United Nations Educational, Scientific and Cultural Organization
GRÓ FTP
Fisheries Training Programme Under the auspices of UNESCO

grocentre.is/ftp Final project 2021

BIOMASS AND GEOGRAPHICAL DISTRIBUTION OF SEVEN SMALL PELAGIC FISH SPECIES IN RELATION TO TEMPERATURE CONDITIONS IN MAURITANIAN WATERS

Sidi Ahmed Hemed
Mauritanian Institute of Oceanographic Research and Fisheries, IMROP
ouldhemmed@gmail.com

Supervisor:
Anna Heiða Ólafsdóttir Ph.D.
anna.olafsdottir@hafogvatn.is

ABSTRACT

The focus for this study was to research small pelagic fish resources within the Mauritanian EEZ, to calculate stock biomass and investigate whether species distribution is related to temperature conditions.

Acoustic backscatter data from the RV Dr Fridjof Nansen were post-processed using the software Large-Scale Survey System (LSSS) Version 2.0. Species allocation based on the species proportion in catch and biomass estimates were calculated following FAO guidelines.

The study results show that temperature influences species' geographical distribution. Chub mackerel, Atlantic horse mackerel, and sardines are more prevalent in the colder waters of the northern part of the EEZ, while round sardinella, flat sardinella and Cunen horse mackerel are more prevalent in the warm waters of the central and southern part of the EEZ. Though anchovy and Cunen horse mackerel were found in both colder and warmer waters from the north to the southern area. The biggest biomass estimate was the anchovy followed by Cunen horse mackerel and flat sardinella, generally, these species were found in shallower areas.

Key words: stock biomass, species distribution, temperature, pelagic species, Mauritania

This paper should be cited as:
Hemed, A. H. 2022. *Biomass and geographical distribution of seven small pelagic fish species in relation to temperature conditions in Mauritanian waters.* GRÓ Fisheries Training Programme under the auspices of UNESCO, Iceland. Final project.
https://www.grocentre.is/static/gro/publication/1740/document/Hemed21prf.pdf

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Mauritanian fisheries

The coastline of Mauritania is about 720 km along the eastern edge of the Atlantic Ocean in northwest Africa. Mauritania has an Exclusive Economic Zone (EEZ) of 200 nautical miles, with an area of 234,000 km² including a large continental shelf of 39,000 km² (Figure 1). Mauritanian waters are renowned for their species diversity and abundance of commercially important fisheries resources. Approximately 600 species of fish have been recorded within the EEZ of which more than 200 can be commercially exploited (Fisheries ministry, 2015).

Since 1985, the Mauritanian Fisheries and Oceanography Institute Research (IMROP) has organized a multidisciplinary working group on the management of fishery resources every 4 or 5 years in which national (Université de Nouakchott Al-Aasriya "UNA") and international scientific experts from Institut National de Recherche Halieutique (INRH) Morocco, Centre de Recherche Océanographique de Dakar Thiaroye (CRODT) Senegal, El Instituto Español de Oceanografía (IEO) Spain, an administration body (Free Zone Authority "AZF", Central Bank of Mauritania "BCM"), other professionals, and the civil society (NGOs working on fishing and environmental protection) meet to evaluate the results of its research programs and activities. Current evaluation of total annual fishery resources available in Mauritanian waters is 1.9 million tons of which 1.4 million tons is small pelagic fish stocks (Khallahi et al., 2020).

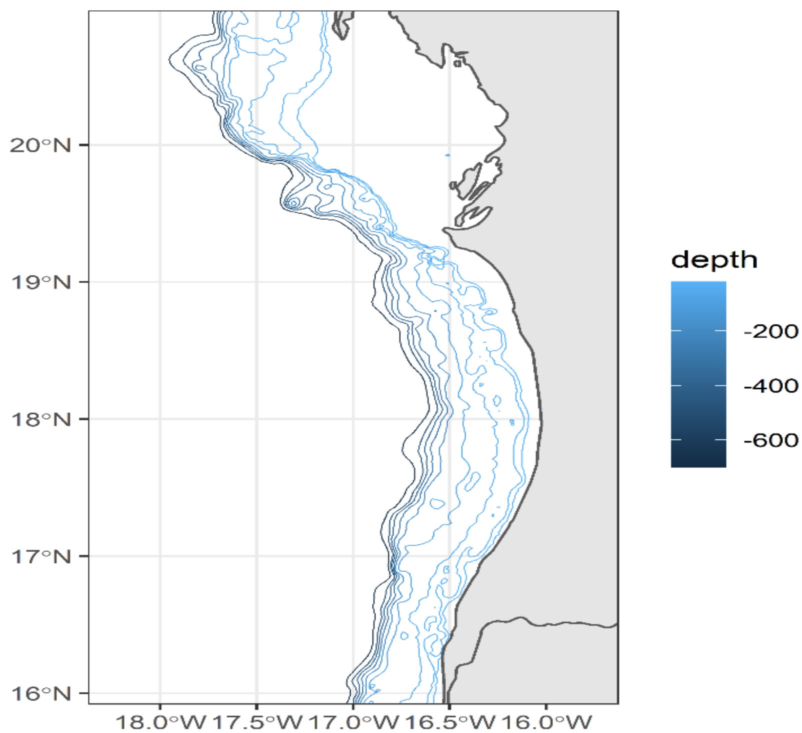

Figure 1. Bathymetric contours of fishing areas in Mauritania.

1.2. Pelagic fisheries

The pelagic resources exploited in Mauritania are mainly composed of ten coastal small pelagic fish species and tuna species (Khallahi et al., 2020). Small pelagic species represent around 85% of pelagic catches (1.4 million tons) in Mauritania's EEZ.

Small pelagic fish stocks in Mauritanian EEZ are managed with neighboring countries, through the national body research and fisheries department in Gambia, CRODT in Senegal, and INRH in Morocco. Under the auspices of FAO, the Fishery Committee for the Eastern Central Atlantic (CECAF) organizes annual working groups on small pelagic fish management conducted by scientists of national fisheries institutes in all four countries (FAO, 2019).

Major fisheries stock assessment is conducted using independent data series from research surveys. For small pelagic fish with swim bladders, acoustic recordings in combination with trawl sampling are used to estimate age segregated stock index (Simmonds & MacLennan, 2005). Several acoustic research surveys have been performed in Mauritania´s waters by the international research vessel RV Dr. Fridtjof Nansen, from 1994 to 2017 (FAO, 2019).

This study will contribute to strengthening the capacity of the scientist team specializing in small pelagics fish species assessment at the Mauritanian Research Institute of Oceanography and Fisheries by focusing on the processing and analysis of acoustic data.

1.3. Objectives

The goal of this project is to analyze raw acoustic backscatter data to research small pelagic fish resources within the Mauritanian EEZ in order to calculate stock biomass indexes and relate species distributions to temperature conditions. Development of such skills will strengthen the research capacity at IMROP in Mauritania.

The specific objectives of this project are to:

1. Scrutinize raw acoustic data to fish species from the DR Fridtjof Nansen survey in Mauritanian EEZ from June 27 to July 9, 2017.
2. Calculate stock biomass from scrutinized acoustic data and trawl catch, and research spatial distribution of small pelagics fish species.
3. Analyze temperature data from the DR Fridtjof Nansen survey in Mauritanian EEZ from June 27 to July 9, 2017, and research impact on fish spatial distribution.

2. LITERATURE REVIEW

2.1. Small pelagic fish catches in Mauritanian EEZ

Three different types of fishing fleets exploit small pelagic fish stocks in the Mauritanian EEZ: artisanal, coastal, and offshore (Khallahi et al., 2020). The fleets differ in vessel size, fishing strategy, and gear. Artisanal and coastal fleets mainly target clupeids sardines, round sardinella and bonga shad. Deep-sea fleets target all small pelagic stocks (Khallahi et al., 2020).

The total catch in the Mauritanian EEZ increased from 1990 to 2011, exceeding 1 million tons in 2010-2011, then declined to 550 thousand tons in 2013 and increased to 1.2 million tons in 2018 (Figure 2, Khallahi et al., 2020). Between 2013-2015, fishing regulations changed with the offshore fleets, banning fishing within the 20 nm shoreline, causing a massive decline in their catch from 960,000 tons in 2011 to 243,000 tons in 2013 (Khallahi et al., 2020). The artisanal and coastal fleets are still allowed to fish within the 20 nm shoreline. This 75% decline in catch by the offshore fleet was partially replaced by increased catch by the coastal fleet, which almost doubled its catch between 2011 and 2013, exceeding that of the offshore fleet in some years. After the introduction of the coastal fleet in 2014, its catches increased quickly from a few tons in 2014 to 360,000 tons in 2017 and 638,000 tons in 2018 (Khallahi et al., 2020).

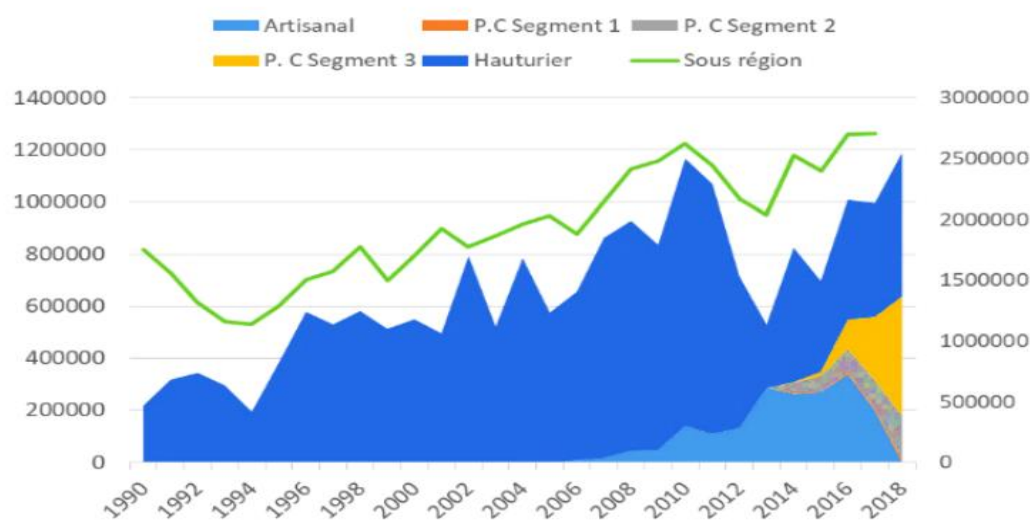

Figure 2. Changes in fish landings (tons) of small pelagic fish over time by different fleets operating within the Mauritanian EEZ from 1990 to 2018 (Khallahi et al., 2020). The yellow colour represents P.C Segment 3, light blue represents Artisanal, orange represents P.C Segment 1 (coastal), darker blue represents Hauturier (offshore), grey represents P.C Segment 2 (coastal), green represents Sous region (total from Mauritania and neighbouring countries).

2.2. Biology, spatial distribution, migration movement of small pelagic fish species in Mauritanian waters

The pelagic fishery in the Mauritanian EEZ targets ten coastal small pelagic fish stocks. For seven of the ten stocks, a stock abundance index is estimated by acoustic research surveys in Mauritanian waters, see Table 1. The three species whose abundance is not measured during acoustic surveys are false scad (*Caranx rhonchus*), bonga shad (*Ethmalosa fimbriata*) and silver scabbard *(Truchiurus lepturus*) (Krastad, et al., 2017). Six of the ten stocks are shared with neighboring countries. The seven stocks, measured during acoustic surveys, can be split into two different groups based on the water temperatures they occupy called tropical and temperate affinities.

Table 1. The seven small pelagic fish stocks whose abundance index is measured during acoustic research surveys in Mauritanian EEZ and various biological and ecological information about the stocks. All seven fish stocks are shared with neighboring countries. (1) Amenzoui et al. (2005), 2) Coombs et al. (2006), 3) FAO-FIGIS (2005), 4) Overko & Mylnikov. (1979), 5) Zeeberg et al.(2008), 6) Boely et al. (1982), 7) Fischer et al. (1981), 8) Zeeberg et al. (2008), 9) FAO (1985), 10) Gushchin & Corten (2017), 11) Froese & Pauly (2021), 12) Fischer et al. (1981), 13) FAO-FIGIS (2005), 14) Reiner (1996), 15) Dorr et al. (1985), 16) FAO (2002), 17) Diouf et al. (2010), 18) Bâ (1988), 19) Hernández & Ortega (2000), 20) FAO (2019))

Species	**Geographical distribution range of stock (seasonal migration)**	**Spawning season (peak spawning)**	**Spawning temperature (feeding temperature) (°C)**	**Total length (L_{50}) when 50% of year class is mature (cm)**	**Vertical distribution (m)**	**Assessment Situation**	**Major prey items**
Sardina pilchardus	Found in one area on the outer shelf north of Cape Timiris.	Jan - Dec (Nov - Feb)[1]	(16-18) [2]	16.3±0.31 and 17.5 ±0.35 respectively in males and females[1]	5 – 100[3]	Not fully Exploited[20]	copepods and eugraulid larvae[4]
Sardinella aurita	Found from the Cap blank to Ndjago [5]	Jan - Dec [6]	18-25[12]	27.7 et 27.9 respectively in males and females[11]	5-350 [9]	Overexploited[20]	Zooplankton, copepods, and larvae of mysids, also some phytoplankton[9]
Sardinella mederensis	Found throughout the Mauritanian EEZ[11]	July and September [9]	24 [3]	16.5[11] 11 - 19.5[11]	5-80[14]	Overexploited[20]	Small planktonic invertebrates, fish larvae and phytoplankton[9 et 15]
Trachurus trachurus	Found throughout the Mauritanian EEZ[11]	September to April with a peak in december [4]	15-16[4]	21[4]	100- 200[11]	Fully exploited[20]	Zooplankton, eggs, fish larvae and bottom algae[10]
Trachurus trecae	Found throughout the Mauritanian EEZ[11]	February and April [4]	18.5- 25.5[4]	31.5[4]	20-100[11]	Fully exploited[20]	Zooplankton, eggs, fish larvae and bottom algae[10]

Species	Geographical distribution range of stock (seasonal migration)	Spawning season (peak spawning)	Spawning temperature (feeding temperature) (°C)	Total length (L_{50}) when 50% of year class is mature (cm)	Vertical distribution (m)	Assessment Situation	Major prey items
Engraulis encrasicolus	Found throughout the Mauritanian EEZ[11]	April to November	18-20[18]	14.3[11]	400[11]	Fully exploited[20]	planktonic organisms[11]
Scomber colias	Found throughout the Mauritanian EEZ[11]	January to March [4]	17.2- 22[4]	31[4]	-300[19]	Fully exploited[20]	Zooplankton, eggs, fish larvae and bottom algae and detritus [10]

2.2.1. Biology and ecology of Sardine (Sardina pilchardus, Walbaum, 1792)

Sardine can reproduce throughout the year with a maximum breeding season between November and February. Females become mature at a total length between 15.5 to 18 cm, while males reach maturity at a total length between 15.5 to 16.5 cm (Amenzoui et al., 2005). Maximum length and age recorded is 27.5 cm (Macer, 1974) and 15 years (Nielsen et al, 1999). Optimum spawning temperatures for sardines were determined to be 16.0°-18.0°C for all north-west African regions (Coombs et al., 2006). Sardines have a large geographical distribution from northeast Atlantic in Iceland (rare) and North Sea, southward to Bay de Gorée, Senegal, and has also been found in the Mediterranean Sea and Sea of Marmara and Black Sea (Froese & Pauly, 2021). Sardines can be found in a depth range from 10-100m (Quero et al., 1999; FAO, 2005; Froese & Pauly, 2021). Sardine feed mainly in Mauritanian waters on planktonic crustaceous, algae, larvae of mollusks, crustaceous and fish (Gushchin & Corten, 2015).

2.2.2. Biology and ecology of Round Sardinella (Sardinella aurita, Valenciennes 1847)

Round sardinella is characterized by a large distribution from Gibraltar to Saldanha Bay in South Africa (FAO, 1985), with intense occurrence in west African upwelling areas, from Mauritania to Guinea, from Côte d'Ivoire to Ghana and from Gabon to Angola (Cury & Fontana, 1899). Round Sardinella reproduction takes place throughout the year in Senegal and Mauritanian waters, with two peaks in June and September (Boely et al., 1982). Round sardinella average length at maturity is 18.8 cm but ranges between 13-25 cm (Froese & Pauly, 2021). It usually occupies waters with temperatures between 18-25°C (Fischer et al., 1981). Round sardinella feeds mainly on zooplankton, especially copepods, but also some phytoplankton, especially by juveniles (FAO, 1985; Bianchi et al., 1999). Round sardinella can be found at depths of 0-350m (FAO, 1985; Froese & Pauly, 2021).

2.2.3. Biology and ecology of Flat Sardinella (Sardinella maderensis, Lowe, 1838)

Flat sardinella distribution starts in the eastern Atlantic Ocean by Gibraltar and extends southward to Angola (FAO, 1985; Quero et al., 1999; Gourène & Teugels, 2003). Flat sardinella spawn during warm season between July and September. They are schooling fish, prefer waters of 24°C, dwell from the surface down to 50m depth, and are strongly migratory (FAO 1985; Reiner, 1996; Quero et al., 1999). Average length at maturity is 13.4 cm (ranges from 11 to 19.5 cm) (Froese & Pauly, 2021). The flat sardinella diet is composed of four major types of prey: crustaceans, mollusks, fish, and detritus (Baali, et al., 2020).

2.2.4. Biology and ecology of Atlantic Horse Mackerel (Trachurus trachurus, Linnaeus 1758)

Horse mackerel is very common throughout the Mediterranean Sea and the Atlantic Ocean from Norway to South Africa (Froese & Pauly, 2021). Horse mackerel feeds mainly on Zooplankton, fish, crustaceans, and mollusks (Gushchin & Corten, 2017). Spawning season of Atlantic horse mackerel is in winter but can extend into summer (January to June), with peak spawning in January and February (El Achi et al., 2021). Average length at maturity is estimated at 21.75 cm total length (TL) for males, and 22.75 cm TL for females (El Achi et al., 2021). Atlantic horse mackerel can be found in depth range 0 - 1,050 m, often 100 - 200 m (FAO, 2005).

2.2.5. Biology and ecology of Cunene Horse Mackerel (Trachurus trecae, Cadenat, 1950)

The Cunene horse mackerel distribution in the Eastern Atlantic Ocean ranges from the coast of Morocco to Angola, in some years expanding further southwards to northern Namibia (Bianchi et al., 1999). It lives at depth range between 30 – 250 m and usually inhabits waters with temperature ranging between 14-18°C (Overko & Mylnikov., 1979). Cunene horse mackerel spawning season extends from October to April (Overko & Mylnikov., 1979). It feeds mainly on mesopelagic fish, crustaceans, molluscs, and copepods (Gushchin & Corten, 2017) and average length at maturity is 24.1 cm (Froese & Pauly, 2021).

2.2.6. Biology and ecology of Anchovy (Engraulis encrasicolus, Linnaeus, 1758)

Anchovy is a small coastal pelagic fish (Brehmer et al., 2007) living in dense schools in the Atlantic Ocean, where it is distributed from Norway to South Africa, as well as the Black Sea and the Mediterranean Sea (Nelson & Wongratana, 1988).

In Mauritanian waters, planktonic crustaceous, algae, larvae of mollusks, crustaceous, fish and detritus make up the main diet of anchovy (Gushchin & Corten, 2017). Anchovy reaches sexual maturity at twelve months with length at maturity ranging from 8.2 to 9.0 cm (Sinovcic & Zorika, 2006; Mandic et al., 2015). Anchovy in Mauritanian and Senegal waters is observed with high abundance in waters with temperatures between 18 – 20°C (Bâ., 1988; Ndour et al., 2021). Anchovy can be found in a depth range of 0-400m (Schneider, 1990) .

2.2.7. Biology and ecology of Chub Mackerel (Scomber colias, Gmelin, 1789)

Chub mackerel is widely distributed in the Atlantic Ocean, the Mediterranean Sea, southern Black Sea, and in the Indo-Pacific (Froese & Pauly, 2021). Juveniles and adults of chub mackerel feed mainly on zooplankton, and sometimes cephalopods, crustaceans and small pelagics, depending on size (Froese & Pauly, 2021). Atlantic chub mackerel grow rapidly during the first year of life, adults prefer temperatures of 15-20°C, while juveniles tend to be found closer inshore than adults (Anonymous, 2022). Chub horse mackerel spawning is most intense in January and lower in December (Pascual et al., 2008).

3. METHODS

3.1. Acoustic survey data

Research vessel DR Fridtjof Nansen did nine acoustic surveys between 2000 -2017 in Mauritania and neighboring countries of northwest Africa (FAO, 2019). All the surveys followed the same protocol and survey design, acoustic scrutinizing methods, biomass estimation methods, and collected the same set of environmental data. In the current report, a partial re-analysis of the 2017 survey data will be presented.

Data were recorded on board the R/V Dr Fridtjof Nansen during acoustic surveys on 27 June – 9 July 2017, using a Simrad EK80 Scientific Split Beam Echo Sounder equipped with keel-mounted transducers at nominal operating frequencies of 18, 38, 70, 120, 200 and 333 kHz (FAO, 2019). Acoustic backscatter was scrutinized, *i.e.*, backscatter allocated to species, using a post-processing software called Large-Scale Survey System (LSSS) Version 2.0 (Krastad et al., 2017). In LSSS, backscatter was manually allocated to species in proportion with trawl catch(es) from the same transect. If there was not trawling on a transect then backscatter data cannot be allocated at the species level. Integration of backscatter was for 0.1 nm horizontally and 10 m vertically. Only east-to-west transect transversion the shelf and shelf edge were included in calculations. Trawling and sampling at CTD stations was excluded from calculations. Surface 10 m were excluded from calculations. The acoustic data were preprocessed prior to current LSSS analysis and noise signal had been removed from the raw files.

The R/V Dr Fridtjof Nansen survey of the pelagic resources in Northwest Africa were subdivided into four legs. Leg 1 covered the region between Morocco and Cape Blanc leg 2 was an experimental survey for mesopelagic resources of the region, leg 3 and leg 4 conducted pelagic surveys for Mauritania and Senegal EEZs, respectively (FAO, 2019).

Overall survey objectives and the sampling plan were agreed with the respective national partner institutions (INRH, IMROP and CRODT), and a detailed survey plan was prepared that describes sampling and survey track in detail (FAO, 2019). The specific objectives of the survey which is included in the re-analysis of the current report were:

> *"To obtain information on abundance, distribution (also by size) of sardine, round sardinella, flat sardinella, Atlantic horse mackerel, cunen horse mackerel, chub horse mackerel and anchovy using acoustic methods and a systematic grid survey strategy."*

3.2. Biomass estimates

Target strength (TS) function was applied to convert s_A-values (mean integrator value for a given species or group of species in a specified area) to number of fish following Krastad et al. (2017) as described below:

$$TS = 20 \log L - 72\ dB$$

Which can be converted to the area form scattering cross sections of acoustic targets as mentioned in Toresen et al. (1998) as described below:

$$C_{Fi} = 1.26\ 10^6\ L^{-2}$$

Where:
L is total length in 1 cm length group i
C_{Fi} (m^{-2}) is the reciprocal back scattering strength, or so-called fish conversion function

To split and convert the allocated S_A-values (m^2 /NM^2) to fish densities (numbers per length group per NM2) Krastad et al. (2017) as described below:

$$\rho_i = Sa. \frac{\rho_i}{\sum_1^n \rho_i / CF_i}$$

Where:
ρi = density of fish in length group
S_a = mean integrator value
pi = proportion of fish in length group i

$$\sum_{i=1}^{n} \frac{Pi}{Cfi}$$

The relative back scattering cross section (m^2) of the length frequency sample of the target species, and C_{fi} = reciprocal back scattering cross section (σbs^{-1}) of a fish in length group i. (Jiyid et al., 2018)
Acoustic backscatter is converted to number of specimens using the target strength equation. Then length distribution of the trawl catch is used to allocated number of specimens to different length bins. Weight-at-length in the trawl catch is used to calculate species biomass index from number of specimens per length bin.

3.3. Biological data

Sampling of the fish was carried out using pelagic or bottom trawls. In shallow water (<30 m) or at night when pelagic fish was close to the surface the pelagic trawl with floats or bottom trawl with floats was used for sampling.

All catches were analyzed for composition by weight and numbers of each species caught. Species identification was based on the FAO Species Identification Sheets.

Data collected include total length to the nearest cm below, weight, sex, maturity, and stomach fullness, for 30 fish of all target species. The length measurements were used to estimate the length-weight relationship used in the biomass calculations (Krastad, et al., 2017).

3.3.1. Descriptive summary statistics of biological data

In total, 30 trawl hauls were made to identify acoustic targets during the survey, which included 24 pelagic trawls and 6 bottom trawls, particularly in coastal areas. Trawl species composition differed between stations. A total of 113 species were recorded as caught at trawl stations. 78 species were caught by pelagic trawls and 73 species by bottom trawls. The number of species per station fluctuated from a single species at station 28 to 26 species at station 19, with an average species diversity of 10 per station.

Seven species of small pelagic fish (sardine, round sardinella, flat sardinella, Atlantic horse mackerel, cunen horse mackerel, chub horse mackerel and anchovy) were sampled by collecting data on total length and total weight.

3.4. Environmental data

34 CTD stations have been carried out from Cap Blanc to N'diago (Figure 3). We calculate the average temperature per species according to s_A-value vertical distribution (figure 8). Standard hydrographic sections were sampled approximately each degree of latitude, mostly close to the coast (between 20 and 30 m bottom depth) to 1000 m bottom depth. Some hydrographic sections ended at 500 m (Krastad et al., 2017).

3.5. Study area

The R/V Dr Fridtjof Nansen surveyed the Mauritania shelf and upper slope area between Cap Blanc 20 ° 36' N and N'diago 16 °04'N (figure 3).

The ecosystem in Mauritanian waters is distinguished by two main upwelling regions. The Saharan and northern Mauritanian coast feature a permanent upwelling and the southern coast of Mauritania has seasonal upwelling in winter (Khallahi et al., 2020). The most active upwelling

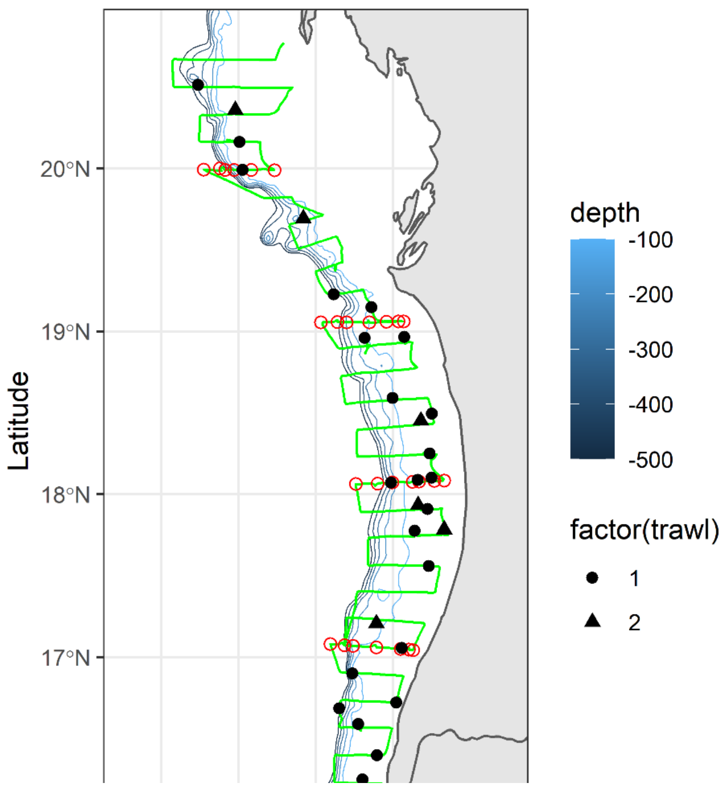

Figure 3. Course tracks (green line) with trawl stations along Mauritania shelf. ● pelagic trawl; ▲ bottom trawl ○ CTD station (EAF, 2017).

season is the cold season in winter (from January to May), followed by the hot cold season (from June to July). The low seasons of upwelling intensity are the hot/cold (November to December) season then the hot season in summer runs from August to October (LEGRAA, 2019).

4. RESULTS

4.1 Catch distribution by species

During this survey, trawl sampling was carried out at 30 stations with a total catch of 46,533 kg. The catch of the seven target species (25,442 kg) represents 55% of the total catch with an average catch per station of 410 kg. Maximum catch per species was 14,788 kg for anchovy. Cunen horse mackerel was caught most frequently at 14 stations, compared to sardines which were caught only at two stations (Table 2). Average catch weight ranged from 15 kg to 1542 kg for Atlantic horse mackerel and anchovy, respectively. Maximum trawl catch at a single station was 14.8 tons for anchovy and minimum catch was 15 kg for Atlantic horse mackerel.

The catch of the target species as well as the distribution varied from one species to another. The survey results show that sardine and horse mackerel were more abundant in the northern zone, and anchovy in the northern and central zone, both sardinella species are present in the central and southern zone, Chub mackerel and Cunen horse mackerel show a wide distribution throughout the survey area (Figure 4).

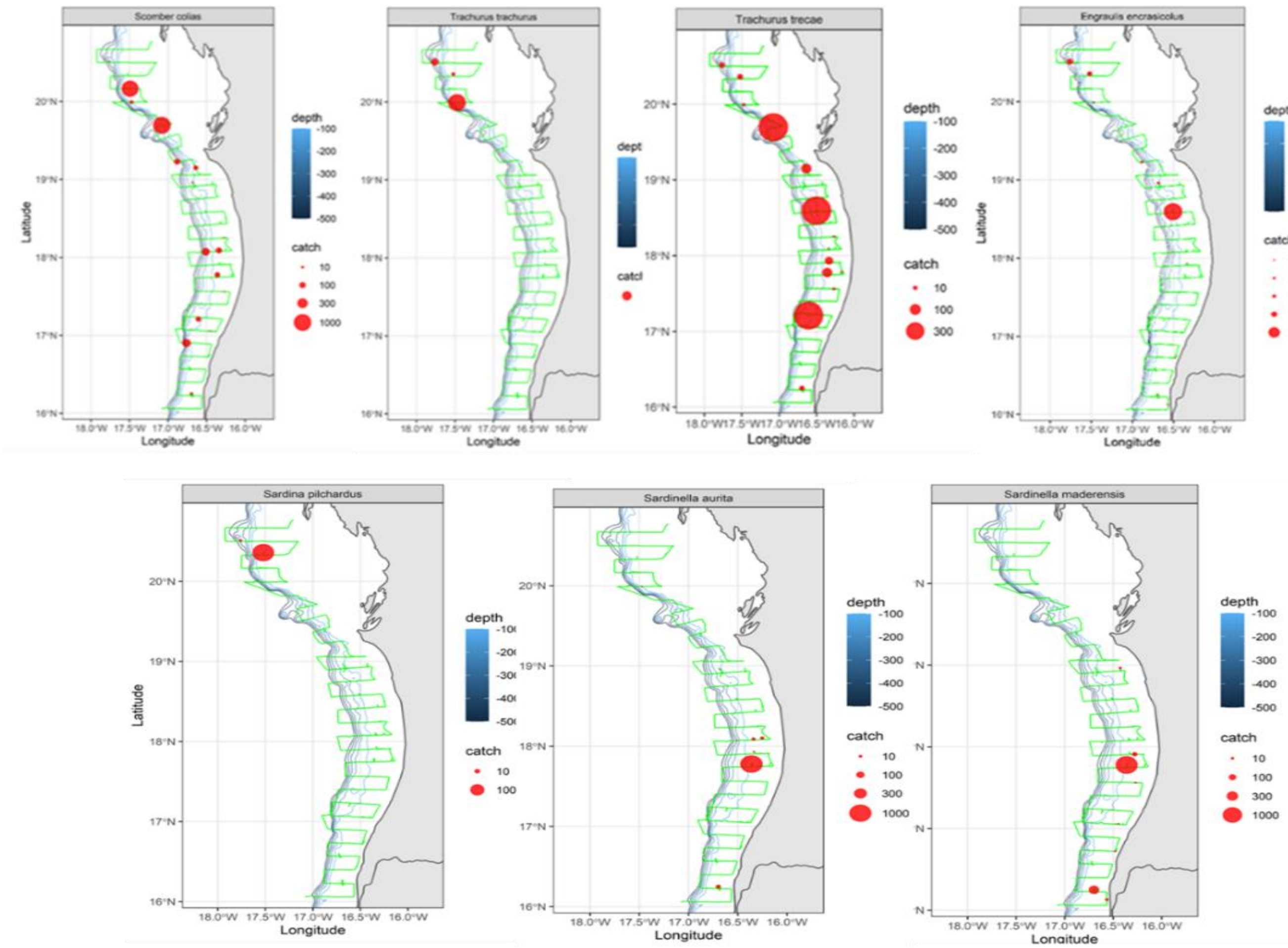

Figure 4. Catch distribution for chub mackerel (*Scomber colias*), Atlantic horse mackerel (*Trachurus trachurus*) and cunen horse mackerel (*Trachurus trecae*), anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), round sardinella (*Sardinella aurita*) and flat sardinella (*Sardinella maderensis*).

Table 2. Mean and maximum catches for target species. Calculations only include stations with species present.

Species	***Sardina pilchardus***	***Sardinella aurita***	***Sardinella maderensis***	***Trachurus trachurus***	***Trachurus trecae***	***Engraulis encrasicolus***	***Scomber colias***
Mean catches kg/h	129.53	135.76	205.481	15.24	196.611	1541.81	168.419
Max catches kg/h	257.27	1029.21	1339.47	39.69	835.620	14787.950	1021.97
Number of stations	2	8	8	3	14	11	16

4.4. **Target species length distribution and weight-at-length distribution**

In total, 2,393 specimens were measured for length and weight. The largest number of individuals was measured for chub horse mackerel (n = 880), sardine (510), and anchovy (345) respectively, while a smaller number of flat sardinella (38) and Atlantic horse mackerel (159) were measured with an average of 342 specimen (Figure 5).

Measured length-weight distribution shows a correlation between length and weight and the largest individuals measured were chub mackerel, round and flat sardinella (38.5 and 35.5 cm, respectively), while smaller sizes were measured for the remaining species (Anchovy, Sardine, Atlantic and cunen horse mackerel; Figure 6).

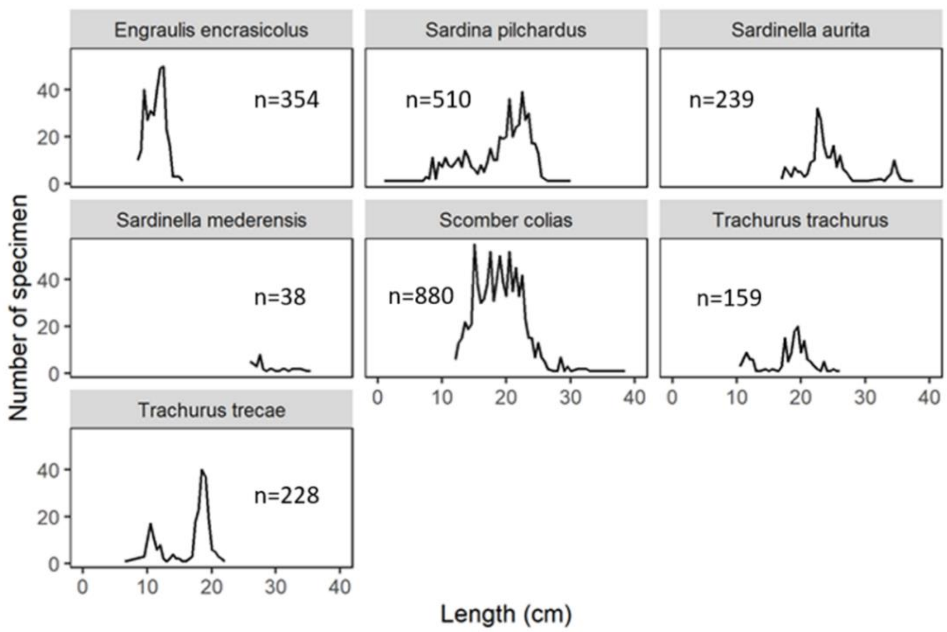

Figure 5. Number of specimen and length distribution for anchovy (*Engraulis encrasicolus)*, sardine (*Sardina pilchardus*), round sardinella (*Sardinella aurita*) and flat sardinella (*Sardinella maderensis*), chub mackerel (*Scomber colias*), Atlantic horse mackerel (*Trachurus trachurus*) and cunen horse mackerel (*Trachurus trecae*).

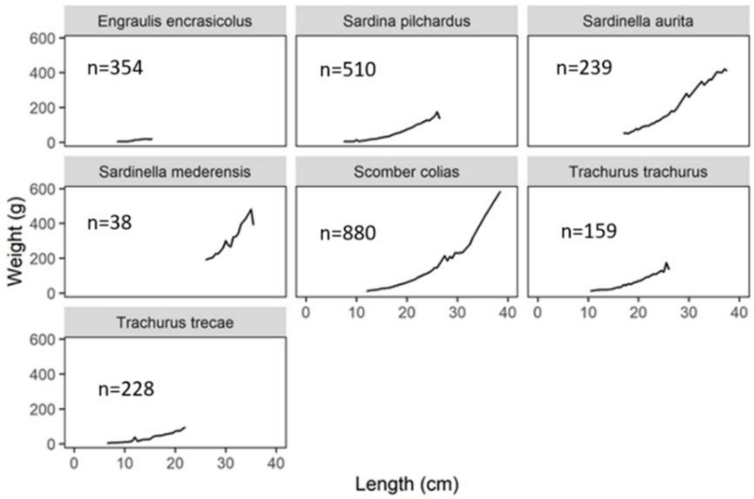

Figure 6. Weight and length distribution for anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), round sardinella (*Sardinella aurita*) and flat sardinella (*Sardinella maderensis*), chub mackerel (*Scomber colias*), Atlantic horse mackerel (*Trachurus trachurus*) and cunen horse mackerel (*Trachurus trecae*).

Vertical backscatter distribution of the seven target species shows a concentration in water less than 100m (figure 7). However, during this survey, only Cunen horse mackerel backscatter appeared in waters above 150m (figure 8).

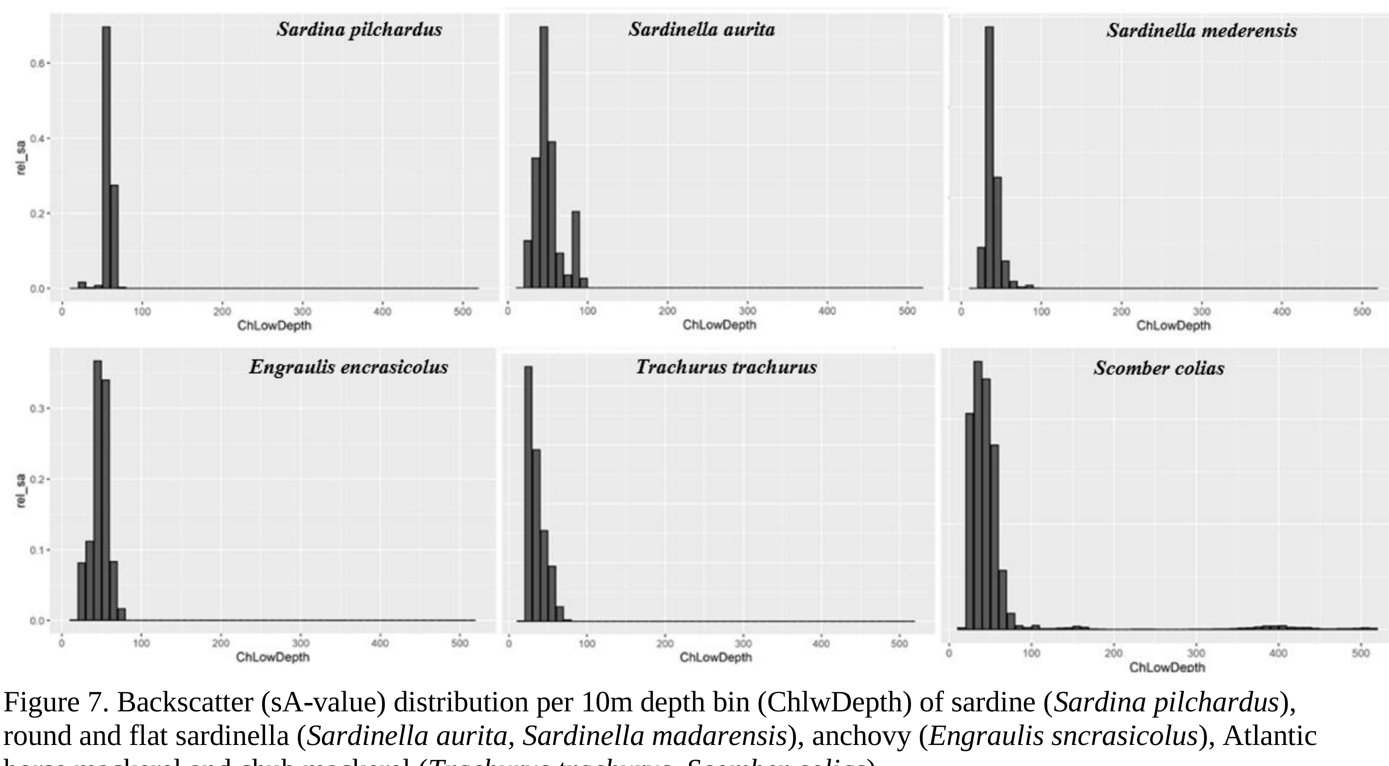

Figure 7. Backscatter (sA-value) distribution per 10m depth bin (ChlwDepth) of sardine (*Sardina pilchardus*), round and flat sardinella (*Sardinella aurita, Sardinella madarensis*), anchovy (*Engraulis sncrasicolus*), Atlantic horse mackerel and chub mackerel (*Trachurus trachurus, Scomber colias*).

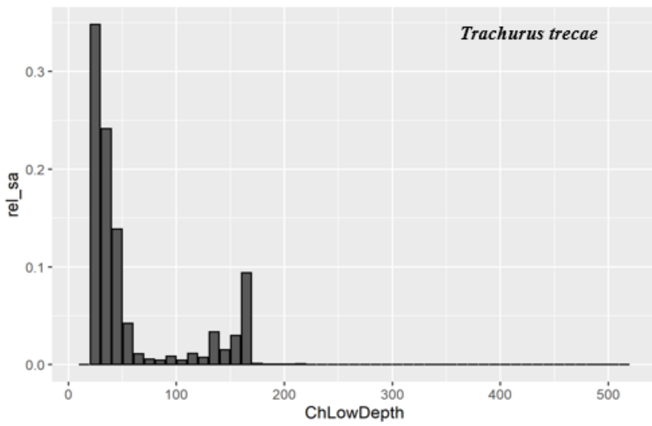

Figure 8. Backscatter (sA-value) distribution per 10m depth bin (ChlwDepth) of cunen horse mackerel (*Trachurus trecae*).

4.5. **Spatial distribution**

Acoustic analysis showed different geographical distributions of small pelagic fish species along the track survey (figure 9). Sardine, Atlantic and chub mackerel were observed in the northern zone during this period. Anchovy and Cunen horse mackerel covered the study area from north to south, and round sardinella presence was limited to the southern zone, while flat sardinella was present in center and southern area (figure 9).

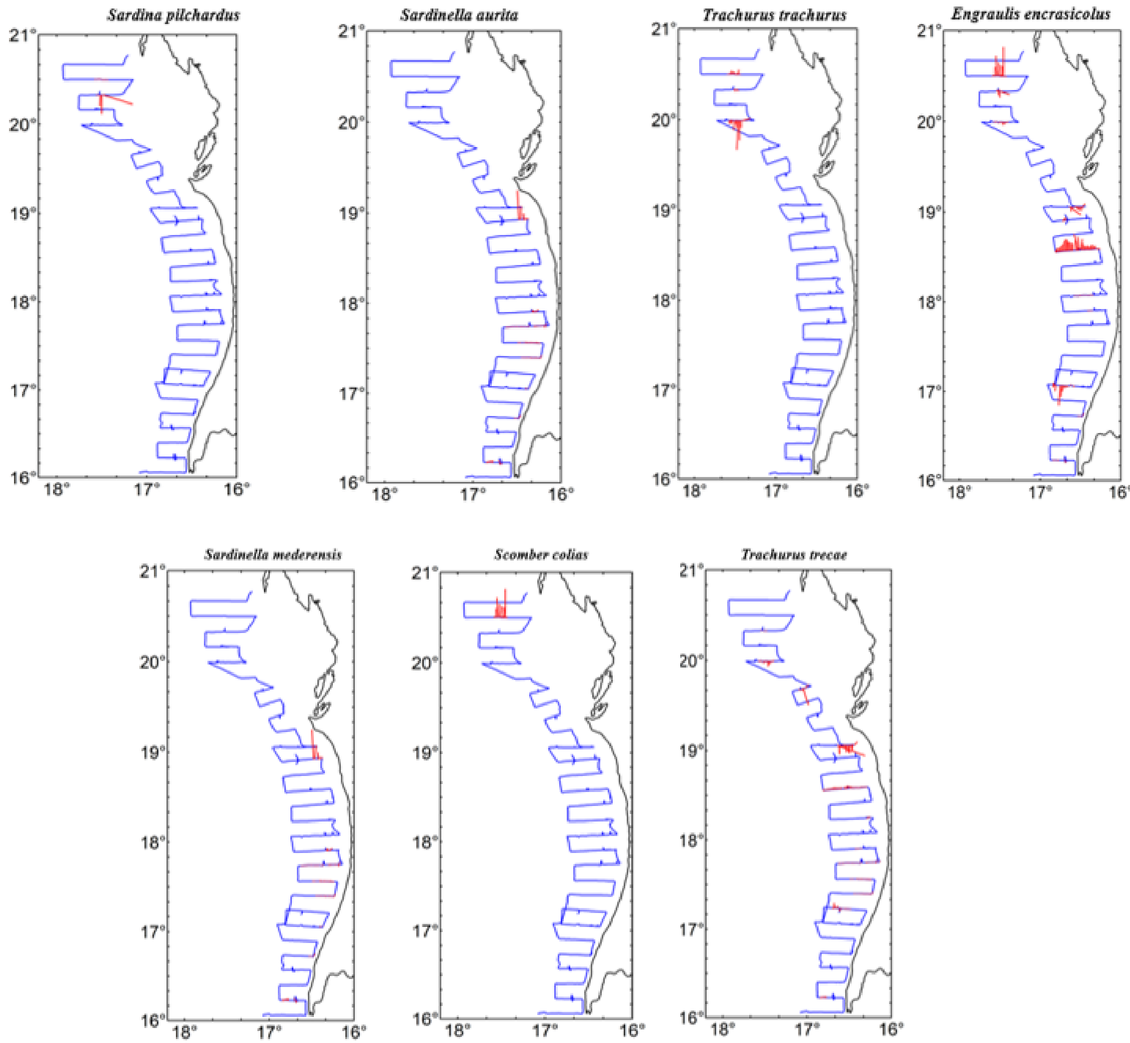

Figure 9. Geographical distribution backscatter values for (sA) for sardine, round sardinella, Atlantic horse mackerel, anchovy, flat sardinella, chub mackerel and cunen horse mackerel.

4.6. **Biomass calculations**

Biomass in the study area was estimated according to the methodology cited above. Estimated biomass per species ranged from 552 thousand tons for anchovy to 166 tons for chub horse mackerel (Table 3). Current biomass estimates were similar to estimates presented in the cruise report for only one species, flat sardinella. For the other species, the current estimate ranged from being a fraction of the survey results (chub mackerel) to being seven times higher (anchovy). The calculations for each species are presented in Appendix 1.

Table 3. Biomass estimates for the seven target species calculated in the current report, compared to the survey cruise report (Krastad et al., 2017).

English names	**Sardine**	**Round sardinella**	**Flat sardinella**	**Atlantic horse mackerel**	**Cunen horse mackerel**	**Anchovy**	**Chub mackerel**
Species	Sardina pilchardus	Sardinella aurita	Sardinella maderensis	Trachurus trachurus	Trachurus trecae	Engraulis encrasicolus	Scomber Colias
Biomass (thousand tons)	21.1	62.1	115.7	37.3	130.8	551.5	0.166
Survey biomass (thousand tons)	61.3	34	115.9	91.8		78.2	25.3

4.7. Environmental conditions

Small pelagic fish species distribution in relation to ambient temperature shows that sardine and Atlantic horse mackerel were limited in northern areas (latitude ≥ 20°N) with temperatures colder than 17°C (Figure 10). Anchovy and Cunen horse mackerel were measured in northern and southern parts of Mauritanian waters where temperatures fluctuated between 17° and 27°C (Figures 10-11). Round and flat sardinella were located in the southern part (latitude < 19°N) where temperature ranged from 20° to 27°C. Chub mackerel were only found in very limited areas above 20°N. These areas are not covered by the CTD samplings, therefore the result of CTD sampling only started from 20° to 16°C (Figure 10).

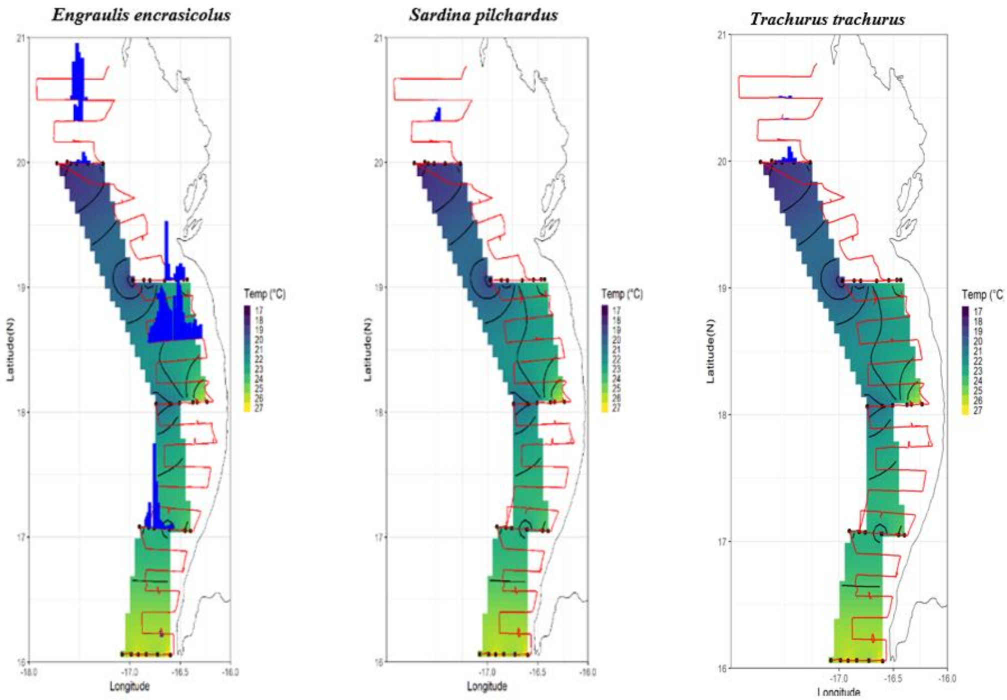

Figure 10. Anchovy, Sardine, Atlantic horse mackerel sA-values (blue vertical bars) with the survey track (red line) and average temperature at vertical depth (shaded area).

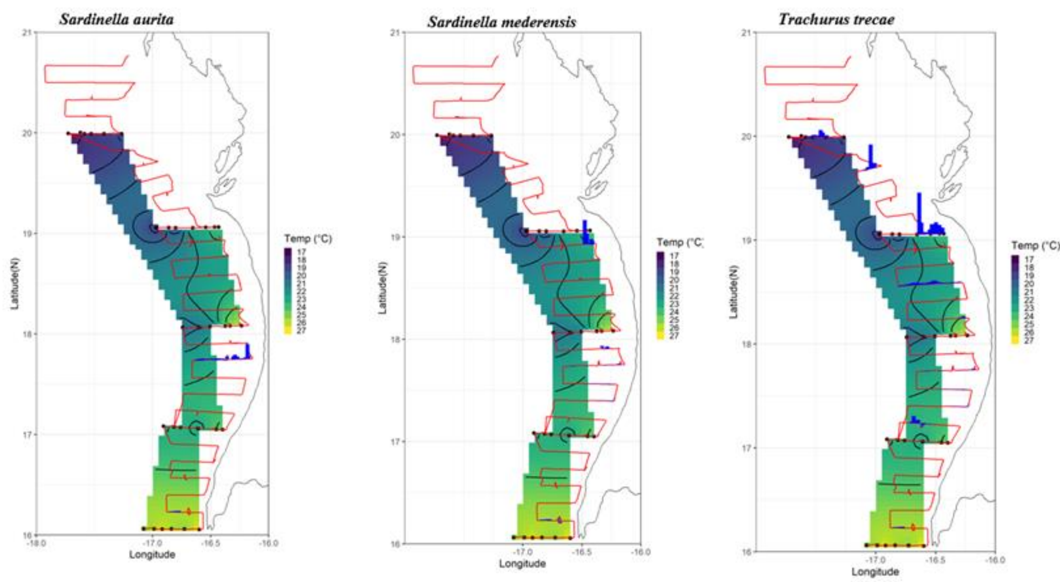

Figure 11. Round sardinella, flat sardinella and Cunen horse mackerel sA-values (blue vertical bars) with the survey track (red line) and average temperature at vertical depth (shaded area).

5. DISCUSSION

5.1. **Environmental variability and small pelagic fish distribution**

Temperature affinity of the seven species reported in the current report agrees well with previous research on distribution of these species in relation to ambient temperature. Chub mackerel were found at latitudes above 20°N, which was not covered by CTD sampling in this study, however there is information on temperatures in the northern part Mauritanian waters (> 20°N) (Gushchin & Corten, 2015; Gushchin & Corten, 2017; Cervantes, et al., 2017; Narcisse, et al., 2020). Sardine and Atlantic horse mackerel preferred colder water in the northern area with a temperature range between 17° C and 22°C, which agrees with temperature affinity of these species reported in the literature (Gushchin & Corten, 2015; Gushchin & Corten, 2017; Cervantes, et al., 2017; Narcisse, et al., 2020). The round and flat sardinella found in the center and southern areas appeared in warmer waters more than 20°C, which also agrees with previous research (Gushchin & Corten, 2015; Gushchin & Corten, 2017; Cervantes, et al., 2017; Narcisse, et al., 2020). Anchovy and Cunen horse mackerel were found in both colder and warmer waters from the north to the southern area, which agrees with previous research (Gushchin & Corten, 2015).

These results show that the classification of these species is identical to the Canary Current Large Marine Ecosystem (CCLME) (Narcisse et al., 2020), which identified two thermal preferences for small pelagic species: cold water (chub mackerel, Atlantic horse mackerel, and sardine) and warm water (round sardinella, flat sardinella and Cunen horse mackerel).

Mauritanian waters are known as one of the most productive fishery regions in the world, due to the Canary Current and constant upwelling along the whole coast of Mauritania (Gushchin & Corten, 2015).

5.2. **Biomass estimates**

The biomasses estimated in this study show significant differences between the biomasses calculated in the survey report (Krastad et al., 2017) for all species, except for the flat sardinella. This biomass is identical to that calculated in the survey report.

Two steps in the biomass estimation are likely to have contributed to these discrepancies. First, in the current report, backscatter allocation to species is based solely on the proportions of target species in trawl catches. Usually, additional specialized knowledge is used in combination with trawl catches to allocate backscatter to species. Without training at sea such specialized knowledge cannot be acquired, hence only trawl catches were used. Second, in the current report the estimated surface area was 17961.14 nm^2. The surface area used in the calculations for the cruise report is unknow and may be different.

6. CONCLUSIONS

Reanalysis of biomass and distributions in relation to ambient temperature of seven small pelagic species from R/V Dr Fridjof Nansen surveys in June 2017 show large discrepancies for biomass estimates, for all species except one, whereas distribution related to temperature agrees with results presented in the primary literature. It appears that more training is needed in analysis of acoustic data, specifically hands-on training during a research survey, and in calculating biomass from acoustic and trawl data.

ACKNOWLEDGEMENTS

The GRO-FTP team are sincerely thanked for their sponsorship, support, and guidance especially Thor Asgeirsson and Mary Frances Davidson for giving me the opportunity to take part in this program, Stefan Úlfarsson and Dr Tumi Tómasson for their support, guidance, and hospitality in Iceland. My special thanks to Julie Ingham, the program administrator, for her kindness and understanding.

I am especially grateful to the Director of the Mauritanian Oceanography and Fisheries Research Institute (IMROP), Mohamed El Hafed Ejiwen, and Deputy Director Mohamed Elmoutapha Bouzouma. I would also like to thank Beyah Meisse, Manager of the Evaluation of Living Aquatic Resources Laboratory (LERVA) for his encouragement, advice, and the efforts made to obtain the raw acoustic data.

I thank my supervisor Dr. Anna Heiða Ólafsdóttir for her guidance and sharing her vast knowledge with me. I also thank Agnes Eydal and Jonas Jónasson. I have learned so much which I intend to apply in my work duties when I go back to my home country.

I offer my sincere thanks to my family and friends, especially my mother Mrs. Salke Sidi Hemmed and my wife Mrs. Khadijetou Memoud Mohamdy who always believed in me and kept encouraging me. Lastly, I thank you, Ahmed Sidi Ahmed Hemed, my son, for your love and for allowing me to be away from you for six months.

REFERENCES

Dorr, J. A., Schneeberger, P. J., Tin , H. T., & Flat , L. E. (1985). Studies on adult, juvenile and larval fishes of the Gambia river, West Africa, 1983-1984. *Univ. Michigan Inter. Prog. Rep, 11*, 291.

Gourène, G., & Teugels, G. G. (2003). Clupeidae. The fresh and brackish water fishes of West Africa,. *Coll. faune et flore tropicales 40. Institut de recherche de développement,, Volume 1*, 125-142.

LEGRAA, M. E. (2019). Evaluation de la vulnérabilité des côtes de la Mauritanie face aux pollutions. *Université de Nouakchott Al-Assriya/ Ecole Doctorale sciences et technologies* , 268p.

Amenzoui, K., Tachinante, F. F., Yahyaoui, A., Mesfioui, A. H., & Kifani, S. (2005). Etude de quelques aspects de la reproduction de Sardina pilchardus (Walbaum, 1792) de la région de Laâyoune (Maroc). *Bulletin de l'Institut Scientifique INRH*(26-27), 43-50.

Anonymous. (2015). *National responsible management strategy for sustainable fisheries develpement and the maritim economy 2015-2019.* Ministry of Fisheries and Maritime Economy. Fisheries ministry and maritim economic of Mauritania .

Anonymous. (2022). Review of 2022 Atlantic chub mackerel specifications. *Mackerel, Squid, Butterfish Monitoring Committee.*

Bâ., I. S. (1988). Biology and dynamics of Anchovy populations (Engraulis encrasicolus) of the Mauritanian coast. 41-66.

Baali, A., Ouazzani, K. C., Touhami, F., El-Achi, A., & Amenzoui, K. (2020). Diet composition of round sardinella (Sardinella aurita) and flat sardinella (Sardinella maderensis) in the south of Atlantic Moroccan coast. *Egyptian Journal of Aquatic Biology & Fisheries, Vol. 24(7)*, 73 – 91.

Bianchi, G., Carpenter, K. E., Roux, J. P., Molloy, F. J., Boyer, D., & Boyer, H. J. (1999). FAO species identification guide for fishery purposes. Field guide to the living marine resources of Namibia. 265p. Retrieved from www.fao.org/docrep/009/x3478e/x3478e00.htm

Boely , T., Chabanne, J., Fréon, P., & Stequert, B. (1982). Cycle sexuel et migration de sardinella aurita sur le plateau continental ouest africain; des iles Bissagos à la Mauritanie. *Cons. Int. Explore. Mer* , 350-355.

Brehmer, P., Gerlotto, F., Laurent, C., Cotel, P., Achury, A., & Samb, B. (2007). Schooling behaviour of small pelagic fish:phenotypic expression of independent stimuli. *MARINE ECOLOGY PROGRESS SERIES, 334*, 263–272.

Cervantes, A., Mohaned, E. B., & Sophie, D. C. (2017, octobre 03 au 05). Rapport de la Réunion annuelle du Comité Scientifique Conjoint relattif à l'Accord de pêche signé entre la République islamique de Mauritanie et l'Union européenne. Retrieved from ttps://ec.europa.eu/fisheries/sites/fisheries/files/docs/publications/appd_ue-mrt-csc_2016_fr.pdf.

Coombs, S. H., Smyth, T. J., Conway, D. V., Halliday, N. C., Bernal, M., Stratoudakis, Y., & Alvarez, P. (2006). Spawning season and temperature relationships for sardine (Sardina pilchardus) in the eastern North Atlantic. *Journal of the Marine Biological Association of the UK*, 1246-1252.

Cury, P., & Fontana, A. (1899). Compétition et stratégies démographiques comparées de deux espèces de sardinelles (Sardinella aurita et Sardinella maderensis) des côtes ouest-africaines. *Aquat. Living. Resour.*, 165-180.

Diankha, O., Thiaw, M., Sow, B. A., Brochier, T., Gaye, A. T., & Brehmer, P. (2015). Round sardinella (Sardinella aurita) and anchovy (Engraulis encrasicolus) abundance as related to temperature in the Senegalese waters. *Thalassas, 31*, 9-17.

Diouf, K., Samb, B., & Sylla , M. (2010). Contribution à la connaissance de la biologie des sardinelles (Sardinella aurita et Sardinella maderensis) du littoral sénégalais. *Symposium sur la science et le défi de l'aménagement des pêcheries de petits pélagiques sur les stocks partagés en Afrique nord -occidentale.* (pp. 39–56). Casablanca: FAO.

El Achi, A., Nafia, M., Manchih, K., Baali , A., & Moncef, M. (2021). Reproductive biology of horse mackerel Trachurus trachurus (Linnaeus, 1758) in the North Atlantic Moroccan coast. *Egyptian Journal of Aquatic Biology & Fisheries*, 647-666.

FAO. (1985). *Clupeoid fishes of the world (suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. Part I,.*

FAO. (2002). *Report of the sardine (sardina pilchardus) otolith workshop Kalininigrad, RUSSIAN FEDERATION, 28–31 AUGUST 2001.* FAO Fisheries Report No. 685. , Rome. Retrieved from https://www.fao.org/3/y4097b/y4097b02.htm

FAO. (2019). *Report of the Working Group on the Assessment of Small Pelagic Fish of Northwest Africa Casablanca, Morocco.* Fishery Committee For The Eastern central Atlantic. FAO.

FAO-FIGIS (Ed.). (2005). A world overview of species of interest to fisheries. Chapter: Sardina pilchardus. Retrieved from http://www.fao.org/figis/servlet/species?fid=2910

FAO-FIGIS. (2005). A world overview of species of interest to fisheries. Chapter: Sardinella maderensis. In *FIGIS Species Fact Sheets. Species Identification and Data Programme-SIDP,*. Retrieved from www.fao.org/figis/servlet/species?fid=2089. 2p.

Fischer, W., Bianchi, G., & Scott, W. B. (1981). Species identification sheets for fishery purposes. Eastern Central Atlantic; fishing areas 34, 47 (in part). Department of Fisheries and Oceans Canada and FAO. Vol. 2. pag. var. Retrieved from www.fao.org/docrep/009/ag419e/ag419e00.htm

Froese, R., & Pauly, D. (2021). World Wide Web electronic publication. *FishBase.*

Gushchin, A. V., & Corten, A. (2017). Feeding of Pelagic Fish in Waters of Mauritania: Atlantic Chub mackerel Scomber colias, Atlantic horse mackerel Trachurus trachurus, Cunene horse mackerel Trachurus treca. *Journal of Ichthyology, 57*, 410-423.

Gushchin, V. A., & Corten, A. (2015). Feeding of Pelagic Fish in Waters of Mauritania: 1. European Anchovy Engraulis encrasicolus, European Sardine, Sardina pilchardus, Round Sardinella Sardinella aurita, and Flat Sardinella S. maderensis. *Journal of Ichthyology (Voprosy Ikhtiologii), 55*, 54-62.

Hernández, C. J., & Ortega, S. A. (2000). Synopsis of biological data on the chub mackerel (Scomberjaponicus Houttuyn, 1782). *FAO Fisheries Synorsis, 157*, 77p.

Jiyid, M. A., Sleiman, A., & Ba, B. (2018). *Acoustic survey report Al-AWAM March 2018.* Institut Mauritanien de Recherches Oceanographiques et des Pëches , Nouadhibou.

Khallahi, B., Taleb, H., Barham, C., Habibe, B. M., Kane, E. A., & Bouzouma, M. E. (2020). *Aménagement des ressources halieutiques et gestion de la biodiversité au service du développment durable.* Institut Mauritanien De Recherches Oceanographiques Et Des Peches. Nouadhibou:: IMROP.

Kimmerer, W., Avent, R. S., Bollens, M. S., Feyrer, F., Grimaldo, L. F., Moyle, P. B., . . . Visintainer, T. (2005). Variability in Length–Weight Relationships Used to Estimate biomass of estuarine fish from survey data. *Transactions of the American soceity, 134(2)*, 481–495.

Krastad, J. O., Johannessen, T., Bagøien,, E., & Jeyid, M. A. (2017). *Suvey of the pelagic fish resources and ecosystem off west africa.* Institut Mauritanien de Recherches Oceanographiques et des Pêches Nouadhibou, Mauritania and Institute of Marine Research of Bergen, Norway . Krakstad J.O., Johannessen, T., Bagøien, E., Jeyid, M. A.

Macer, C. T. (1974). Some observations on the fecundity of the pilchard (Sardino pilchardus Walbaum) off the south-west coast of England. ICES: C.M. *ICES: C.M. J(9)*, 11.

Mandic', M., Regner, S., Durovic', M., Joksimovic', A., Pesic' , A., & krpoc-etkovic' , J. (2015). Distribution and abundance of eggs and estimation of spawning stock biomass of anchovy, Engraulis encrasicolus (Linnaeus, 1758), in the south-eastern Adriatic Sea. *the Marine Biological Association of the UK*, 1-9.

Narcisse, N. E., Liming, S., Hongxing, C., & Shuangquan, X. (2020). Relationship Between the Spatiotemporal Distribution of Dominant Small Pelagic Fishes and Environmental Factors in Mauritanian waters. *Ocean University of China (Oceanic and Coastal Sea Research), Science Press and Springer-Verlag GmbH Germany 20, 19*, 393-408.

Ndour, I., Ndoye, S., Bâ, C., Diadhiou, H. D., Ndiaye, O., & Diop, M. (2021). Size at first sexual maturity of anchovy, Engraulis encrasicolus in Senegalese waters. *AACL Bioflux, 14*(1), 424-420. Retrieved from http://www.bioflux.com.ro/aacl

Nelson, G J; Wongratana, T. (1988). FAO Species Catalogue. Clupeoid fishes of the world (Suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies and wolf-herrings. *7*, 305-579.

Nielsen., Mus. B.J. and J.G. (1999). Sea fish. *Scandinavian Fishing Year Book Hedehusene, Denmark..*, 340 p.

Overko, S. M., & Mylnikov., N. I. (1979). *Report of the Ad Hoc Working Group on West African Coastal Pelagic Fish from Mauritania to Liberia (26°N to 5°N).* Rome: FAO. Retrieved from https://www.fao.org/3/n0952e/n0952e0l.htm

Pascual, A. P., Sancho, A., Hernández, E., Santamaría,, M. T., Duque, V., Balguerías, E., . . . Presas, C. (2008). Reproductive aspects of sardine (Sardina pilchardus Walbaum, 1792) round sardinella (Sardinella aurita Valenciennes, 1847) flat sardinella (Sardinella madarensis Lowe, 1838) and mackerel (Scomber colias Gmelin,1798) in Mauritanian waters, Northwest Africa. *FAO Fisheries and Aquaculture Proceedings/FAO Comptes rendus des pêches et de l'aquaculture*, 419-423.

Quero, J. C., Hureau, J. C., Karrer, C., Post, A., & Saldanha, L. (1999). Check-list of the fishes of the eastern tropical Atlantic (CLOFETA). *JNICT, Lisbon; SEI, Paris; and UNESCO, 1*, 208-227.

Quéro, J., & Vayne, J. (1997). French fish sea fish. Ifremer, Delachaux and Niestlé (Ed.). 304pp.

Reiner, F. (1996). Catálogo dos peixes do arquipélago de Cabo Verde. *Publ. Avuls. Inst. Port. Invest. via Catalogue of Life*, 2:339 p.

Schneider, W. (1990). FAO species identification sheets for fishery purposes. Field guide to the commercial marine resources of the Gulf of Guinea. *FAO Regional Office for Africa*, 286p. Retrieved from http://www.fao.org/docrep/009/t0438e/t0438e00.htm

Simmonds, E. J., & MacLennan, D. N. (2005). *Fisheries Acoustics: Theory and Practice.* Oxfor: Blackwell Publishing.

Sinovcic, G., & Zorika, B. (2006). eproductive cycle and minimal lengthat sexual maturity ofEngraulis encrasicolus(L.) in the Zrmanja Riverestuary (Adriatic Sea, Croatia). *Estuarine and Coastal Shelf Science, 96*, 439–448.

Zeeberg , J. J., Corten, A., Tjoe-Awie , P., Coca , J., & Hamady , B. (2008). Climate modulates the effects of Sardinella aurita fisheries off Northwest Africa. *Elsevier Fisheries Research, 89*, 65-75.

APPENDICES

A1. Anchovy biomass index estimate

Species Anchovy
TS = m*log (L) + b = 20
b = -72
ea = 5,711,643.8
Sigma = 4 * pi*10$^{(ts/10)}$
mNASC = 318
area.nmi = 17,961.144
m.sigma = 0.000108671
TS = -50.6309478
n fish = ea / m.sigma = 52,558,871,347
biomass in ton = n fish / 1,000,000 = 551538

Length	L = length + 0.25	Count	Weight (g)	Count. weight	Part	Target strength	Sigma	Count. sigma	Sigma. part	ea	n fish	Biomass	CountL	Count. weight
8.5	8.75	10	4.8	48	0.0282486	-53.159839	6.071E-05	0.0006071	0.01578	90129.869	1.485E+09	7.127E+09	87.5	48
9	9.25	14	4.8571	68	0.039548	-52.677165	6.784E-05	0.0009498	0.024689	141014.62	2.079E+09	1.01E+10	129.5	68
9.5	9.75	40	4.9	196	0.1129944	-52.219908	7.537E-05	0.0030149	0.078372	447632.75	5.939E+09	2.91E+10	390	196
10	10.25	27	5	135	0.0762712	-51.785523	8.33E-05	0.0022492	0.0584659	333936.68	4.009E+09	2.004E+10	276.75	135
10.5	10.75	31	6.0968	189	0.0875706	-51.371831	9.163E-05	0.0028405	0.0738363	421726.85	4.603E+09	2.806E+10	333.25	189
11	11.25	30	8.1034	243.1	0.0847458	-50.97695	0.0001003	0.0030105	0.078256	446970.57	4.454E+09	3.609E+10	337.5	243.10345
11.5	11.75	41	9.625	394.63	0.1158192	-50.599243	0.0001095	0.0044882	0.1166678	666365.07	6.087E+09	5.859E+10	481.75	394.625
12	12.25	51	14.5	739.5	0.1440678	-50.237278	0.000119	0.0060681	0.1577371	900938.17	7.572E+09	1.098E+11	624.75	739.5
12.5	12.75	55	14	770	0.1553672	-49.889796	0.0001289	0.0070891	0.1842785	1052532.9	8.166E+09	1.143E+11	701.25	770
13	13.25	29	15.87	460.22	0.0819209	-49.555682	0.0001392	0.0040368	0.1049352	599352.59	4.306E+09	6.833E+10	384.25	460.21739
13.5	13.75	18	17.5	315	0.0508475	-49.233946	0.0001499	0.0026983	0.0701406	400618.07	2.672E+09	4.677E+10	247.5	315
14	14.25	3	20	60	0.0084746	-48.923703	0.000161	0.000483	0.0125557	71713.945	445414164	8.908E+09	42.75	60
15	15.25	4	19.5	78	0.0112994	-48.334603	0.0001844	0.0007376	0.019173	109509.63	593885552	1.158E+10	61	78
15.5	15.75	1	18.333	18.333	0.0028249	-48.054389	0.0001967	0.0001967	0.0051127	29202.077	148471388	2.722E+09	15.75	18.333333
										Sum	52.558871	551538.42		
										mean			11.620056	10.493726

A2. Atlantic horse mackerel Biomass index estimate

TS = m*log (L) + b = 20
b = -72
ea = 179611
Sigma = 4 * pi*$10^{(ts/10)}$
mNASC = 10

Length	L = length + 0.25	Count	Weight (g)	Count. weight	Part	Target strength	Sigma	Count. sigma	Sigma. part	ea	n fish	Biomass	CountL	Count. weight
10.5	10.75	3	13.3333	40	0.01886792	-51.3718307	9.1628E-05	0.00027488	0.0062517	1122.87616	12254767.3	163396897	32.25	40
11	11.25	6	15	90	0.03773585	-50.9769496	0.00010035	0.0006021	0.01369355	2459.51782	24509534.6	367643019	67.5	90
11.5	11.75	9	15.5556	140	0.05660377	-50.5992427	0.00010947	0.00098521	0.02240671	4024.4999	36764301.9	571889140	105.75	140
12	12.25	6	17.5	105	0.03773585	-50.2372782	0.00011898	0.00071389	0.01623616	2916.19866	24509534.6	428916855	73.5	105
12.5	12.75	6	19.1667	115	0.03773585	-49.8897963	0.00012889	0.00077336	0.01758861	3159.114	24509534.6	469766079	76.5	115
13	13.25	1	20	20	0.00628931	-49.5556824	0.0001392	0.0001392	0.00316586	568.624325	4084922.43	81698448.6	13.25	20
13.5	13.75	1	20	20	0.00628931	-49.233946	0.0001499	0.0001499	0.0034093	612.349086	4084922.43	81698448.6	13.75	20
14.5	14.75	2	22.5	45	0.01257862	-48.6241596	0.0001725	0.000345	0.00784646	1409.31383	8169844.86	183821509	29.5	45
15	15.25	1	25	25	0.00628931	-48.3346031	0.0001844	0.0001844	0.00419372	753.239984	4084922.43	102123061	15.25	25
15.5	15.75	2	30	60	0.01257862	-48.0543888	0.00019668	0.00039337	0.00894645	1606.88497	8169844.86	245095346	31.5	60
16.5	16.75	1	35	35	0.00628931	-47.5197038	0.00022245	0.00022245	0.00505929	908.705801	4084922.43	142972285	16.75	35
17	17.25	3	46.6667	140	0.01886792	-47.264218	0.00023593	0.0007078	0.01609753	2891.29983	12254767.3	571889140	51.75	140
17.5	17.75	15	46.3333	695	0.09433962	-47.0160329	0.00024981	0.00374712	0.08522122	15306.7029	61273836.4	2839021088	266.25	695
18	18.25	5	53	265	0.03144654	-46.7747426	0.00026408	0.0013204	0.03003001	5393.7327	20424612.1	1082504444	91.25	265
18.5	18.75	9	51.6667	465	0.05660377	-46.5399746	0.00027875	0.00250874	0.05705646	10247.9909	36764301.9	1899488929	168.75	465
19	19.25	18	59.7222	1075	0.11320755	-46.3113853	0.00029381	0.00528864	0.12028009	21603.6758	73528603.7	4391291611	346.5	1075
19.5	19.75	20	62.75	1255	0.12578616	-46.088658	0.00030927	0.00618549	0.14067728	25267.244	81698448.6	5126577648	395	1255
20	20.25	9	68.3333	615	0.05660377	-45.8714994	0.00032513	0.00292619	0.06655066	11953.2566	36764301.9	2512227294	182.25	615
20.5	20.75	14	72.5	1015	0.08805031	-45.659638	0.00034139	0.00477941	0.10869862	19523.5107	57188914	4146196265	290.5	1015
21	21.25	6	81.6667	490	0.03773585	-45.4528213	0.00035804	0.00214822	0.04885724	8775.31666	24509534.6	2001611990	127.5	490
21.5	21.75	5	91	455	0.03144654	-45.2508148	0.00037508	0.00187542	0.04265287	7660.94254	20424612.1	1858639705	108.75	455
22	22.25	3	93.3333	280	0.01886792	-45.0533997	0.00039253	0.00117758	0.02678188	4810.33102	12254767.3	1143778280	66.75	280
22.5	22.75	2	102.5	205	0.01257862	-44.860372	0.00041037	0.00082073	0.01866606	3352.63655	8169844.86	837409098	45.5	205
23	23.25	1	110	110	0.00628931	-44.6715409	0.0004286	0.0004286	0.00974778	1750.81231	4084922.43	449341467	23.25	110
23.5	23.75	5	110	550	0.03144654	-44.4867277	0.00044724	0.00223618	0.05085773	9134.62893	20424612.1	2246707336	118.75	550
24	24.25	1	120	120	0.00628931	-44.3057651	0.00046627	0.00046627	0.01060433	1904.6587	4084922.43	490190691	24.25	120
24.5	24.75	1	130	130	0.00628931	-44.1284959	0.00048569	0.00048569	0.01104613	1984.01104	4084922.43	531039916	24.75	130
25	25.25	2	122.5	245	0.01257862	-43.9547724	0.00050551	0.00101103	0.02299389	4129.96564	8169844.86	1000805995	50.5	245
25.5	25.75	1	175	175	0.00628931	-43.7844553	0.00052573	0.00052573	0.01195678	2147.57404	4084922.43	714861425	25.75	175
26	26.25	1	135	135	0.00628931	-43.6174138	0.00054635	0.00054635	0.01242563	2231.78469	4084922.43	551464528	26.25	135
										sum	0.64541774	37234.0679		
										mean			18.3003145	57.32704

area.nmi = 17,961.144

m.sigma = 0.000276537
TS = -46.57456904
n fish = ea / m.sigma = 649502666.2
biomass in ton = n fish / 1,000,000 = 37234

A3. Chub mackerel biomass index estimate

TS = m*log (L) + b = 20
b = -72
ea = 1796.114
Sigma = 4 * pi*$10^{(ts/10)}$

area.nmi = 17,961.144

m.sigma = 0.000668184
TS = -42.74314029
n fish = ea / m.sigma = 2688054.456
biomass in ton = n fish / 1,000,000 = 166

Length	L = length + 0.25	Count	Weight (g)	Count. weight	Part	Target strength	Sigma	Count. sigma	Sigma. part	ea	n fish	Biomass	CountL	Count. weight
12	12.25	6	11.67	70	0.006818	-50.2373	0.000118982	0.000713893	0.002587	4.64645	39051.6386	455602.4502	73.5	70
12.5	12.75	13	13.85	180	0.014773	-49.8898	0.000128893	0.001675612	0.006072	10.9059	84611.8836	1171549.158	165.75	180
13	13.25	15	15.67	235	0.017045	-49.5557	0.000139201	0.002088011	0.007566	13.59004	97629.0965	1529522.511	198.75	235
13.5	13.75	22	17.5	385	0.025	-49.2339	0.000149905	0.003297903	0.011951	21.46476	143189.341	2505813.476	302.5	385
14	14.25	19	19.74	375	0.021591	-48.9237	0.000161005	0.003059097	0.011085	19.91046	123663.522	2440727.412	270.75	375
14.5	14.75	21	21.43	450	0.023864	-48.6242	0.000172502	0.00362254	0.013127	23.57769	136680.735	2928872.894	309.75	450
15	15.25	55	27.36	1505	0.0625	-48.3346	0.000184395	0.010141735	0.036751	66.00856	357973.354	9795452.68	838.75	1505
15.5	15.75	39	26.71	1041.710526	0.044318	-48.0544	0.000196685	0.00767071	0.027796	49.92564	253835.651	6780083.831	614.25	1041.711
16	16.25	30	29.83	895	0.034091	-47.7829	0.000209371	0.006281131	0.022761	40.88141	195258.193	5825202.756	487.5	895
16.5	16.75	32	31.41	1005	0.036364	-47.5197	0.000222454	0.007118516	0.025795	46.33162	208275.406	6541149.464	536	1005
17	17.25	38	35.13	1335	0.043182	-47.2642	0.000235933	0.008965441	0.032488	58.35253	247327.044	8688989.586	655.5	1335
17.5	17.75	52	39.42	2050	0.059091	-47.016	0.000249808	0.012990023	0.047072	84.54695	338447.534	13342643.18	923	2050
18	18.25	31	43.87	1360	0.035227	-46.7747	0.00026408	0.008186482	0.029665	53.28259	201766.799	8851704.747	565.75	1360
18.5	18.75	40	48.63	1945	0.045455	-46.54	0.000278748	0.011149937	0.040404	72.57055	260344.257	12659239.51	750	1945
19	19.25	50	52	2600	0.056818	-46.3114	0.000293813	0.014690661	0.053235	95.61573	325430.322	16922376.72	962.5	2600
19.5	19.75	39	56.67	2210	0.044318	-46.0887	0.000309274	0.012061704	0.043708	78.50489	253835.651	14384020.21	770.25	2210
20	20.25	34	62.42	2122.424242	0.038636	-45.8715	0.000325132	0.011054493	0.040058	71.94935	221292.619	13814024.07	688.5	2122.424
20.5	20.75	53	66.73	3536.730769	0.060227	-45.6596	0.000341386	0.018093473	0.065566	117.7633	344956.141	23019188.63	1099.75	3536.731
21	21.25	37	72.86	2695.714286	0.042045	-45.4528	0.000358037	0.013247364	0.048005	86.22188	240818.438	17545343.34	786.25	2695.714
21.5	21.75	49	78.89	3865.555556	0.055682	-45.2508	0.000375084	0.01837911	0.066601	119.6224	318921.715	25159379.75	1065.75	3865.556
22	22.25	35	86.52	3028.030303	0.039773	-45.0534	0.000392527	0.013738456	0.049784	89.41821	227801.225	19708257.51	778.75	3028.03
22.5	22.75	43	94.05	4044.047619	0.048864	-44.8604	0.000410367	0.017645791	0.063943	114.8495	279870.077	26321114.34	978.25	4044.048
23	23.25	29	99.78	2893.695652	0.032955	-44.6715	0.000428604	0.012429503	0.045041	80.89875	188749.587	18833926.13	674.25	2893.696
23.5	23.75	16	108	1728	0.018182	-44.4867	0.000447236	0.007155782	0.025931	46.57417	104137.703	11246871.91	380	1728
24	24.25	20	112.3	2246.666667	0.022727	-44.3058	0.000466266	0.009325311	0.033792	60.69478	130172.129	14622669.12	485	2246.667
24.5	24.75	9	119.3	1073.571429	0.010227	-44.1285	0.000485691	0.004371221	0.01584	28.45056	58577.4579	6987453.905	222.75	1073.571
25	25.25	15	130.8	1961.538462	0.017045	-43.9548	0.000505513	0.0075827	0.027478	49.35281	97629.0965	12766881.85	378.75	1961.538
25.5	25.75	7	145	1015	0.007955	-43.7845	0.000525732	0.003680123	0.013336	23.95247	45560.245	6606235.528	180.25	1015
26	26.25	6	145	870	0.006818	-43.6174	0.000546347	0.003278081	0.011879	21.33574	39051.6386	5662487.596	157.5	870
26.5	26.75	2	170	340	0.002273	-43.4535	0.000567358	0.001134717	0.004112	7.385424	13017.2129	2212926.187	53.5	340
27.5	27.75	1	192.5	192.5	0.001136	-43.1347	0.000610571	0.000610571	0.002213	3.973963	6508.60643	1252906.738	27.75	192.5
28	28.25	1	215	215	0.001136	-42.9796	0.000632771	0.000632771	0.002293	4.118459	6508.60643	1399350.383	28.25	215
28.5	28.75	7	185	1295	0.007955	-42.8272	0.000655368	0.004587579	0.016624	29.85875	45560.245	8428645.329	201.25	1295
29	29.25	1	210	210	0.001136	-42.6775	0.000678362	0.000678362	0.002458	4.415192	6508.60643	1366807.351	29.25	210
29.5	29.75	3	200	600	0.003409	-42.5303	0.000701752	0.002105257	0.007629	13.70229	19525.8193	3905163.859	89.25	600
30	30.25	1	231.7	231.6666667	0.001136	-42.3855	0.000725539	0.000725539	0.002629	4.722246	6508.60643	1507827.157	30.25	231.6667
31	31.25	2	230	460	0.002273	-42.103	0.000774301	0.001548602	0.005612	10.07924	13017.2129	2993958.959	62.5	460
32.5	32.75	3	232.5	697.5	0.003409	-41.6958	0.000850418	0.002551254	0.009245	16.60511	19525.8193	4539752.986	98.25	697.5
33	33.25	1	280	280	0.001136	-41.5642	0.000876583	0.000876583	0.003176	5.705335	6508.60643	1822409.801	33.25	280
35.5	35.75	1	315	315	0.001136	-40.9345	0.001013356	0.001013356	0.003672	6.595534	6508.60643	2050211.026	35.75	315
38.5	38.75	1	347.5	347.5	0.001136	-40.2346	0.001190565	0.001190565	0.004314	7.748922	6508.60643	2261740.735	38.75	347.5
76	76.25	1	380	380	0.001136	-34.3552	0.004609879	0.004609879	0.016705	30.00389	0.00024082	0.091511006	76.25	380
										sum	0.00572107	350.8584849		
										mean			19.43	61.68

A4. Round Sardinella Biomass index estimate

TS = m*log (L) + b = 20
b = -72
ea = 215533.68
Sigma = 4 * pi*$10^{(ts/10)}$

area.nmi = 17,961.144

m.sigma = 0.000498303
TS = -44.01716583
n fish = ea / m.sigma = 432535605.4
biomass in ton = n fish / 1,000,000 = 62019

Length	L = length + 0.25	Count	Weight (g)	Count. weight	Part	Target strength	Sigma	Count. sigma	Sigma. part	ea	n fish	Biomass	CountL	Count. weight
17	17.25	2	52.5	105	0.008368	-47.2642	0.000235933	0.000471865	0.003962	853.9688	3619544.81	190026102.8	34.5	105
17.5	17.75	7	52.143	365	0.029289	-47.016	0.000249808	0.001748657	0.014683	3164.671	12668406.9	660566928.7	124.25	365
18	18.25	5	52	260	0.020921	-46.7747	0.00026408	0.0013204	0.011087	2389.624	9048862.04	470540825.9	91.25	260
18.5	18.75	3	60	180	0.012552	-46.54	0.000278748	0.000836245	0.007022	1513.414	5429317.22	325759033.3	56.25	180
19	19.25	7	65.714	460	0.029289	-46.3114	0.000293813	0.002056693	0.017269	3722.145	12668406.9	832495307.4	134.75	460
19.5	19.75	5	79	395	0.020921	-46.0887	0.000309274	0.001546372	0.012984	2798.582	9048862.04	714860100.9	98.75	395
20	20.25	5	73	365	0.020921	-45.8715	0.000325132	0.001625661	0.01365	2942.076	9048862.04	660566928.7	101.25	365
20.5	20.75	3	83.333	250	0.012552	-45.6596	0.000341386	0.001024159	0.0086	1853.494	5429317.22	452443101.9	62.25	250
21	21.25	4	91.25	365	0.016736	-45.4528	0.000358037	0.001432147	0.012025	2591.861	7239089.63	660566928.7	85	365
21.5	21.75	9	95	855	0.037657	-45.2508	0.000375084	0.003375755	0.028345	6109.348	16287951.7	1547355408	195.75	855
22	22.25	10	94	940	0.041841	-45.0534	0.000392527	0.003925273	0.032959	7103.851	18097724.1	1701186063	222.5	940
22.5	22.75	32	105	3360	0.133891	-44.8604	0.000410367	0.013131751	0.110263	23765.48	57912717	6080835289	728	3360
23	23.25	27	109.63	2960	0.112971	-44.6715	0.000428604	0.011572296	0.097169	20943.22	48863855	5356926326	627.75	2960
23.5	23.75	16	120.31	1925	0.066946	-44.4867	0.000447236	0.007155782	0.060085	12950.34	28956358.5	3483811884	380	1925
24	24.25	11	123.18	1355	0.046025	-44.3058	0.000466266	0.005128921	0.043066	9282.18	19907496.5	2452241612	266.75	1355
24.5	24.75	11	134.55	1480	0.046025	-44.1285	0.000485691	0.005342604	0.04486	9668.897	19907496.5	2678463163	272.25	1480
25	25.25	16	145.94	2335	0.066946	-43.9548	0.000505513	0.008088214	0.067914	14637.83	28956358.5	4225818571	404	2335
25.5	25.75	7	151.43	1060	0.029289	-43.7845	0.000525732	0.003680123	0.030901	6660.186	12668406.9	1918358752	180.25	1060
26	26.25	12	162.92	1955	0.050209	-43.6174	0.000546347	0.006556163	0.05505	11865.16	21717268.9	3538105057	315	1955
26.5	26.75	6	180	1080	0.025105	-43.4535	0.000567358	0.00340415	0.028584	6160.737	10858634.4	1954554200	160.5	1080
27	27.25	5	177	885	0.020921	-43.2927	0.000588766	0.002943831	0.024718	5327.664	9048862.04	1601648581	136.25	885
27.5	27.75	3	193.33	580	0.012552	-43.1347	0.000610571	0.001831712	0.01538	3314.981	5429317.22	1049667996	83.25	580
28	28.25	1	215	215	0.004184	-42.9796	0.000632771	0.000632771	0.005313	1145.172	1809772.41	389101067.6	28.25	215
29.5	29.75	1	247	247	0.004184	-42.5303	0.000701752	0.000701752	0.005892	1270.012	1809772.41	447013784.6	29.75	247
30	30.25	1	263.5	263.5	0.004184	-42.3855	0.000725539	0.000725539	0.006092	1313.06	1809772.41	476875029.4	30.25	263.5
32.5	32.75	2	280	560	0.008368	-41.6958	0.000850418	0.001700836	0.014281	3078.126	3619544.81	1013472548	65.5	560
33	33.25	1	260	260	0.004184	-41.5642	0.000876583	0.000876583	0.00736	1586.416	1809772.41	470540825.9	33.25	260
33.5	33.75	3	305	915	0.012552	-41.4345	0.000903145	0.002709435	0.02275	4903.46	5429317.22	1655941753	101.25	915
34	34.25	4	350	1400	0.016736	-41.3068	0.000930103	0.003720412	0.031239	6733.099	7239089.63	2533681370	137	1400
34.5	34.75	10	330	3300	0.041841	-41.1809	0.000957457	0.009574574	0.080395	17327.8	18097724.1	5972248945	347.5	3300
35	35.25	5	345	1725	0.020921	-41.0568	0.000985208	0.004926042	0.041363	8915.015	9048862.04	3121857403	176.25	1725
35.5	35.75	2	360	720	0.008368	-40.9345	0.001013356	0.002026712	0.017018	3667.887	3619544.81	1303036133	71.5	720
36.5	36.75	1	360.5	360.5	0.004184	-40.6949	0.00107084	0.00107084	0.008992	1937.977	1809772.41	652422952.9	36.75	360.5
37	37.25	1	383	383	0.004184	-40.5775	0.001100177	0.001100177	0.009238	1991.069	1809772.41	693142832	37.25	383
37.5	37.75	1	405	405	0.004184	-40.4617	0.00112991	0.00112991	0.009488	2044.88	1809772.41	732957825	37.75	405
										Sum	0.43253561	62019.09063		
										mean			24.65586	143.3849

A5. Flat Sardinella Biomass index estimate

TS = m*log (L) + b = 20
b = -72
ea = 305339.38
Sigma = 4 * pi*$10^{(ts/10)}$

area.nmi = 17,961.144

m.sigma = 0.000705884
TS = -42.50476785
n fish = ea / m.sigma = 432563370.1
biomass in ton = n fish / 1,000,000 = 115768

Length	L = length + 0.25	Count	Weight (g)	Count. weight	Part	Target strength	Sigma	Count. sigma	Sigma. part	ea	n fish	Biomass	CountL	Count. weight
26	26.25	5	192	960	0.13158	-43.617	0.000546347	0.002731734	0.101841	31096.01	56916232.9	10927916718	131.25	960
27	27.25	3	200	600	0.07895	-43.293	0.000588766	0.001766299	0.065849	20106.21	34149739.7	6829947949	81.75	600
27.5	27.75	8	205.625	1645	0.21053	-43.135	0.000610571	0.004884564	0.1821	55602.2	91065972.7	18725440626	222	1645
28	28.25	2	225	450	0.05263	-42.98	0.000632771	0.001265543	0.04718	14405.98	22766493.2	5122460962	56.5	450
28.5	28.75	1	225	225	0.02632	-42.827	0.000655368	0.000655368	0.024433	7460.221	11383246.6	2561230481	28.75	225
29	29.25	2	242.5	485	0.05263	-42.677	0.000678362	0.001356724	0.05058	15443.93	22766493.2	5520874592	58.5	485
29.5	29.75	2	260	520	0.05263	-42.53	0.000701752	0.001403504	0.052324	15976.44	22766493.2	5919288222	59.5	520
30	30.25	1	300	300	0.02632	-42.385	0.000725539	0.000725539	0.027049	8258.987	11383246.6	3414973974	30.25	300
30.5	30.75	1	275	275	0.02632	-42.243	0.000749722	0.000749722	0.02795	8534.267	11383246.6	3130392810	30.75	275
31	31.25	2	265	530	0.05263	-42.103	0.000774301	0.001548602	0.057733	17628.12	22766493.2	6033120688	62.5	530
31.5	31.75	2	322.5	645	0.05263	-41.965	0.000799277	0.001598554	0.059595	18196.73	22766493.2	7342194045	63.5	645
32	32.25	1	325	325	0.02632	-41.829	0.000824649	0.000824649	0.030743	9387.186	11383246.6	3699555139	32.25	325
32.5	32.75	2	345	690	0.05263	-41.696	0.000850418	0.001700836	0.063408	19361.04	22766493.2	7854440141	65.5	690
33	33.25	2	395	790	0.05263	-41.564	0.000876583	0.001753166	0.065359	19956.73	22766493.2	8992764799	66.5	790
34	34.25	2	430	860	0.05263	-41.307	0.000930103	0.001860206	0.06935	21175.18	22766493.2	9789592060	68.5	860
35	35.25	1	480	480	0.02632	-41.057	0.000985208	0.000985208	0.036729	11214.87	11383246.6	5463958359	35.25	480
35.5	35.75	1	390	390	0.02632	-40.934	0.001013356	0.001013356	0.037779	11535.28	11383246.6	4439466167	35.75	390
										sum	0.43256337	115767.6177		
										mean			29.71053	267.6316

A6. Sardine biomass index estimate

TS = m*log (L) + b = 20
b = -72
ea = 89805.7 89805.7

Sigma = 4 * pi*$10^{(ts/10)}$

area.nmi = 17,961.144

m.sigma = 0.000306451
TS = -46.12848954
n fish = ea / m.sigma = 293050854.4
biomass in ton = n fish / 1,000,000 = 21019

Length	L = length + 0.25	Count	Weight (g)	Count. weight	Part	Target strength	Sigma	Count. sigma	Sigma. part	ea	n fish	Biomass	CountL	Count. weight
7.5	7.75	3	5	15	0.00601	-54.214	4.76E-05	0.00014287	0.000934	83.9029	1761828.78	8809143.921	23.25	15
8	8.25	2	5	10	0.00401	-53.671	5.4E-05	0.00010793	0.000706	63.38554	1174552.52	5872762.614	16.5	10
8.5	8.75	11	5	55	0.02204	-53.16	6.07E-05	0.00066776	0.004367	392.158	6460038.88	32300194.38	96.25	55
9	9.25	2	5	10	0.00401	-52.677	6.78E-05	0.00013568	0.000887	79.68302	1174552.52	5872762.614	18.5	10
9.5	9.75	9	5.11111	46	0.01804	-52.22	7.54E-05	0.00067836	0.004436	398.386	5285486.35	27014708.02	87.75	46
10	10.25	7	15	105	0.01403	-51.786	8.33E-05	0.00058312	0.003813	342.4507	4110933.83	61664007.45	71.75	105
10.5	10.75	11	6.36364	70	0.02204	-51.372	9.16E-05	0.0010079	0.006591	591.9185	6460038.88	41109338.3	118.25	70
11	11.25	8	10	80	0.01603	-50.977	0.0001	0.0008028	0.00525	471.4627	4698210.09	46982100.91	90	80
11.5	11.75	7	11.4286	80	0.01403	-50.599	0.000109	0.00076627	0.005011	450.0141	4110933.83	46982100.91	82.25	80
12	12.25	9	13.125	118.125	0.01804	-50.237	0.000119	0.00107084	0.007003	628.8789	5285486.35	69372008.38	110.25	118.125
12.5	12.75	11	15.9091	175	0.02204	-49.89	0.000129	0.00141783	0.009272	832.6555	6460038.88	102773345.7	140.25	175
13	13.25	7	17.5	122.5	0.01403	-49.556	0.000139	0.00097441	0.006372	572.2451	4110933.83	71941342.02	92.75	122.5
13.5	13.75	14	20.3571	285	0.02806	-49.234	0.00015	0.00209867	0.013724	1232.497	8221867.66	167373734.5	192.5	285
14	14.25	11	20.5	225.5	0.02204	-48.924	0.000161	0.00177106	0.011582	1040.099	6460038.88	132430796.9	156.75	225.5
14.5	14.75	7	25	175	0.01403	-48.624	0.000173	0.00120751	0.007896	709.1439	0.06577494	1.644373532	103.25	175
15	15.25	6	27	162	0.01202	-48.335	0.000184	0.00110637	0.007235	649.7455	0.06401311	1.728354039	91.5	162
15.5	15.75	4	31.25	125	0.00802	-48.054	0.000197	0.00078674	0.005145	462.0334	0.06283856	1.963705003	63	125
16	16.25	8	33.5714	268.571429	0.01603	-47.783	0.000209	0.00167497	0.010953	983.6691	0.05637852	1.8927075	130	268.5714
16.5	16.75	5	35	175	0.01002	-47.52	0.000222	0.00111227	0.007274	653.2087	0.05520397	1.932138909	83.75	175
17	17.25	9	41.25	371.25	0.01804	-47.264	0.000236	0.00212339	0.013886	1247.019	0.04991848	2.059137404	155.25	371.25
17.5	17.75	15	47.3333	710	0.03006	-47.016	0.00025	0.00374712	0.024504	2200.596	0.04580755	2.168223974	266.25	710
18	18.25	10	52.2222	522.222222	0.02004	-46.775	0.000264	0.0026408	0.017269	1550.879	0.03934751	2.054814407	182.5	522.2222
18.5	18.75	10	54	540	0.02004	-46.54	0.000279	0.00278748	0.018229	1637.023	0.0346493	1.871062192	187.5	540
19	19.25	20	62.8947	1257.89474	0.04008	-46.311	0.000294	0.00587626	0.038427	3450.991	0.03053837	1.920702497	385	1257.895
19.5	19.75	19	68.1579	1295	0.03808	-46.089	0.000309	0.00587621	0.038427	3450.961	0.02525288	1.721183119	375.25	1295
20	20.25	20	75	1500	0.04008	-45.871	0.000325	0.00650264	0.042523	3818.848	0.01879284	1.409463067	405	1500
20.5	20.75	36	80.8333	2910	0.07214	-45.66	0.000341	0.01228991	0.080369	7217.57	0.01468191	1.186787489	747	2910
21	21.25	20	85.7895	1715.78947	0.04008	-45.453	0.000358	0.00716074	0.046827	4205.331	0.00646004	0.554203383	425	1715.789
21.5	21.75	24	94.375	2265	0.0481	-45.251	0.000375	0.00900201	0.058868	5286.668	5.6966E-10	5.37615E-08	522	2265
22	22.25	25	103.125	2578.125	0.0501	-45.053	0.000393	0.00981318	0.064172	5763.049	5.0388E-10	5.19629E-08	556.25	2578.125
22.5	22.75	39	106.41	4150	0.07816	-44.86	0.00041	0.01600432	0.104659	9398.958	4.3987E-10	4.68067E-08	887.25	4150
23	23.25	27	113.462	3063.46154	0.05411	-44.672	0.000429	0.0115723	0.075676	6796.135	3.7703E-10	4.27786E-08	627.75	3063.462
23.5	23.75	30	120	3600	0.06012	-44.487	0.000447	0.01341709	0.08774	7879.539	3.2065E-10	3.84783E-08	712.5	3600
24	24.25	17	126.875	2156.875	0.03407	-44.306	0.000466	0.00792651	0.051835	4655.054	2.6545E-10	3.36788E-08	412.25	2156.875
24.5	24.75	17	125	2125	0.03407	-44.128	0.000486	0.00825675	0.053994	4848.994	2.1553E-10	2.69413E-08	420.75	2125
25	25.25	13	137.917	1792.91667	0.02605	-43.955	0.000506	0.00657167	0.042975	3859.388	1.6972E-10	2.34076E-08	328.25	1792.917
25.5	25.75	3	150	450	0.00601	-43.784	0.000526	0.0015772	0.010314	926.2496	1.3038E-10	1.95563E-08	77.25	450
26	26.25	2	175	350	0.00401	-43.617	0.000546	0.00109269	0.007146	641.7131	9.5726E-11	1.67521E-08	52.5	350
26.5	26.75	1	135	135	0.002	-43.454	0.000567	0.00056736	0.00371	333.1961	6.5188E-11	8.80034E-09	26.75	135
										sum	65774941.8	820498370.8		
										mean			19.07966	71.72591

Cunen horse mackerel Biomass index estimate

TS = m*log (L) + b = 20
b = -72
ea = 916018.14

Sigma = 4 * pi*10$^{(ts/10)}$

area.nmi = 17,961.144

m.sigma = 0.000231913
TS = -47.33885526
n fish = ea / m.sigma = 3949842114
biomass in ton = n fish / 1,000,000 = 130852

Length	L = length + 0.25	Count	Weight (g)	Count. weight	Part	Target strength	Sigma	Count. sigma	Sigma. part	ea	n fish	Biomass	CountL	Count. weight
6.5	6.75	1	5	5	0.004386	-55.413925	3.61258E-05	3.61258E-05	0.000683	625.8385	17323868.9	86619344.61	6.75	5
9.5	9.75	3	5.85	17.55	0.013158	-52.219908	7.53736E-05	0.000226121	0.004276	3917.286	51971606.8	304033899.6	29.25	17.55
10	10.25	10	6.65	66.5	0.04386	-51.785523	8.33024E-05	0.000833024	0.015754	14431.2	173238689	1152037283	102.5	66.5
10.5	10.75	17	7.5	127.5	0.074561	-51.371831	9.16277E-05	0.001557671	0.029459	26984.89	294505772	2208793288	182.75	127.5
11	11.25	11	7.9	86.9	0.048246	-50.97695	0.000100349	0.001103844	0.020876	19122.84	190562558	1505444209	123.75	86.9
11.5	11.75	6	8.3333	50	0.026316	-50.599243	0.000109468	0.000656806	0.012422	11378.41	103943214	866193446.1	70.5	50
12	12.25	8	10	80	0.035088	-50.237278	0.000118982	0.000951858	0.018002	16489.86	138590951	1385909514	98	80
12.5	12.75	2	10.294	20.5882353	0.008772	-49.889796	0.000128893	0.000257787	0.004875	4465.86	34647737.8	356667889.6	25.5	20.58824
13	13.25	1	11.818	11.8181818	0.004386	-49.555682	0.000139201	0.000139201	0.002633	2411.496	17323868.9	204736632.7	13.25	11.81818
13.5	13.75	2	15.833	31.6666667	0.008772	-49.233946	0.000149905	0.000299809	0.00567	5193.859	34647737.8	548589182.6	27.5	31.66667
14	14.25	4	38.125	152.5	0.017544	-48.923703	0.000161005	0.00064402	0.01218	11156.92	69295475.7	2641890011	57	152.5
14.5	14.75	2	15	30	0.008772	-48.62416	0.000172502	0.000345004	0.006525	5976.801	34647737.8	519716067.7	29.5	30
15	15.25	2	20	40	0.008772	-48.334603	0.000184395	0.00036879	0.006975	6388.876	34647737.8	692954756.9	30.5	40
15.5	15.75	1	22.5	22.5	0.004386	-48.054389	0.000196685	0.000196685	0.00372	3407.343	17323868.9	389787050.8	15.75	22.5
16	16.25	1	25	25	0.004386	-47.782933	0.000209371	0.000209371	0.00396	3627.116	17323868.9	433096723.1	16.25	25
17	17.25	3	25	75	0.013158	-47.264218	0.000235933	0.000707798	0.013386	12261.8	51971606.8	1299290169	51.75	75
17.5	17.75	18	27.5	495	0.078947	-47.016033	0.000249808	0.004496546	0.085039	77897.58	311829641	8575315117	319.5	495
18	18.25	23	40	920	0.100877	-46.774743	0.00026408	0.006073841	0.114869	105222.4	398448985	15937959409	419.75	920
18.5	18.75	40	45	1800	0.175439	-46.539975	0.000278748	0.011149937	0.210869	193160	692954757	31182964061	750	1800
19	19.25	37	45.85	1696.45	0.162281	-46.311385	0.000293813	0.010871089	0.205596	188329.3	640983150	29389077434	712.25	1696.45
19.5	19.75	19	46.667	886.666667	0.083333	-46.088658	0.000309274	0.005876215	0.111132	101798.8	329153510	15360497112	375.25	886.6667
20	20.25	6	48.889	293.333333	0.026316	-45.871499	0.000325132	0.001950793	0.036894	33795.28	103943214	5081668217	121.5	293.3333
20.5	20.75	5	53.913	269.565217	0.02193	-45.659638	0.000341386	0.001706931	0.032282	29570.66	86619344.6	4669912492	103.75	269.5652
21	21.25	3	55.875	167.625	0.013158	-45.452821	0.000358037	0.001074111	0.020314	18607.75	51971606.8	2903913528	63.75	167.625
21.5	21.75	2	60.135	120.27027	0.008772	-45.250815	0.000375084	0.000750168	0.014187	12995.81	34647737.8	2083546397	43.5	120.2703
22	22.25	1	61.842	61.8421053	0.004386	-45.0534	0.000392527	0.000392527	0.007424	6800.092	17323868.9	1071344525	22.25	61.84211
										sum	3.94984211	130851.9578		
										mean			16.7193	33.1284