Report on BCLME project LMR/CF/03/08

Benguela Environment Fisheries Interaction & Training Programme

Review of the state of knowledge, research (past and present) of the distribution, biology, ecology, and abundance of non-exploited mesopelagic fish (Order Anguilliformes, Argentiniformes, Stomiiformes, Myctophiformes, Aulopiformes) and the bearded goby (*Sufflogobius bibarbatus*) in the Benguela Ecosystem.

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1 Introduction

The Benguela upwelling system on the south west coast of Africa is one of the worlds' four major western boundary upwelling regions, and one of the most productive marine ecosystems in the world (Shannon, 1985). This marine system is characterised by a high primary production rate due to strong upwelling occurring throughout the year and peaking in late winter and spring. Essential nutrients are convected from the deeper waters to the ocean surface as a result of this upwelling - the offshore movement of the surface water masses, caused by strong southerly winds and the presence of colder deep water masses (Garrison, 1998). The primary production is the basis for the large production of pelagic fish of which the commercial species like sardine, anchovy, round herring and horse mackerel has received most attention. However the most abundant species are maybe the non-commercial mesopelagics and the gobies that play a key role in the ecosystem, assimilating plankton and as prey making this energy available for species higher in the food chain. The northern part of the ecosystem, the northern Benguela, is also characterised by widespread areas of low oxygen waters overlying the diatomaceous mud belt of the central Namibian shelf (Chapman and Shannon 1985, Dingle and Nelson 1993), affecting the distribution of many demersal and pelagic species. Gobies and some mesopelagic species seem to be among those species well adapted to this hostile environment and are frequently found in these regions.

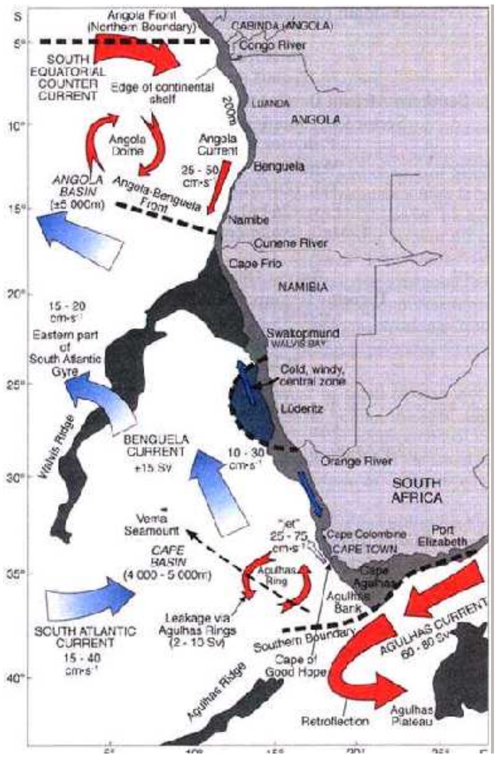

Figure 1: The Benguela Current Large Marine Ecosystem (BCLME). (Taken from Sumaila *et al.* 2003).

Gobies are reported to be the largest family of marine fishes (possibly > 2,000), and also common in fresh and brackish waters. The smallest fishes (and vertebrates) in the world belong to this family. Gobies are grouped together on the basis of several hard to discern characters: bones of the head, and a family-unique sperm gland. Most live in or on the bottom and are aptly adapted to a demersal existence. They are roughly torpedo-cylindrically shaped, and have reduced lateral line systems coupled with enhanced vision. Generally gobies lack swim-bladders and display degrees of fusion of their pelvic fins that are located anteriorly under their pectorals and used as a sort of suction disc to help them stay in place. Total length is usually reported to be < 10 cm but 50 cm maximum length is known with some species. Most species are found in shallow coastal waters and around coral reefs. The species are most commonly cryptic bottom dwelling carnivores of small benthic invertebrates; others are planktivores. Some species have symbiotic relationships with invertebrates (e.g. shrimps) and others are known to remove ecto-parasites from other fishes. The gobies are typically nest spawners with non-spherical eggs guarded by the male. Many are popular aquarium fishes. The following subfamilies are recognized: Oxudercinae, Amblyopinae, Sicydiinae, Gobionellinae and Gobiinae (Froese & Pauly 2005; Miller 1990; Nelson, 1994).

The *Sufflogobius bibarbatus* belongs to subfamily Gobiinae and is an abundant, presently non-commercial species indigenous to the northern region of the Benguela ecosystem. It is roughly confined to the coast of Namibia and the west coast of South Africa, but has also been reported from the southern Angola (Figure 1 and 2, Nansen program, unpublished data), distributed from the coast to approximately 350m bottom depth. The species is reported to occur both benthic and pelagic, and are often referred to as the pelagic goby (Crawford *et al.* 1985), although this name seems not to reflect the true nature of a primarily demersal species. However it commonly exhibits diel vertical migration to midwater, and some life stages may also be found close to the surface (O'Toole 1978, Crawford *et al.* 1985). The pelagic goby seems to be well adapted to the often hypoxic environment of the Namibian shelf. The goby play a key role in the ecosystem, both as predator on small prey as they feed on copepods and krill, but also since it is abundant in the diet of a variety of commercially interesting fish species, most noticeably the hakes, (*Merluccius capensis* and *M. paradoxus*), but also horse mackerel (Andronov 1985), and seals and seabirds (Mecenero *et al.*, in prep.)

Mesopelagic fish are part of a group of organisms referred to as micronekton, which generally range in size from 1 to 15 cm (Salvanes & Kristoffersen 2001), with few exceeding 30 cm in length (Smith & Heemstra 1991). These fish have a worldwide distribution, oceanic as well as pseudo oceanic (neritic zone), and encompass more than thirty described fish families (Gjøsæter & Kawaguchi 1980; Nelson 1994). They inhabit the mesopelagic zone, generally described as the water column between 200 and 1 000m depth, and are found in one or more of several deep scattering layers during daytime. Some lanternfish (Myctophidae) and light fish (Photichthyidae) species as well as other mesopelagic fish species occupying this zone migrate to shallower waters for feeding purposes during night time, while others undertake only partial or no migrations at all (Gjøsæter & Kawaguchi 1980; Prosch *et al.* 1995; Smith & Heemstra 1991). The diel vertical migratory behaviour makes these fish vital transporters of organic matter (nutrients) from the productive epipelagic zone down to the lesser productive aphotic deep ocean. In other words “they form a vital link between the zooplankton community and larger marine predators” (Prosch *et al.* 1995).

In the Benguela region many species belonging to most of the 30 odd families (Table 1) have been observed and/or recorded in the catch logs of both research and commercial fishing vessels. As with the goby, mesopelagic fish play a central part in the trophic dynamics and ecology of the Benguela current system, preying mostly on zooplankton and being preyed upon by fish, sharks, birds, and seals amongst others. Only one lanternfish species has been of commercial interest the last three decades, being targeted by the South African purse seine fishery. The question remains whether mesopelagic fish species are a potentially harvestable resource, and if so, whether this can be done without adverse effects on the entire Benguela system. Cruickshank (1982) argued that the full role of these fish in the food web of the oceans was not known and that extensive harvesting of these species should be monitored in order to avoid any detrimental effect on the stocks of the predator species dependent on them.

2 Materials and Methods

The main objectives of this report are really twofold: a) to provide an overview of the knowledge on the pelagic goby and mesopelagic fish species (mesopelagics) occurring in the Benguela current system, and b) to present meta-data summary tables of data collected onboard various research and fishing vessels that operated in the region. The first objective included obtaining general and scientific information published in books, scientific articles, thesis, and institutional reports, as well as popular articles. Regarding the Benguela region the bulk of research done on mesopelagics has been focused on members of the lanternfish (Myctophidae) and the hatchet fish *Maurolicus muelleri* (Sternoptychidae). There is an apparent lack of knowledge and information on mesopelagics occurring north of 15°S, as well as families other than the Myctophidae and Sternoptychidae. The information available on southern and northern Benguela mesopelagics was in many cases supplemented with knowledge on the same or similar families/species studied in other marine systems. This information is generally mentioned separately in and at the beginning of each sub-section. For the second objective metadata tables were compiled for the Nan-Sis database (located at the Institute of Marine Research, Bergen), as well as data available from various research and fishing vessels that have worked or still are operating in Namibian (data located at NatMIRC, Swakopmund) and South African (data located at MCM, Cape Town) waters. Additionally a number of people working at various research institutions and also fishing companies or associations were contacted in order to obtain additional inputs (Annex 16).

2.1 Regional data sources

Typically gobies and mesopelagic species have not been target species during regular fisheries surveys within the region. However during cruises with these vessels incidental catches of gobies and mesopelagic fish have been recorded.

Only two databases have been used more extensively in this study. These are described in more detail below.

2.1.1 Nan-Sis

The Nansen Survey Information System (Nan-Sis) is currently an MS-DOS based database programme designed primarily to capture and store station, catch and biological data collected during scientific cruises onboard the Norwegian research vessel RV Dr. Fridtjof Nansen (Strømme 1992). In recent years the Namibian Ministry of Fisheries and Marine Resources (MFMR) has also used this database to capture bottom trawl survey data collected onboard commercial fishing boats.

Strømme (1992) gives a detailed description and outline of the database. The database is made up of several region or country specific projects (Table 3 in results section), and species catalogues relevant to those regions or countries. In essence three types of data are collected: a) station data, b) catch data, and c) biological data. Station data includes information relevant to a uniquely numbered sampling station. The information captured is the date, positional coordinates, type of gear used, sampling and bottom depth, duration of a tow, i.e. tow start and end, speed, and tow distance. Each station number has unique catch data linked to it. The catch data informs on type, quantity and weight of species identified in a sample. Species common in an area are stored in a species catalogue, where the full Latin and common name is linked to a species-specific identifier, i.e. species code. It is this species code that is stored in the databases interface when information is entered. Should biological data be collected for a certain species, for instance in the form of length frequencies, sex or weight, a biological sample number is linked to that species code entered under a unique station number in the catch data interface.

For the purpose of this report we extracted station and catch data linked to 18 selected fish families that include mesopelagic species (shown in bold in Table 1). Each project linked to the Benguela region and stored in the database was searched for every species code separately. These species codes are shown in Appendix 4 – 7.

MCM data
The RV Africana is one of four research vessels of the Cape Town based research institute Marine & and Coastal Management (MCM). It has been used since the mid 1980's to conduct pelagic and demersal surveys along the southern African coast. During these surveys, besides the usual station and catch information, various different fish species were identified and data on them recorded. The data is stored in the 'Africana Demersal Data System' and each survey saved as a separate data file. This makes it somewhat cumbersome to extract data, and programming is required to find the desired data. Although species codes exist for most of the species, fish were generally only classified to the family or genus level. A summary of these species and genus codes is provided in Appendix 8 together with the number of stations for every species or genus. Since the Africana surveys usually do not extend beyond the 450 m isobath, and many of the relevant species occur beyond this depth, the data quantity for some of the genera and species is very limited. In addition, the Africana trawl gear does not include a fine mesh cod-end liner, resulting in many small fish escaping through the large meshes and thus even less mesopelagic specimens caught.

The data from the Africana used in this report was kindly provided by Tracey Fairweather from MCM, Cape Town.

2.1.2 NatMIRC data

The bulk of the Namibian research data was collected onboard the RV Welwitchia and the RV Benguela I and II. Data on gobies and mesopelagics was generally not collected systematically during Namibian research surveys and are located in the different research programs at NatMIRC, making it difficult to obtain the data. Table 9 lists various data sources and their possible locations, while some data from recent horse mackerel surveys with the RV Welwitchia received for this report showing catch locations of gobies and mesopelagics is presented in Annex 13.

The overview of the Namibian data used in this report was kindly provided by Angie Kanandjembo from NatMIRC, Swakopmund

3 Overview and Results

3.1 Gobies

3.1.1 Species identity and diversity

According to Fishbase (Froese & Pauly 2005) the family Gobiidae is the largest family of marine fishes in the world with possibly > 2,000 species. Also according to the same source several species have been reported from South African (25), Namibian (6) and Angolan (8) territorial waters. A closer look at the registered data leads one to conclude that some of the reported species in this region must have been misidentified or alternatively that the distributional range has been wrongly reported, and that the actual number of marine goby species in the region is lower. However this report will not address this as it only deals with the *Sufflogobius bibarbatus* (von Bonde 1923). The species is popularly called the pelagic goby or also bearded goby. The name ‘pelagic’ may be misleading since this species, as most other goby species, is primarily demersal but may as other demersal fish species exhibit diel vertical migration behaviour. *S. bibarbatus* is endemic to the Benguela ecosystem and it is abundant throughout the northern Benguela where it plays a key role within this ecosystem (O’Toole 1978; Shannon & Jarre-Teigman 1999). The first record in Namibia has commonly been reported to be the study by Barber and Haedrich (1969) while the species has been known much longer in South Africa (von Bonde 1923). However a scientific reports from the 1920’s found in the NatMIRC library show that the pelagic goby was reported off central Namibia at that time (von Bonde 1928; Bronwen Currie, NatMIRC, pers. com.). The main historic source for information on the gobies in the Benguela ecosystem are publications derived from the extensive monitoring program off Namibia during the 1970’s, namely the South West Africa Pelagic Egg and Larvae Surveys (SWAPELS). Of all the publications from these surveys we wish to draw attention to the works by O’Toole (1976, 1977 and 1978) who offers a comprehensive overview of the early life stages of the goby and its distribution, which this report only give an overview of.

3.1.2 Species distribution

The distributional range of the pelagic goby has been reported by several authors mainly during the late 1970’s and the beginning of the 1980’s. O’Toole (1976) reporting from the SWAPEL surveys in 1972-73 found gobies to be abundant and widely distributed between Hollams Bird Island (24°38’S) and Möwe Point (19°23’S) and up to 85 km offshore. The southern limit was not defined because the survey did not extend south of Hollams Bird Island. The recorded range in South Africa was defined from St. Helena Bay on the west coast to St. Sebastian Bay on the Southeast coast. Cruickshank *et al.* (1980) reviewing the SWAPELS data from October 1978 to June 1979 extended the distribution of gobies in South African waters northwards across the border to Namiba to roughly 28°00’S. The distribution in northern Namibia was extended from Möwe Point to north of Cape Frio (17°40’S), and in the south from Hollams Bird Island (24°38’S) to Lüderitz (26°30’S). (Refer also to O’Toole (1978), Cruickshank (1980), and Le Clus *et al.* (2002)). This extension of the distribution is attributed mainly to increased data sampling, but the authors still reported a gap in the distribution between 26°30’S and 28°00’S. New data collected with the RV Dr. Fridtjof Nansen in the region between 1990 and 2005 extend the distribution reported by the previous authors (Smith 1965; O’Toole

1976 & 1978; Cruikshank *et al.* 1980) further and show that the distribution is continuous between South African and Namibian waters (Figure 2 and 3; Nansen programme unpublished data). The data available show that the *S. bibarbatus* has been found throughout the region from Tiger Bay at 16°50'S in Angola, along the shelf of Namibia to south of 34°00'S in South Africa. The main concentration can be found in the central part of this area from Ambrose Bay to north of Lüderitz in Namibia.

The distribution of *S. bibarbatus* presented in Figure 2 and Figure 3 has been calculated using data from Nan-Sis and the Africana Demersal Data System from the period 1990 – 2005. All trawl catches during the time period have been divided into 20 x 10 nm squares, and the frequency of occurrence calculated and plotted to illustrate the distribution of *S. bibarbatus* in two different ways. Figure 2 takes only presence or absence of gobies in trawl catches into consideration, and gives an overview of the total area of distribution of gobies within the region, represented by the green line. This area mainly corresponds with the shelf area, but with a more narrow distribution along the coast south of Alexander Bay. Figure 3 takes into consideration the relative proportion of gobies in each trawl catch and gives and overview of where the occurrence of gobies in the catches is highest relative to other species. It is evident from Figure 3 that the highest abundance of gobies in the catches is found on the central Namibian shelf (also see Figure 4). It is noteworthy to mention here that the main abundance of gobies corresponds with the diatomaceous mud belt characterised by regular periodic high sulphur concentrations and anoxic water.

O'Toole (1976) suggested that there might be two populations of the pelagic goby in the northern Benguela, based on observations of two different core spawning areas with different peak spawning periods 200-400 nm apart. It was considered unlikely though that the small poor-swimming goby would be able migrate these distances. This hypothesis has recently been strengthened by a genetic study by De Silva (2005) based on the PCR-RFLP analysis of the mitochondrial control region and the ND3/4 region. The study shows that the goby populations from Lüderitz in the south differ genetically from those off Walvis Bay (central) and Ambrose Bay (north). It is assumed that the difference is due to the complex circulation pattern and existing oceanographic barriers around Lüderitz.

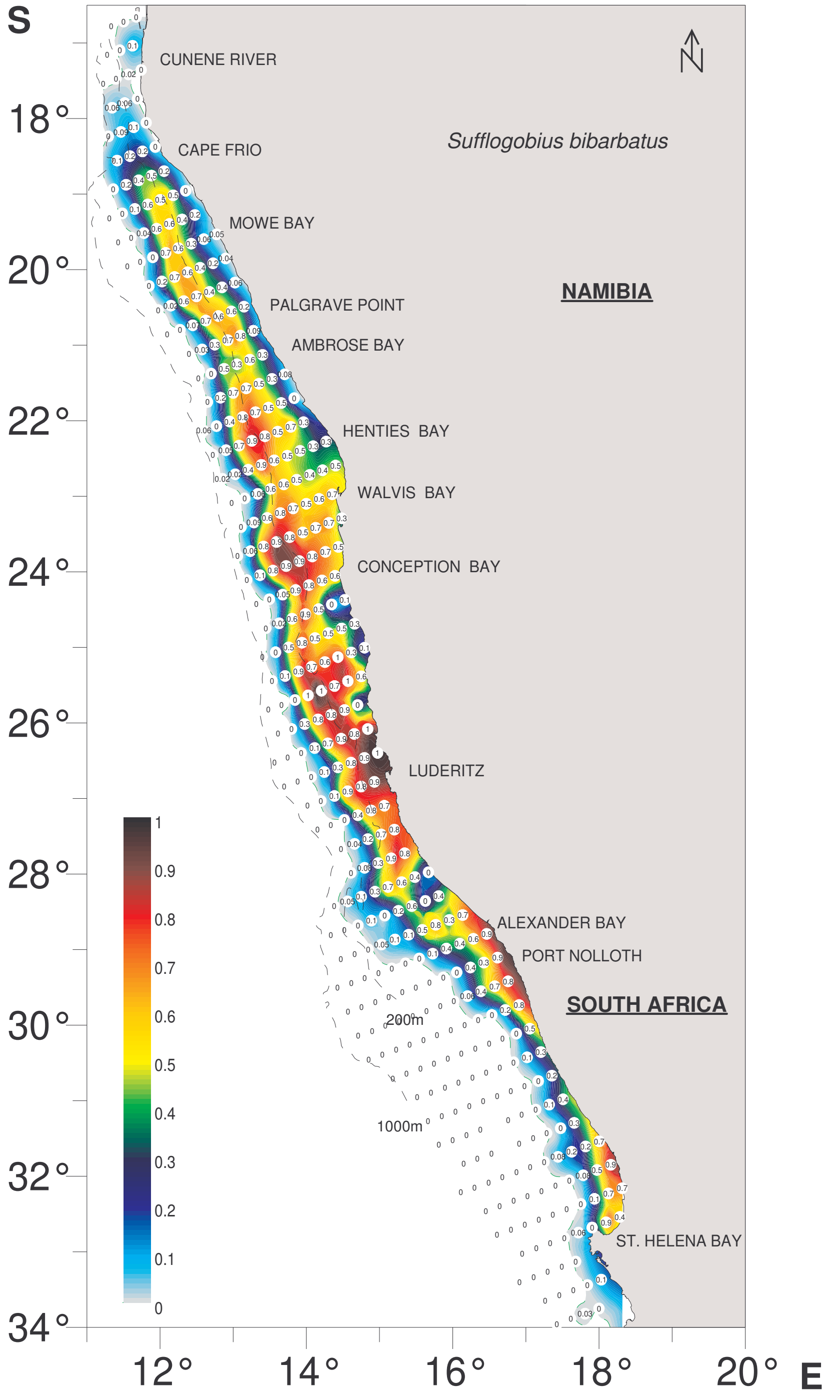

Figure 2: Distribution of *Sufflogobius bibarbatus* in the Benguela. The figure represents a measure of frequency of occurrence from all trawl hauls captured in Nan-Sis and the Africana Demersal Data System. The data was collected on surveys conducted with RV Dr. Fridtjof Nansen between 1990-2005, Namibian commercial vessels used for the hake swept area trawl surveys in the period 2000-2005 and the RV Africana in the period 1985-2004. The green line outlines the maximum distribution area (refer to text for details).

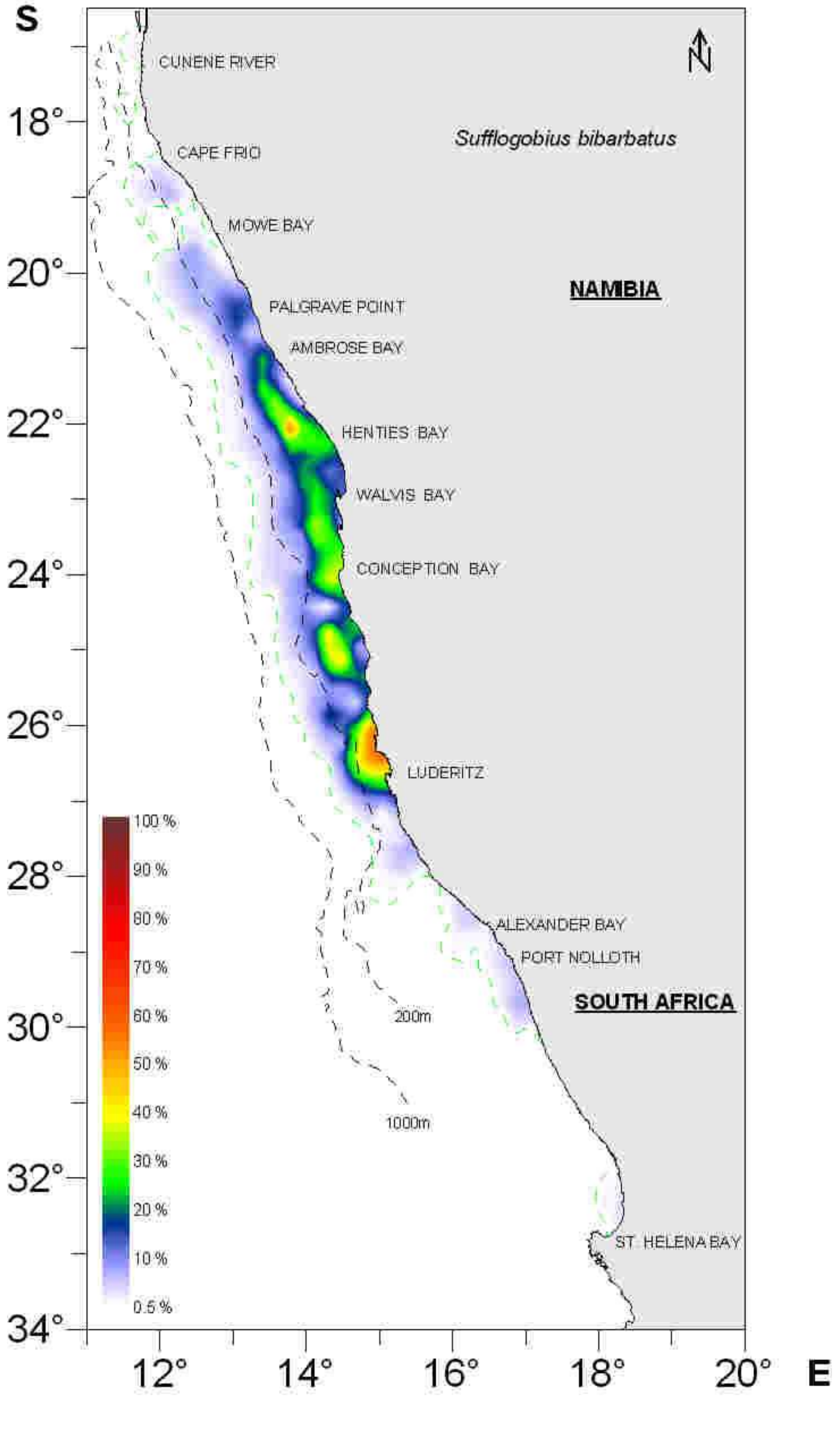

Figure 3: Distribution of *Sufflogobius bibarbatus* in the Benguela. The figure represents a measure of mean relative abundance of gobies from all trawl hauls captured in Nan-Sis and the Africana Demersal Data System. The data was collected on surveys conducted with RV Dr. Fridtjof Nansen between 1990-2005, Namibian commercial vessels used for the hake swept area trawl surveys in the period 2000-2005 and the RV Africana in the period 1985-2004.

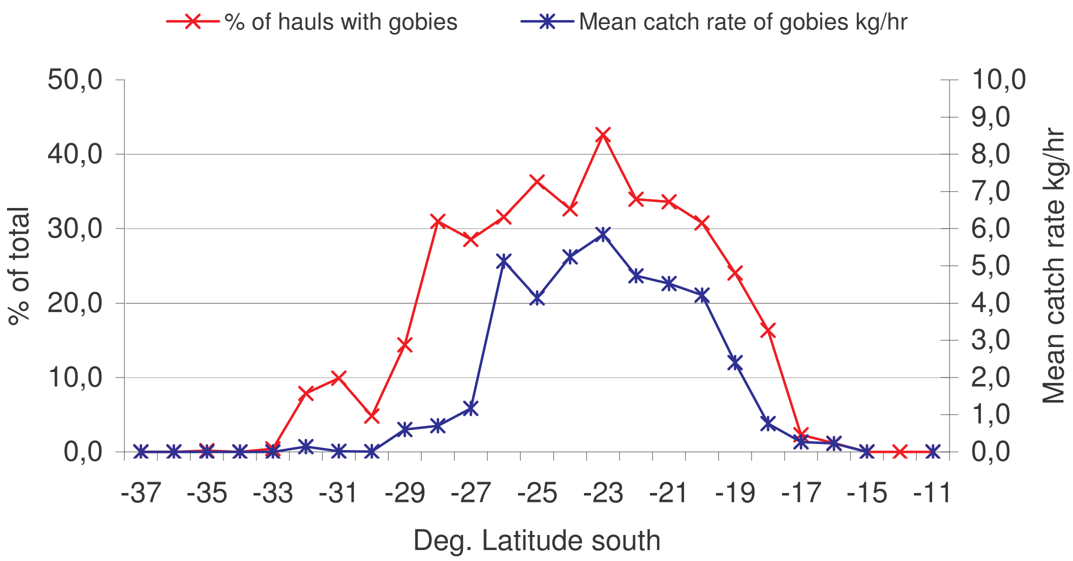

Figure 4: Frequency of trawl hauls and mean catch rate of gobies per latitude - data from all swept area trawl hauls made by the RV Dr. Fridtjof Nansen in the period 1990 to 2005, Namibian commercial vessels used for the hake swept area trawl surveys in the period 2000-2005 and the RV Africana in the period 1985-2004 was combined.

Seasonal

Little information is available on changes in seasonal distribution patterns. However, O'Toole (1976) reported that larvae and early juvenile stages were more widespread in summer than during the winter both offshore and along the coast. O'Toole (1977) did not find any seasonal differences for adult fish. Mecenero (2005) reported that the frequency of gobies in the diet of seals at Cape Cross was highest during the period from August to January, possibly an indication that other food items were less available during that period. At Atlas Wolf Bay and Van Reenen Bay the frequency of gobies in the seal diet was highest in the period February to July, the same period as the upwelling is at a minimum. A clear seasonal difference in fish size was observed, with much larger fish in the seal diet in the period August to January than during January to August. The observed differences reported in this study could either be attributed to real differences in goby behaviour or seasonal differences in the seals foraging pattern.

Distribution Inshore-Offshore

In general all observations indicate that larger gobies are found further offshore and are considered more demersal than smaller specimen (O'Toole 1978; Nansen programme, Unpublished data). According to Le Clus *et al.* (2002) based on data from the SWAPEL surveys in 1978 and 1979, the cross-shelf abundance of young males and females in the pelagic zone peaked 10-15nm offshore and petered out about 35nm from the coast. This distribution is consistent with a two-celled cross-shelf circulation model (Barange & Pillar 1992) whereby pelagic goby, phytoplankton and the euphausiid *Nyctiphanes capensis* are concentrated inshore of the coastal upwelling front. Young gobies occured further offshore during November-April, a period of low upwelling, compared to August-October when upwelling is usually more pronounced. The along-shore abundance of young gobies peaked between 21–22°S and between 23–26°S, concomitant with local peaks in chlorophyll a. Analyses of catch data from the Nan-Sis database showed that the highest catch rates were between 100–200m depth and that the gobies are frequently found at a depth of 300m bottom depth and occasionally to a max depth of 350 m (Figure 5). No catches were reported or registered offshore of 400m depth. It is difficult to establish any distributional limit in the shallow area due to the low number of trawl stations inshore of 50m bottom depth, but gobies are frequently found inshore to 50m depth, with decreasing catch rates inshore of 100 m depth (Figure 5). The distribution becomes shallower in the low-density areas south of Lüderitz (Figure 3).

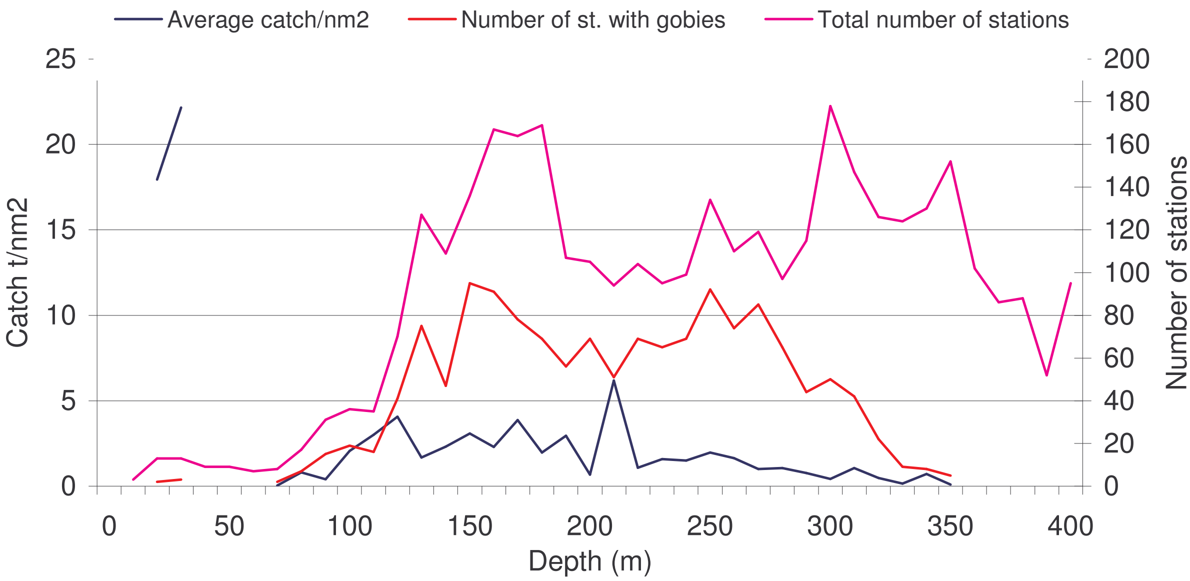

Figure 5: Catches of gobies per depth stratum off Namibia. Catch rates in t/nm^2, number of stations with catches of gobies and total number of trawl stations.

Diurnal

The bearded goby *S. bibarbatus* is a major component of the sound scattering layer over the continental shelf in the northern Benguela region, and its diurnal behaviour has been recorded hydro-acoustically (Le Clus *et al.* 2002; Nansen programme, unpublished data; Salvanes *et al.* 2004). Generally the goby stays closer to the bottom during the day and higher in the water column at night, but variations in this general pattern have been observed. Larger gobies have been reported to exhibit less diurnal migration tendency than smaller ones, and observations where gobies stayed close to the bottom or higher in the water column with no apparent diurnal migration have been made (Salvanes *et al.* 2004; Rengqe 2005; Krakstad *et al.* 2006). Catches of gobies support the general finding that gobies stay in the pelagic zone during the night and near the sea floor during the day

(Le Clus *et al.* 2002; Salvanes *et al.* 2004; Krakstad *et al.* 2006; Nansen programme, unpublished data).

Environmental parameters

The goby is an opportunistic species living in the inner shelf environment of Namibia where large fluctuations in environmental parameters, particularly oxygen, sulphur and temperature, can be observed regularly (Hamukuaya *et al.* 2001). Hamukuaya *et al.* (2001) reported that this inner shelf environment was typically characterised by bottom temperatures between 10-12.5°C, a salinity of 34.8-35.2ppt , and dissolved oxygen <1 ml/l, with all values observed for average bottom depth <200 m. However these are bottom average measurements only and the major part of the goby resource is found in pelagic water masses. O'Toole (1976) reported main concentrations of adult gobies in water masses with temperatures from 14.5°C to 17,5°C, and juveniles in water masses from11-15°C. More recently several surveys focusing on the behaviour and tolerance of gobies to environmental parameters have been undertaken. During a survey in 2003 off Namibia, gobies tended to be associated with depths of low oxygen concentrations. Trawls often gave high catches in oxygen concentrations of 0.2-1.0 ml/l (Salvanes *et al.* 2004). Adults tended to be present at lower oxygen concentrations as well as deeper than juveniles.

Shipboard experiments conducted during 2003 off Namibia indicated that gobies are exceptionally tolerant to anoxic and sulphuric water. Recovery following exposure to total anoxia and concentrations of up to 100umol$\cdot$l^{-1} of sulphide indicated some specialized physiological adaptation - there were no indications in the behaviour of the goby of an escape strategy (Salvanes *et al.* 2004). During the experiments onboard Dr. Fridtjof Nansen in 2006, adult gobies showed a remarkably high tolerance to low concentrations of dissolved oxygen. Their response to decreasing oxygen levels was an intermediate increase in the gill ventilation volume and frequency at ca 0.2ml DO/l (called critical oxygen level) followed by a sudden drop in the gill beat frequency (<0.2mlDO/l). The critical oxygen level is the oxygen level at which fish shift from aerobic to anaerobic metabolism. The gobies tolerated 4.5 hours at oxygen levels of < 0.01ml DO/l without showing signs of equilibrium loss. When oxygen levels increased after having been under oxygen stress for up to 9 hours the gobies recovered rapidly to normal breathing and behaviour. When the fish were "attacked" (poked by a stick) after having been in < 0.01ml DO/l for 4.5 hours, they responded immediately with an escape response, implying that their brain was 'turned on' also after a long time of anaerobic metabolism (Krakstad *et al.* 2006). These observations probably illustrate rather typical values. It has been suggested that gobies may be using oxygen from their inflated swim bladder (O'Toole 1976) while they are passively hiding from predators in oxygen poor layers during the day, and that they migrate to the surface at night partly to refill this supply of oxygen.

3.1.3 Biology

The goby has generally been recorded on soft bottom communities. Goosen *et al.* (2000) analysed videotapes taken from the research submersible Jago operating off the Orange River Mouth in 1996 and 1997. They found that nekton communities on soft sediments were dominated by *S. bibarbatus*, together with juvenile hake, cuttlefish, false jacopever, and kingklip. It has been suggested that the distribution roughly overlays the diatomaceous mud belt off Namibia, and more recently that this also coincided with the main distribution area for gelatinous zooplankton (Jellyfish) in the region (Krakstad *et al.* 2006).

Observations of the goby *in situ* and in aquaria showed that it is a poor swimmer and may remain relatively inactive over long periods (O'Toole 1976; Goosen *et al.* 2000; Salvanes *et al.* 2004; Krakstad *et al.* 2006). The colouration and pigmentation has been described by O'Toole (1976), and the species is able to change coloration (darker-lighter) according to the substrate (pers com A.C. Palm, University of Bergen).

3.1.4 Ecology

According to Crawford *et al*. (1987) Barber and Haedrich (1969) found phytoplankton of the genus *Delphineis* (=*Fragilaria*) *karstenii* and *Coscinodiscus* spp. to dominate the diet of juvenile gobies, while Ryther (1969, as referred to by Crawford *et al.* 1987) also drew attention to the importance of the large, chain forming *Delphineis* in the food of gobies. O'Toole (1978) found that the diet of adults, juveniles, and larvae consisted predominantly of *Delphineis* and *Chaetoceros*, although he also observed remains of copepods and euphausiids. However D'Arcangues (1976) in her study found mainly copepods and euphausiids in the stomachs of the juvenile and adult gobies. Crawford *et al.* (1987) found that in 1979-1981 gobies contained numerically 93% phytoplankton (mostly diatoms) and 7% zooplankton. Zooplankton was present in 80% of the stomachs examined and phytoplankton in 90%. *Delphineis karslenii* was the most abundant phytoplankton species, with *Chaetoceros* and *Coscinodiscus* spp. also eaten, and euphausiids and copepods were the dominant zooplankton groups (Crawford *et al.* 1985). Similarity between the diet of gobies and of adult pilchard was noted by Crawford *el al.* (1985), who considered it likely that in the intense perennial upwelling system situated between 22°S and 27°S gobies partially replaced pilchards during the 1970s. A new study on the diet of gobies in the northern Bengula, also comparing between depth and the type of prey found in stomachs, is underway. The gobies collected for this study were mainly collected with a bottom trawl. Preliminary results show that small crustaceans (mostly euphausiids) dominate the diet at depths less than 200 m, while polychaetes dominate the stomach content of fish caught at greater depths. This study also indicates that gobies feed throughout the day, with a probable peak in feeding at early morning and early evening. Although fish of all sizes fed on similar prey, larger fish appeared to feed on larger quantities and larger individuals of prey (Vaarland *et al.* 2002; M. Gibbons, University of Western Cape, pers. com.). Preliminary result from the goby surveys in 2004 and 2006 (Salvanes *et al.* 2004; Krakstad *et al.* 2006) showed the presence of crustaceans, mainly copepods and amphipods, polychaeta, fish larvae, including own larvae and bottom sediment - mainly dead diatoms and sulphur bacteria. The information available suggests that *S. bibarbatus* is an opportunistic feeder that takes what it is presented with. Sulphur bacteria have not before been registered in goby stomachs.

Crawford *et al.* (1987) give a summary of the major predators of the bearded goby. During the 1970s and early 1980s pelagic gobies were a major food item for many species off Namibia, including cape horse mackerel (*Trachurus trachurus capensis*; Venter 1976), cape hakes (*Merluccius* capensis; Chlapowski 1977; Assorov & Kalimna 1979; Prenski 1980; Andronov 1983; Konchina 1986), kingklip (*Genypterus capensis*; Macpherson 1983), monk (*Lophius vomerinus*; Macpherson 1985), large-eye dentex (*Dentex macrophthalmus*; Kuderskaya 1985), west coast sole (*Austroglossus microlepis*; A. Badenhorst, pers. com.), some coastal-breeding seabirds, and the cape fur seal (*Arctocephalus pusillus pusillus*; Crawford *et al.* 1985). Not exploited commercially to any great extent, the pelagic goby must therefore be of considerable importance in the northern Benguela ecosystem.

3.1.5 Growth parameters

A combined length-weight relationship for both goby sexes has been published by a) Cruickshank *et al*. (1980), while Melo and Le Clus (2005) published age-weight relationships for each sex separately, b) observing that the growth rate in males is faster than females. More details on the measurements can be found in the respective publications.

a)		$W = 0.0143L_c^{3.0543}$	$R^2 = 0.97$	N = 200
b_1)	Males	$W = 1.105e^{0.4838x}$	$R^2 = 0.7427$	N = 72, excl. back calc.
b_2)	Females	$W = 1.363e^{0.3448x}$	$R^2 = 0.5194$	N = 40, excl. back calc.

Where: W = Weight measured to the nearest 0.1 grams
L_c = Caudal length measured to the nearest millimetre below
x = Number of hyaline zones

S. bibarbatus can attain a length of 13 cm (Hoese 1991) and an age of 6 years (Melo & Le Clus 2005). Mecenero *et al.* (*in press*) report on remnants of gobies with 17 cm in length, based on back calculated length estimates from otholits found in seal scats caught at the Atlas-Wolf Bay south of Lüderitz. Unpublished data collected during hake abundance surveys off Namibia with the RV Dr. Fridtjof Nansen also shows gobies of this size, with two records in the database showing gobies with a total length of 20 and 21cm.

3.1.6 Reproduction

The main spawning season for pelagic goby has been reported to be from July to February, with a peak in late winter to early spring (O'Toole 1977). Spawning has been reported to be most intense in costal waters south of Walvis Bay, but with less intense spawning over a more extended area during summer (O'Toole 1977).

The reproduction of *S. bibarbatus* as reported by Melo and Le Clus (2005) suggests a late maturation at 2-3 years of age, and males maturing at a greater size and age than females. They observed that two batches of yolked oocytes were present in the ovaries during their study and that the maximum gonadosomatic index was 14.3%. Batch fecundity was significantly correlated with standard length, $R^2 = 0.88$, and ovary-free body weight, $R^2 = 0.92$. Fecundity ranged from about 2 000 eggs in females 5.0-5.5cm long to about 10 000 eggs in a female 9.8cm long. The mean fecundity was 842 ±189 eggs per gram of ovary-free body weight. Melo and Le Clus (2005) suggest that the pelagic goby may be a serial batch spawner, based on the extended spawning season from July to April, and the presence of more than one batch of yolked oocytes in the ovaries.

The SWAPEL surveys in the 1970's investigated the presence of egg and larvae in the upper part of the water column <50 m depth. While goby larvae were common in pelagic plankton net hauls and pelagic trawl hauls goby eggs were never reported (O'Toole 1977). It was therefore suggested that the pelagic goby has demersal eggs like several other goby species around the world. This however has still not been verified.

The larval morphology, pigmentation and development has been described in details and the reader is referred to O'Toole (1976, 1977) for a comprehensive overview.

3.1.7 Abundance

Little information on biomass is available from the literature on the abundance of *S. bibarbatus*. Circumstantial evidence from diet studies of the cape gannet (*Morus capensis*), jackass penguin (*Spheniscus demersus*) and the cape comorant (*Phalacrocorax capensis*) during 1957-58 and in 1980 suggests that the goby resource was relatively low in the period of the first study (Crawford *et al.* 1985), since gobies were not present in the diet of these bird species in 1957-58, but frequent in 1980. Also, according to Crawford *et al.* (1985) gobies were not registered in Purse seine catches before 1972. Observations from plankton surveys in the 1960's off Namibia did not register gobies while the species had become abundant during the SWAPEL surveys in 1972-1973 and 1978-1979 (O'Toole 1976, 1978). However, reports from scientific surveys from the 1920's found in the NatMIRC library show that the goby was found off central Namibia in the same areas as they occur in these days. No quantitative information was given but the number of stations where gobies were present indicates that it was common in that period (B. Currie, NatMIRC, pers. com). Generally two published biomass estimates exists. Hewitson and Cruickshank (1993) estimated a biomass of 600 000mt based on data from bongo net hauls during the SWAPEL surveys in 1978-79. The initial biomass of the surveyed fish was calculated to be 150 000mt (based on data from the upper 50 m), but the total biomass was assumed to be four times larger. A raising factor of 4 based on several considerations was summarized to the effect that the rest of the water column and the bottom layer contained higher densities of fish than the surface layer. A further estimate of abundance was presented by Shannon and Jarre-Teichmann (1999). Based on the results of an ECOPATH model they present an estimated average biomass of $1.45 \cdot 10^6$mt for the northern Benguela during the 1980's.

Recent estimates of demersal goby abundace based on day time trawl data from swept area bottom trawl surveys conducted with the Dr. Fridtjof Nansen suggest that the demersal component could have been in the range of 10 000 - 100 000mt during the 1990's, increasing in the last part of the period until 2005 (Figure 6; Nansen Programme, unpublished data). **Note** that the demersal surveys did not cover the full distributional range of the gobys and also that no estimate of the pelagic component was made. The estimates are therefore lower than the actual abundance and should be treated as an index only. The pelagic component is possibly the larger part of the resource, although two dedicated goby surveys in 2004 and 2006 (Salvanes *et al.* 2004; Krakstad *et al.* 2006) focusing on the goby's diel vertical migration indicated that the pelagic component may be smaller than previously assumed. However, applying similar assumptions to the Hewitson and Cruickshank (1993) estimate, the pelagic component may be between 3 and 5 times that of the demersal component. From these results it seems that the estimate from the ECOPATH results for the 1980's is unrealistically high and does not represent the situation during the 1990's. Also, during the 1990's the pelagic purse seine industry in Namibia has been in an almost constant crisis with decreasing catches of all clupeid species. Despite this and the fact that the pelagic goby is slow moving and distributed over a well-defined area, only sporadic catches of this species occurred in the landing statistics, suggesting that the species might be less abundant than often believed.

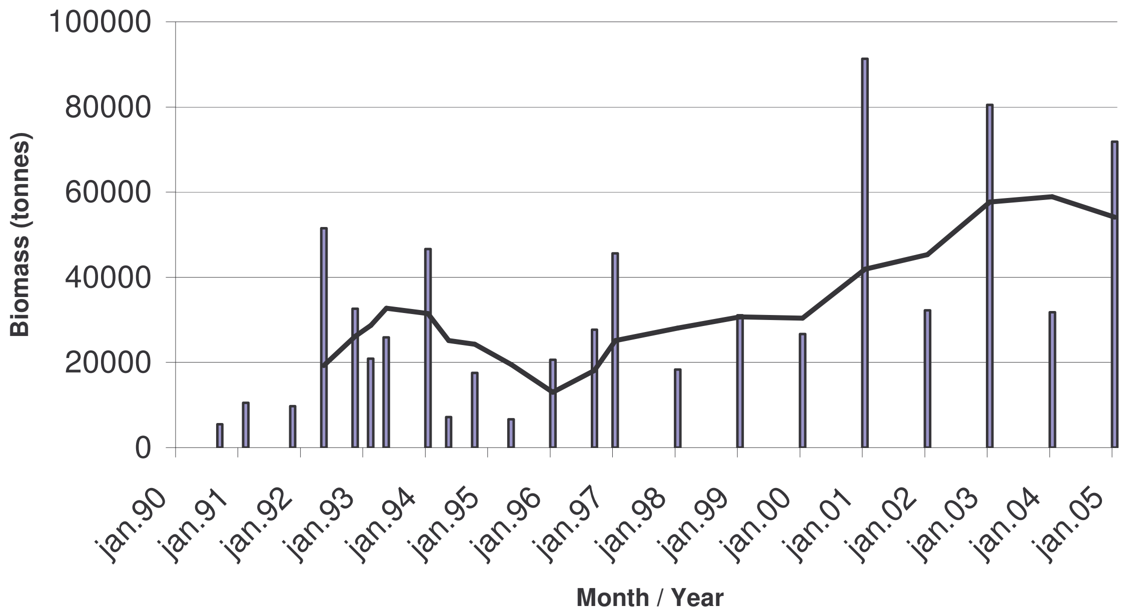

Figure 6: Abundance of *Sufflogobius bibarbatus* calculated from the swept area trawl surveys conducted in Namibia from 1990 until present. The figure only represents the biomass of gobies that stayed on the bottom during the survey period (during day time). Also the surveys did not cover the full distributional range of the goby resource. **Therefor these estimates should be treated as an index only**.

3.1.8 Catch history

The *S. bibarbatus* has never been targeted commercially in Namibia or South Africa. Bycatch of the species occurs both in the pelagic fishery, the midwater fishery and the demersal fishery, but the mesh size regulation enforced on the midwater and demersal fisheries probably prevent any large catches in the fishery being made. Also, infrequent low catches of low value small sized fish are probably either dumped or made into fishmeal, thus catches from these fisheries have only rarely been reported. The purse seine fishery operates with a finer (sardine, or anchovy) net mesh, and irregular records of gobies are registered in that fishery. Annex 14 gives yearly catches of gobies in Namibia and South Africa as reported by the FAO (www.fao.org/fi). The catches vary substantially from year to year but are generally very low. Average catches of 216 tons/year are reported in Shannon and Jarre-Teichmann (1999), but no information on where this information comes from.

3.2 Mesopelagics

3.2.1 Species identity and diversity

Mesopelagic fish have a worldwide distribution, oceanic as well as pseudo oceanic, and encompass more than thirty fish families (Gjøsæter & Kawaguchi 1980; Nelson 1994). The taxonomic arrangement and naming of some of the families listed in Table 1 might differ between various classification systems. For instance, in FishBase (Froese and Pauly 2005) the families Chauliodontidae, Astronesthidae, Idiacanthidae, Malacosteidae, and Melanostomatidae are listed as subfamilies of the family Stomiidae.

Table 1: Families of mesopelagic fish with corresponding numbers of genera. Families shown in bold were searched for in the Nan-Sis database.

Order	Family	Common name	FishBase 2005	Gjøsæter & Kawaguchi 1980	Smith & Heemstra 1991
Anguilliformes	**Nemichthyidae**	snipe eels	3	5	2
Argentiformes	**Argentinidae**	argentines	2	2	4
	Ophistoproctidae	barreleyes	6	4	3
	Bathylagidae	deep-sea smelts	1	2	1
	Platytroctidae	tubeshoulders	13		6
Stomiiformes	**Stomiidae**	scaly dragonfish	27	2	2
	Chauliodontidae	viperfishes	*	1	1
	Astronesthidae	snaggletooths	*	6	3
	Idiacanthidae	sawtail fishes	*	1	1
	Malacosteidae	loosejaws	*	4	3
	Phosichthyidae	lightfishes	7		7
	Gonostomatidae	bristlemouths	7	20	6
	Sternoptychidae	hatchetfishes	10	3	5
	Melanostomatidae	scaleless dragonfish	*	15	10
Aulopiformes	**Scopelarchidae**	pearleyes	4	5	4
	Giganturidae	telescopefish	2	2	1
	Omosudidae	omosudids	1	1	1
	Anotopteridae	daggertooths	1	1	1
	Alepisauridae	lancetfishes	1	1	1
	Paralepididae	barracudinas	12	5	7
	Notosudidae	notosudids	3		3
	Evermannellidae	sabretoothed fishes	3	3	2
Myctophiformes	**Myctophidae**	lanternfishes	32	30	28
	Neoscopelidae	blackchins	3		2
Lampriformes	Trachypteridae	ribbonfishes	3	3	3
	Lophotidae	crestfishes	2	2	2
	Regalecidae	oarfishes	2	2	2
Beryciformes	Anoplogasteridae	flashlight fish	1	2	1
	Melamphaidae	bigscale fish	5	2	5
Perciformes	Gobiidae	gobies	212		
	Chiasmodontidae	swallowers	4	5	3
	Gempylidae	Snake mackerels	16	20	15
	Trichiuridae	frostfishes	9	8	5
	Centrolophidae	medusafishes	7	1	1
	Tetragonuridae	squaretails	1	1	1

The most specious families are the Stomiidae, Myctophidae and Sternoptychidae (Nelson 1994), with 279, 247, and 71 species listed respectively (FishBase 2005). In terms of genera per family the Gonostomatidae, Melanostomatidae, Myctophidae, and Gempylidae are the most diverse (Gjøsæter & Kawaguchi 1980; Table 1). The numbers of genera listed in Table 1 under Smith and Heemstra (1991) are those found in southern African waters and differ to those listed under FishBase (2005) and Gjøsæter & Kawaguchi (1980). For an overview of the various families and their corresponding genera occurring in southern African waters, Smith and Heemstra (1991) provide detailed descriptions of each family and its species, while additional information for some of these species can be found in FishBase (2005). Picture plates of some selected mesopelagic species are shown in Annex 1-3.

3.2.2 Species distribution

In the northern Benguela region off the Namibian coast Rubis (1985) reported on a total of 41 myctophid species. Of these, twenty-five originated solely from the 400 mile offshore Valdivia Bank on the Walvis Ridge, ten were specific to the northern Benguela area, and six common in both areas (Rubies 1985). Two species belonging to the oceanic lanternfish genus *Symbolophorus* and the pseudo oceanic warm-water genus *Diaphus* were also common off the coast of Namibia (Prosch *et al.* 1995). Of the 14 species of sternoptychids (hatchet fishes) found in South African waters, 11 have been recorded in the eastern south Atlantic (Prosch *et al.* 1995).

Hulley (1991) gives a general account of 28 genera, comprising 125 species, of myctophids likely to be found in the southern African region. This account covers the detailed description by Hulley (1986) of the distribution of myctophids occurring in the southern Benguela. This study describes 65 species in 23 genera in the area between $28^0$40'S and $40^0$00'S, and lists 61 oceanic myctophid species, describing their distribution patterns according to Hulley (1981).

Geographic (horizontal)

The most frequently described lanternfish is *Lampanyctodes hectoris,* also the most prominent pseudo oceanic myctophid species described for the Benguela region (Hulley 1986; Hulley and Lutjeharms 1989; Hulley 1992). Pseudo oceanic species generally inhabit the pelagic and mesopelagic zone over the continental shelf and slope, and are associated with land environments and land orientated food chains (Hulley 1986). In the northern Benguela *L. hectoris* has been reported on the outer shelf edge more than 30 miles offshore as well as just 5 miles off the Lüderitz coast (Cruickshank 1982). O'Toole (1976) also provided distribution maps of several myctophid species caught in bongo nets in the northern Benguela between Hollams Bird Island and Cape Frio. According to his findings the majority of *L. hectoris* were found 30 – 112km offshore, but also close inshore (at 28m bottom depth) south of Walvis Bay. Other myctophids like *Symbolophorus boobs* and several *Diaphus* species were found 30–112km offshore between 18^0S and 25^0S (O'Toole 1976).

In the southern Benguela data collected onboard the RV Africana in 1988 showed that *S. boobs* occurred far offshore in waters deeper than 500m, while *Diaphus hudsoni* was caught mainly deeper than 300m (Augustyn 1988). Hulley & Lutjeharms (1989), based on catch data collected between 25^{0}30'S and 34^{0}55'S, grouped the lanternfish into two groups, which were correlated to bottom depth. Inshore of the 800m isobath, *L. hectoris* was the dominant species, while the 'off-shore' group included the oceanic species *C. warmingii*, *D. hudsoni*, *D. meadi*. A study on the genetic variation of the *L. hectoris* from 4 locations along the South African west coast showed little genetic differences, suggesting a genetically homogenous population (Florence *et al.* 2002). In addition, seasonal spawning populations of these fish seem to be confined to the continental slopes (Prosch *et al.*1995).

Off southern Africa the occurrence of the hatchet fish *Maurolicus muelleri* is generally confined to an area east of the thermal front, which is characterized by the upwelling of water along the west coast (Prosch *et al.* 1995). They occur in Angolan waters and their distribution extends all along the west coast to Cape Point in South Africa. Within this area, their distribution is patchy with marked seasonal differences. A detailed account of the distribution of *M. muelleri* in the southern Benguela is given by Armstrong & Prosch (1991). This species, classified as a shelf resident, was recorded up to 100nm offshore, with the highest densities observed between the 100 and 500m depth contours. Augustyn and Hulley (1988) reported that few hatchetfish were caught beyond the 500 m isobath. In the northern Benguela this species has been recorded in bongo net catches between 43 and 112km offshore, at bottom depths ranging from 140 to 670m (O'Toole, 1976).The scaly dragon fish *Stomias boa boa* (Stomiidae) was found far offshore in the northern Benguela. The maximum bottom depth of the stations where this species was sampled in the upper 50m during night hours was 3000m (O'Toole, 1976).

Diurnal and vertical distribution

Mesopelagic fish perform diel vertical migrations to upper water layers mostly in search of food. Some species only partially migrate during night hours (semi migrant species), while some species are non-migrant (Watanabe 1999; Williams 2001). Even within a species, this behaviour may vary depending on season, sex and age (Prosch *et al.* 1995).

Huse *et al.* (1998) described the diurnal vertical distribution of some lanternfish species in the northern Benguela off Namibia. They observed four vertically migrating mesopelagic layers at night, dominated by the myctophid species *L. hectoris* and *S. boobs*. The hatchetfish *M. muelleri* was observed in all four mesopelagic layers and progressively increased in size with increasing depth. Larger *L. hectoris* and *S. boobs* were found in the top layer than in the second layer, but then increased in size with increasing depth (Huse *et al.* 1998). Size stratification with depth is also exhibited by some lanternfish in the southern Benguela (Hulley 1991).

Hulley & Prosch (1987) described *L. hectoris'* and *M. muelleris'* vertical distribution in the southern Benguela, based on commercial catch data as well as research data. Highest catch rates of *L. hectoris* were in the 101-200m and 201-300m depth ranges, while highest catch rates in the 0-100m fishing depth were observed inside the 100m isobath, suggesting an inshore (lateral vector) to the vertical migration (Hulley & Prosch 1987). Based on data from 1988, Huley (1992) described the vertical distribution of 51 lanternfish fish species in the Cape Canyon and the Cape Point valley. He observed an increase in species diversity with depth and simultaneously a decrease in catch rates. His findings confirmed that *L .hectoris* was the dominant species at 300 m bottom depth, and that the subantartic species dominated catches at deeper depths. Armstrong and Prosch (1991) reported on the diel vertical migration behaviour of the lightfish *M. muelleri.* In the southern Benguela this species ascends during the afternoon in dense schools. These dense schools disperse into a diffuse scattering layer in the mid to upper water column during darkness, and at dawn rise to the surface. Before sunrise these layers fish descend in a narrow layer at a rate of $0.03 m \cdot s^{-1}$.

Seasonal

Information on seasonal influences on the distribution of mesopelagic fish is very limited, and no dedicated studies on the effects of environmental factors on the distribution of mesopelagic fish have been done. Many authors have shown though, that the oceanic distribution of lanternfish in particular can be related to physical, chemical, and biological characteristics of the water column (see references in Hulley 1992).

The little information that is available from the Benguela is not surprisingly on *L. hectoris.* This species displayed a seasonal migratory behaviour, moving farther offshore during low-level upwelling winter months in order to spawn (Hulley & Lutjeharms 1989). Mean catch rates during summer between 100 and 300m depth ranged from 4.9 to 5.6 specimens/hour, while in winter daily catch rates ranged from 73.6 to 153.9 specimens/hour (Hulley 1986). Additionally during summer months this species occurred mainly inshore of the 300 m isobath, with an offshore limit at 500 m bottom depth. In winter months this off shore limit extended to the 1000 m isobath. It is suggested that in the southern Benguela, this distribution pattern is governed by frontal dynamics, which influence the food availability during the different seasons. Such a seasonal distribution pattern does not seem to apply to the oceanic myctophids (Hulley & Lutjeharms 1989).

Environmental parameters

Migrant mesopelagic species are described as eurythermal, occupying different temperature ranges during the day and night habitat. Most non-migrants on the other hand occupy a more temperature stable environment (Watanabe 1999). In the Northwest Pacific mesopelagic species show a specific zoogeographical affinity, also associated with hydrographic structures (Moku 2000).

Hulley (1992) found that in the southern Benguela, where the horizontal and vertical temperature structuring of the water column was noticeable, the distribution of oceanic lanternfish was limited by the 300 m isobath. He further pointed out that temperatures and bottom depths correlated with the down slope distribution of fish species. Armstrong and Prosch (1991) report that while performing diel vertical migrations, *M. muelleri* experiences temperature differences of 10^0C, and that the horizontal distribution of *M. muelleri* was not related to the temperature structure during two surveys done in the southern Benguela in the 80's. Cruickshank (1982) reports that *L. hectoris* occurred in waters with surface temperature of 10^0 to 25^0C, while Hulley and Lutjeharms (1989) found only little correlation between relative abundance of *L. hectoris* and temperature, with a tendency though of greater abundances found in waters with a sea-surface temperature of less than 16,4^{0}C. Ahlstrom *et al.* (1976) reported that more than 60% of *L. hectoris* larvae occurred where sea surface temperatures ranged between 14 ^{0}C and 15,5 ^{0}C .

3.2.3 Biology

Mesopelagic fish are generally small, mostly <30 cm. Many have large, sensitive eyes and well-developed ventral and dorsal light organs that emit light in the visible spectrum (Salvanes & Kristoffersen 2001; Smith & Heemstra 1991). Deep living fish have reduced metabolic rates, low oxygen consumption and probably reduced swimming activity. On the other hand migrating species have well developed muscles and gills, as well as large hearts and usually swim bladders (Salvanes & Kristoffersen 2001). Some fish, like the *L. hectoris*, build up lipid reserves during summer months, when food availability is high, to use these reserves during the winter spawning months (Hulley & Lutjeharms 1989).

In the southern Benguela sex ratios of *M. muelleri* and *L. hectoris* were female biased (Centurier-Harris 1974; Prosch 1991). Females migrating closer to the surface than males during darkness as well as a sampling bias might explain the skewed ratio observed in numbers of males and females observed (Hulley & Prosch 1987). Young *et al.* (1987) also observed female biased sex ratios among *L. hectoris* off Tasmania, and suggested a spatial segregation of the sexes as a possible reason. Other factors such as species size and depth distribution can account for observed biased sex ratios (Young *at al.* 1987). Crawford (1980) also reports on female biased sex ratios in commercial landings of *L. hectoris,* and explains this with the fact that most catches were taken from January to April, outside the main spawning season. This also suggests that there is some connection between the sexual cycle and the pattern of distribution (Centurier-Harris 1974).

3.2.4 Ecology

As already mentioned many species migrate to the epipelagic zone at night in order to feed on the abundant zooplankton of the surface waters, while others migrate only partially or not at all (Hulley 1991; Smith & Heemstra 1991), feeding on zooplankton like copepods, amphipods, euphausiids and fish (Oven 1990; Hopkins *et al.* 1996; Prosch *et al.* 1995; Williams 2001; Watanabe 2002; Young & Blaber 1986). Feeding habits of the four most common myctophid species found in the western North Pacific suggest resource partitioning (Watanabe 2002). The fish species investigated migrated to the upper 1m layer, and respectively fed mainly on euphausiids, amphipods, appendicularians, and pteropods, which are all zooplankton species (Watanabe 2002). Similarly, members of the lanternfish in the southwest Atlantic primarily feed on copepods, amphipods, and euphausiids (Oven 1990). An investigation into the feeding behaviour of myctophid and stomiiform fishes from the western North Pacific and off southern Tasmania, showed non-migratory species feeding mainly on a single prey item, while migratory species had a diel feeding pattern, feeding on different species during night and day respectively (Moku 2000; Williams 2001). Also, while some species fed throughout the diel cycle, others showed changes in the state of stomach fullness or so called feeding periodicity, depending on the time of day. The feeding strategies of the investigated species suggest a trade off between high and low energy demands of their respective life styles (Moku 2000).

Hulley (1991) described the lanternfish as opportunistic feeders, preying on small crustaceans, fish eggs, and fish larvae. In the southern Benguela *L. hectoris* preyed on a range of crustaceans such as copepods (61.6%), amphipods (26.6%) and euphausiids (11.6%) (Prosch *et al.* 1995; unpublished data in Prosch 1986). Hewitson and Cruickshank (1993) estimated the consumption of meso - and macro zooplankton by lanternfish in the northern Benguela at $1.65 \cdot 10^6$ tons. They used a 40:60 proportion of meso- to macroplankton in the diet composition of lanternfish to estimate the total annual consumption of zooplankton.

Mesopelagic fish are an important food source for fish such as the cape hake and deep-sea hake (Assorov 1979; Huse 1998; Payne *et al.* 1987; Pillar & Barange 1997; Punt 1992; Traut 1996), horse mackerel (Andronov 1983; Konchina 1986), snoek (Nepgen 1979), orange roughy (Rosecchi 1988), various squaloid sharks (Ebert 1992), cephalopods (Jackson, 1998; Villanueva 1993), seals (David 1987), various bird species (Jackson 1988), and several cetaceans (Prosch *et al.* 1995).

Punt *et al.* (1992) estimated that in the southern Benguela, based on data from 1988 and 1990, hakes consumed an estimated 84 000 and 312 000 tons of myctophids annually. When considering the estimated consumption of Stomiiformes and Aulopiformes as well the total consumption of mesopelagic species increases to between 140 000 and 565 000 tons. These numbers suggest that mesopelagic fish are an abundant and an important prey source in the Benguela region. According to Shannon and Jarre-Teichmann (1999) about $1.7 \cdot 10^6$ tons of mesopelagic fish (lanternfish and lightfish) are required among others to support predators such as hakes of the northern Benguela region. ·

3.2.5 Life history

Table 2 gives an overview of various life history parameters of selected mesopelagic families, showing ranges instead of single values for most parameters mentioned. It becomes apparent that parameters such as maximum length, length infinity, growth parameters, age at maturity etc. are highly variable within and between families. Making generalizations based on this table would be difficult. Therefore the information will not be discussed in detail in the following paragraphs, but merely referred to where applicable.

Gartner (1993) reported average lifespans of 300 and 375 days for two lanternfish found in the Gulf of Mexico, while an ageing study of the most abundant lanternfish in the southern oceans, *Electrona antarcticus*, suggested a maximum life span of 3.5 years (Greely 1999). This is fairly short compared to some life spans shown in Table 2. Species belonging to the Bathylagidae and Argentinidae can grow to be older than 20 years, while myctophid species' longevity is 0.7 – 20.2 years. Some species living at higher latitudes

Table 2: Life history data of some selected mesopelagic families. The information shown is a summary of data obtained from referenced literature listed in FishBase (2005, www.fishbase.org). The references shown for each family do not contain the data listed in the table, but instead refer to chapters in Smith and Heemstra (1991) with information on the specific family.

Family	L_{max} (cm)	L∞	K	t_0	M	Tm	A_m	Reference
Nemichthyidae	55 – 160.7	57.1 – 164	0.19 – 0.51	-1.15 – -0.27	0.21 – 0.61	5.6 – 15.2	1.3 – 3.6	Castle 1991; Nelson 1994
Argentinidae	7 – 70	7.5 – 52.5	0.12 – 1.22	-1.22 – -0.19	0.19 – 1.98	2.3 – 23.6	0.8 – 5.6	Cohen 1991a
Bathylagidae	9.3 – 26.6	9.9 – 27.9	0.11 – 0.31	-2.21 – -0.69	0.24 – 0.59	9.0 – 25.7	2.7 – 6.8	Cohen 1991b; Gon 1990
Platytroctidae	9.3 – 33	9.9 – 35	0.75 – 2.36	-0.37 – -0.09	0.88 – 2.68	1.2 – 3.8	0.4 – 1.2	Matsui 1991
Stomiidae								Gibbs 1991a
Chauliodontidae*								Gibbs 1991b
Astronesthidae*								Gibbs 1991c
Idiacanthidae*	2.5 – 53	2.7 – 55.1	0.15 – 2.46	-1.6 – -0.12	0.27 – 1.71	1.1 – 19	0.4 – 4.4	Gibbs 1991d
Malacosteidae*								Goodyear & Gibbs 1991
Melanostomatidae*								Gibbs 19912
Photichthyidae	4 – 30	4.3 – 34.5	1.01 – 7.11	-0.39 – -0.04	1.37 – 6.15	0.4 – 2.8	0.2 – 1.6	Schaefer *et al.* 1991
Gonostomatidae	2 – 36	2.2 – 37.6	0.17 – 1.98	-2.0 – -0.14	0.42 – 3.21	1.4 – 16.7	0.5 – 6.1	Schaefer *et al.* 1991
Sternoptychidae	2 – 14	2.1 – 14.9	0.42 – 2.14	-0.81 – -0.15	0.7 – 1.96	1.3 – 7	0.7 – 2.6	Weitzman 1991
Scopelarchidae	3.7 – 35	4.0 – 36.6	/	/	0.52	/	/	Johnson 1991
Notosudidae	11 – 50	11.7 – 52	0.31 – 1.06	-0.79 – -0.19	0.43 – 1.19	2.6 – 9.2	0.8 – 2.6	Krefft 1991
Evermannellidae	18.5	19.5	0.38 – 0.61	-1.08 – -0.32	0.93	4.6 – 7.4	1.3 – 3.4	Johnson 1991
Myctophidae	2.3 – 30	2.5 – 31.5	0.17 – 3.65	-1.74 – -0.07	0.42 – 6.73	0.7 – 20.2	0.3 – 5.1	Hulley 1991
Neoscopelidae	20 – 30.5	21 – 32	0.26 – 0.46	-1.48 – -0.39	0.63	6.1 – 10.9	1.7 – 4.6	Hulley 1991

L_{max} – maximum length (can be TL or SL, cm); L∞ - length infinity (cm); K – curvature parameter (growth rate); t_0 – initial condition parameter; M – natural mortality; T_m – longevity (max age, years); A_m – age at maturity (years); * In FishBase (2005) these families are listed as subfamilies of the family Stomiidae.

can become larger and older (Salvanes & Kristoffersen 2001). Still, an ageing study on the lightfish *Electrona antarcticus* suggests higher growth rates of mesopelagic species than previously thought of (Greely 1999), suggesting shorter life spans covering one or a few years. Generally mesopelagic fish living in warm waters reach their maximum size in a year or less and grow quicker than species living in cold waters (Gjøsæter & Kawaguchi 1980). This also seems to be the case with lantern and light fish off southern Africa (Prosch *et al.* 1995). The max age of *L. hectoris* from eastern Tasmania was estimated at 3 years (Young *et al.* 1988), similar to that from the southern Benguela (Prosch 1986). The fish reached a similar maximum size L∞ (7.3cm SL) to those recorded off South Africa (7cm SL, Olivar *et al.* 1998), while Gjøsæter & Kawaguchi (1980) report on a L_∞ of 10cm, and a growth rate K of 0.31. Length at age data suggested three year-classes, and annual mortality of *L. hectoris* was calculated at 79 % (Young *et al.* 1988), compared to 50% for *B. glaciale*, 55% for *N. kroeyeri* and 83% for *M. muelleri* (Gjøsæter & Kawaguchi 1980). For southern African *L. hectoris* and *M. muelleri* Prosch (1986) estimated total annual mortality at 99% and 90% respectively.

An age and growth study of lanternfish from the Gulf of Mexico puts the age at sexual maturity at 140 and 180 days for *B. suborbitale* and *Lepidophanes guentheri* respectively (Gartner 1991). Length at sexual maturity (L_m) was estimated at 2.3 and 4.3cm respectively for these two species, while other lanternfish L_m ranged from 1.7 to 5.5cm (Gartner 1993). In the southern Benguela length at first maturity for both *L. hectoris* sexes was 3.6cm L_c, while 2.4 and 2.6cm L_c for male and female *M. muelleri* respectively (Prosch 1991).

Crawford (1980) described the length weight relationship parameters for *L. hectoris* as follows:

$$W = 0.0242L_c^{2.6838} \qquad r = 0.96 \qquad n = 800$$

L. hectoris can reach 7 to 8 cm in standard length (SL) (Crawford 1980; O'Toole 1976; Olivar *et al.* 1998), while some *Symbolophorus* species reach 7.5 cm, but can grow to be between 12 and 16cm in length (O'toole 1976; Prosch *et al.* 1995). Based on incidental catches off Namibia, O'Toole (1976) lists standard lengths of several other mesopaelagic species. The maximum recorded length of the hatchetfish *M. muelleri* was 3.5 cm, of the scaly dragonfish *Stomias boa boa* 13 cm and of two bristlemouth species 4.2 cm.

Many mesopelagic fish species exhibit sexual dimorphism, with usually females being larger in size than male fish. *M. muelleri* and *L. hectoris* females for example are larger in size than their male counterparts (Hulley & Prosch 1987; Prosch 1991). The modal length of male *L. hectoris* was 4.3 cm compared to between 5.6 and 5.9 cm for females (Hulley & Prosch 1987). Possible explanations for this are a lower mortality and/or higher growth rates among females (Salvanes & Kristoffersen 2001).

The fecundity of mesopelagic fish is as a result of their small size generally low. Yet they still have a higher reproductive rate than long-lived epipelagic species, which have a higher fecundity (Salvanes & Kristoffersen 2001). The average absolute fecundity of the myctophid *P. choriodon*, found in the Southwest Atlantic, was 84400 eggs (with an average length of 8.5 cm; Oven 1990). The females of this species lay an average 8900 eggs in a batch (Oven 1990). Young *et al.* (1987) reported fecundities for *L. hectoris* and *M. muelleri* off Australia that ranged between 1309 – 2798 and 104 – 942 respectively. Off southern Africa the fecundity of *L. hectoris* ranged from 571 to 1431, with a mean of 646 eggs/g wet body mass. *M. muelleri* fecundity varied between 161 and 738, and had an average of 334 eggs/g wet body mass (Prosch 1991).

3.2.6 Spawning and early life stages

Many lantern and lightfish do not seem to grow older than a few years, implying that in this time period the fish must mature and spawn. Some species are batch spawners, and spawn repeatedly throughout an extended season spanning several months. The produced eggs do not differ from those of pelagic fish, and range in diameter between 0.5 and 1.65 mm (Salvanes & Kristoffersen 2001). In temperate and sub-tropical regions, peak spawning of lanternfish seems to coincide with periods of high zooplankton abundance from late winter to early summer (Gjøsæter & Kawaguchi 1980; Prosch *et al.* 1995; Sabatés & Olivar 1989).

Sabatés and Olivar (1989) provide an overview of fish larvae species (Order Stomiiformes and Myctophiformes) identified in plankton samples collected between 1979 and 1986 in the northern Benguela ($17^0$30'S – $29^0$30'S; also see Olivar & Shelton 1993 for distribution maps). They found that larvae of the pseudo-oceanic species *L. hectoris* and *M. muelleri* were more abundant than for example the more oceanic *Symbolophorus* species. This confirms the findings by O'Toole (1977), who reports that *L. hectoris* and *M. muelleri* larvae were more numerous than *Symbolophorus* species larvae. Peak *L. hectoris* and *M. muelleri* larval abundance was recorded during the main upwelling season winter and spring months, with the main spawning areas located beyond the 150 – 200 m isobath (O'Toole 1977; Olivar & Shelton 1993; Sabatés & Olivar 1989). Similarly high densities of *L. hectoris* larvae were found outside the Lüderitz upwelling area and north above the continental slope, between the 500 and 1000m isobath and beyond (Olivar *et al.* 1998). Olivar *et al.* (1998) also describe high densities of *L. hectoris* larvae further offshore than the 4000m isobath. They suggested that unusually long upwelling filaments, as mentioned in Shannon (1986), transported these larvae away from their usual spawning area. According to Olivar *et al.* (1992) more than 70% of *L. hectoris* eggs and larvae are located in the upper 100m. Mean number of *L. hectoris* eggs and larvae during winter and spring months was 1.416 and $878 \cdot 10m^{-2}$ (Olivar & Shelton 1993).

Prosch (1991) gives an overview of existing data on the reproductive biology of *L. hectoris* and the hatchet fish *M. muelleri* in the southern Benguela. In the study egg and larval data collected in the period August 1977 to August 1978 was analysed. Temporal distributions indicated peak spawning between July/August and October for both species, with prolonged *M. muelleri* spawning occurring also in November (Hulley & Prosch 1987; Prosch 1991; Olivar & Shelton 1993). No gonad activity was observed between December and March (Hulley & Prosch 1987). Highest densities of *L. hectoris* eggs and larvae were observed during maximum spawning in August, offshore of the 200m isobath off Cape Columbine and Cape Peninsula. Average densities of eggs and larvae were 170 and $667 \cdot 10m^{-2}$ (Olivar & Shelton 1993), compared to moderate densities of 110 – $1000 \cdot 10m^{-2}$ reported by Prosch (1991).

John and Kloppmann (1993) give a detailed description of the vertical distribution of *M. muelleri* eggs in the northern Benguela. Eggs of this species occurred from the surface to a depth of at least 200m. The maximum number of eggs was recorded between 25 and 60 m depth and this egg maximum occurred at a temperature range of 13-14^0C. The mean abundance of eggs was $555 \cdot 10m^{-2}$, and for larvae $339 \cdot 10m^{-2}$ (Olivar & Shelton 1993).

In the southern Benguela *M. muelleri* eggs were present closer inshore than lanternfish eggs. Highest densities followed the 200 m isobath and were observed between Cape

Columbine and Cape Town, as well as the western edge of the Agulhas Bank. Moderate densities of *M. muelleri* larvae (110-1000·10m^{-2}) stretched northwards from the Cape Peninsula to approximate 31.5^{0}S (Prosch 1991). Similarly Olivar and Shelton (1993) report egg and larvae abundances of 734 and 107 ·10m^{-2} respectively off southern Africa. Eggs of *M. muelleri* were most abundant at 0 – 40m depth, with fewer found deeper then 100m (John & Kloppmann 1993). More on *M. muelleri* ichthyology can be found in Prosch (1991) and John and Kloppmann (1993).

The myctophid *S. boobs* was observed to spawn over the slope in the southern northern Benguela towards the Orange River (Olivar 1990). The larvae of this species had the highest density at 20-40m depth. Olivar and Beckley (1994) provided additional information on the distribution and morphometrics of other *Symbolophorus* species off Namibia, while Olivar (1987) described the larval development and some spawning characteristics of the lanternfish *D. hudsoni* in the area between 17^{0}30'S and 35^{0}S. *D. hudsoni* larvae were most abundant in an area around 20^{0}S and between 29^0 and 30^{0}S, in waters with bottom depth greater than 400m. With the exception of autumn, spawning of this species takes place during most of the year. The presence of larvae as far as 300km offshore suggests that this species also spawns in oceanic waters (Olivar, 1987).

O'Toole (1977) reported on the relative abundance of a *Chauliodus spp*. (Chauliodontidae) and *Stomias boa boa* (Stomiidae) larvae during SWAPEL surveys from 1972-1974. Since only few specimens of these two families were caught no additional information was provided.

3.2.7 Abundance

The lanternfish have the highest abundance of all organisms in the mesopelagic zone, while their larvae make up the biggest part of the vertebrate plankton abundance (Prosch *et al.* 1995).

Research done in the North-east Atlantic suggests that abundance of mesopelagic fishes varies depending on bottom topography and bathymetric depth. Higher biomasses were observed in oceanic deep water compared to both seamount slopes and plateaus (Pusch 2002). Williams & Koslow (1997) observed a marked day/night shift in micronekton distribution off Tasmania. During the day 0.2% of the micronekton biomass, dominated by myctophids, was found shallower than 300m, while during nightime 53% of the biomass was found above 300 m. May and Blaber (1989) suggested that seasonal peaks in abundance of mesopelagic fish, of which *L. hectoris* made up >90%, was linked to seasonal cycles in water temperature, nutrients and primary productivity. The seasonal increases in abundance they argued could be related to the southward penetration of the East Australian current.

An estimate of abundance of mesopelagic fish for the entire Benguela region is not available, but a number of abundance estimates have been calculated for the southern Benguela current region and the south-eastern Atlantic Ocean for some mesopelagic fish families or species.

Shelton and Davis (1979) first suggested the existence of large *L. hectoris* and *M. muelleri* populations over the southern Benguela shelf, while Cruickshank *et al.* (1982) reported on substantial stocks of lanternfish in the northern Benguela. Based on acoustic abundance data from 1983 and 1987, as well as egg abundance and catch rate data, Armstrong and Prosch (1991) estimated mean densities of *M. muelleri* in the southern Benguela ranging from 4 to $10 t \cdot km^{-2}$. Using a mean of $7.41 t \cdot km^{-2}$, the total biomass for the surveyed region was 547 900mt, and extrapolating this to the un-surveyed northern Benguela region gives about $1 \cdot 10^6$ tons of lightfish (Armstrong & Prosch, 1991). Based on SWAPELS[1] data from 1978/79 to 1983, Hewitson and Cruickshank (1993) estimated the abundance of lanternfish in the northern Benguela (between 15^0 and 29^0S and inshore to 500m bottom depth) at $0.4 \cdot 10^6$mt. This estimate was based on incidental catches of fish in bongo nets, and was subsequently corrected for biases such as net avoidance and under sampling during the day due to vertical migration of the fish. A correction factor of two was applied and the estimate adjusted to $0.8 \cdot 10^6$mt. Hulley (1986) estimated the offshore stock of myctophids in the eastern south Atlantic ($28^0$40'S to $40^0$00'S) at between $8 \cdot 10^6$ and $12 \cdot 10^6$mt, depending on the gear and cruise data used. This is approximately 50-70% of the entire mesopelagic stock estimated to be $18 \cdot 10^6$mt for the eastern south Atlantic (Gjøsæter and Kawaguchi, 1980). In comparison, acoustic estimates of mesopelagic fish in specific areas off New Zealand ranged from $0.44 \cdot 10^6$mt to $0.67 \cdot 10^6$mt (McClatchie, 2003).

3.2.8 Catch history

L. hectoris is the only mesopelagic fish species that has been targeted and caught in reasonable amounts by the purse seine fishery in South Africa (Crawford 1980; Crawford 1987). This species has also been recorded as by-catch in Namibian waters. During the 1979 season for instance 1141mt of lanternfish were caught (Cruickshank 1982). Although catches of lanternfish in Namibian waters have been recorded, no official catch statistics are available. Statistics of the pelagic goby and *L. hectoris* catches made in South African waters are listed in Annex 14.

Crawford (1980) gives a detailed description of the occurrence and distribution of *L. hectoris* catches by the South African purse-seine fishery between 1968 and 1976. During this period the majority of catches were made between Olifants River and Dassen Island, with highest availability in January and February (no fishing was allowed between September and December). Catches were usually processed to fishmeal, although the high oil content of mesopelagic species (mostly *L. hectoris*) turned out to be a major problem for the industry by clogging the fishmeal machinery (D.Boyer, pers. com.; Crawford 1987; Hulley & Prosch 1987). In the 90's attempts to target mesopelagics in Namibian waters were thwarted again due to similar previously experienced processing problems (D.Boyer, pers. com).

3.3 Regional data sources

3.3.1 Nan-Sis

A total of 146 demersal and pelagic surveys done in the Benguela current region and captured in the Nan-Sis database have been identified and queried for the purpose of this report (Table 3).Between 1985 and 2005 a total of 47, 51 and 8 country specific surveys were conducted in Angolan, Namibian, and South African waters respectively. Of the Namibian surveys queried the data of eight surveys (NC) were collected onboard commercial fishing vessels. In addition 37 multi disciplinary and multi national BENEFIT surveys have been completed in the region since 1997 (Table 3). The data gathered during the time period of the surveys was collected on various vessels, i.e. the old and new RV Fridtjof Nansen and various commercial fishing vessels. For comparison purposes the fishing gear specifications were identical on each of the vessel used. In the Namibian projects searched no records of members of the families Platytroctidae, Scopelarchidae, and the Evermannellidae could be found. Likewise records of the Idiacanthidae, Scopelarchidae, Evermannellidae, and the Neoscopelidae were absent in the Angolan projects (Table 4). The total number of stations found was highest in Namibia, followed by Angola, South Africa and the BENEFIT project (Table 5). There was considerable variation between the numbers of stations per family identified, from as few as one to 1820. Based on the ranking of the five most frequently found families, Angola and Namibia had four families in common, Angola and South Africa two, and Namibia and South Africa three (Table 6).

Table 3: Summary of project related surveys captured in the Nan-Sis database.

Country / Organization	Project code	Year / Period	# of surveys	Station # range
Angola	AN	1985 – 1986	6	1 – 992
	A2	1989	3	1 – 531
	A3	1991 – 1993	6	1 – 838
	A4	1994 – 2005	29	1 – 3896
	NA	1992	1	1276 – 1297
	N1	1996	1	1646 – 1662
	BE	1997	1	1257 – 1285
Namibia	NA	1990 – 1993	15	1 – 2090
	N1	1994 – 1998	22	1 – 2457; 2506 – 2595
	N2	1999 – 2002	6	2596 – 2980
	NC	1998 – 2005	8	2231 – 2442; 2600 – 4047
South Africa	SA	1994 – 1995	3	1 – 27
		2000 – 2001	4	28 – 385
		2004	1	903 – 949
BCLME	SA	2004 – 2005	2	806 – 855; 950 – 1108*
	BC	2004	1	865 – 902
BENEFIT	BE	1997 – 2005	33	1 – 80; 128 – 1552
	SA	2002 – 2005	4	386 – 805; 1109 – 1151*

* SA project codes under BENEFIT & BCLME are found in the database under the SA project code, i.e. the station range found in the SA project is from 1 – 1151.

Table 4: Orders and families searched for in the Nan-Sis database. Tick marks indicate that members of a certain family were found in any one of a countries projects, while a cross indicates the absence.

Order	Family	Country (projects)		
		Angola	Namibia	South Africa
Argentiformes	Argentinidae	√	√	√
	Bathylagidae	√	√	√
	Platytroctidae	√	**x**	√
Stomiiformes	Stomiidae	√	√	√
	Chauliodontidae	√	√	√
	Astronesthidae	√	√	√
	Idiacanthidae	**x**	√	√
	Malacosteidae	√	√	√
	Photichthyidae	√	√	√
	Gonostomatidae	√	√	√
	Sternoptychidae	√	√	√
	Melanostomatidae	√	√	√
Aulopiformes	Scopelarchidae	**x**	**x**	√
	Notosudidae	√	√	√
	Evermannellidae	**x**	**x**	√
Myctophiformes	Myctophidae	√	√	√
	Neoscopelidae	**x**	√	√
Anguilliformes	Nemichthyidae	√	√	√
Perciformes	Gobiidae	√	√	√

Table 5: Total number of stations for mesopelagic families and Gobiidae stored in Nan-Sis. The total number of stations by country is the sum of stations identified in that countries respective projects, e.g. NA, NC, N1 and N2 are projects linked to Namibia (refer to Table 3).

Order	Family	Country			Project
		Angola	Namibia	South Africa	BENEFIT
Argentiformes	Argentinidae	2	3	9	---
	Bathylagidae	7	151	15	13
	Platytroctidae	8	---	4	---
Stomiiformes	Stomiidae	303	194	8	41
	Chauliodontidae	24	16	36	3
	Astronesthidae	19	15	19	1
	Idiacanthidae	---	3	11	---
	Malacosteidae	---	30	31	6
	Photichthyidae	416	1044	255	134
	Gonostomatidae	694	354	30	54
	Sternoptychidae	63	181	317	75
	Melanostomatidae	244	80	51	2
Aulopiformes	Scopelarchidae	---	---	9	---
	Notosudidae	21	54	65	7
	Evermannellidae	---	---	2	---
Myctophiformes	Myctophidae	943	1820	912	418
	Neoscopelidae	---	65	28	2
Anguilliformes	Nemichthyidae	199	196	70	9
Perciformes	Gobiidae*	273	1868	98	113
	Total	2943	4206	1872	765

*Not included in the total.

Table 6: Percentage of stations per family by country and their ranking. Shaded cells indicate the five most common families identified in each country.

Order	Family	Country						Project	
		Angola		Namibia		South Africa		BENEFIT	
		%	rank	%	rank	%	rank	%	rank
Argentiformes	Argentinidae	0.1	**13**	0.1	**13**	0.5	**14**		
	Bathylagidae	0.2	**12**	3.6	**7**	0.8	**12**	1.7	**6**
	Platytroctidae	0.3	**11**			0.2	**16**		
Stomiiformes	Stomiidae	10.3	**4**	4.6	**5**	0.4	**15**	5.4	**5**
	Chauliodontidae	0.8	**8**	0.4	**12**	1.9	**7**	0.4	**10**
	Astronesthidae	0.6	**10**	0.4	**12**	1.0	**11**	0.1	**12**
	Idiacanthidae			0.1	**13**	0.6	**13**		
	Malacosteidae			0.7	**11**	1.7	**8**	0.8	**9**
	Photichthyidae	14.1	**3**	24.8	**2**	13.6	**3**	17.5	**2**
	Gonostomatidae	23.6	**2**	8.4	**3**	1.6	**9**	7.1	**4**
	Sternoptychidae	2.1	**7**	4.3	**6**	16.9	**2**	9.8	**3**
	Melanostomatidae	8.3	**5**	1.9	**8**	2.7	**6**	0.3	**11**
Aulopiformes	Scopelarchidae					0.5	**14**		
	Notosudidae	0.7	**9**	1.3	**10**	3.5	**5**	0.9	**8**
	Evermannellidae					0.1	**17**		
Myctophiformes	Myctophidae	32.0	**1**	43.3	**1**	48.7	**1**	54.6	**1**
	Neoscopelidae			1.5	**9**	1.5	**10**	0.3	**11**
Anguilliformes	Nemichthyidae	6.8	**6**	4.7	**4**	3.7	**4**	1.2	**7**

The Myctophidae was the most frequently observed family in the region (Table 6). The percentage of stations with Myctophidae ranged from 32% (Angola) to 54.6% (BENEFIT). With regard to the Angolan data many of the myctophids were only identified to the family level. When identification was done to genus or species level, the dominant genus was *Diaphus* and the dominant species *Diaphus dumerili* (Appendix 4, Table A). In Namibia and South Africa the most frequently identified lanternfish were *L. hectoris* and *S. boobs* (Appendix 5, Table A; Appendix 6, Table B). The distribution map for this family shows very clearly the prominent presence over the shelf and slope along the entire southwest African coast (Appendix 12, Table 1A). Average depths where various species of this family were caught ranged from 325-595m bottom depth and from 280-565m fishing depth.

The other family abundant in all three countries was the Photichthyidae (lightfish), ranking at either two or three (Table 6). In contrast to the distribution of the Myctophidae, fish from this family occurred in deeper waters on the continental slope (Appendix 10, Figure 1B), with an average bottom and fishing depth of 530 and 515m. The species *Yarella blackfordi* was identified most frequently in Angola and Namibia (Appendix 4, Table B; Appendix 5, Table A), while *Photichthys argentus* was the dominant lightfish species in South Africa (Appendix 6, Table B).

Stomias boa boa (Stomiidae) was the most abundant of the scaly dragonfish in Angolan and Namibian waters, ranked 4th and 5th respectively (Appendix 4, Table B; Appendix 5, Table B). Ranking at 15th place and also apparent from the distribution map, this family was less abundant in South African waters (Appendix 9, Figure 1A). In Namibia and Angola the average bottom depth where this family was taken was 560 m.

Also abundant both in Namibia and Angola, but mainly only identified to genus level in Namibia, were the bristlemouths (Gonostomatidae). The most prevalent member of this family, which ranked as the 2nd most abundant in Angola, was *Triplophos hemingi* (Appendix 4, Table A). The depth distribution was similar to that of the scaly dragonfish, averaging at 560 m bottom depth. The distribution map for this family shows the patchy presence in the southern Benguela, and the obvious absence between 13 and 17^{0}S (Appendix 10, Figure 1C). It needs to be mentioned here that the general absence in this region is not due to the actual physical absence of the families, but the lack of data. The reason for this is that along this stretch the shelf is very narrow, and the sampling density thus was much lower here than anywhere else.

The Melanostomatidae (scaleless dragonfish), which ranked 6th and 8th in Namibia and South Africa respectively, was the 5th most common family in Angolan waters, with *Melanostomias* the dominant genus (Appendix 4, Table A). The major Nemichthyidae (snipe eel) genus observed was *Nemichthys* and ranked 4th both in Namibia and South Africa (Appendix 5, TableA, Appendix 6, Table B).

M. muelleri (Sternoptychidae) ranked 2nd in South Africa, compared to 7th and 6th in Angola and Namibia respectively (Table 6). This species often referred to as a lightfish but classified as a hatchetfish, showed a broad distribution in the southern Benguela (Appendix 10, Figure 1D). Although the average bottom at which this species was caught was app. 340 m, it seems that it occurs both on the shelf and further offshore on the slope.

Members of the family Evermannellidae (sabretoothed fishes) were never or rarely identified, with no records from Angola and Namibia, and only two stations in South African waters. Also infrequent (<0.6 % of total number of stations) in all three countries were the families Argentinidae (argentines), Platytroctidae (tubeshoulders), (pearleyes), and Idiacanthidae (sawtail fishes; Table 6)

3.3.2 MCM data

A total of 50 surveys were performed by the RV African between 1985 and 2004 (Table 7). Some 4664 stations were sampled out of which 2274 contained one or more mesopelagic fish species (Appendix 6, Table D – G). The most frequently sampled family was the myctophids, followed by the hatchetfishes, lightfishes, snipe eels, and viper fishes (Table 8). The ranking of the families recorded was nearly identical to that of the data from the Nansen, with the only difference that instead of the notosudids the viperfish ranked 5th (Table 8).

3.3.3 NatMIRC data

Very little data except for the data captured in Nan-Sis during the annual demersal abundance estimate surveys with commersial vessels was available from NatMIRC. Surveys with the RV Welwitchia have however regularly collected information on gobies and mesopelagic species as part of the abudance surveys of horse mackerel, sardine and monk. The data are however scattered and not in a centralized database and therefor difficult to obtain easily. An overview of the origin and location of some of the mesopelagics data is given in Table 9, while the location of goby and mesopelagic by-catches during the annual horse mackerel surveys is shown in Annex 13.

Table 7: Summary of relevant surveys conducted by the RV Africana in the period from 1985 to 2004.

Year	Cruise #	# of surveys	# of station
1985	C028, C033	2	196
1986	C039, C046, C048	3	300
1987	C050, C054, C056	3	300
1988	C059, C063, C066	3	311
1989	C069, C072, C075	3	231
1990	C079, C082, C084, C086	4	354
1991	C088, C093, C095	3	292
1992	C100, C102, C106	3	296
1993	C109, C111, C116	3	326
1994	C118, C122, 125	3	319
1995	C127, C129, C131	3	322
1996	C133, C135	2	186
1997	C139, C144	2	203
1999	C150, C152	2	171
2001	C160	1	80
2002	C161	1	47
2003	C173, C177, C182	3	273
2004	C188,C191,C200	3	291

Table 8: Total number of stations, percentages and ranking of mesopelagic families and the Gobiiodae stored in the Africana Demersal Data System.

Order	Family	# stations	% stations	RANK
Argentiformes	Argentinidae	2	0,8	**9**
	Bathylagidae	19	0,7	**10**
	Platytroctidae	10	0,4	**12**
Stomiiformes	Stomiidae	13	0,5	**11**
	Chauliodontidae	64	2,3	**5**
	Astronesthidae	18	0,7	**10**
	Idiacanthidae	22	0,8	**9**
	Malacosteidae	40	1,5	**7**
	Photichthyidae	313	11,5	**3**
	Gonostomatidae	29	1,1	**8**
	Sternoptychidae	777	28,5	**2**
	Melanostomiidae	48	1,8	**6**
Aulopiformes	Scopelarchidae	11	0,4	**12**
	Notosudidae	49	1,8	**6**
	Evermannellidae	2	0,1	**13**
Myctophiformes	Myctophidae	1237	45,4	**1**
Anguilliformes	Nemichthyidae	70	2,6	**4**
Perciformes	Gobiidae*	313		
	TOTAL	2724		

*Not included in the total.

Table 9: Overview of mesopelagic data availability from Namibian waters.

Activity	Vessel / Source	Species / Fishery	Period	Comments
Research surveys	RV Benguela	Pelagic	1980's - early 1990's	No records of by-catch captured electronically. Hard copies contain some by-catch records.
	RV Nansen	All		Annex 5, project codes NA, N1 and N2
	RV Welwitchia	Horse mackerel - pelagic	1999 – present (February)	Trawl by-catch data captured in an access database. Records are registered at species and family level, i.e. gobies, myctophids etc
		Pilchard - pelagic	Mar/Apr and October	Same as above
		Monk - demersal	2000 – Present (November)	Limited mesopelagics data
	FV Blue Sea	Hake - demersal	2001 – Present (Jan/Feb)	Annex 5, project code NC
Commercial fishing	Logsheet – midwater fishery	Horse mackerel	1997 – present	No records of mesopelagics. Mesh size > 60 mm. Maybe occasionally caught and possibly processed to fishmeal.
	Logsheet – pelagic fishery	Horse mackerel, pilchard, anchovy	1997 – present	Some bycatch data of mesopelagics captured. Available in an access database.
	Historical	Midwater	Before 1997	Catch logs contain no records of mesopelagics
		Pelagic	From early 1970's (1973 – 1989)	ICSEAF records contain data on all species caught in the ICSEAF area, including records on mesopelagics *Lampanyctodes hectoris*, and gobies. These are listed but not available in electronic format.

3.4 Ongoing and recently completed research projects

BENEFIT / BCLME Project No. N01/017
Project Name: Biology and Ecology of Pelagic Gobies
Duration of Project (2001 - 2005) - Cruises conducted in 2003, 2004, 2006.

This project was originally proposed, and funded, in 2000 with the goal of improve the understanding of the feeding biology and of the abundance of *S. bibarbatus* off Namibia. One should as part of the project investigate ways to develop a methodology suitable for estimation of biomass and distribution of *S. bibarbatus* off Namibia. The project has been through several iterations in order to allow for an overlap with a project entitled "The Ecology of Gobies in the Benguela Ecosystem" that was successfully submitted to the

South Africa – Norway Programme on Research Cooperation for funding in 2003. The latter project is described in more detail below. The BENEFIT projects level of support as a consequence shifted from one essentially based on the provision of running expenses, to one based largely on ship's time.
The project is essentially being used as a student training exercise and it has been constructed around a number of small, discrete studies. The students include MSc students from RSA that are studying in RSA, and MPhil students from the region studying in Norway. It also includes Norwegian and other students studying at the MPhil and PhD level in Norway.

Original Objectives

- Improve our understanding of the feeding biology of *S. bibarbatus* off Namibia
- Improve our understanding of the biomass and distribution of *S. bibarbatus* off Namibia

Additional Objectives arising from the SA-Norway Programme on Research Co-operation

- Improve our understanding of the behaviour of *S. bibarbatus* off Namibia, with particular reference to diel vertical migration and tolerance of low oxygen water

NORWAY-SOUTH AFRICA RESEARCH COOPERATION Norwegian Research Council Project No: 152309/v10
Project Name: The Ecology of Gobies in the Benguela Ecosystem
Duration of project (2003-2006)

The project essentially expanded the aims to include more focused studies on the food and feeding, behaviour and physiology of *S. bibarbatus*.

Objectives: Investigate the feeding ecology, and reproductive and population biology of S. bibarbatus and its role of the Benguela ecosystem by

- Study diet and feeding biology of S. bibarbatus
- Study population biology of S. bibarbatus.

MASTER PROGRAM STUDIES
The following three students have all received higher degrees through data collected, in part, through the BENEFIT goby project and the Norway-South Africa research cooperation on gobies. All students received bursary funding through the NORAD programme: the first two students are South Africans and were based at M&CM in Cape Town, whilst the third comes from Sri Lanka.

Shipokazi Nduane (2004) Population genetic studies of *S. bibarbatus* in the Benguela ecosystem – M.Phil. University of Bergen, Norway. Supervisor: Prof AGV Salvanes

Rengque Judy Lungelwa (2005) Diel Vertical Migrations of the Pelagic goby *S. bibarbatus* in the Northern Benguela ecosystem – M.Phil. University of Bergen, Norway. Supervisor: Prof AGV Salvanes and MJ Gibbons.

Mangala Pallgae de Silva (2005) Population genetic structure of the pelagic goby, *S. bibarbatus,* in the Northern Benguela Ecosystem, based on PCR, RFLP analysis of the mitochondrial control region and the ND ¾ region – M.Phil. University of Bergen, Norway. Supervisor: Prof AGV Salvanes

IN PROGRESS

Anthony, KA *Studies on the diet and feeding of the pelagic goby,* Sufflogobius bibarbatus. MSc Thesis, University of the Western Cape, South Africa. Supervisor: Professor MJ Gibbons.

Staby, A. *Investigating swimming dynamics and feeding behaviour of mesopelagic fish in the Benguela current system and a Norwegian fjord using acoustics*, PhD studies in progress, University of Bergen, Norway. Supervisors: Professor Anne Gro Vea Salvanes and Professor Stein Kaartvedt from the University of Oslo. This will be a comparative study of behaviour, distribution and biology of mesopelagic species in the Benguela system and a Norwegian fjord system.

4 Summary

Gobies

Given that pelagic gobies together with the mesopelagic fish resources are currently of the few unexploited resources in the region that could be sufficiently numerous to have the potential for future exploitation, it is likely that regional governments may allow, or even encourage, a targeted goby fishery. The increased predation pressure, coupled with any focussed fishery, is likely to have a severe influence on the population dynamics and production of gobies, and research has been needed to determine the knowledge available on this resource and identify gaps where more research is needed.

The species is abundant in the region and a key species in the diet of many predator fish species, seals and seabirds. But the stock is possibly not as abundant as some authors have suggested. Data collected from swept area surveys of Namibia with RV Dr. Fridtjof Nansen suggests that the stock is much smaller than previously reported. The index of abundance presented in this report does however underestimate the stock to some extent. The report from the BENEFIT Project No. N01/017 suggests that acoustic abundance estimation is not suitable for gobies with today's technology, and it may be difficult to find any reliable direct way of estimating the entire stock.

There is still a lack of knowledge regarding the life history parameters of the species although a resent study (Melo and Le Clus 2005) has expanded our knowledge in this field. The distribution maps presented in this report are the most extensive and up-to- date available and has not previously been published. We should now have a complete overview of the distribution area of the species although more research is needed on seasonal dynamics, and spatial and temporal variations in fish size distribution. Two different populations /subpopulations have been suggested from genetic studies and more knowledge is needed on the distribution and overlap of these. There is no knowledge on where the spawning area(s) for the species can be found and on how the early life stages cope with the hostile conditions on the Benguela shelf. There is also a question on what physiological adaptations adult gobies have developed to cope with the anoxia and high sulphur concentrations on the shelf. These questions should be looked into in future studies.

Mesopelagics

The amount of knowledge on any of the aspects covered in this report with regard to the species *L. hectoris* and *M. muelleri* is much greater than that of any of the other mesopelagic families found in the Benguela current region. These two species seem to be the most abundant in the region, based on previous abundance estimates, which might also explain the amount of information available on them. Yet, there are still gaps with regard to life history parameters, their ecology and trophic dynamics.

Little if any information is available on mesopelagic families other than the Myctophidae and the Sternoptychidae (Table 8). Some species, like *Yarella blackfordi* and *Photichthys argenteus* (Photichthyidae) are widely distributed and abundant in trawl catches from the Benguela region. Little however is known about their biology, ecology, vertical

Table 8: Summary of available information on the most common mesopelagic families in the Benguela region.

	Mycoph.[*]	*Sternopty.*[**]	*Photich.*	*Gonostom.*	*Stomiidae*	*Other*
Species diversity	+	+/-	+/-	+/-	+/-	+/-
Species distribution	+	+/-	+/-	+/-	+/-	+/-
Biology	+	+	-	-	-	-
Ecology	+	+	-	-	-	-
Life history	+	+	-	-	-	-
Spawning & early life stages	+	+	-	-	-	-
Abundance	+	+	-	-	-	-
Catch history	+	-	-	-	-	-

[*]*L.hectoris;* [**] *M. muelleri*

distribution and behaviour, life history parameters, or abundance. The same can be said about *Stomias boa boa* (Stomiidae) and the bristlemouth fish *Triplophos hemingi* (Gonostomatidae).

4.1 Recommendations on future studies

A proposal for a BENEFIT survey focusing on the distribution of mesopelagics between Walvis Bay and Cape Town, and aiming at providing a possible abundance index of mesopelagic fish, based on acoustic data, has been submitted to BENEFIT. This survey would present an opportunity to collect relevant environmental, biological, ecological and acoustic data on the various mesopelagic species, in addition to data on the more common species like *L. hectoris, M. muelleri*, and *Diaphus* as well as *Symbolophorous* species. The proposal for this survey is attached in Appendix 15.

The lack of data and information on mesopelagic fish species from the northern Benguela extending into Angolan waters is obvious and needs to be addressed. Though some limited data is available on the distribution of mesopelagic species, of which, like the lightfish and myctophids, seem to be fairly abundant, virtually little or nothing is know about these species' life history parameters, ecology, trophic interactions, or abundance.

No proposals for future studies on *S. bibarbatus* are known to date but it is expected that the work currently undertaken in the before mentioned research projects funded by BENEFIT and by the Norway-South Africa Research Cooperation Initiative will lead towards applications for further research. Such research initiatives should focus on topics mentioned in the summary of this paper, namely; spawning areas, adaptations of all life stages to hypoxic conditions and high sulphur concentrations in the water column. Improving the knowledge on the abundance of the goby and how to assess the stock. It is important that the suggested proposal for a survey on the mesopelagic species also collect distribution and abundance data on egg and larvae of the goby resource. There is still a need to find suitable methods to estimate the abundance of gobies in the water column and information from the suggested cruise may aid in reaching this goal.

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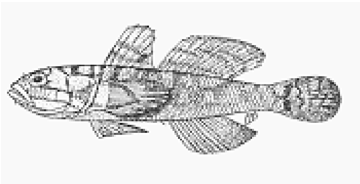
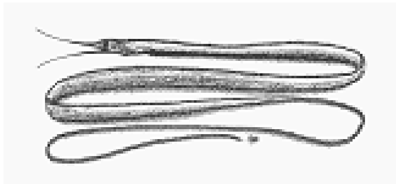
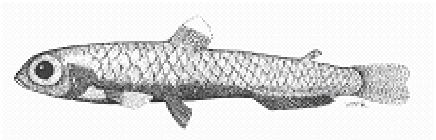
Annex 1: Picture gallery of some mesopelagic species



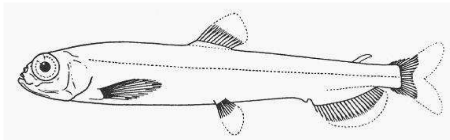
Order Perciformes
Family **Gobiidae**
Species *Sufflogobius bibarbatus*



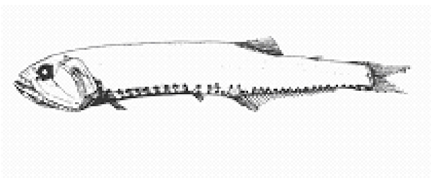
Order Anguilliformes
Family **Nemichthyidae (snipe eels)**
Species *Nemichthys scolopaceus*



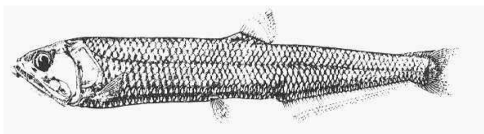
Order Argentiformes
Family **Bathylagidae (deep-sea smelts)**
Species *Bathylagus antarcticus*



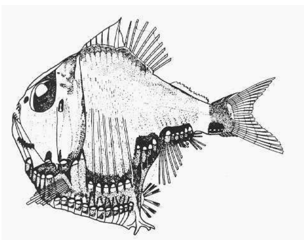
Species *Bathylagus bericoides*



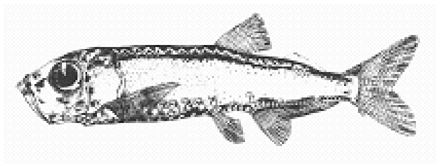
Order Stomiiformes
Family **Gonostomatidae (bristlemouths)**
Species *Gonostoma denudatum*



Species *Diplophos maderensis*



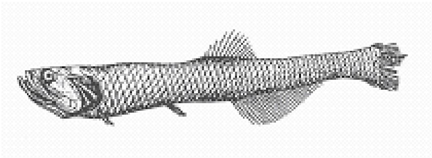
Family **Sternoptychidae (marine hatchetfishes)**
Species *Argyropelecus aculeatus*



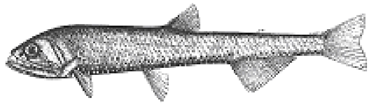
Species *Maurolicus muelleri*

NOTE: All pictures were obtained from Fish Base (2005). P.C. Heemstra from the South African Institute for Biodiversity provided the originals to FishBase.

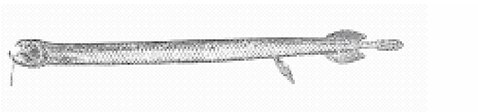
Annex 2: Picture gallery of some mesopelagic species



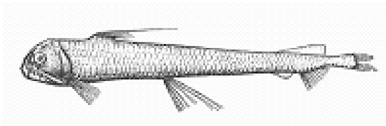
Order Stomiiformes
Family **Photichthyidae (lightfishes)**
Species *Yarella blackfordi*



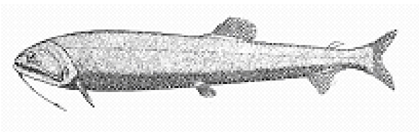
Species *Photichthys argenteus*



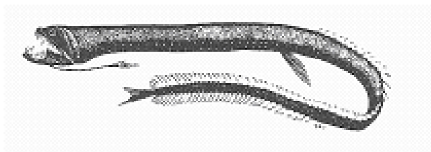
Family **Stomiidae (scaly dragonfishes)**
Species *Stomias boa boa*



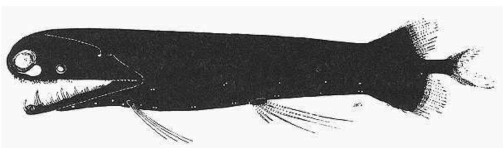
Family **Chauliodontidae (viperfishes)**
Species *Chauliodus sloani*



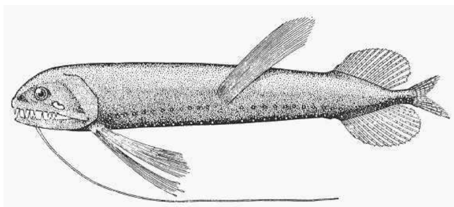
Family **Astronesthidae (snaggletooths)**
Species *Borostomias monomena*



Family **Idiacanthidae (sawtail fish)**
Species *Idiacanthus atlanticus*



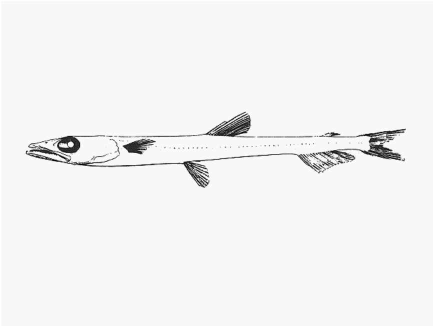
Family **Malacosteidae (loosejaws)**
Species *Malacosteus niger*



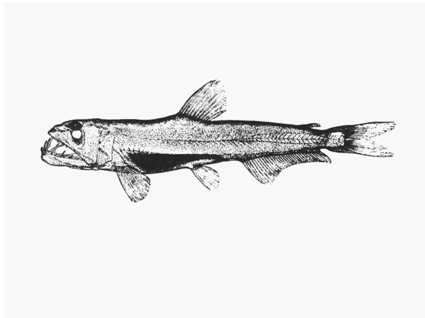
Family **Melanostomiatidae**
Species *Bathophilus nigerrimus*

NOTE: All pictures were obtained from Fish Base (2005). P.C. Heemstra from the South African Institute for Biodiversity provided the originals to FishBase.

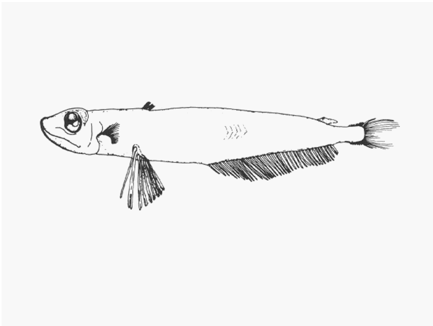
Annex 3: Picture gallery of some mesopelagic species



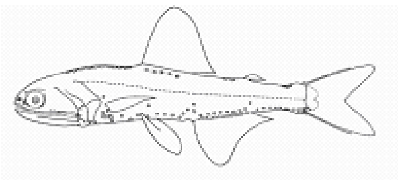
Order Aulopiformes
Family **Notosudidae (waryfishes)**
Species *Scopelosaurus meadi*



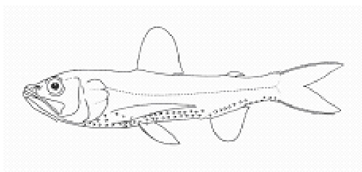
Family **Evermannellidae**
Species *Evermannella balbo*



Family **Scopelarchidae (pearleyes)**
Species *Benthalbella macropinna*



Order Myctophiformes
Family **Myctophidae (lanternfishes)**
Species *Lampanyctodes hectoris*



Family **Neoscopelidae (blackchins)**
Species *Neoscopelus macrolepidotus*

NOTE: All pictures were obtained from Fish Base (2005). P.C. Heemstra from the South African Institute for Biodiversity provided the originals to FishBase.

Annex 4: Nan-Sis database mesopelagic species listed - Angola

Table A: Families and species captured in the Nan-Sis species catalogue AN, searched for and found in Angolan projects AN, A2, A3 and A4 (Families in alphabetic order).

Family	Genus / Species	Database code	# of stations *			
			AN	A2	A3	A4
Argentinidae		ARGAA00	---	---	---	2
Astronesthidae		ASTAA00	---	---	2	12
	Astronesthes sp.	ASTAS00	---	---	---	1
	Borostomias sp.	ASTBO00	---	---	1	3
Bathylagidae		BAHAA00	---	---	---	---
	Bathylagus sp.	BAHBA00	---	---	---	2
	Bathylagus longirostris	BAHBA01	---	---	1	---
	Bathylagus bericoides	BAHBA02	---	1	---	---
	Bathylagus glacilis	BAHBA03	---	---	---	3
Chauliodontidae		CHOAA00	---	---	---	3
	Chauliodus sp.	CHOCH00	---	---	---	3
	Chauliodus sloani	CHOCH01	---	---	---	18
Gobiidae		GOBAA00	27	38	10	134
	Gobies sp.	GOBSG00	---	---	---	---
	Sufflogobius bibarbatus	GOBSU01	---	---	---	33
	Thorogobius angolensis	GOBTH01	---	---	11	20
Gonostomatidae		GONAA00	6	8	55	156
	Diplophos sp.	GONDI00	---	1	---	19
	Gonostoma sp.	GONGO00	---	---	---	41
	Gonostoma elongatum	GONGO01	---	3	---	45
	Gonostoma denudata	GONGO02	---	---	---	43
	Triplophos sp.	GONTR00	---	5	4	111
	Triplophos hemingi	GONTR01	---	---	---	197
Malacosteidae		MAAAA00	---	---	---	---
Melanostomatidae		MELAA00	---	7	30	119
	Leptostomias gracilis	MELLE01	---	---	1	---
	Melanostomias sp.	MELME00	---	6	3	56
	Melanostomias macrophotus	MELME01	---	---	---	1
	Photonectes braueri	MELPH01	---	---	2	19
	Photonectes parvimanus	MELPH02	---	---	---	---
Myctophidae		MYCAA00	64	36	60	703
	Diaphus sp.	MYCDI00	---	---	---	17
	Diaphus dumerili	MYCDI03	---	1	40	5
	Lampadena sp.	MYCLA00	---	1	--	7
	Myctophum sp.	MYCMY00	---	---	1	7
	Notoscopelus sp.	MYCNO00	1	---	---	---
Nemichthyidae		NECAA00	---	2	3	32
	Avocettina acuticeps	NECAV01	---	---	---	---
	Nemichthys sp.	NECNE00	---	---	---	---
	Nemichthys scolopaceus	NECNE01	---	7	7	144
	Nemichthys curvirostris	NECNE02	---	---	---	4
Notosudidae		NOSAA00	---	---	---	6
	Scopelosaurus sp.	NOSSC00	---	---	---	14
	Scopelosaurus meadi	NOSSC01	---	---	---	1
Photichthyidae		PHOAA00	---	---	---	---

Annex 4: Nan-Sis database mesopelagic species listed – Angola contnd.

Table B: Families and species captured in the Nan-Sis species catalogue AN, searched for and found in Angolan projects AN, A2, A3 and A4 (Families in alphabetic order).

Family	Genus / Species	Database code	# of stations * AN	A2	A3	A4
	Photichthys sp.	PHOPH00	---	---	---	---
	Yarella blackfordi	PHOYA02	---	23	6	387
Platytroctidae		PLTAA00	---	---	---	8
Sternoptychidae		STEAA00	---	---	---	4
	Argyropelecus affinis	STEAR02	---	---	---	2
	Maurolicus muelleri	STEMA01	---	---	4	51
	Sternoptyx sp.	STEST00	---	1	---	1
	Sternoptyx pseudobscura	STEST01	---	---	---	---
Stomiidae		STOAA00	2	2	1	72
	Stomias sp.	STOST00	---	---	---	61
	Stomias affinis	STOST01	---	3	9	28
	Stomias boa boa	STOST02	---	---	---	125

* Stations searched: AN 1-992 ; A2 1-531; A3 1-475; A4 1-3896

Annex 5: Nan-Sis database mesopelagic species listed - Namibia

Table A: Families and species captured in the Nan-Sis species catalogue NA, searched for and found in Namibian projects NA, N1, N2 and NC (Families in alphabetic order).

Family	Genus / Species	Database code	# of stations *			
			NA	N1	N2	NC
Argentinidae		ARGAA00	---	1	---	---
	Nansenia problematica	ARGNA02	1	1	---	---
Astronesthidae		ASTAA00	2	8	---	5
Bathylagidae		BAHAA00	---	10	---	5
	Bathylagus glacilis	BAHBA03	2	29	18	76
	Nansenia sp.	BAHNA00	3	2	---	---
	Nansenia problematica	BAHNA02	1	1	---	2
	Nansenia tenera	BAHNA03	1	1	---	---
Chauliodontidae		CHOAA00	---	2	---	1
	Chauliodus sloani	CHOCH01	---	7	---	6
Gobiidae		GOBAA00	---	3	---	1
	Sufflogobius bibarbatus	GOBSU01	601	630	104	529
Gonostomatidae		GONAA00	20	54	9	225
	Diplophos sp.	GONDI00	4	1	---	2
	Diplophos maderensis	GONDI02	7	1	---	---
	Triplophos sp.	GONTR00	---	16	9	6
Idiacanthidae		IDIAA00	1	---	---	---
	Idiacanthus atlanticus	IDIID01	2	---	---	---
Malacosteidae		MAAAA00	---	4	2	24
Melanostomatidae		MELAA00	4	5	10	38
	Leptostomias gracilis	MELLE01	---	2	---	---
	Melanostomias sp.	MELME00	---	9	---	---
	Odontostomias micropogon	MELOD01	1	2	---	---
	Photonectes braueri	MELPH01	6	2	---	1
Myctophidae		MYCAA00	429	568	26	142
	Diaphus sp.	MYCDI00	11	25	1	7
	Diaphus dumerili	MYCDI03	---	16	---	---
	Diaphus hudsoni	MYCDI05	---	8	5	22
	Lampadena sp.	MYCLA00	5	8	---	5
	Lampanyctodes hectoris	MYCLM01	28	98	35	125
	Symbolophorus boobs	MYCSY01	---	75	38	143
	Symbolophorus barnardi	MYCSY02	---	---	---	---
Nemichthyidae		NECAA00	6	31	4	10
	Nemichthys scolopaceus	NECNE01	27	30	8	70
	Nemichthys curvirostris	NECNE02	4	6	---	---
Neoscopelidae		NEOAA00	---	2	----	---
	Neoscopelus macrolepidotus	NEONE01	3	31	2	24
	Neoscopelus microchir	NEONE02	2	---	---	1
Notosudidae		NOSAA00	---	9	---	9
	Scopelosaurus meadi	NOSSC01	3	27	1	5
Photichthyidae		PHOAA00	3	15	1	6
	Photichthys sp.	PHOPH00	---	14	1	14
	Photichthys argenteus	PHOPH01	55	143	19	79
	Yarella blackfordi	PHOYA02	46	325	49	264

Annex 5: Nan-Sis database mesopelagic species listed – Namibia contnd.

Table B: Families and species captured in the Nan-Sis species catalogue NA, searched for and found in Namibian projects NA, N1, N2 and NC (Families in alphabetic order).

Family	Genus / Species	Database code	# of stations * NA	N1	N2	NC
Sternoptychidae		STEAA00	1	1	---	1
	Argyropelecus affinis	STEAR02	2	4	---	3
	Maurolicus muelleri	STEMA01	37	93	14	25
Stomiidae		STOAA00	---	22	---	16
	Stomias boa boa	STOST02	4	31	16	105

* Stations searched: N1 1-2600; N2 2596-2980; NA 1-2090; NC 2231-4070

Annex 6: Database mesopelagic species listed - South Africa

Table A: Number of stations of families and species captured in the Nan-Sis species catalogue SA (Families in alphabetic order).

Family	Genus / Species	Database code	# of stations
Argentinidae		ARGAA00	---
	Argentina euchus	ARGAR05	9
Astronesthidae		ASTAA00	1
	Astronesthes sp.	ASTAS00	7
	Astronesthes filifer	ASTAS06	---
	Borostomias sp.	ASTBO00	1
	Borostomias monomena	ASTBO02	1
	Borostomias antarcticus	ASTBO03	3
	Neonesthes capensis	ASTNE01	6
Bathylagidae		BAHAA00	---
	Bathylagus sp.	BAHBA00	10
	Bathylagus glacilis	BAHBA03	---
	Bathylagus antarcticus	BAHBA04	3
	Nansenia sp.	BAHNA00	2
	Nansenia problematica	BAHNA02	---
	Nansenia tenera	BAHNA03	---
Chauliodontidae		CHOAA00	1
	Chauliodus sloani	CHOCH01	35
Evermannellidae		EVEAA00	2
	Evermannella balbo	EVEEV01	---
Gobiidae		GOBAA00	---
	Gobidae juvenile	GOBAA90	---
	Sufflogobius bibarbatus	GOBSU01	98
Gonostomatidae		GONAA00	10
	Diplophos sp.	GONDI00	---
	Diplophos taenia	GONDI01	5
	Diplophos maderensis	GONDI02	---
	Gonostoma elongatum	GONGO01	11
	Cyclothone sp.	GONSY00	4
	Triplophos sp.	GONTR00	---
	Triplophos hemingi	GONTR01	---
Idiacanthidae		IDIAA00	1
	Idiacanthus sp.	IDIID00	1
	Idiacanthus atlanticus	IDIID01	9
Malacosteidae		MAAAA00	---
	Aristostomias sp.	MAAAR00	2
	Malacosteus sp.	MAAMA00	3
	Malacosteus niger	MAAMA01	26
Melanostomatidae		MELAA00	8
	Bathophilus longipinnis	MELBA02	23
	Bathophilus nigerrimus	MELBA03	1
	Echiostoma barbatum	MELEC01	9
	Eustomias sp.	MELAU00	---
	Leptostomias gracilis	MELLE01	---
	Melanostomias sp.	MELME00	8
	Odontostomias micropogon	MELOD01	---

Annex 6: Database mesopelagic species listed - South Africa contnd.

Table B: Number of stations of families and species captured in the Nan-Sis species catalogue SA (Families in alphabetic order).

Family	Genus / Species	Database code	# of stations
	Opostomias micripnis	MELOP01	---
	Photonectes braueri	MELPH01	2
Myctophidae		MYCAA00	73
	Bolanichthys supralateralis	MYCBO01	2
	Diaphus sp.	MYCDI00	104
	Diaphus dumerili	MYCDI03	---
	Diaphus hudsoni	MYCDI05	---
	Diaphus effulgens	MYCDI07	23
	Diaphus meadi	MYCDI08	4
	Diogenichthys panurgus	MYCDO01	1
	Electrona risso	MYCEL01	51
	Gymnoscopelus sp.	MYCGY00	66
	Gymnoscopelus bolini	MYCGY01	2
	Hygophum sp.	MYCHY00	1
	Lampadena sp.	MYCLA00	14
	Lampadena luminosa	MYCLA01	2
	Lampadena pontifex	MYCLA04	1
	Lampichthys procerus	MYCLC01	3
	Lampanyctodes hectoris	MYCLM01	338
	Lampanyctus sp.	MYCLP00	9
	Lampanyctus alatus	MYCLP02	1
	Lampanyctus australis	MYCLP10	3
	Myctophum sp.	MYCMY00	15
	Notoscopelus sp.	MYCNO00	4
	Protomyctophum sp.	MYCPR00	6
	Scopelopsis multipunctatus	MYCSC01	1
	Symbolophorus sp.	MYCSY00	21
	Symbolophorus boops	MYCSY01	156
	Symbolophorus barnardi	MYCSY02	11
Nemichthyidae		NECAA00	16
	Avocettina sp.	NECAV00	1
	Avocettina acuticeps	NECAV01	16
	Nemichthys scolopaceus	NECNE01	13
	Nemichthys curvirostris	NECNE02	24
Neoscopelidae		NEOAA00	---
	Neoscopelus macrolepidotus	NEONE01	28
	Neoscopelus microchir	NEONE02	---
Notosudidae		NOSAA00	17
	Luciosudis normanni	NOSLU01	1
	Scopelosaurus sp.	NOSSC00	14
	Scopelosaurus meadi	NOSSC01	23
	Scopelosaurus herwigi	NOSSC02	10
Photichthyidae		PHOAA00	3
	Photichthys sp.	PHOPH00	---

Annex 6: Database mesopelagic species listed - South Africa contnd.

Table C: Number of stations of families and species captured in the Nan-Sis species catalogue SA and the Africana database (Families in alphabetic order).

Family	Genus / Species	Database code	# of stations
Photichthyidae	Photichthys argenteus	PHOPH01	251
	Yarella blackfordi	PHOYA02	1
Platytroctidae		PLTAA00	4
Scopelarchidae		SCPAA00	5
	Benthalbella macropinna	SCPBE02	4
Sternoptychidae		STEAA00	---
	Argyropelecus sp.	STEAR00	20
	Argyropelecus aculeatus	STEAR01	11
	Argyropelecus affinis	STEAR02	---
	Maurolicus muelleri	STEMA01	269
	Polyipnus		
	Sternoptyx sp.	STEST00	---
	Sternoptyx diaphana	STEST02	14
	Argyropelecus gigas	STEST04	3
Stomiidae		STOAA00	3
	Opostomias micripnis		
	Stomias sp.	STOST00	---
	Stomias boa boa	STOST02	5

* Stations searched: SA 1-1151

Annex 6: Database mesopelagic species listed - South Africa contnd.

Table D: Number of stations forl families and genera / species captured in the Africana Demersal Data System (Families in alphabetic order).

Family/Sub Family	Genus / Species	Species code	# of stations
Argentinidae	Argentina euchus	109K	2
	Glossanodon		
Astronesthidae	Astronesthes	103M	9
	Astronesthes boulengeri	104N	
	Astronesthes indicus	104M	
	Astronesthes niger	104G	
	Borostomias antarcticus	104U	1
	Borostomias mononema	103Y	1
	Neonesthes capensis	103X	6
	Neonesthes microcephalus	103W	1
Bathylagidae	Bathylagus	110G	12
	Bathylagus antarcticus	110H	7
Chauliodontidae		104K	14
	Chauliodus sloani	104L	50
Evermannellidae		119P	2
	Coccorella atlantica	124G	
Gobiidae	Gobiidae		
	Caffrogobius caffer		
	Caffrogobius nudiceps		
	Caffrogobius saldanha		
	Psammogobius knysnaensis		
	Speckled Goby		
	Sufflogobius bibarbatus	335	313
Gonostomatidae		105A	14
	Cyclothone	103Z	5
	Diplophos	105P	
	Diplophos taenia	105N	3
	Gonostoma elongatum	105B	7
Idiacanthidae	Idiacanthus	104P	6
	Idiacanthus atlanticus	600	16
	Idiacanthus niger	104Q	
Malacosteidae	Aristostomias	105G	
	Malacosteus	104R	7
	Malacosteus niger	104S	33
Melanostomiidae		105E	15
	Bathophilus ater	108B	
	Bathophilus nigerrimus	108K	
	Echiostoma barbartum	105F, 109A	18
	Eustomias	109B	4
	Eustomias bulbornatus	109C	
	Eustomias filifer	104W	
	Eustomias grandibulbus	104V	
	Eustomias lipochirus	105L	

Annex 6: Database mesopelagic species listed - South Africa contnd.

Table E: Number of stations of families and genera / species captured in the Africana Demersal Data System (Families in alphabetic order).

Family / Sub Family	Genus / Species	Species code	# of stations
Melanostomiidae	Eustomias schmitdti	105J	
	Melanostomias	105I	5
	Melanostomias niger	105Q	3
	Melanostomias valdiviae	105R	
	Opostomias micripnis	105D	1
	Photonectes	105M	2
	Photonectes braueri	105H	
Myctophidae		120A	92
	Benthosema suborbitale	122G	
	Bolinichthys supralateralis	122	4
	Ceratoscopelus warmingii	121E	
	Diaphus	120D	85
	Diaphus diadematus	120Q	
	Diaphus effulgens	119Y	1
	Diaphus hudsoni	120H	18
	Diaphus lucidus	120N	1
	Diaphus meadi	119Z	4
	Diaphus mollis	120Z	
	Diaphus ostenfeldi	120I	2
	Diaphus persipicillatus	119V	
	Diaphus problematicus	120L	
	Diogenichthys panurgus	120DP	1
	Electrona risso	120K	23
	Gymnoscopelus	121K	20
	Gymnoscopelus bolini	121	2
	Gymnoscopelus piabilis	121A	1
	Hygophum	121B	3
	Hygophum hanseni	121H	
	Hygophum hygomii	121C	
	Lampadena	122F	8
	Lampadena luminosa	122E	2
	Lampadena notialis	122D	
	Lampadena speculigera	122B	
	Lampanyctodes hectoris	120B	728
	Lampanyctus	120E	22
	Lampanyctus achirus	120Y	
	Lampanyctus alatus	119T	1
	Lampanyctus ater	120W	
	Lampanyctus australis	120T	3
	Lampanyctus festivus	120X	
	Lampanyctus intricarius	120S	
	Lampanyctus lepidolychnus	120U	
	Lampanyctus macdonaldi	120V	

Annex 6: Database mesopelagic species listed - South Africa contnd.

Table F: Number of stations of families and genera / species captured in the Africana Demersal Data System (Families in alphabetic order).

Family/Sub Family	Genus / Species	Species code	# of stations
Myctophidae	Lampanyctus pusillus	119W	1
	Lampanyctus tenuiformis	119R	
	Lampanyctus turneri	119X	
	Lampichthys procerus	120M	3
	Lepidophanes guentheri	120R	
	Lobianchia	122A	
	Lobianchia dofleini	121Z	
	Metelectrona ventralis	120G	2
	Myctophum	119L	5
	Myctophum nitidulum	119Q	
	Myctophum phengodes	119U	
	Myctophum selenops	120P	32
	Notoscopelus	121I	1
	Notoscopelus caudispinosus	121F	
	Notoscopelus resplendens	121G	
	Protomyctophum	121J	8
	Protomyctophum andriashevi	121D	
	Scopelopsis multipunctatus	122C	1
	Symbolophorus	120C	24
	Symbolophorus barnardi	120J	25
	Symbolophorus boops	120F	114
	Taaningichthys bathyphilus	119N	
Nemichthyidae		460A	33
	Avocettina	460D	18
	Nemichthys		
	Nemichthys curvirostris	460C	8
	Nemichthys scolopaceus	460B	11
	Neoscopelus microchir		
Notosudidae		125A	25
	Luciosudis normani	125E	1
	Scopelosaurus	125	14
	Scopelosaurus ahlstromi	125C	3
	Scopelosaurus herwigi	125B	2
	Scopelosaurus meadi	125D	4
Photichthyidae		104Z	8
	Photichthys argenteus	105C	305
	Polymetme corythaeola	105S	
Platytroctidae		103C	4
	Microrictus taaningi	519	
	Persparsia kopua	103B	6
	Sagamichthys schnackenbecki	103A	
Scopelarchidae		123	7
	Benthalbella elongatum	123B	

Annex 6: Database mesopelagic species listed - South Africa contnd.

Table G: Number of stations of families and genera / species captured in the Africana Demersal Data System (Families in alphabetic order).

Family/Sub Family	Genus / Species	Species code	# of stations
Scopelarchidae	Benthalbella macropinna	123A	4
Sternoptychidae	Argyropelecus	107A	27
	Argyropelecus aculeatus	107F	25
	Argyropelecus gigas	107E	4
	Argyropelecus hemigymnus	107B	5
	Maurolicus muelleri	106	694
	Polyipnus	105T	2
	Polyipnus indicus	105U	1
	Sternoptyx diaphana	107D	19
	Valenciennellus tripunctulatus	106A	
Stomiidae		104D	4
	Macrostomias longibarbatus	103K	1
	Stomias boa	104E	8

Annex 7: Nan-Sis database mesopelagic species listed – BENEFIT

Table A: Families and species captured in the Nan-Sis species catalogue AN, NA and SA, and searched for in the project BE (Families in alphabetic order).

Family	Genus / Species	Database code	# of stations
			BE
Argentinidae		ARGAA00	---
	Argentina euchus	ARGAR05	---
Astronesthidae		ASTAA00	1
	Astronesthes sp.	ASTAS00	---
	Astronesthes filifer	ASTAS06	---
	Borostomias sp.	ASTBO00	---
	Borostomias monomena	ASTBO02	---
	Borostomias antarcticus	ASTBO03	---
	Neonesthes capensis	ASTNE01	---
Bathylagidae		BAHAA00	---
	Bathylagus sp.	BAHBA00	---
	Bathylagus longirostris	BAHBA01	---
	Bathylagus bericoides	BAHBA02	---
	Bathylagus glacilis	BAHBA03	8
	Bathylagus antarcticus	BAHBA04	---
	Nansenia sp.	BAHNA00	---
	Nansenia problematica	BAHNA02	5
	Nansenia tenera	BAHNA03	---
Chauliodontidae		CHOAA00	1
	Chauliodus sp.	CHOCH00	---
	Chauliodus sloani	CHOCH01	2
Evermannellidae		EVEAA00	---
	Evermannella balbo	EVEEV01	---
Gobiidae		GOBAA00	15
	Gobidae juvenile	GOBAA90	---
	Sufflogobius bibarbatus	GOBSU01	93
	Thorogobius angolensis	GOBTH01	5
Gonostomatidae		GONAA00	26
	Diplophos sp.	GONDI00	---
	Diplophos taenia	GONDI01	---
	Diplophos maderensis	GONDI02	---
	Gonostoma sp.	GONGO00	---
	Gonostoma elongatum	GONGO01	---
	Gonostoma denudata	GONGO02	---
	Cyclothone sp.	GONSY00	---
	Triplophos sp.	GONTR00	6
	Triplophos hemingi	GONTR01	22
Idiacanthidae		IDIAA00	---
	Idiacanthus sp.	IDIID00	---
	Idiacanthus atlanticus	IDIID01	---
Malacosteidae		MAAAA00	6
	Aristostomias sp.	MAAAR00	---
	Malacosteus sp.	MAAMA00	---
	Malacosteus niger	MAAMA01	---
Melanostomiatidae		MELAA00	2
	Bathophilus longipinnis	MELBA02	---
	Bathophilus nigerrimus	MELBA03	---

Annex 7: Nan-Sis database mesopelagic species listed – BENEFIT contnd.

Table B: Families and species captured in the Nan-Sis species catalogue AN, NA and SA, and searched for in the project BE (families in alphabetic order).

Family	Genus / Species	Database code	# of stations BE
Melanostomiatidae	Echiostoma barbatum	MELEC01	---
	Eustomias sp.	MELAU00	---
	Leptostomias gracilis	MELLE01	---
	Melanostomias sp.	MELME00	---
	Melanostomias macrophotus	MELME01	---
	Odontostomias micropogon	MELOD01	---
	Opostomias micripnis	MELOP01	---
	Photonectes braueri	MELPH01	---
	Photonectes parvimanus	MELPH02	---
Myctophidae		MYCAA00	178
	Bolanichthys supralateralis	MYCBO01	---
	Diaphus sp.	MYCDI00	19
	Diaphus dumerili	MYCDI03	---
	Diaphus hudsoni	MYCDI05	25
	Diaphus effulgens	MYCDI07	---
	Diaphus meadi	MYCDI08	---
	Diogenichthys panurgus	MYCDO01	---
	Electrona risso	MYCEL01	---
	Gymnoscopelus sp.	MYCGY00	---
	Gymnoscopelus bolini	MYCGY01	---
	Hygophum sp.	MYCHY00	---
	Lampadena sp.	MYCLA00	11
	Lampadena luminosa	MYCLA01	---
	Lampadena pontifex	MYCLA04	---
	Lampichthys procerus	MYCLC01	---
	Lampanyctodes hectoris	MYCLM01	120
	Lampanyctus sp.	MYCLP00	---
	Lampanyctus alatus	MYCLP02	---
	Lampanyctus australis	MYCLP10	---
	Myctophum sp.	MYCMY00	---
	Notoscopelus sp.	MYCNO00	---
	Protomyctophum sp.	MYCPR00	---
	Scopelopsis multipunctatus	MYCSC01	---
	Symbolophorus sp.	MYCSY00	---
	Symbolophorus boops	MYCSY01	65
	Symbolophorus barnardi	MYCSY02	---
Nemichthyidae		NECAA00	1
	Avocettina sp.	NECAV00	---
	Avocettina acuticeps	NECAV01	---
	Nemichthys sp.	NECNE00	---
	Nemichthys scolopaceus	NECNE01	8
	Nemichthys curvirostris	NECNE02	---

Annex 7: Nan-Sis database mesopelagic species listed – BENEFIT contnd.

Table C: Families and species captured in the Nan-Sis species catalogue AN, NA and SA, and searched for in the project BE (families in alphabetic order).

Family	Genus / Species	Database code	# of stations BE
Neoscopelidae		NEOAA00	---
	Neoscopelus macrolepidotus	NEONE01	2
	Neoscopelus microchir	NEONE02	---
Notosudidae		NOSAA00	1
	Luciosudis normanni	NOSLU01	---
	Scopelosaurus sp.	NOSSC00	---
	Scopelosaurus meadi	NOSSC01	6
	Scopelosaurus herwigi	NOSSC02	---
Photichthyidae		PHOAA00	6
	Photichthys sp.	PHOPH00	1
	Photichthys argenteus	PHOPH01	30
	Yarella blackfordi	PHOYA02	97
Platytroctidae		PLTAA00	---
Scopelarchidae		SCPAA00	---
	Benthalbella macropinna	SCPBE02	---
Sternoptychidae		STEAA00	1
	Argyropelecus sp.	STEAR00	---
	Argyropelecus aculeatus	STEAR01	---
	Argyropelecus affinis	STEAR02	2
	Maurolicus muelleri	STEMA01	72
	Sternoptyx sp.	STEST00	---
	Sternoptyx pseudobscura	STEST01	---
	Sternoptyx diaphana	STEST02	---
	Argyropelecus gigas	STEST04	---
Stomiidae	Stomias sp.	STOST00	4
	Stomias affinis	STOST01	---
	Stomias boa boa	STOST02	37

[*] Stations searched: BE 1 - 1650

Annex 8: Distribution maps - Order Anguilliformes and Argentiformes

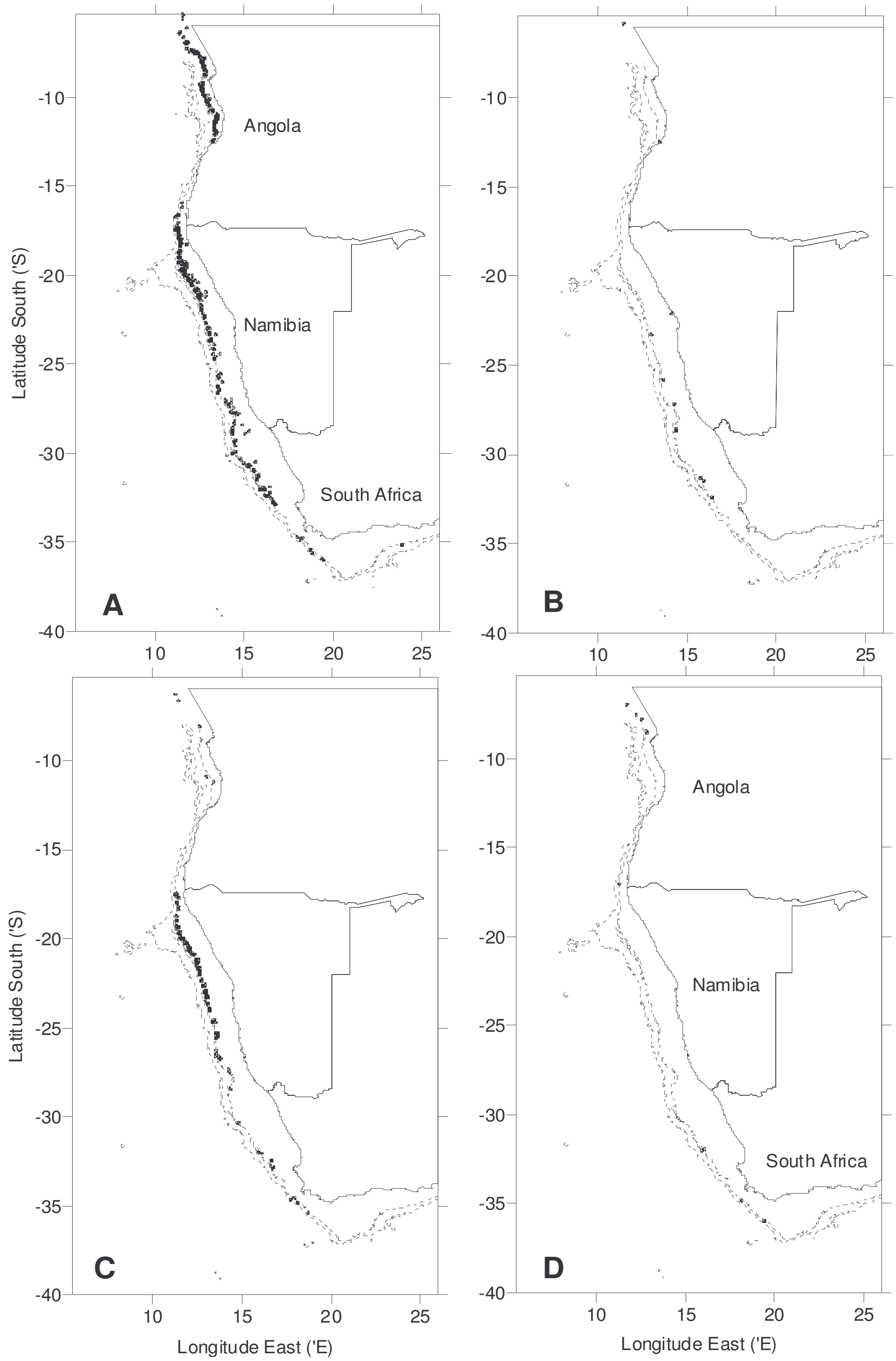


Figure 1: A) Nemichthyidae, B) Argentinidae, C) Bathylagidae, D) Platytroctidae

Annex 9: Distribution maps - Order Stomiiformes

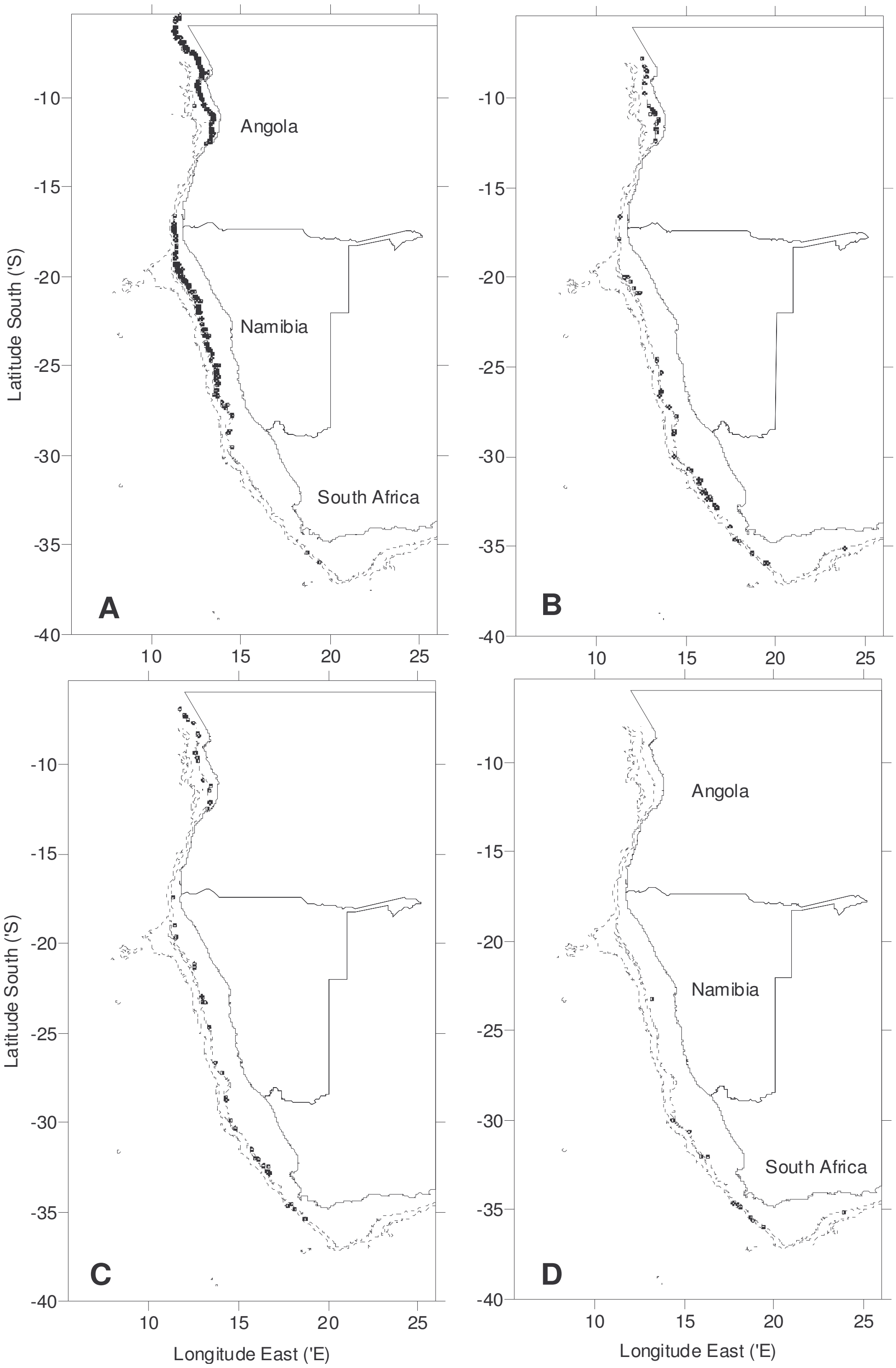


Figure 1: A) Stomiidae, B) Chauliodontidae, C) Astronesthidae, D) Idiacanthidae

Annex 10: Distribution maps - Order Stomiiformes continued

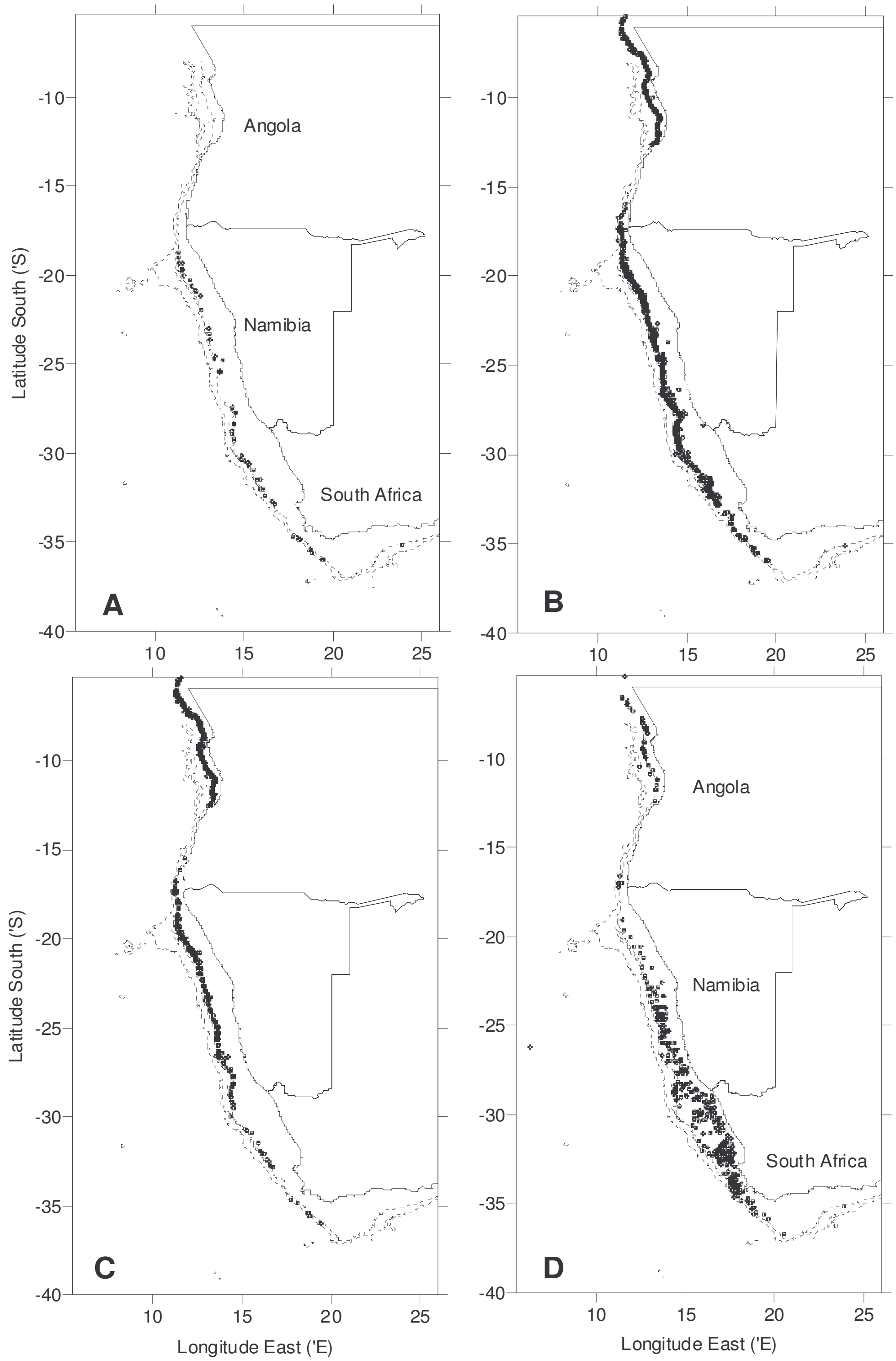


Figure 1: A) Malacosteidae, B) Photichthyidae, C) Gonostomatidae, D) Sternoptychidae

Annex 11: Distribution maps - Order Stomiiformes and Aulopiformes

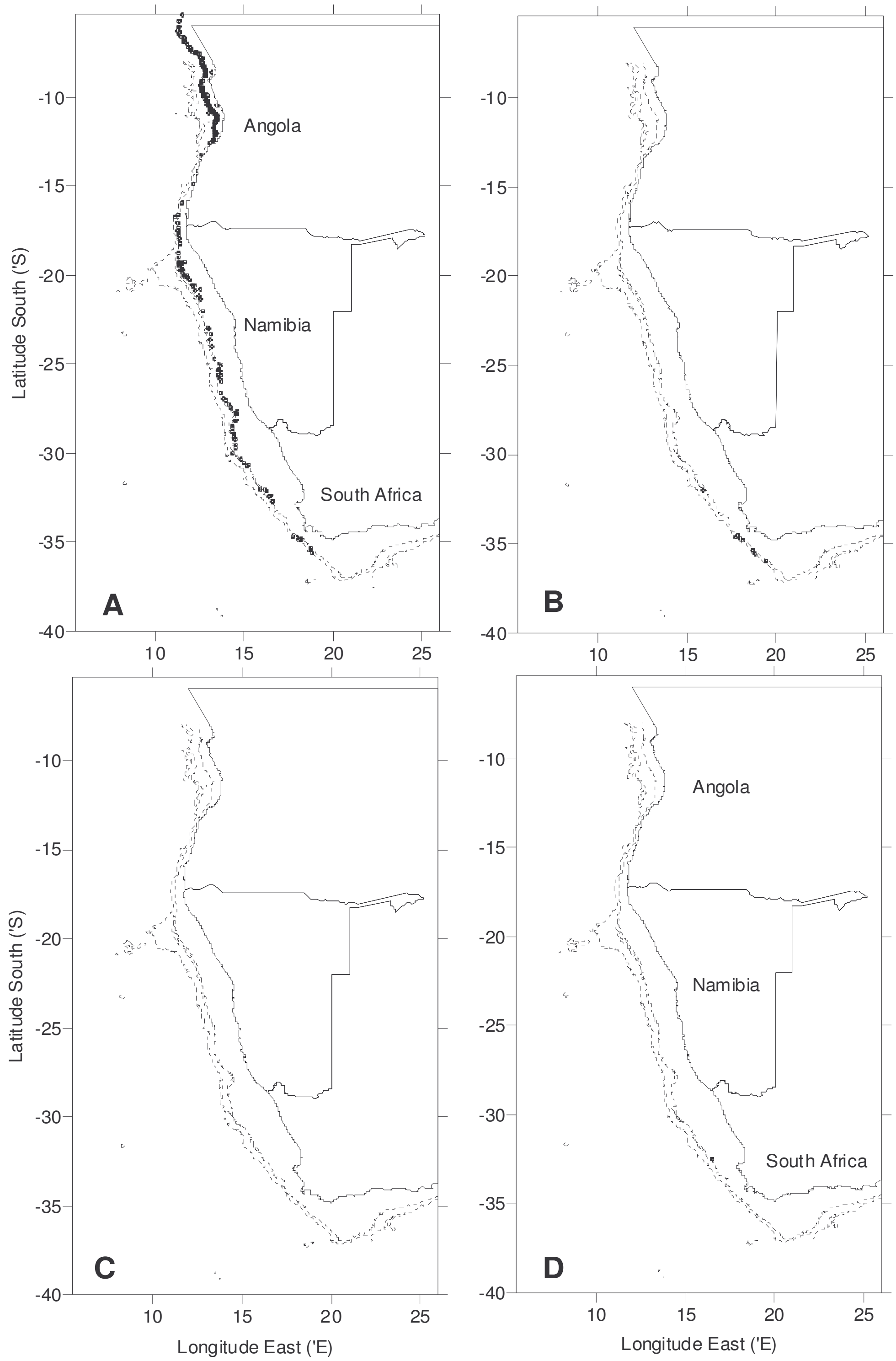


Figure 1: A) Melanostomatidae, B) Scopelarchidae, C) Notosudidae, D) Evermannellidae

Annex 12: Distribution maps - Order Myctophiformes

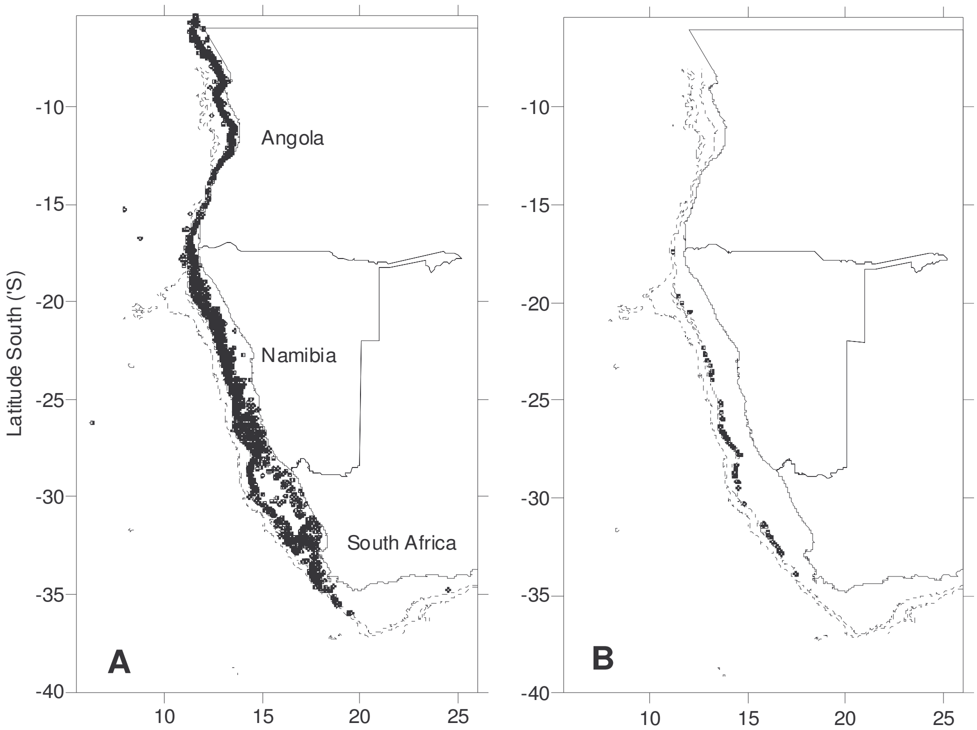


Figure 1: A) Myctophidae, B) Neoscopelidae

Annex 13: Distribution of gobies and mesopelagic species collected by R.V. Welwitchia during horse mackerel surveys.

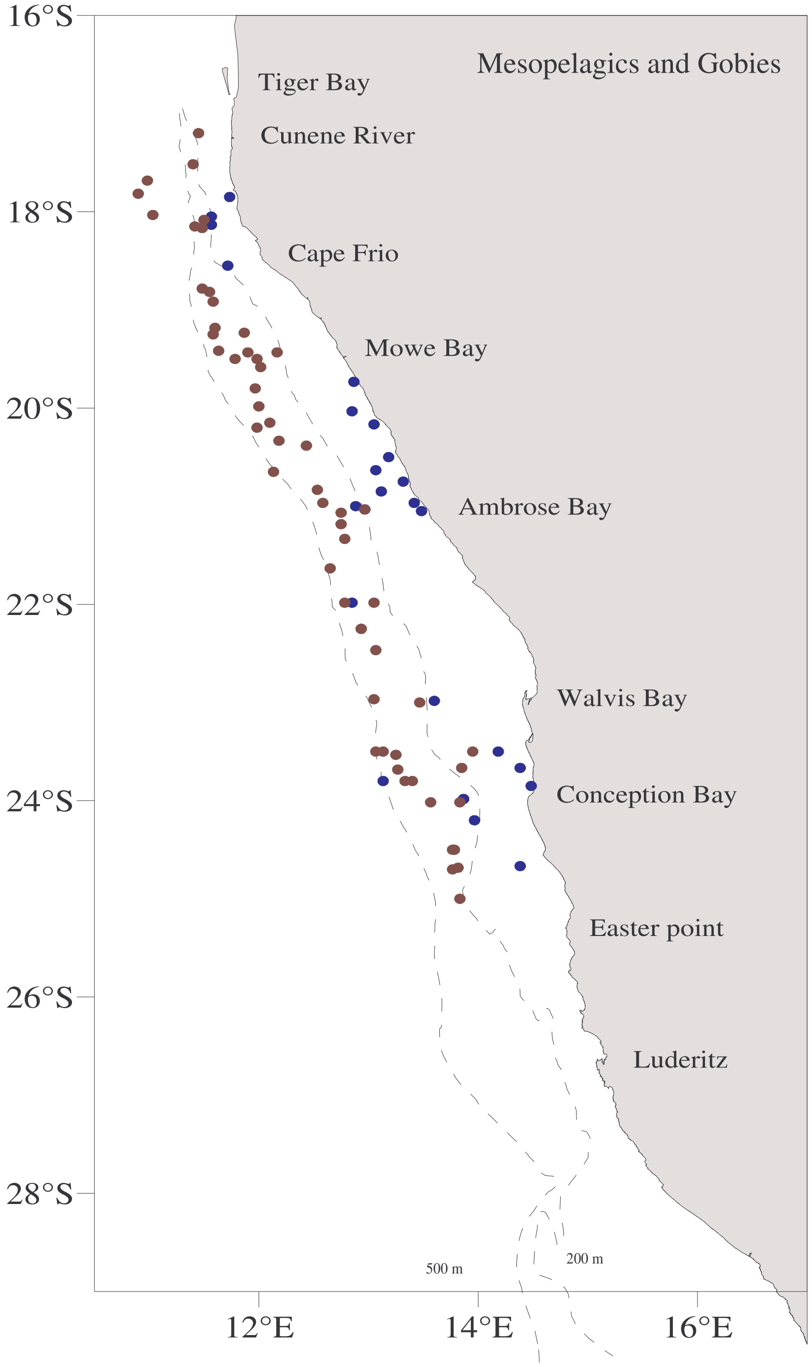


Figure 1: Distribution of catches with gobies (blue) and mesopelagic species (brown) recorded on the R.V. Welwithcia. More information can be obtained from Angie Kanandjembo, NatMIRC.

Annex 14: Catch history

Table A: Landings (t) of lanternfish and gobiidae in South African and Namibian waters (Source FishBase 2005).

Year	Gobiidae SA	Gobiidae NAM	Lanternfish SA *
1965	0	0	0
1966	0	0	0
1967	0	0	0
1968	0	0	0
1969	0	0	0
1970	0	0	18,200
1971	0	0	2,600
1972	0	0	15,200
1973	0	0	42,400
1974	0	0	301
1975	0	0	87
1976	0	0	132
1977	55	0	5,650
1978	62	0	950
1979	300	0	9,885
1980	10	0	40
1981	409	0	10,278
1982	35	0	675
1983	1,254	0	1,633
1984	0	0	13,553
1985	3	0	30,993
1986	626	0	313
1987	185	0	22
1988	32	0	144
1989	0	0	4,704
1990	0	0	571
1991	0	0	662
1992	0	86	656
1993	0	172	1,177
1994	0	19	871
1995	0	5	862
1996	0	552	33
1997	0	287	243
1998	0	20,998	6,553
1999	0	16	0
2000	0	3	0
2001	0	0	0

**Lampanyctodes hectoris*

Annex 15: BENEFIT survey proposal on mesopelagics

BENEFIT PROJECT PROPOSAL AND APPLICATION FOR FUNDING
January 2006

1. **TITLE OF PROJECT**: *Acoustic survey of the meso-pelagic resources of the Benguela region*

2. **DURATION OF PROJECT:**
   January 2006 to December 2007 (2 years)

3. **CATEGORY OF PROJECT:**
   First proposal

4. **KEYWORDS BY WHICH PROJECT CAN BE IDENTIFIED**:
   acoustic surveys, mesopelagic fish, Target strength

5. **RESPONSIBLE PROJECT LEADER (AND CO-LEADERS):**

<u>Project leaders</u>:

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Collaborators:

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Name	Carl van der Lingen
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6. SUMMARY OF FINANCIAL REQUIREMENTS:

	This application 2006	Following year (est.) 2007
Vessel costs	21 days	-
Running expenses	N$ 5 000	N$ 5 000
Travel and per diem	N$ 55 000	N$ 80 000
TOTAL	N$ 60 000	N$ 85 000

7. ORGANISATION RESPONSIBLE FOR ADMINISTRATION OF THE FUNDS

BENEFIT Secretariat

8. OBJECTIVES AND RATIONALE (NEED AND PURPOSE):

Fisheries acoustic surveys in the Benguela region have in the past only focused on commercially important species such as sardine, anchovy, horse mackerel and round herring (Barange *et al*. 1999, Boyer and Hampton 2001). Recently they have also been used to estimate the biomass and target strength of jellyfish in Namibian waters (Brierley *et al*. 2001) and have at times been used to correct estimates of hake biomass obtained from bottom trawl surveys (Iilende *et al*. 2001). Given the synoptic nature of acoustic surveys and improved technology available, these surveys are also ideal for estimating the biomass of non-commercial species such as lanternfish and lightfish in a relatively short time. Despite the perceived high biomass of meso-pelagic fish biomass in both the northern and southern Benguela (Armstrong and Prosch (1991) and their associated importance in the foodweb (Shannon and Jarre-Teichmann 1999), very little effort has, however, been spent on estimating the biomass and target strength of meso-pelagic fish.

The combined biomass of the myctophid *Lampanyctodes hectoris* (the lanternfish) and the sternoptychid *Maurolicus muelleri* (the lightfish) in the southern Benguela was estimated by Armstrong and Prosch (1991) to be in the order of one million tons during two surveys in 1983 and 1987. *L hectoris* is by far the most abundant myctophid in the northern Benguela and is distributed over the outer shelf from Walvis Bay to the Orange River and further south into South Africa's west coast area. The biomass of lantern fish in the northern Benguela has previously been estimated at around 800 000 tons, although negative biases such as under sampling during the day and net avoidance at night were noted for this estimate (Hewitson and Cruikshank 1993). Several acoustic surveys conducted each year in the Benguela region are restricted to the inner shelf area (approximately 200 m isobath) and therefore not suitable for providing simultaneous meso-pelagic fish biomass estimates, as the distributional range of both lanternfish and lightfish extends out to at least a bottom depth of 500 m (Hulley and Prosch 1987).

Several attempts to model trophic flows in the southern and northern Benguela have had to incorporate uncertainty about many of the parameter estimates in the mass balanced models used (Jarre-Teichmann *et al*. 1998, Shannon *et al*. 2004, Roux and Shannon 2004). Whereas biomass estimates of the commercially important fish species are available, data on meso-pelagic production and consumption have not been updated since the mid 1980s. Results from trophic flow models of the region have, however, confirmed that meso-pelagic fish play an important role in the foodweb of the Benguela, particularly as a link between zooplankton and hake (Jarre-Teichmann *et al*. 1998, Shannon and Jarre-Teichmann 1999). Apart from hake, meso-pelagic fish are also consumed by other demersal fish and large horse mackerel, cephalopods, large pelagics such as Tuna and snoek and even by seabirds.

In addition, round herring (*Etrumeus whiteheadi*) is currently not of commercial importance in Namibia and there is limited information on the species from that region. Round herring is also considered to be of little importance to the trophic flow of the northern Benguela and is basically eliminated from the trophic flow models (Jarre-Teichmann *et al*. 1998) due to there being little information available. During May 2004, however, an acoustic survey of the LUCORC region by the R. S. Africana found substantial amounts of round herring (260 000 tons) in the area between Lüderitz and the Orange River (MCM unpublished data). These fish could be an important food source to other top predators such as large pelagic fish (Shannon and Jarre-Teichmann 1999), condrichthyans (Jarre-Teichmann *et al*. 1998), seals and seabirds (Crawford *et al*. 1991), yet not enough information is available to include them into ecosystem models.

Given recent endeavors to move away from single-stock assessments procedures towards an integrated ecosystems approach to fisheries management, some fundamental uncertainties need to be addressed for several species groups. These include greater effort to improve indices of biomass, consumption, predator selectivity and the variability in these related to absolute abundances of prey species (Shannon *et al*. 2004, Roux and Shannon 2004). This proposal aims to address some of the questions related to the meso-pelagic species located in the northern and southern Benguela through a dedicated acoustic survey, with bottom and midwater trawling for target identification, of the entire shelf out to a depth of 500 m between Walvis Bay and Cape Point.

9. KEY QUESTIONS AND RESEARCH APPROACH:

Key Questions

1. What are the biomass and distribution patterns of meso-pelagic fish species in the southern and Northern Benguela?

2. Can the target strength of meso-pelagic fish species in the Benguela region be measured in-situ using high resolution multi-frequency techniques?

3. How do oceanographic variables influence the distribution and behaviour of meso-pelagic fish species in the Benguela region?

4. What oceanographic conditions characterise the spawning habitat of meso-pelagic fish species in the Benguela region?

Research Approach

A dedicated three week acoustic survey is required on the Dr Fridtjof Nansen in either July/August or September 2006 to answer the above key questions. Multi-frequency acoustic data will be collected using a Simrad EK60 echo sounder at 38, 120 and 200 kHz (MCM will supply GPTs if unavailable). The multi-sampler will be required for targeted trawling of individual scattering layers. A temporary CUFES system will need to be set up for egg collection. A comprehensive callibaration of the acoustic system will be required prior to the survey. Specific objectives of the survey include:

- Collection of high resolution multi-frequency acoustic data for target strength estimation of meso-pelagic fish species.
- Training of scientists from the region in disciplines such as acoustic survey techniques, target strength estimation and spatial statistics.
- Estimation of the biomass and population length structure of lanternfish and lightfish by means of echo-integration and targeted midwater/bottom trawling.
- Collection of data for the description of distribution and behaviour patterns of meso-pelagic fish.
- Collection of meso-pelagic fish eggs through the use of a continuous underway fish egg sampler (CUFES) for mapping of spawning habitat and investigation of the influence of oceanographic variables on egg distribution patterns.
- Collection of environmental information to investigate the influence of oceanographic variables on the distributional patterns of meso-pelagic fish species.
- Collection of biological data on reproduction and diet of meso-pelagic fish species

The above specific objectives may be expanded to incorporate other co-occuring species found such as sardine, anchovy, round herring, horse mackerel, juvenile hake and pelagic goby.

10. PROPOSED WORK PLAN:

2006

1. Three week acoustic survey on Dr. Fridtjof Nansen (August/September) with participants from MCM, NATMIRC and Oslo University.

2007

1. Participants of survey to get together in Cape Town or Walvis Bay to analyse data from Survey and plan publication(s) (February/March)
2. Authors involved in publications to meet in Cape Town or Walvis Bay for writing of scientific publication(s) (August/September)

11. END PRODUCTS OF THE PROJECT:

1. Biomass and Target strength estimates of the most important meso-pelagic fish species in the Benguela region.
2. Distribution patterns, behavioural strategies and spawning habitat characterisations of the most important Meso-pelagic fish species in the Benguela region.
3. Revised biomass inputs for mass-balanced models of both the northern and southern Benguela with associated changes in model outputs.
4. Publication of results in scientific literature
5. Training of inexperienced scientists from the region
6. Contribution of data for a PhD thesis (A. Staby)

12. FINANCIAL REQUIREMENTS

2006

Running expenses

Communication expenses, computing consumables (eg DVD,s and CD's) stationery etc	N$ 5 000

Travel costs

One-way travel between Cape Town and Swakopmund for up to MCM participants in cruise (including *per diem*)	N$ 25 000
One-way travel between Cape Town and Swakopmund for up to 4 Namibian participants in cruise (including *per diem*)	N$ 15 000
Return Travel for one student from Bergen University for participation In cruise (including *per diem*)	N$ 15 000
Total	**N$ 60 000**

2007 (estimated)

Running expenses

Communication expenses, computing consumables (eg DVD,s and CD's) stationery etc	N$ 5 000

Travel costs

Four return airfares between Cape Town and Swakopmund for Data processing and finalization of publications	N$ 20 000
Accomodation and *per diem* for 2 participants from MCM to Visit Swakopmund for two periods of 5 days	N$ 20 000
Four return airfares between Swakopmund and Cape Town for Data processing and finalization of publications	N$ 20 000
Accomodation and *per diem* for 2 participants from NATMIRC to Visit Cape Town for two periods of 5 days	N$ 20 000
Total	**N$ 85 000**

Annex 16: Contact details

Table A: Contact details of people approached for additional information on gobies and mesopelagics

Contact person	*Country*	*Institute/ Company*	*Position*	*Adddress*
Angie Kanadjembo	Namibia	National Marine Information & Research Centre (NatMIRC)	Senior Biologist	P O Box 912 Swakopmund, Namibia Tel: +264 64 410 1000 Fax: +264 64 404 385 akanandjembo@mfmr.gov.na
Philomena Vaz Velho	Angola	Instituto de Investigacao Marinha (IMM)	Biologist: Pelagics	P O Bocx 2611 Luanda, Angola
Johan Augustyn	South Africa	Marine & Coastal Management (MCM)	Director: Research	Department of Environmental Affairs & Tourism Tel: +27 21 402 3102 Fax: +27 21 429 6977 augustyn@deat.gov.za
Tracy Fairweather	South Africa	Marine & Coastal Management	Senior Oceanographer	Marine & Coastal Management Tel: +27 21 402 3256 Fax: +27 21 421 7406 tracey@deat.gov.za
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