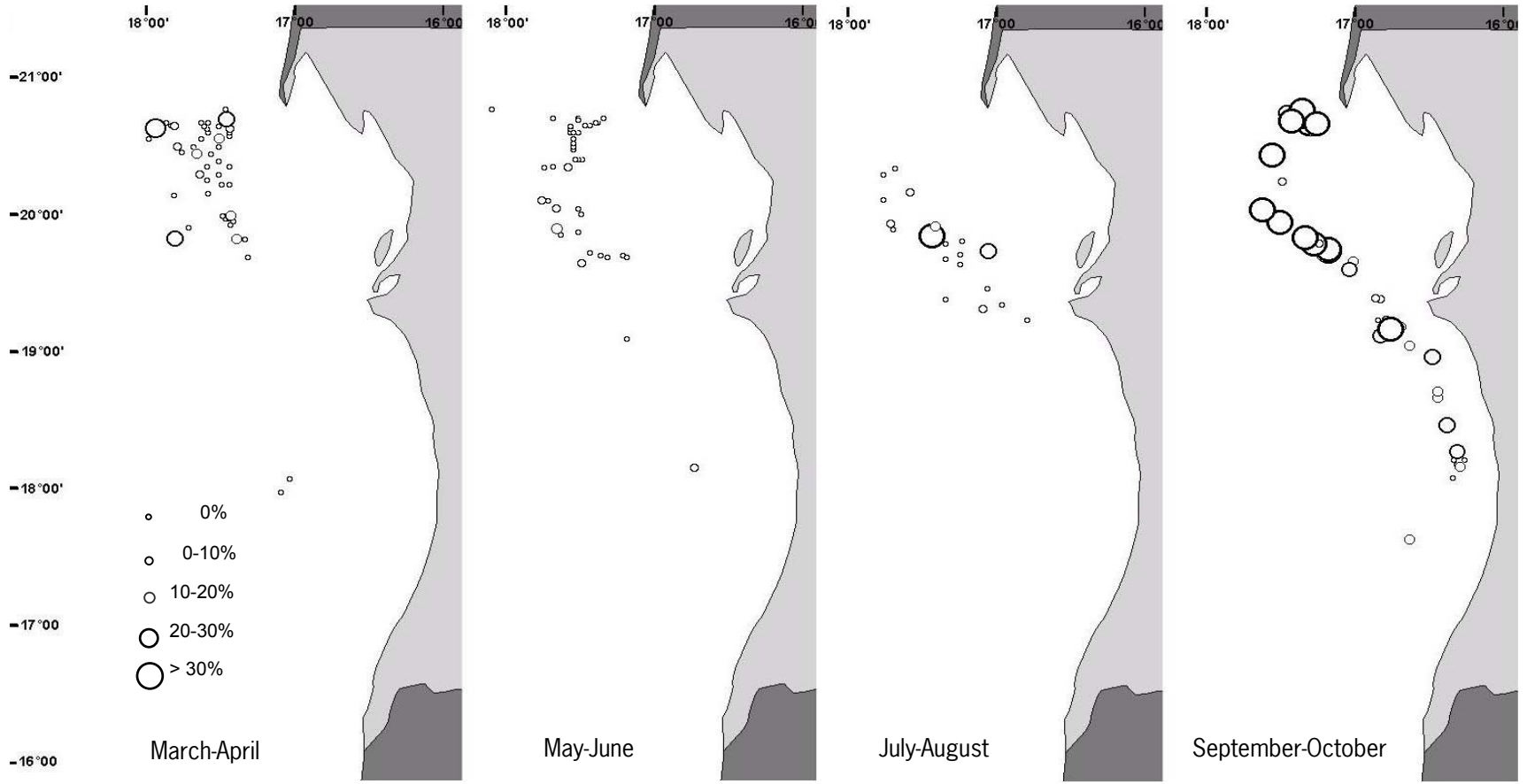

Figure 6. The mean GSI of female fish per month for the industrial fishery (a) and the artisanal fishery (b) in 2002 with 95% confidence intervals.

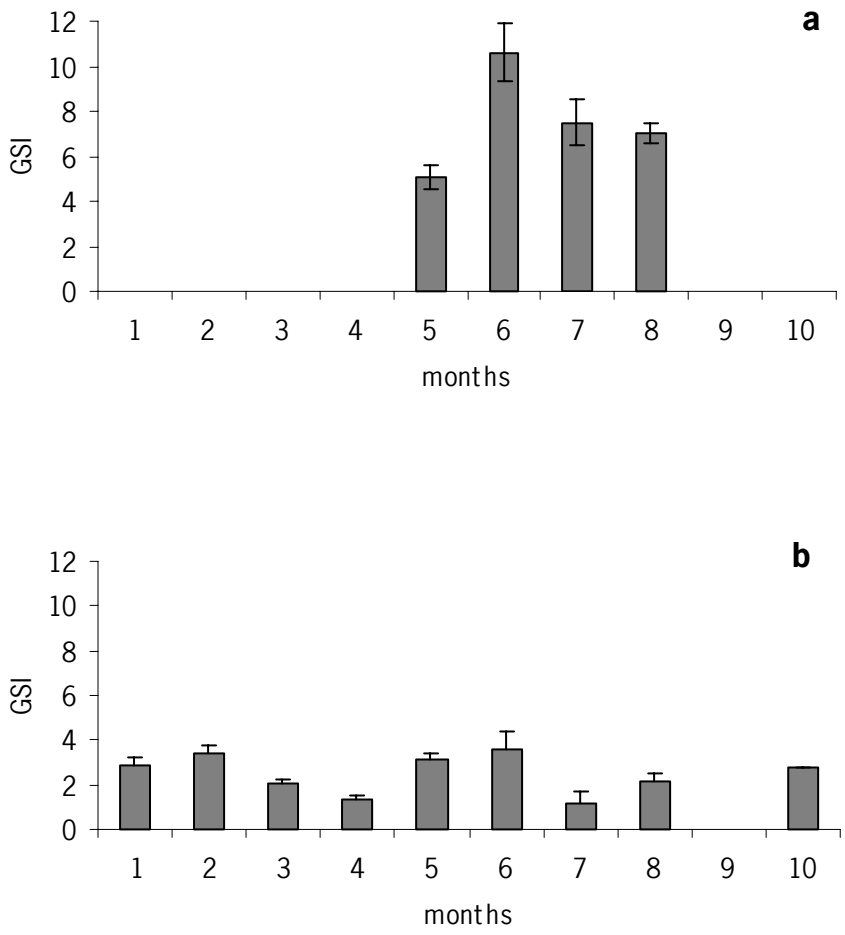

Figure 7. The relation between maturity stage and the corresponding mean GSI for artisanal fisheries (a) and industrial fisheries (b) in 2002 with 95% confidence interval

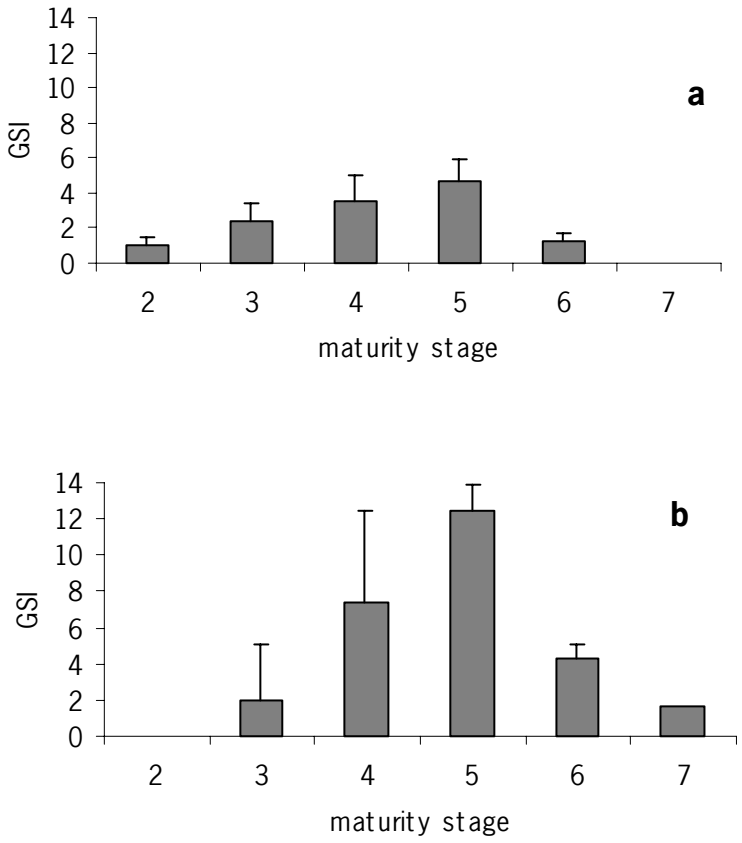

Figure 8. The percentages of fat stages 0,1,2 and 3 per month for artisanal fisheries (a) and industrial fisheries (b) in 2002.

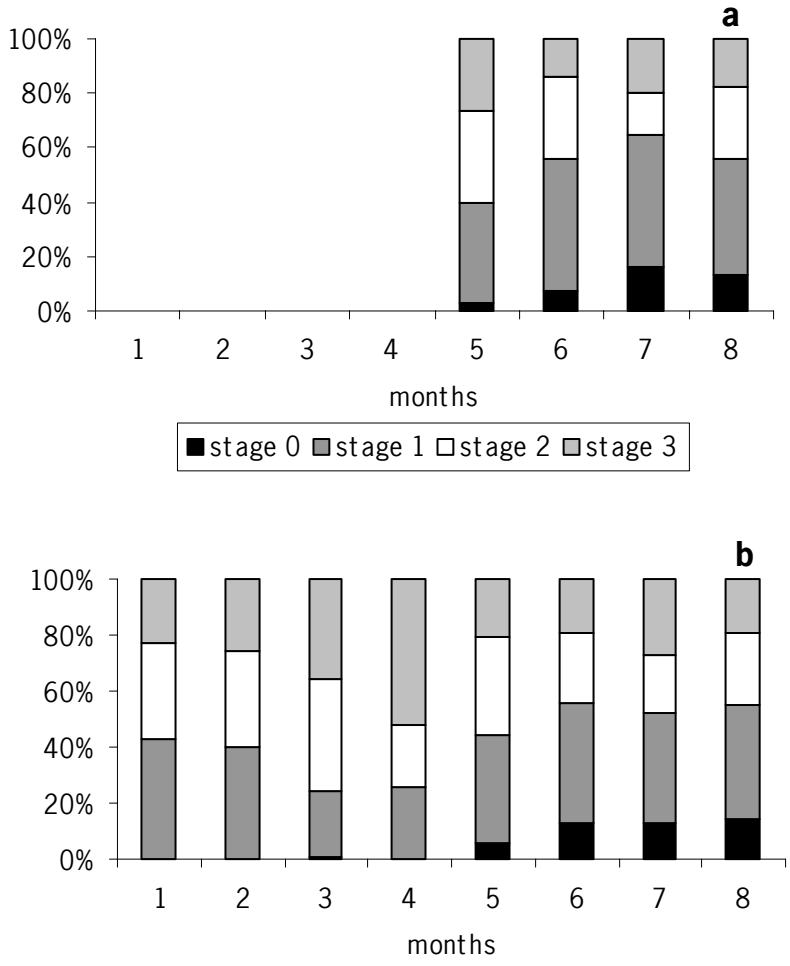

Figure 9. The percentage of stomach filling stages 0,1,2 and 3 per month for industrial fisheries (a) and artisanal fisheries (b) in 2002.