Long-term trends in fish length-at-age, catch-at-length and condition of the Namibian and South African commercially exploited species

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Masters in Ichthyology and Fisheries Science

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By

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Declaration

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Thesis title: Long-term trends of length-at-age, catch-at-length and fish condition of the Namibian and South African targeted and main bycatch resources.

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Abstract

Fish growth rate is a flexible trait that can evolve in response to fishing or environmental change. Therefore, knowledge of fish growth rate patterns, long-term and short-term responses to fishing effort and environmental change is important for fisheries management in the Benguela. Historical and current age length keys have been used as indicators of annual fish growth in the Benguela, the growth rate study on *Merluccius paradoxus* demonstrated long-term changes in growth over three decades as a response to fishing. However, the fish growth rate patterns, in relation to fishing effort and environmental change patterns are still not known for the many commercially important stocks in the Benguela.

The specific objectives of the project were to determine the annual variability and long-term trends, in annual mean lengths-at-age, catch-at-length and fish condition of 17 commercially exploited resources, targeted and bycatch in Namibia and South Africa in relation to environmental changes (sea surface temperature).

The results showed that there was a significant decrease in mean length at age 7 for *Merluccius capensis* (Namibian stock), a significant decrease in mean length at ages 3 to 7 for South African *M. capensis* and a significant increase in mean length at ages 2 to 6 for South African *M. paradoxus* Fishery-induced evolution may be the reason for the increase in mean length in the early stages of hake. A regime shift was detected in the mean length at age 1 for *Etrumeus whiteheadi* (South African stock) caused by changes in water temperatures.

A decrease in mean length of the catch was observed for Namibian *M. capensis* and the reason for this could have been the stock being overexploited during the years of the observed trend (1968 to 1987). Historically both the Namibian *Lophius vomerinus* and *Helicolenus dactylopterus* were bycatch of the hake fishery, therefore, the decrease in their mean length of the catch may be due to increased bycatch mortalities due to increased hake catches. The improvement in the management measures of the *Jasus lalandii* fishery and possible favourable oxygen fluctuation might have caused the stock to increase in mean length of the catch between 1977 and 1982.

Fish condition showed a significant difference in stocks between years. Fish condition of *M. capensis, M. paradoxus* and *T. capensis* were analysed. The rest of the commercial stocks were omitted because there was limited length-weight data. For Namibian *M. capensis* the spawning season may have caused fish to have the best condition in 1987 and while higher temperatures in 1983 may have led to the worst condition in 1983. Higher prey availability in 1979 for Namibian *M. paradoxus* could have been the reason for fish with best condition being found in 1979. *T. capensis* had the highest condition index in 1986 when cooler summer SST prevailed that may have been more favourable for *T. capensis* to live in.

July, September and January SSTs were significantly negatively correlated with the mean length of *M. capensis* at age 3. This was perhaps due to upwelling intensity and plankton productivity which increases in winter and decreases in summer.

A separate study of the impacts of fishery-induced changes and density-dependence on fish growth rate, as well as the effects of other environmental variables is recommended. Since data for some species was outdated, it is suggested to update biological variables and assessment for future work. This study can be used to understand the key life history characteristics of Namibian and South African exploited resources, targeted and bycatch.

List of acronyms

ALK – Age Length Keys

CPUE – Catch per Unit Effort

DAFF – Department of Agriculture, Forestry and Fisheries

DEFF – Department of Environment, Fisheries and Forestry

EEZ – Exclusive Economic Zones

EFZ – Exclusive Fishing Zone

ICSEAF – International Commission of Southeast Atlantic Fisheries

MFMR – Ministry of Fisheries and Marine Resources

MSY – Maximum Sustainable Yield

PUCL – Precautionary Upper Catch Limit

SST – Sea Surface Temperature

TAC – Total Allowable Catch

TAE – Total Allowable Effort

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1. Introduction and literature review

The marine fisheries sector in the Benguela contributes substantially to the economies of the countries, South Africa, Namibia and Angola that are part of this system (Van der Lingen et al. 2006a). The fishing sector is the third largest sector and second largest growing industry in the Namibian economy (Boyer and Hampton 2001). In South Africa, the marine fishery sector has important social and economic benefits (Cochrane et al. 2020). Hence, it is important to face the economic and social challenges faced by the fishery sector in order to sustain the marine resources for future use (Cochrane et al. 2020).

Fish growth rate is a plastic trait and can evolve in response to fishing or environmental change (Hunter et al. 2016). Changes in fish growth rate are important to note for the management of fisheries (Heino et al. 2002). Such changes can be determined in long-term trends of fish growth and environmental variability. Long-term environmental studies are difficult to maintain but are important to provide an understanding on ecology, environmental change and management (Lohner and Dixon 2013). Long-term fish monitoring programs are also important in assessing the potential impact of environmental change (Lohner and Dixon 2013).

1.1. Fish Growth rates

Biological information is needed on exploited aquatic resources in order to determine how to manage the fishery and avoid depletion of the stock. Collection of accurate age data is useful because it can give fisheries managers information on fish mortality and fish growth rates (Coggins et al. 2013). The somatic fish growth rate of a population can be used to determine its important biological characteristics, such as life history traits (Peters 1983; Calder 1984). There are several ways in which fish growth can be determined, the most commonly used method is through using otolith data to calculate mean length at age for the whole population (Pilling et al. 2002). Otoliths, specifically in bony fishes, have long been used for age determination, as they are calcium carbonate structures that have a continual growth and distinct structure (Ghanbarzadeh et al. 2014). There are various techniques to determine growth of fishes using otoliths. A widely accepted technique is to use fish lengths at age and equations such as the von Bertalanffy growth function to calculate annual growth rates at a population level (Morrongiello and Thresher 2015). There has been a couple of studies done on the aging of fish using otoliths. For example, Wilhelm et al. (2020), aged fish by transversely sectioning otoliths and once imaged measured the width of each otolith growth increment using ImageJ. Each growth increment was either measured from the end of the translucent zone to the end of the next translucent zone, from the dorsal edge to the nucleus of the sectioned otolith perpendicular to the annual growth zone or along the axis of maximum growth. After increments were marked and cross-dated, each fish was allocated a final age-a-capture and Cohort (Wilhelm et al. 2020). In a study by Healy et al. (2021), otoliths for Pacific cod were aged through microscopically counting the number of growth rings.

1.1.1. Impact of fishing on fish growth rate

Fishery-induced evolution is an aquatic organism’s response to exploitation where the exploited resources may experience variation in life history traits such as somatic growth rates (Hunter et al. 2016). Fishing may increase mortality rates and select certain sizes of fish, which may lead to altered fish growth rate patterns (Enberg et al. 2012). Thus, fishing has led to demographic and evolutionary changes in many exploited fish populations, such as faster growth before sexual maturation, earlier sexual maturation and early-reproducing individuals when fishing selects adult fish (Tanner et al. 2019). Not only can fishing exploitation remove fast or slow growing individuals from a population, it may also affect the growth of the fish that remain (Morrongiello et al. 2019).

An example of fisheries-induced evolution was described by Morrongiello et al. (2019) for *Notolabrius funicola* (purple wrasse) a reef fish inhabiting an ocean warming hotspot in Tasmania, Australia. They showed that mean growth rates increased as a response to warming temperatures and to fishing. They were also the first study to show fishing-induced changes in thermal reaction norms; growth did not increase with fish size in relation to temperature after fishing. Fishing can induce shifts at an individual level where larger purple wrasse individuals are able to access larger foraging areas in warmer years (Morrongiello et al. 2019). Therefore, after the removal of larger individuals, smaller individuals were able to access more resources by improving their thermal growth responses, causing an increase in fish growth rate and therefore decreasing the thermal reaction norm slope after fishing. No-trawl areas or areas with less fishing activity usually allow species to grow to a larger size than those found in heavily fished areas (Giacalone et al. 2010).

Another example of fishery-induced evolution is that of the *Coregonus clupeaformis* (lake white fish), where their somatic growth rate and mean condition factor decreased as an evolutionary response to the selective gillnet fishery (Enberg et al. 2012). Fishery induced evolution also occurred in Namibia when there was an increase in fishing mortality (observed in demersal trawl and longline fishing) from 1997 to 2016 on *Merluccius paradoxus*, which led to an increased growth of pre-mature individuals (increased mean lengths at ages 3 and 4 years) and decreased growth of post-mature individuals (decreased mean lengths at ages 7 and 8 years) in the population (Wilhelm et al. 2020).

Density dependent constraints are, for example when a large population exhausts its food resources due to intra-specific competition for food (Lorenzen and Enberg 2001). An example of intraspecific competition for food was illustrated by Wagner et al. (2007) with the annual fish somatic growth rate of *Sander vitreus* (walleye) in northern Wisconsin, which was fast at low density and slow at high density within individual lakes (Wagner et al. 2007). For *Sardinops sagax* (sardines) in the Benguela, length at 50% maturity (L_{50}) and fish condition factor were density-dependent, showing high L_{50} and low condition factor and low relative gonad mass in years in which sardine population abundance was high, and the opposite with low population abundance (Van der Lingen et al. 2006b). Another example of density-dependent constraints, was the decline in *Jasus lalandi* (West coast rock lobster) growth rates in November 1988 in Elands Bay and Donkins Bay, South Africa (32°18'S 18°19'E) and this was correlated to a reduction of their preferred food source, the ribbed mussel (Pollock et al. 1997). It forced rock lobster to switch to a less abundant and less nutritious food source, hence, a reduction in their somatic growth rates (Pollock et al. 1997). The rock lobster example demonstrated the reduction in food source could influence annual somatic growth rates, i.e. density dependence. Density dependency does not only affect growth but survival and reproduction of stocks as well (Tanner et al. 2019).

Length-weight relationships and mean fish condition provide information on stock condition of fish populations (Ndjaula et al. 2013a). Weight-length relationships enable fishery managers to predict the weight from the length of a fish and compare mean fish condition spatially or temporally between fish groups (Hamid et al. 2015). It is assumed that the heavier the fish at a certain length, the better the condition, as was the case for three species found in the Temengor

Reservoir (Hamid et al. 2015). Weight-length relationships of the same species may vary according to sex, temporal/spatial factors, food availability or fishing pressure (Giacalone et al. 2010). For example, the *Mullus barbatus* (red mullet) stock off the coast of northern Sicily (central Mediterranean Sea) experienced various fishing effort levels and showed a better fish condition when they were trawled compared to in untrawled areas (Giacalone et al. 2010). Giacalone et al. 2010 explains the reason for this could be to the decrease of competition at lesser population densities and providing better conditions for individuals, meaning, a relaxation of density dependent constraints.

1.1.2. Impact of environmental change on fish growth rate

Individual populations and marine ecosystems constantly change sometimes due to human impact, mainly through fishing and climate change (Tanner et al. 2019). Climate change can either be favourable or unfavourable to marine species living at specific regions. For example, it is expected that the sea temperature of the South African coastal areas will increase by at least 4° by the year 2100, along with changes in sea levels, wind direction and strength (Fitchet et al. 2016). The increase in sea temperatures may have unfavourable impacts on the marine life. For example, the increases in sea temperatures and increases in El Nino events, caused the coral bleaching in the West Indian Ocean that resulted in the mortality of corals across the region (Clark 2006).

Temperature is noticeably the most influential of environmental factor on marine species (Potts et al. 2015). Fish are ectotherms which means that, changes in water temperature can easily impact their physiology. Water temperature may also affect the phenology and behavioural responses of a population at any life history stage (Hollowed et al. 2013). The phenology and behavioural responses are species-dependent (on a genetic level). Thus, biological processes such as growth, reproduction and productivity may also be altered due to climate change (Izzo et al. 2016). For example, the warming of sea temperatures could lead to the increase of somatic growth of the stock, hence, also affecting total biomass and catch (Rountrey et al. 2014).

As stated above, growth rates may vary by species in response to environmental changes. Warming temperatures are usually linked with faster growth rates. However, increased water temperatures in the North Sea, it led to a decline in body sizes of *Melanogrammus aeglefinus, Clupea harengus*, and *Pleuronectes platessa* (Baudron et al. 2014). There is also a variation in the way that the same species respond to warming of the water, depending on the region they are found in. In the case of the haddock and whiting populations found in Scotland, lengths decreased in the Clyde region, while lengths increased in the Western shelf region after the increase in water temperatures (Hunter et al. 2016). A study done on the rock bass in Ozark streams indicated that the growth rate of the species decreased in the summer (warmer temperatures) because it decreased in body condition (Guyette and Rabeni 1995). Another example of fish growth rate response to temperature is the warmer temperatures and low upwelling in the northern Benguela was related to slow growth of *M. paradoxus* and high upwelling and cooler temperatures impacting growth of *M. paradoxus* positively (Wilhelm et al. 2020).

1.1.3. Regime shifts

Apart from fishing effects, and environmental variability, changes in somatic growth rates (or mean lengths at age) of fish stocks can also reflect ecosystem regime shifts (e.g. Smolinski and Mirny 2017; Lauerburg et al. 2018; Tanner et al. 2019). A regime shift occurs when a large marine ecosystem goes through a shift over a decadal period, usually due to environmental change, but sometimes due to fishing (Cury and Shannon 2004). Marine species respond to environmental changes by a fluctuating somatic growth rate and population abundance and as a result the trophic structure of the ecosystem changes, in order to adapt to the new habitat (Cury and Shannon 2004). For example, the northern Benguela ecosystem went through a regime shift in the 1970s, where the collapse of the sardine stock (caused by heavy fishing) led to the restructuring of the food web, overall, changing the ecosystem (Van der Lingen et al. 2006a). The structural changes of the northern Benguela system are the reason behind the very low pelagic fish stock biomass and a very high jellyfish biomass (Roux et al. 2013). The decline in small pelagic fish in the northern Benguela system led to most predators switching diet toward less suitable prey species, for example, bearded goby and horse mackerel (Roux et al. 2013). Similarly, a shift from sardine to anchovy in the southern Benguela, from the mid-1960s to the mid-1990s, following a gradual increase in sea surface temperature, led to a change in trophic structure in the southern Benguela (Cury and Shannon 2004).

1.2. Benguela current system

The Benguela current system is known as one of the major upwelling systems in the world and it is divided into the northern and southern Benguela by the Luderitz upwelling cell at about 27°S (Van der Lingen et al. 2006a). The system extends from the southern part of Angola to the south of South Africa and is mainly dominated by strong coastal upwelling (Demarcq et al. 2003). The Benguela ecosystem is home to several marine species that are both economically and ecologically important to that region (Van der Lingen et al. 2006a). Commercial fisheries that target pelagic and demersal fish species are well developed in the northern and southern Benguela (Van der Lingen et al. 2006a).

The distinctive differences between the northern and southern Benguela regions are mainly due to the warm Agulhas current that is boundary to the southern Benguela (Cury and Shannon 2004). Other differences include the total size of catch and the population sizes of stocks found in each region (Hutchings et al. 2009). For example, the total catch of sardine and anchovy have remained high in the southern Benguela, while there was a stock collapse of sardine in the northern Benguela (Hutchings et al. 2009). Horse mackerel catches remained low in the southern Benguela and the catches in the northern Benguela were high, reaching a total of about 250 000 t in the year 2000 (Hutchings et al. 2009).

1.2.1. Historic development and management of fisheries in southern Africa

The Benguela current is highly productive and species such as anchovy and sardine have been targeted since the 1950s, but since the 1960s hake and horse mackerel have comprised the principle targeted species in the northern Benguela (Bekiashev and Serebrikov 1981). The FAO developed a convention to conserve the marine resources of the Southeast Atlantic because catches were continuously increasing in the Southeast Atlantic since the 1960s. The International Commission for the Southeast Atlantic Fisheries (ICSEAF) was then established for the implementation of the aims of the convention (Bekiashev and Serebrikov 1981). The ICSEAF was an intergovernmental organization that was established in 1969 and came into effect in 1979 (Miles 1989; Van der Westhuizen 2001) and was contributed to the study of marine resources of the Southeast Atlantic (Bekiashev and Serebrikov 1981). The countries that collaborated in the ICSEAF were as follows;

Angola, Bulgaria, Cuba, France, German Democratic Republic, Federal Republic of Germany, Iraq, Israel, Italy, Japan, Republic of Korea, Poland, Portugal, Romania, South Africa, Spain and the USSR (Miles 1989). In addition to research by ICSEAF, a further objective was to set catch quotas (Miles 1989).

The ICSEAF areas included Angola, Namibia and South Africa, but it focused mostly on the resources off Namibia as this was the richest fishing area at the time (Saetersdal et al. 1994). Although, the ICSEAF was initially established with the purpose of "good management", the commission ended up exploiting the resources off the southeast Atlantic, mostly off Namibian waters (Nichols 2003). After Namibia's independence in 1990 the Ministry of Fisheries and Marine Resources (MFMR) took over management of the marine fisheries (Kirchner 2011), while the South African government declared a 200nm Exclusive Economic Zone (EEZ) and excluded the foreign fleets in 1978 (DAFF 2005).

For management purposes, the ICSEAF divided the Southeast Atlantic fishing area into several divisions (Hutton and Sumaila 2002). The West coast of South Africa was known as Division 1.6 and the South coast was Division 2.1 and 2.2 (Hutton and Sumaila 2002). Namibia was Division 1.3, 1.4 and 1.5 and Angola was Division 1.1 and 1.2, (see Fig 1; Saetersdal et al. 1994).

Two annual reports by different member countries of the ICSEAF was introduced containing the following information: species, ICSEAF division, month, type of vessel and gear and effort unit. The first report consisting of catch and fishing effort statistics was later printed out into the final version as the ICSEAF "Statistical Bulletin" (FAO 1982). Biological sampling of length and age increased over the years. The data was processed and printed out tables on age-length keys, length frequency and length-weight relationship and published as "Sampling Bulletin" (FAO 1982). Currently there is a total of 16 volumes of the ICSEAF Sampling Bulletins published from 1972 to 1987 containing data from 1968 to 1987.

Merluccius capensis (shallow-water Cape hake) and *Merluccius paradoxus* (deep-water Cape hake) are major commercially exploited resources caught by demersal trawling in Namibian waters (Boyer and Hampton 2001). The two species of hake are very similar, hence, landings for the two species are combined and they are currently assessed as one stock in Namibia (Kirchner et al. 2012; Jones et al. 2020). The hake fishery in Namibia began in the mid-1960s and it is a valuable part of the fishery sector in Namibia (Wilhelm et al. 2015). The fishery was managed by the ICSEAF from 1976 until 1989 and the management was taken over by the MRFR in 1990 (Wilhelm et al. 2015; Jones et al. 2020). The exploitation of the stock started in 1964 when there was open access fishing on the stock and the fishery remained unregulated until 1974 (Kirchner et al. 2012; Wilhelm et al. 2015). The fishery was then managed through TACs from 1977 to 1989 (Kirchner et al. 2012). There was a drastic decline in stock biomass in 1972, when catches were at 800 000 t. Catches from 1981 to 1989 ranged between 300 000 t and 400 000 t (Wilhelm et al. 2015). By the time MRFR took over the management of the hake fishery, it was one of the most depleted marine resources in Namibia (Payne et al. 2001). After 1990, biomass of hake continued decreasing, but there has been some recovery in the recent years largely due to better management measures (Jones et al. 2020). Management measures included the banning of foreign fleets with the introduction of the 200-mile-EEZ (Exclusive Economic Zone) and a 200 m depth restriction (Paterson et al. 2013; Wilhelm et al. 2015; Jones et al. 2020).

The most valuable fishery in South Africa is the trawl fishery for Cape hakes (*M. capensis* and *M. paradoxus*) (Parker et al. 2020). The fishery began towards the end of the First World War and catches averaged around 1000 t per annum. Subsequently catches increased in the early 1960s to around 170 000 t per annum, due to an increase of foreign fleets. The introduction of the 200 nautical mile exclusive fishing zone (EFZ) in 1977 and the departure of international shipping fleets had positive results as the stock biomass increased through the 1980s and 1990s (Rademeyer et al. 2008; DEFF 2020). An operational management procedure (OMP) was developed in 1990 for the management of the hake fishery in South Africa. The two stocks were initially assessed as one stock but are now assessed, with quotas for two separate stocks. The fishery obtained its first eco-label by the Marine Stewardship Council (MSC) in 2006 and the eco-label was subsequently renewed twice in 2010 and 2015. The stock status in 2020 was that *M. capensis* was underexploited, while *M. paradoxus* was fully exploited (DEFF 2020).

Trachurus capensis (Cape horse mackerel), which is a pelagic species as a juvenile, are an important commercial species found throughout the Benguela region. Three stocks are believed to be found in Namibian and South African waters, each in different ICSEAF divisions – one in Division 1.3 and 1.4 (northern Benguela), one in Division 1.6 (southern Benguela) and another in Division 2.1 and 2.2 (South African South coast) (Naish et al. 1991; see Fig 1). Length-at-age data showed a slower fish growth rate of *T. capensis* in the northern Benguela than in the southern Benguela (Naish et al. 1991). However, recent genetic evidence revealed no significant mtDNA differentiation between the stocks found in Angolan and South African waters (Healey et al. 2020).

T. capensis is one of Namibia's most commercially important resources and is caught in two fisheries, namely, adult horse mackerel are caught by midwater trawlers or bottom trawlers and juveniles are caught as bycatch in the sardine targeted purse-seine fishery (Boyer and Hampton 2001; Kirchner et al. 2010). The resource is also caught as a bycatch in the bottom trawl hake fishery (Kirchner 2011). Juvenile horse mackerel were targeted by the purse-seine fishery to produce fish meal until 2014 (MFMR 2015) and the purse-seine fishery has been closed since then. The total horse mackerel catches increased from less than 50 000 t in the 1960s to approximately 500 000 t in the 1980s (Boyer and Hampton 2001) and from 1970 to 1989 the horse mackerel fishery was managed by the ICSEAF. After independence in 1990, when Namibia (MFMR) took over the fisheries management average annual catches decreased to 325 000 t in the 1990s and then to 284 000 t in the 2000s. Since 1990, the average annual landings for the pelagic purse-seine fishery was 55 270 t and for the midwater trawl fishery 252 680 t (Kirchner et al. 2010). The biomass was estimated to be 1.0-1.5 million t in 2010 (Kirchner et al. 2010). The resource catches by 2006 had declined to lower than 250 000 t (Kirchner 2011). The fishery is managed through TAC and it is mostly allocated to the midwater trawl fishery (MFMR 2015).

The *T. capensis* purse-seine fishery (targeting juveniles) in South Africa began in the mid-1940s and the demersal trawl fishery (targeting adults) began in the 1960s (Barange et al. 1998; Pecquerie et al. 2004). By the 1950s the purse-seine catches of *T. capensis* were at 118 000 t, but decreased in the late 1960s (DEFF 2020). *T. capensis* catches had remained stable since 1978 and did not have a total allowable catch (TAC) until 1991. Foreign fleets that targeted *T. capensis* in South Africa were only phased out in 1992 (Naish et al. 1991). As local interest in *T. capensis* increased, it led to increased targeting of this species by the mid-water trawl fishery and a decrease in foreign involvement. As a result, annual catches decreased to 10 000 t in 1995 (Kerstan and Leslie 1994). The stability of the catches of the stock shows that fisheries management had been effective. In 2020, the stock status and fishing pressure of *T. capensis* was fully exploited (DEFF 2020).

Sardinops sagax (sardine) and *Engraulis encrasicolus* (anchovy) form the basis of the important small pelagic fishery in the region. *S. sagax* stocks are distributed along the Namibian and South African coasts and are divided into two stocks by the strong perennial Luderitz upwelling cell and South African and Namibian sardine fisheries are managed separately (Boyer et al. 2001).

Initially the Namibian sardine stock was targeted by the purse-seine fishery after World War I and had a biomass of over 1 million tons by the late 1960s (Payne et al. 2001; Japp and Augustyn 2019). Catches decreased to 300 000 t in the early 1970s due to discards and illegal fishing and was reduced to bycatch of 12 000 in 1980 (FAO 2005). The ICSEAF was managing the fisheries for the sardine stock (FAO 2005). This stock was depleted by the time of Namibia's independence with catches averaging to about 5 000 t (Payne et al. 2001; FAO 2005). There were signs of recovery in the early 1990s when unwanted catch discards were not allowed and fishery observers were placed on fishing vessels (Boyer et al. 2001). It was believed that the Namibian sardine stock was able to recover with favourable conditions, after observing a slight improvement in stock size (Boyer et al. 2001). After the sardine stock collapse, the stock had not fully recovered ever since and even in 2017 the sardine catch was below 5 000 t (Wilkinson and Japp 2020). In order to protect the recruitment of small pelagic fishery, trawling was not permitted along the shore lines and the 200 m depth contour (Japp and Augustyn 2019).

Anchovy and horse mackerel became abundant in Namibia after the decline of the sardine stock, thereafter the anchovy stock has decreased (Boyer et al. 2001; FAO 2005). In Namibia, anchovy were caught before 1966 (Boyer et al. 2001). After the decline in sardine, anchovy appeared to be caught in small quantities in the purse seine fisheries, but then fluctuated between 200 000 t and 350 000 t from the mid-1970s to mid-1980s. There was peak catch of approximately 360 000 t in 1987, before declining to 50 000 t in the early 1990s and then to zero in the mid-1990s (David 2012). Catches of anchovy in the late 1990s were severely depleted and continued at zero until 2006, excluding 2002, where there were catches at 40 000 t (David 2012).

The purse-seine fishery for small pelagics is the second most valuable fishery in South Africa, after the hake fishery (DEFF 2020; Parker et al. 2020). The small pelagic fishery in South Africa has been in operation since 1935, but only became commercially operational in 1943 in St Helena Bay and sardines is one of the target species (DEFF 2020; Parker et al. 2020). Sardines are caught of the west and south coast of South Africa (Japp and Augustyn 2019; DEFF 2020; Parker et al. 2020). Sardine catches increased from less than 200 000 t in the 1950s to over 400 000 t in the 1960s. Their catches increased through the 1990s into the 2000s and reached 374 000 t in 2004, and this was due to changes in management strategy which had a more conservative approach. There was a decline of sardine catches between 2008 and 2014 to 90 000 t, and then to less than 40 000 t between 2017 and 2018. Catches severely declined to 2 100 t in 2019 and in 2020 the stock status was depleted and fishing pressure was at an optimal (DEFF 2020). The low biomass of the sardine stock might have an impact on the higher trophic levels that depend on them or the whole ecosystem (Parker et al. 2020).

The anchovy stock in South Africa, was only exploited after the mid-1960s when small meshed purse-seine were allowed in the fishery (Lluch-Belda et al. 1989). After the collapse of sardines, anchovy dominated the purse seine fishery from 1966 to 1995 (30 years), before sardine was dominant again in the fishery (Schwartzlose et al. 1999). Anchovy was the most important contributor to the purse-seine fishery in 1978, with fairly low catches until 1986 (Crawford 2007). Anchovy catches were approximately 600 000 t in the late 1980s and then declined to 40 000 t in 1996 (Crawford 2007; DEFF 2020). After the increase in catches in 1987, catches were much lower with as little as 1000 t in 1997 (Schwartzlose et al. 1999). However, catches increased again in the early 2000s with an excess of 500 000 t annually between 2001 and 2005 (Crawford 2007; DEFF 2020). Anchovy catches dominated the purse-seine fishery again after the decline of sardine catches in the 2000s and anchovy catches were averaging around 220 000 t between 2000 and 2018, but then declined to 165 000 t in 2019. The stock status and fishing pressure of the anchovy fishery in 2020 was at an optimal (DEFF 2020).

Juvenile round herring (*Etrumeus whiteheadi*) are caught off Namibia as small bycatch in the purse-seine fishery. The adult stock of round herring caught off Namibia is much smaller than the one caught off South Africa. Round herring is the latest exploited target species in the pelagic fishery (Kanandjembo et al. 2001). There was variation in the landings of (round herring) in Namibia during the early 1980s and then landings reached as high as 79 000 t in 1995 and 97 000 t in 1997 (Kirchner 2011). The high landings in 1995 and 1997 may have been due to the fishing effort being focused on the round herring instead of the anchovy fishing at the time (Kirchner 2011). Catches of juvenile round herring in Namibia reached at least 1 000 t per year, with the highest recorded catches being 14 000 in 1996 (Hampton et al. 1999). Landings of round herring form 1997 have been between 40 000 t and 65 000 t, except in 2000 and 2005 where landings were lower than 40 000 t (Kirchner 2011).

The third most important target species by the pelagic fishery in South Africa after sardine and anchovy is *Etrumeus whiteheadi* (redeye or round herring). Round herring are mostly used as fish meal and protein supplements in aqua-feeds (DEFF 2020). Juvenile round herring are caught as bycatch in the juvenile anchovy and sardine inshore fishery and adults are caught in targeted fishing further offshore (Hampton et al. 1999). Although round herring catches were recorded since the 1960s, they never dominated the pelagic fishery and their catches never exceeded 100 000 t (DEFF 2020). Catch of round herring remained stable between 2000 and 2019, with an average catch of 51 000 t since 2016, which is only half of the 100 000 t precautionary upper catch limit (PUCL). The low catches show that there is difficulty in catching the stock using purse-seine nets. The Department of Environment, Forestry and Fisheries (DEFF), South Africa, aims at utilizing the round herring resource off the south coast by exploring a mid-water trawl fishery in order to make up for the depleted sardine resource. Stock status of round herring in 2020 was abundant, with a light fishing pressure (DEFF 2020).

There are various other important commercial resources, of high economical value that are also found off the west coasts of South Africa and Namibia. *Scomber japonicus* (chub mackerel) in Namibia is caught by bottom and midwater trawlers. Trawlers fishing off Namibia in ICSEAF times were from South Africa and Spain (Wysokinski 1986). Between 1976 and 1978, there was a decline in this stock's size in South Africa and an increase in stock size in Namibia, suggesting a possible migration of the stock from South Africa to Namibia (Wysokinski 1986). A catch limit of 20 000 t for chub mackerel in Namibia was placed by the ICSEAF in 1980 (Wysokinski 1986).

Chub mackerel is also part of South Africa's purse-seine fishery (Crawford and de Villiers 1984). Landings of chub mackerel in South Africa started in 1954 with 4 000 t and it continued to increase until 1975, with a high of 128 000 t recorded in 1967 (Butterworth 1983). A closed season for chub mackerel was introduced in the early 1960s and quotas were introduced in the 1970s (Butterworth 1983). Since 1976, catches of chub mackerel by purse-seine fishing declined and catches through midwater and bottom trawlers increased (Crawford and de Villiers 1984). The annual catches for chub mackerel in South Africa between 1971 and 1983 ranged between 50 000 t and 60 000 t and had a maximum of around 200 000 t in 1978 and a minimum of 16 000 t in 1980 (Wysokinski 1986).

Lampanyctodes hectoris (lanternfish) are the most common lanternfish found in southern Africa, with the distribution extending from northern Namibia to Port Elizabeth, South Africa (Florence et al. 2002). Since most commercially targeted fish stocks are decreasing in size, alternative fish stocks are considered and these include the mesopelagic fish (Japp 2014). Lanternfishes are the most widespread and have the highest abundance of the mesopelagic resources (Japp 2014). Lanternfish are normally used as fishmeal and fish oil, but in a few instances are used for human consumption (Japp 2014). Lanternfish are caught as bycatch in the anchovy and sardine fisheries and also as bycatch in the horse mackerel and hake fisheries in both South Africa and Namibia (Hulley and Prosch 1987). In late 1980s lanternfish were also fished by USSR fleet as food for farmed predatory animals (e.g. foxes, minks). Catches of lanternfish declined between 1978 and 1983 in South Africa, with catches not reaching above 1 000 t, except in 1979 and 1981 where catches were above 10 000 t (Wysokinski 1986). A precautionary upper catch limit (PUCL) of 50 000 t was implemented for lanternfish in South Africa in 2014 (Japp 2014). There are limited operations targeting lanternfish in South Africa, thus, making the resource unexploited (Japp 2014).

Catches of *Genypterus capensis* (kingklip) in Namibia were not as high in the 2000s as in the 1980s, because of the exploitation by foreign fleets before 1990 (Branch 1995). During 2000-2010, there was no TAC allocated to the Namibian kingklip fishery as it was only caught as bycatch (Nashima and Chilamba 2013). Catches of kingklip were quite high in 2002 and 2008 (Nashima and Chilamba 2013). Kingklip is trawled off the Namibian coast within the 200 Nautical Miles of the country's EEZ and it is also caught as by-catch in the hake fishery (Nashima and Chilamba 2013). There is currently no quota and no directed fishery for kingklip in Namibia (Jones et al. 2020). Also, there is difficulty in tracking the stock status of kingklip, possibly because they reside in rocky areas and that's not suitable for trawling and their stock is not targeted by commercial vessels (Jones et al. 2020). Kingklip are benthic fish that are endemic to southern Africa (Punt and Japp 1994). *G. capensis* is currently assessed as two separate stocks, the Namibian or South

African stock, but, according to findings by Schulze et al. (2020), the stock found in the southern Benguela might be shared between the two countries.

The South African kingklip stocks are divided into the west coast and south coast (Japp 1990). It is an important bycatch species in South Africa with a high economical value (DEFF 2020). *G. capensis* is caught as bycatch in the hake trawl and longline fishery in South Africa (DEFF 2020). Annual catches of kingklip (as bycatch in the hake trawl fishery) were between 400 t and 700 t between the 1930s and the 1940s. They then increased to 5 800 t in 1973 and remained between 3 000 t and 5 000 t until 1983. The kingklip directed longline fishery began in 1983, before its closure in 1990. There was an increase in catches between 1983 and 1989, with a maximum of 8 000 t in 1986 (DEFF 2020). Kingklip catches increased in the hake trawl sectors due to the closure of the kingklip-directed longline fishery. Thereafter catches declined after 2002, leading to the implementation of PUCL in 2005 (Henriques et al 2017; DEFF 2020). In addition to the set PUCL, a closed area was introduced in 2008 near Port Elizabeth in order to assist in the recovery of the stock. In 2020, the stock status and fishing pressure of kingklip were both at an optimal (DEFF 2020).

Loligo reynaudi (chokka squid) is infrequently found on the shelf off Namibia (Arkhipkin et al. 2015). Jones et al. (2020) recorded landings for squid in Namibia for three seasons (2014-2015, 2015-2016, 2016-2017) were at average of 1 391 t for trawl landings.

Different to Namibia the squid fishery is of great importance in South Africa. The South African squid fishery mainly consists of one species namely; *Loligo reynaudi* (chokka squid) and it was the most valuable export fishery in South Africa in the 1990s (Roberts and Sauer 1994). Squid are caught with jigs that are attached to hand-lines and are dropped to the bottom of the sea (David and Wickens 2003) and it is also caught as bycatch in the hake-directed demersal trawl fishery. The squid fishery provides jobs for around 3000 people in South Africa. Between the 1960s and 1970s the resource was heavily exploited by foreign fleets and then foreign activity was phased out in the late 1970s and early 1980s due to the introduction of Exclusive Fishing Zone (EFZ) in 1977 (DEFF 2020). Squid catches were trawled until the early 1980s and the commercial jig fishery only started in 1984 (Augustyn et al. 1992; DEFF 2020). In 1989, chokka squid had high landings of 10 730 t and after that there were fluctuations in landings with a low of 2 800 t in 1992 and a high of 7 500 t in 1996 (FAO 2011). Catches in the 1990s were between 1 900 t and 7 400 t and in the 2000s it was between 2 600 t and 13 900 t. Annual catches of squid in both the jig and trawl fishery decline after 2010, but started to increase again in 2018 (DEFF 2020). Current management measures involve effort control since 1988 and closed seasons implemented in 2014 (FAO 2011; DEFF 2020). Stock status and fishing pressure of squid in 2020 off South Africa was at full exploitation (DEFF 2020).

Helicolenus dactylopterus is commonly known as jacopever and is a demersal species (Kainge et al. 2015; Nansen 1994). It is found along the entire Namibian coast and is caught as a bycatch in the hake fishery (Kainge et al. 2015). The annual catch per unit effort (CPUE) increased from 1990, before declining in 2003 and then increasing again after 2007 (Kainge et al. 2015). Cape hake fishing effort was reduced after 1990 and this also reduced fishing mortality of jacopever bycatch (Saetersdal et al. 1999). There is little variation in the recruitment of the stock and density would depend on fishing and natural mortality (Saetersdal et al. 1994). Landings for jacopever for three seasons (2014-2015, 2015-2016, 2016-2017) were at a total of 2 891 t for trawl landings as bycatch in the hake fishery (Jones et al. 2020).

Little is known on the stock structure of jacopever in South Africa, as there is no stock assessment and no directed fishery (Lloyd’s register 2019). In 1994, the demersal trawl landings for jacopever in South Africa was shown to be at 729 t (Hutton 2000).

Chelidonichthys capensis (Cape gurnard) is another bycatch species of the hake fishery (Kainge et al. 2015). In Namibia, its CPUE has been increasing since 1990, with its highest CPUE recorded in 2008 (Kainge et al. 2015).

Catch for Cape gurnard on the west coast of South Africa seems to be under-reported due to discarding of small and larger fish (Lloyd’s register 2019). The average catch from assessments from 2015 was higher than the replacement yield (Lloyd’s register 2019).

Thyrsites atun (snoek), along with other species are caught using a handline or a rod and there is no set TAC for snoek but it has a closed season (David and Wickens 2003). Between 1970 and 1980, the abundance of snoek in Namibia increased and this was due to the increase in their prey stock, juvenile horse mackerel. During this period, catches of snoek by the international midwater trawl fleet operating off Namibia increased to over 20 000 t per annum. Since independence in

1990, catches of snoek have been fairly constant and it is estimated that the population in 1999 was stable (Hampton et al. 1999). The commercial fishery on snoek in Namibia is currently unrestricted (Hampton et al. 1999)

Since the commercial fishery in South Africa developed after World War II, snoek has contributed the most to the (Hampton et al. 1999). Snoek is commercially exploited by handline fishers and demersal trawlers in South Africa (Crawford and de Villiers 1985). Snoek landings increased from just over 20 000 t in the 1980s to around 35 000 t in 1990 and then decreased again to 12 000 t in 1997 (FOA 2011). Catches of snoek in the commercial linefish fishery averaged 6 650 t over five years till 1999 (Hampton et al. 1999). The annual catch of snoek is very variable between years because it is dependent on their availability to nearshore linefishers. In 2020, snoek remains underexploited and its fishing pressure is at an optimal (DEFF 2020).

Dentex macrophthalmus (large-eye dentex) is a sparid fish of commercial importance in Namibia. *D. macrophthalmus* may be small, but it is an important sparid fish that is found in the deep waters of the south-east Atlantic between the equator and south of Luderitz (Potts et al. 2010). It is of high abundance and it is caught in both the artisanal and commercial fishery in Angola (Potts et al. 2010). Although there were high densities of large-eye dentex reported in Namibia between 1990 and 1999, commercial catches still remained lower than 1 000 t (Kirchner 2011). There were a few catches of large eye dentex and bycatch in the hake directed fishery (Kirchner 2011). Density of large-eye dentex between 2000 and 2009 was less than 1 500 t, but increased to 3 000 t in 2010 (Kirchner 2011).

Lophius vomerinus is the most important monkfish species in southern Africa and the monkfish demersal trawl fishery is an important commercial fishery in Namibia (Maartens and Booth 2001). *L. vomerinus* is the more abundant of the two main monkfish species found in southern Africa and contributes the most to the total catches of monkfish species in southern Africa (Boyer and Hampton 2001). Exploitation of monkfish began as far back as 1974, with catches of more than 14 000 t recorded by the ICSEAF between 1981 and 1982 (Maartens 1998). Monkfish catches increased from 1 500 t in 1990 to over 12 000 t in 1994, but declined to 10 000 t in 1995 (Maartens 1998). Catches then increased to approximately 17 000 t in 1998 and then declined to 16 000 t in 1999 (Maartens and Booth 2001). Catches stabilized between 1999 and 2005 to range between 9

000 t and 14 000 t (David 2012). Monkfish in Namibia have been an important bycatch to the hake fishery, but due to the increase in market demand, monk fishery has since 2001 become a directed fishery (Maartens and Booth 2001; Kathena et al. 2018). After a decrease to about 7 000 t in 2009, catches increased to 12 000 t in 2012 (Kathena et al. 2018). The TAC of *L. vomerinus* in 2017 was set at around 10 000 t and the total landings were approximately 9 000 t. *L. vomerinus* was targeted by 19-24 fishing vessels in 2017 (Kathena et al. 2018).

L. vomerinus is an important by-catch in the hake trawl fishery in South Africa (WWF 2011). The monkfish annual catches were around 4 700 t between 1974 and 1994 in the South African hake trawl fishery and then increased to over 10 000 in 2001. The increase in total annual catches led the management plan to aim for more sustainable management efforts as there were concerns of overexploitation. Annual catches then decreased from 10 000 t in 2001 to around 7 000 t in 2018 (DEFF 2020). The main measures of regulating the catches of monkfish is the PUCL which was first introduced in 2006. In 2020, the stock status and fishing pressure of monkfish was at an optimal (DEFF 2020).

Austroglossus microlepis (West coast sole) occurs from northern Namibia to False Bay, South Africa and it is part of the demersal fishery (De Astarloa 2002). The ICSEAF started recording landings of West coast sole in Namibia in 1975 (ICSEAF 1975) The Food and Agriculture Organization of the United Nations (FAO) only started recording West coast sole landings in Namibia in 1987 (De Astarloa 2002). Recordings started with a landing of 300 t in 1987 before declining to less than a 100 t in 1992 and then reaching a maximum of 658 t in 1994 (De Astarloa 2002). Landings declined again after 1994 (De Astarloa 2002). Landings of *A. microlepis* as a bycatch in the monk fishery fluctuated between 300 t and 850 t from 1999 and 2016, by 2017 the landings were at around 250 t. Management measures of the sole fishery in Namibia include setting bycatch levies to the targeted monk fishery (Kathena et al. 2018).

West coast sole is said to be one of the most valuable species caught off South Africa (Wysokinski 1986). Recordings of the annual landings of West coast sole in South Africa began in 1950 through the FAO (De Astarloa 2002). There were long-term fluctuations in landings between the 1950s and early 1980s, however, after 1982 landings decreased from 1 900 t to 3 t in 1997 (De Astarloa 2002).

Jasus lalandii (West coast rock lobster) is a major crustacean fishery found off Namibia and South Africa and it is one of the most valuable fisheries in South Africa (Boyer and Hampton 2001; Cochrane et al. 2020). West coast rock lobster is caught by hoopnets close inshore and harvested by traps in deeper waters (David and Wickens 2003). There is a commercial fishery and recreational fishery for rock lobster, which is controlled through TAC (De Moor et al. 2015). The stock is shared between Namibia and South Africa, though, their fisheries are under separate management by the countries' governments, respectively (Kirchner 2011).

The first rock lobster canneries were built in Luderitz in the early 1920s, but there was little exploitation of the stock before the Second World War (David 2012). Catches decreased from 8 800 t in 1966, to 5 500 t in 1967 (David 2012). Catches started to increase again between 1968 and 1969, before falling again in 1970 to 2 200 t (David 2012). Thereafter, catches then increased to 3 000 t in 1973 to 1974, before decreasing to an average of 1 500 t in 1990 and then reaching an all-time low of between 214 t and 365 t from 1998 to 2005 (David 2012). The decrease in catches of the resource may be linked to oxygen fluctuations in the bottom waters, caused by overfishing (Hampton et al.1999). In the 1960s and 1970s rock lobster in Namibia were exported as tails and then only as whole cooked rock lobsters in 1980s (Boyer and Hampton 2001).

The stock is estimated to be exploited, but has shown improvement after the implementation of TAC since 1992 (Hampton et al.1999). A TAC of between 100 t and 400 t was set in the 1990s and other management measures after that were included such as; closed areas and season, effort limitations and minimum legal size limits of 65 mm carapace length. The resource was estimated to be at 2 500 t in Namibia in 2000, but has since decreased to 900 t in 2011. This assessment was just for the commercial fishing grounds and not the entire stock (Kirchner 2011). The TAC for the 2011 season was set at 275 t (Kirchner 2011). The resource is heavily depleted in Namibia and very sensitive to environmental variability (Kirchner 2011).

The commercial fishery of West coast rock lobster in South Africa began in the 1880s and the fishery was not regulated until 1946 (Kirchner 2011). Catches of the resource between 1950 and 1965 were around 10 000 t, but then declined to around 2 000 t in recent years (DEFF 2020). The fishery operated on minimum size limit catches due to the decline in somatic growth rates in the 1980s, when the landed mass was between 3 500 t and 4 000 t (Cockcroft et al. 2008; Kirchner

2011). After the implementation of a TAC in the early 1980s, average annual catches ranged between 3 500 t and 4 000 t until 1989, the catches then declined in the 1990s and early 2000s with the lowest catch being 1 500 t in 1996. The decline in catches may have been caused by changes in fishing methods and management measures and overfishing (DEFF 2020). The South African stock underwent major decline in 1960 and the resource was estimated to be overexploited in 2011 (FAO 2011). The decline in catches was partly environmentally induced caused by a reduction of their primary food source, changes in primary production and regime shifts (Hampton et al. 1999). There was also an eastward shift in biomass of West coast rock lobster since 2004, possible due to environmental changes, exploitation or food availability (Kirchner 2011). The West coast rock lobster fishery in South Africa is managed through minimum size limits, closed seasons, restrictions on the landing of females and annual TACs (David and Wickens 2003; Hampton et al. 1999; Kirchner 2011). An Operational Management Procedure (OPM) was introduced in 1997 in order to rebuild the status of the resource. The South African West coast rock lobster status was heavily depleted and there was heavy fishing pressure on the resource in 2020 (DEFF 2020). Overall, there is a serious problem of illegal fishing in the rock lobster fishery and there has been difficulty to control the illegal fishing. Rock lobster is easily accessible; hence, stricter measures need to be put in place in order to sustain the fishery (Cochrane et al. 2020).

The increase in wind-driven upwelling in the southern Benguela over the last two decades has led to an increase in cool, nutrient rich water at the surface from deep below (Verheye et al. 2016). Upwelling causes an increase in primary and secondary production, which is beneficial to the growth of species in higher trophic levels. The increased south-westerly winds in the northern Benguela have also led to increased upwelling of cool, nutrient rich water from below (Verheye et al. 2016). It is important to understand somatic growth rate patterns of the stocks, in response to fishing and their sensitivity to climate change in order to develop climate change mitigation and adaptation plans for the management of the fisheries of the Benguela ecosystem. Fishing, environmental change or other factors may cause a change in population age structure of stocks and the mean length of the catch is known to be a good indicator of this change (Fairweather et al. 2006). Information on somatic growth rate trends of exploited populations and on their links to environmental drivers will assist in understanding the implications of environmental change on marine stocks and ultimately improve fisheries management (Tanner et al. 2019).

1.3. Specific objectives

It is important to understand fish growth rate patterns, and long-term and short-term responses of stocks to fishing effort and environmental change. These patterns and responses can be reflected through otoliths as they can be used for growth estimation. Historical and current age length keys (ALKs) can be used as indicators of annual fish growth in the Benguela to provide long-term changes in growth (over three decades) as a response to fishing, as was demonstrated by the growth study on *M. paradoxus* (Wilhelm et al. 2020). However, these patterns are unknown for the other main stocks in the Benguela. Therefore, this research project attempted to fill the gap in knowledge by investigating the long-term fish growth rate trends of important commercial Namibian and South African targeted and bycatch resources for which the historical and current ALK data exists.

The specific objectives of the project were: 1) to determine the annual variability and long term trends, and resulting decadal shifts, in annual mean lengths-at-age (as indicator of somatic growth rates) and 2) to determine the catch-at-length of Namibian and South African commercially exploited resources, targeted and bycatch; 3) to determine fish condition (as indicator of annual relatively short-term condition of the fish) of Namibian and South African commercially exploited resources, targeted and bycatch; 4) to determine whether the mean lengths of age of species is related to environmental changes (sea surface temperature).

The following species were chosen to determine the growth estimates and overall specific objectives of the project: *Merluccius capensis* (shallow-water Cape hake), *M. paradoxus* (deep-water Cape hake), *Trachurus capensis* (Cape horse mackerel), *Sardinops sagax* (sardine), *Engraulis encrasicolus* (anchovy), *Etrumeus whiteheadi* (round herring), *Scomber japonicus* (chub mackerel), *Lampanyctodes hectoris* (lanternfish), *Genypterus capensis* (kingklip), *Loligo reynaudi* (chokka squid), *Helicolenus dactylopterus* (jacopever), *Chelidonichthys capensis* (Cape gurnard), *Thyrsites atun* (snoek), *Dentex macrophthalmus* (large-eye dentex), *Lophius vomerinus* (monkfish), *Austroglossus microlepis* (West coast sole), and *Jasus lalandii* (West coast rock lobster). These species were chosen because they have been the most important commercial (targeted or bycatch) species (ICSEAF and current times) and have the longest time series of lengths at age and/or mean length of the catch and/or weight at length available starting from the start of the ICSEAF times (1968-1987).

1.4. Research hypotheses

The following null hypotheses were tested for each of the chosen species in Namibia and South Africa and each objective: 1) There are no significant long-term changes in annual mean length-at-age of stocks from 1968 to 2019, 2) There are no significant long-term changes in annual mean catch at length of stocks from 1968 to 1987, 3) There are no significant differences in fish condition between years 4) the mean length-at-age does not correlate to annual sea surface temperature (SST).

2. Research methods

2.1. Study area

The International Commission for Southeast Atlantic Fisheries (ICSEAF) sampling divisions were used for the study area to ensure effective comparison of historic and current time series data. Division 1.3, 1.4 and 1.5 were regarded as Namibia (Figure 1). Division 1.3 included southern Angola (15°S) to northern Namibia (20°S), division 1.4 was central Namibia (20°S to 25°S), and division 1.5 was southern Namibia (25° S) to part of northern South Africa (30° S). Off the West coast of South Africa, it was Division 1.6 (30° to 35°S) and up to Cape Agulhas (10° to 20°E (Figure 1). Recent data (after 1987) were from Namibia and South Africa along the country borders.

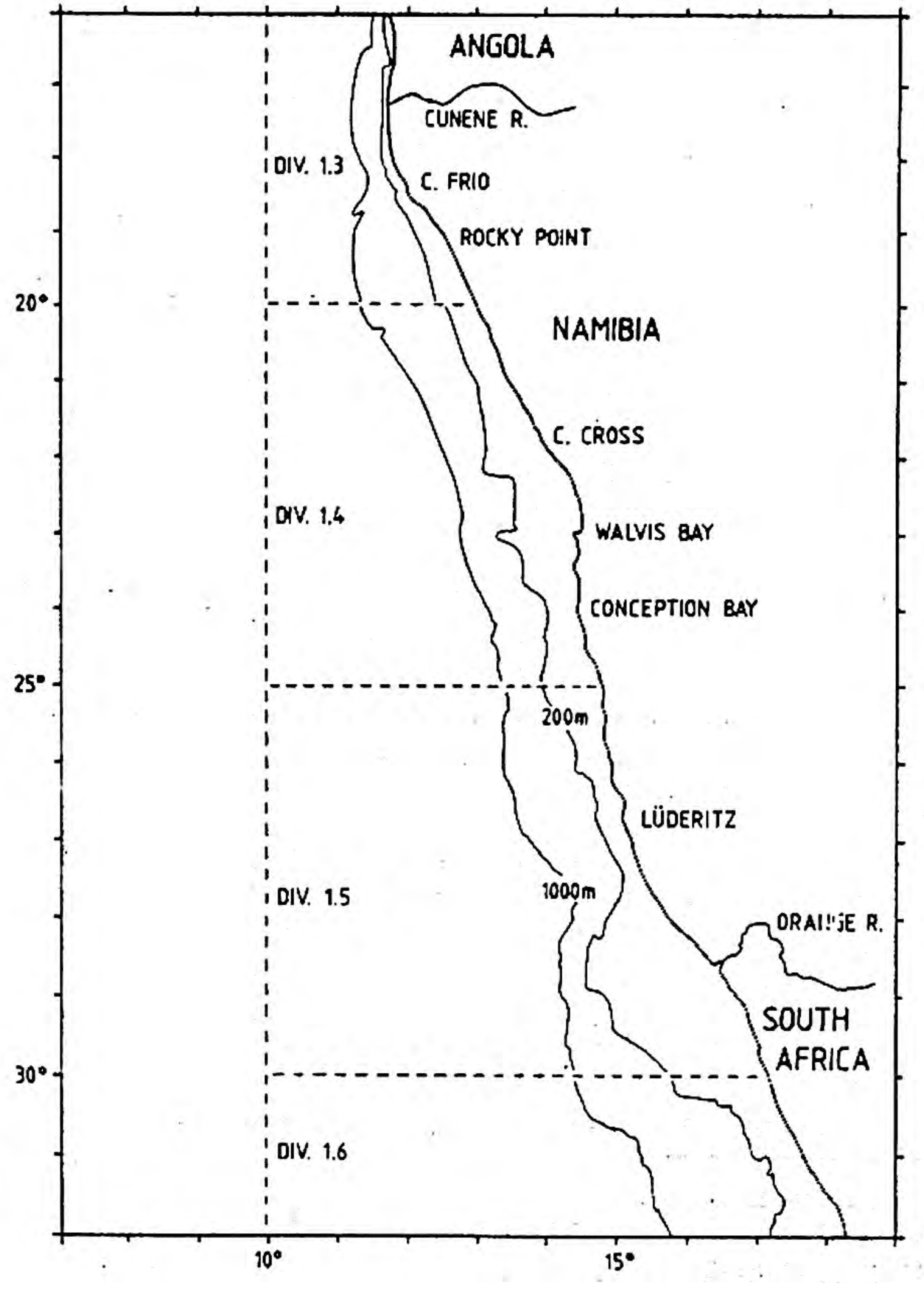

Figure 1: International Commission for Southeast Atlantic Fisheries (ICSEAF) sampling divisions for the Namibian and South African coast. (Saetersdal et al. 1994).

2.2. Biological data collection

Data since 1968 to 1987 Age-length keys (ALK) (Appendix Tables A1 and A2), length frequency distributions of the commercial catches (Appendix Tables A3 and A4) and weight-length (WL) (Appendix Table A5) data were retrieved (ICSEAF, 1973, 1974, 1975, 1976a, 1976b, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987) for Divisions 1.3 to 1.6. The countries from which the historical data for the Namibian stock were collected were; Bulgaria (BGR), Soviet Union (SUN), Spain (ESP), Poland (POL), Portugal (PRT), Romania (ROM), South Africa (ZAF), German Democratic Republic (DDR), Germany (DEU), Cuba (CUB), Japan (JPN), Angola (ANG) and the Union of Soviet Socialist Republics (USSR) (Table 1). Current data of mean lengths-at-age were provided by the Ministry of Fisheries and Marine Resources (MFMR), Namibia for the following *M. capensis* from 2000 to 2017 and for *T. capensis* for 2004, 2014, 2015, 2016 and 2018, all collected from January-February research surveys.

Current data of mean lengths-at-age were provided by the South African Department of Environment Forestry and Fisheries (DEFF) for each of *M. capensis* and *M. paradoxus* (West coast) for 1992, 1993, 1994, 1995, 1997, 1999, 2004, 2005, 2006, 2007 and 2008 from January-February research surveys.

All historical length frequency data and age-length keys (ALKs) as well as parameters for the weight-length relationships were transferred to Microsoft Excel^{TM}.

2.2.1. Mean length at age and mean length of the catch

Annual age –length-keys were used to calculate the mean lengths for each age group by dividing the sum of lengths for each individual fish (number at length x mid-length) in that age group by the total number of fish in the age group. Mean lengths of the catch for each stock were calculated from length-frequency distributions by dividing the sum of (number at each length x the mid-length of the class) by the total number of fish in the catch.

2.2.2. Fish condition

For historical data only, a relationship of the form $W = aL^b$. L where W was the weight, L the length of the fish, a and b parameters, was available, so no condition could be calculated. The a and b parameters for the equations for weight-length relationships for the Namibian stocks were extracted from ICSEAF sampling bulletins, (Appendix Table A5). Data for the weight-length relationship of South African *M. capensis* were only available for June and September of 1982. Therefore, this analysis was restricted to Namibian stock.

Recent weight-length data provided by MFMR were available for *M. capensis* (1975 to 2020) and *M. paradoxus* (1976 to 2013) from January/February research surveys. Since recent data were only available for these two summer months, for historical data also, only the weight-lengths relationships for January and February were used for *M. capensis* and *M. paradoxus* because fish condition is seasonal (Wilhelm et al. 2020). Weight-length relationships for January, February and March were used for *T. capensis* because those three months contained the most data but no recent data were available.

To make the historical data comparable to recent data, a mean weight at a certain length was calculated from the equation for each year. The mean weight was calculated at length 35 cm for *M. capensis* and 35 cm for *M. paradoxus* and 23 cm for *T. capensis* because these are usually the lengths of the maturing fish. The weight-length relationships of all other species were not used because they did not have enough data.

2.3. Environmental data collection

Monthly mean sea surface temperatures (SST) for January 1982 to 2019 were obtained from the NOAA National Centre for Environmental System (NCEP) database (Reynolds et al. 2002) for four areas Namibia North: 17° to 20°S and 10° to 12°E, Namibia Centre: 20° to 24°S and 12° to 14°E, Namibia South 24° to 28°S and 13° to 15°E and South Africa West coast North 28° to 31°S and 14° to 16°E.

2.4. Data analysis

For both the Namibian and South African data, I only used mean lengths of ages 1 to 7 if the age group contained > 20 fish. Age 0 was not considered because smaller fish for that age group are usually under-sampled. Mean lengths for Namibian sardine in the years 1977, 1980, 1981 and Namibian horse mackerel in 1974 were not included because they contained samples of less than 20 fish (see Appendix A1).

One-way ANOVA was used to determine if there were significant difference in mean length-at-age 3 between different Divisions (1.3; 1.4 and 1.5), countries and months for the Namibian *M. capensis* and *T. capensis*. Age 3 was used because it was the most consistently recorded age group in the ICSEAF sampling bulletins (ICSEAF, 1973, 1974, 1975a, 1975b, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987). This was all done using the BIOMOD2 package in R (Thuiller and Georges 2012). Data from countries which showed mean lengths at age 3 significantly different from the others were removed from further analysis. Annual mean lengths at age were then plotted against year for each stock and linear regression analysis was used to determine if there were significant long-term changes in annual mean length-at-ages 1 to 7 in each stock from 1968 to 2019. This was not done for the following species; South African *T. capensis, S. sagax, S. japonicus* and Namibian *G. capensis* and *H. dactylopterus* due to limited data available.

Monthly mean lengths of the catch were plotted against years for each stock. The average mean lengths of the catch were calculated for each year and each fishery (country) in each division for both Namibian and South African stocks. For the South African small pelagic species sardine anchovy and round herring the average mean length of the catch was calculated separately for summer months (January, February and March) and all other months for each year as they visually showed distinct separation of mean lengths. South African horse mackerel was separated for pelagic and demersal stock depending of the type of fishing gear used as stated in the ICSEAF sampling bulletins (purse seine or otter trawl respectively). For Namibian *T. capensis* the catches from the purse seine gear only consisted of 19 points for 6 years so, they were removed and only the midwater and bottom trawl catches were used in further analyses. There were some species that had poorly sampled periods in the beginning of the time series. "Behaviour" of linear regression and interpretation of results may potentially be impact because the species size structure might be subjected to seasonal variability. Therefore, such data series should be taken cautiously.

Linear regression analysis was used to determine if there were significant long-term changes in annual mean lengths of the catch from 1968 to 1987 or 2019.

Linear regression analysis was also used to determine the trends in weight at length over time against year.

The Pearson's Product Moment correlation was used to determine the relationship between mean length at age 3 for *M. capensis* and *T. capensis* and SST of each area and each month of the previous year.

3. Results

3.1. Annual mean length at age

Merluccius capensis (shallow-water Cape hake)

Appendix Table A6 shows one-way ANOVA that determined that there was a significant difference in mean length between the different countries for the Namibian *M. capensis*. Appendix A9 shows post-hoc test for country, showing SUN and ROM lengths at age 3 were different only for individual data points. All data points were therefore included in further analysis.

Figure 2 shows a significant decrease in mean length at age 7 for *M. capensis* (Namibian stock) from 1968 to 2017 (t-stat=15.2, df=12 $P<0.05$) (Table 1). Figure 3 shows a significant increase in mean length at age 3 (t-stat=2.77, df=39, $P<0.05$), age 4 (t-stat=4.05, df=37, $P<0.05$), age 5 (t-stat=3.39, df=39, $P<0.05$), age 6 (t-stat=3.55, df=31, $P<0.05$) and age 7 (t-stat=2.94, df=21, $P<0.05$) for *M. capensis* (South African stock) between 1968 and 2008 (Table 2).

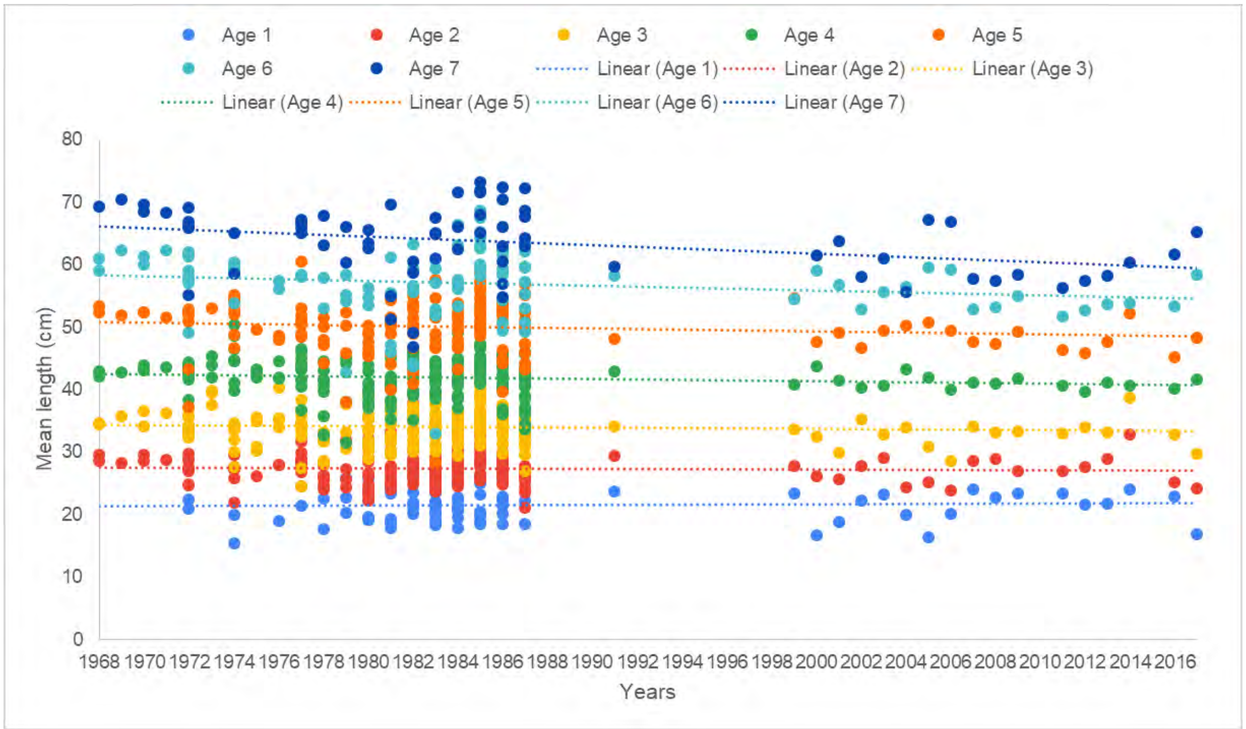

Figure 2: Annual mean length at ages 1 to 7 against year for shallow-water Cape hake *M. capensis* (Namibian stock) from 1968 to 2017, for divisions 1.3, 1.4 and 1.5. Linear regression lines fitted for each age are represented by the dotted lines.

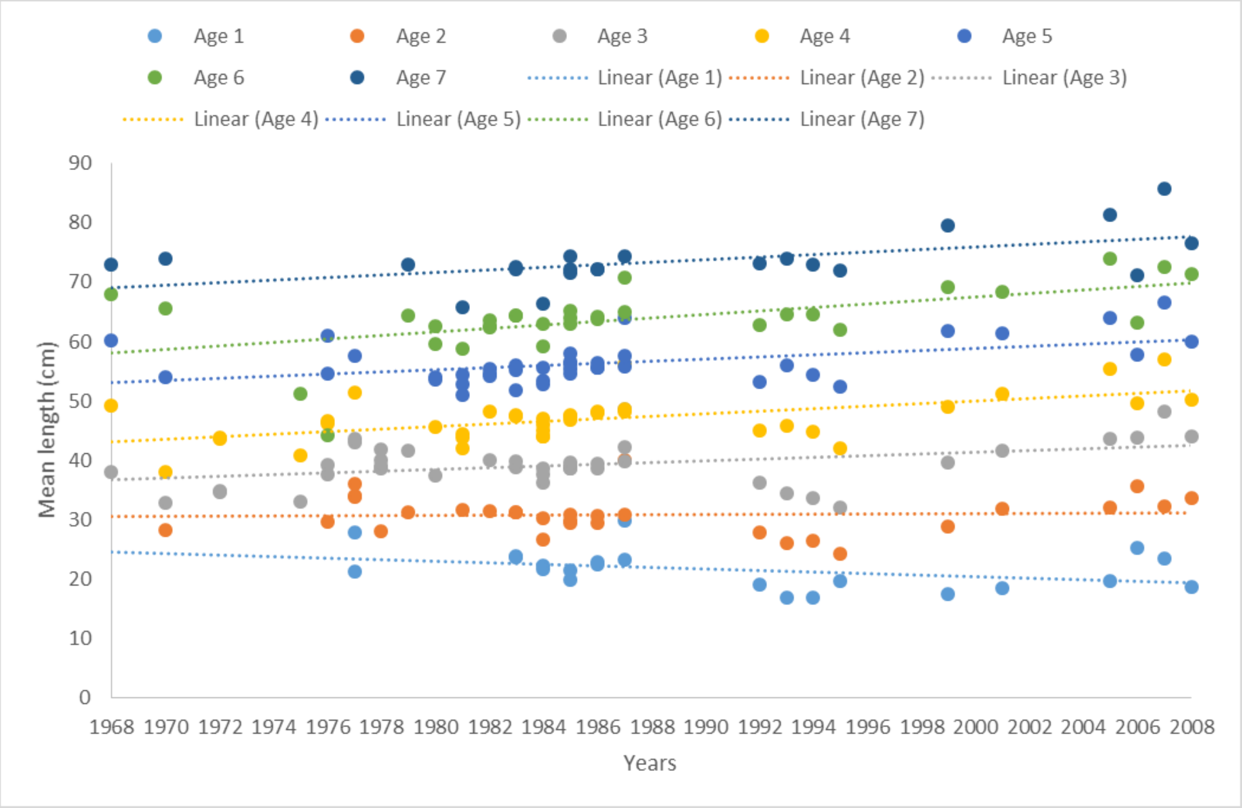

Figure 3: Annual mean length at ages 1 to 7 against year for shallow-water Cape hake *M. capensis* (South African stock) from 1968 to 2008. Linear regression lines fitted for each age are represented by the dotted lines.

Table 1 : Regression results of mean length at ages 1 to 7 against years 1968 to 2017 of shallow-water Cape hake *M. capensis* (Namibian stock), * denotes significant year slopes at the 5% level.

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 105				
Intercept	22.06	2.59	8.5	<0.001
Year	-0.00009	0.0007	-0.13	0.95
2-year, DF= 219				
Intercept	30.19	2.46	12.27	<0.001
Year	-0.00008	0.00008	-0.096	0.34
3-year, DF= 268				
Intercept	37.85	2.26	16.72	<0.001
Year	-0.0001	0.00007	-1.52	0.13
4-year, DF= 225				
Intercept	45.57	2.21	20.63	<0.001
Year	-0.0001	0.00007	-1.59	0.11
5-year, DF= 167				
Intercept	55.58	3.06	18.18	<0.001
Year	-0.0002	0.0001	-1.75	0.08
6-year, DF= 107				
Intercept	62.09	4.47	13.90	<0.001
Year	-0.0002	0.0001	-1.17	0.25
7-year, DF= 71				
Intercept	75.81	4.99	15.19	<0.001
Year	-0.0004	0.0002	-2.46	**0.02 ***

Table 2: Regression results of mean length at ages 1 to 7 against years 1968 to 2008 of shallow-water Cape hake *M. capensis* (South African stock), * denotes significant slopes at the 5% level, ** denotes significant slopes at the 1% level and *** denotes significant slopes at the 0.1% level.

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 21				
Intercept	33.39	6.77	4.93	<0.001
Year	-0.0004	0.0002	-1.74	0.10
2-year, DF= 29				
Intercept	29.50	5.42	5.44	<0.001
Year	0.00004	0.0002	0.24	0.81
3-year, DF= 39				
Intercept	26.25	4.72	5.56	<0.001
Year	0.0004	0.0002	2.77	**0.01 ***
4-year, DF= 37				
Intercept	28.17	4.69	6.01	<0.001
Year	0.0006	0.0001	4.05	**0.0003 *****
5-year, DF= 39				
Intercept	40.34	4.77	8.45	<0.001
Year	0.0005	0.0002	3.39	**0.002 ****
6-year, DF= 31				
Intercept	37.41	7.50	4.99	<0.001
Year	0.0008	0.0002	3.55	**0.001 ****
7-year, DF= 21				
Intercept	54.06	6.70	8.06	<0.001
Year	0.0006	0.0002	2.94	**0.008 ****

Merluccius paradoxus (deep-water Cape hake)

Figure 4 shows a significant increase at ages 2 (t-stat=2.38, df=55, P<0.05), 3 (t-stat=4.41, df=50, P<0.05), 4 (t-stat=5.20, df=42, P<0.05), 5 (t-stat=5.28, df=40, P<0.05) and 6 (t-stat=5.99, df=32, P<0.05) for *M. paradoxus* (South African stock) between 1976 and 2008 (Table 3).

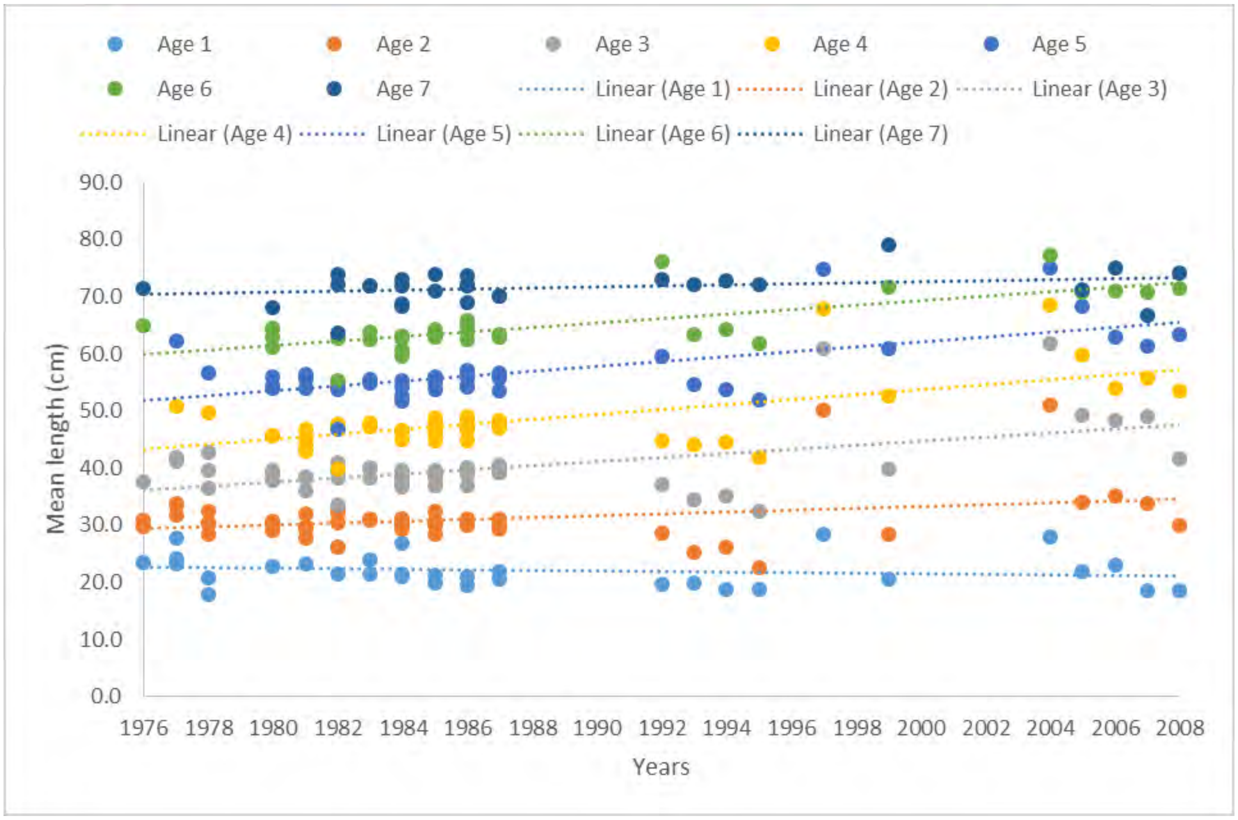

Figure 4: Annual mean length at ages 1 to 7 against year for deep-water Cape hake *M. paradoxus* (South African stock) from 1976 to 2008. Linear regression lines fitted for each age are represented by the dotted lines.

Table 3: Regression results of mean length at ages 1 to 7 against years 1976 to 2008 of deep-water Cape hake *M. paradoxus* (South African stock), * denotes significant slopes at the 5% level and *** denotes significant slopes at the 0.1% level.

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 31				
Intercept	26.49	4.78	5.54	<0.001
Year	-0.0001	0.0001	-0.93	0.36
2-year, DF= 55				
Intercept	16.34	6.17	2.65	0.01
Year	0.0005	0.0002	2.39	**0.02 ***
3-year, DF= 50				
Intercept	8.54	7.16	1.19	0.24
Year	0.001	0.0002	4.41	**<0.001 *****
4-year, DF= 42				
Intercept	8.82	7.64	1.15	0.26
Year	0.001	0.0002	5.20	**<0.001 *****
5-year, DF= 40				
Intercept	18.52	7.31	2.53	0.02
Year	0.002	0.0002	5.28	**<0.001 *****
6-year, DF= 32				
Intercept	29.85	5.88	5.07	<0.001
Year	0.001	0.0002	6.00	**<0.001 *****
7-year, DF= 18				
Intercept	63.43	5.77	11.00	<0.001
Year	0.0002	0.0002	1.41	0.17

Trachurus capensis (horse mackerel)

Appendix Table A10 shows one-way ANOVA results that determined that there was a significant difference in mean length between the different countries for the Namibian *T. capensis*. Appendix Table A13 shows post-hoc test that determined that countries that were different were DDR and

ZAF in 1980. The mean length data for DDR and ZAF in were therefore removed from further analysis. Tables A11 to A12 show no significant differences in mean length at age 2 between divisions or countries.

Figure 5 shows a significant increase in mean length at age 6 for *T. capensis* (Namibian stock) between 1972 and 2018 (t-stat=2.3, df1=80, P<0.05) (Table 4).

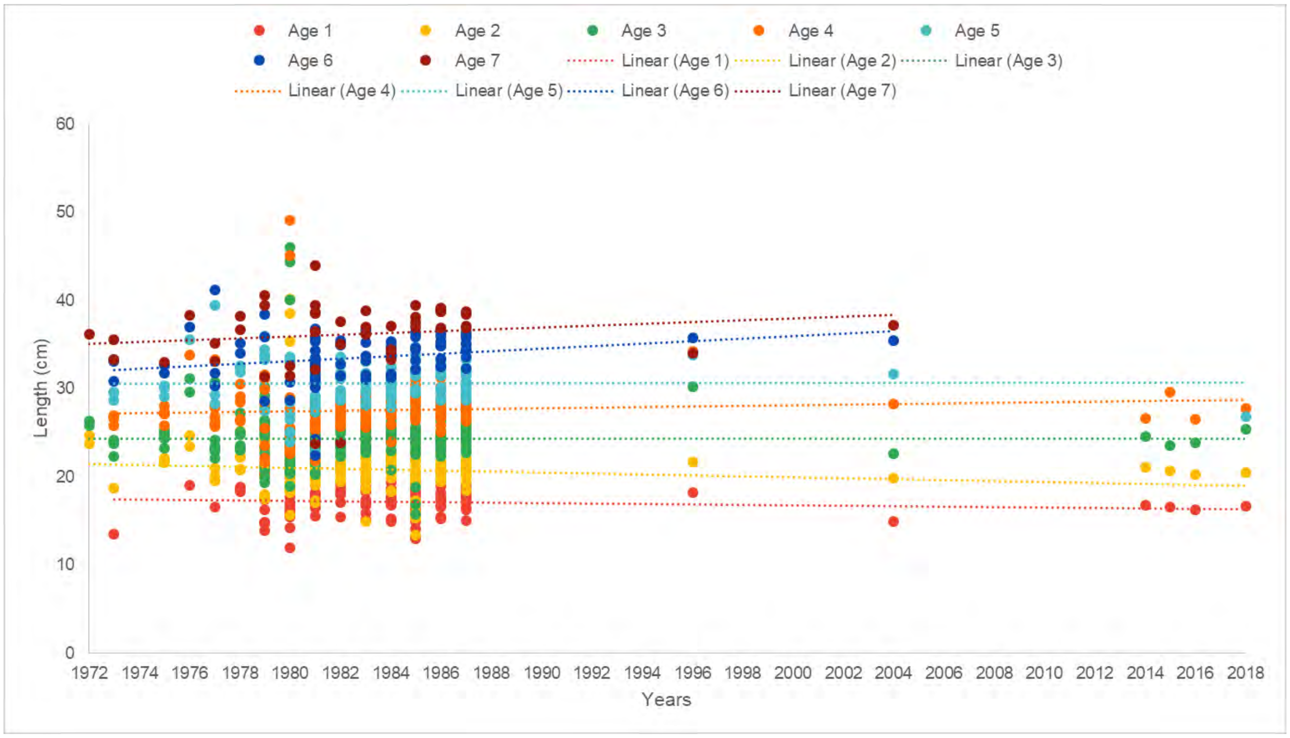

Figure 5: Annual mean length at ages 1 to 7 against year for horse mackerel *Trachurus capensis* (Namibian stock) from 1972 to 2018, for divisions 1.3, 1.4 and 1.5. Linear regression lines fitted for each age are represented by the dotted lines.

Table 4: Regression results of mean length at ages 1 to 7 against years 1976 to 2018 of horse mackerel *Trachurus capensis* (Namibian stock), * denotes significant year slopes at the 5% level.

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 126				
Intercept	19.14	2.02	9.49	<0.001
Year	-0.000065	0.000065	-0.996	0.32
2-year, DF= 199				
Intercept	25.3995	2.94	8.63	<0.001
Year	-0.00015	0.000096	-1.55	0.12
3-year, DF= 219				
Intercept	24.14	2.96	8.15	<0.001
Year	0.0000055	0.000097	0.06	0.96
4-year, DF= 197				
Intercept	24.46	2.901	8.43	<0.001
Year	0.0001	0.000095	1.06	0.29
5-year, DF= 148				
Intercept	29.92	3.28	9.13	<0.001
Year	0.000022	0.000107	0.202	0.84
6-year, DF= 80				
Intercept	20.84	5.54	3.77	0.0003
Year	0.000417	0.000182	2.29	**0.02 ***
7-year, DF= 46				
Intercept	27.03	8.34	3.24	0.002
Year	0.000301	8.34	3.24	0.28

Sardinops sagax (sardine)

Regression results in Table 5 showed that there was a significant increase in mean length at age 1 (t-stat=0.18, df=9, P<0.05), 2 (t-stat=-0.40, df=10, P<0.05), 3 (t-stat=3.53, df=14, P<0.05), 4 (t-stat=3.38, df=16, P<0.05), 5 (t-stat=2.79, df=15, P<0.05) and age 6 (t-stat=3.77, df=8, P<0.05) for *S. sagax* (Namibian stock) between 1975 and 1987 (Figure 6).

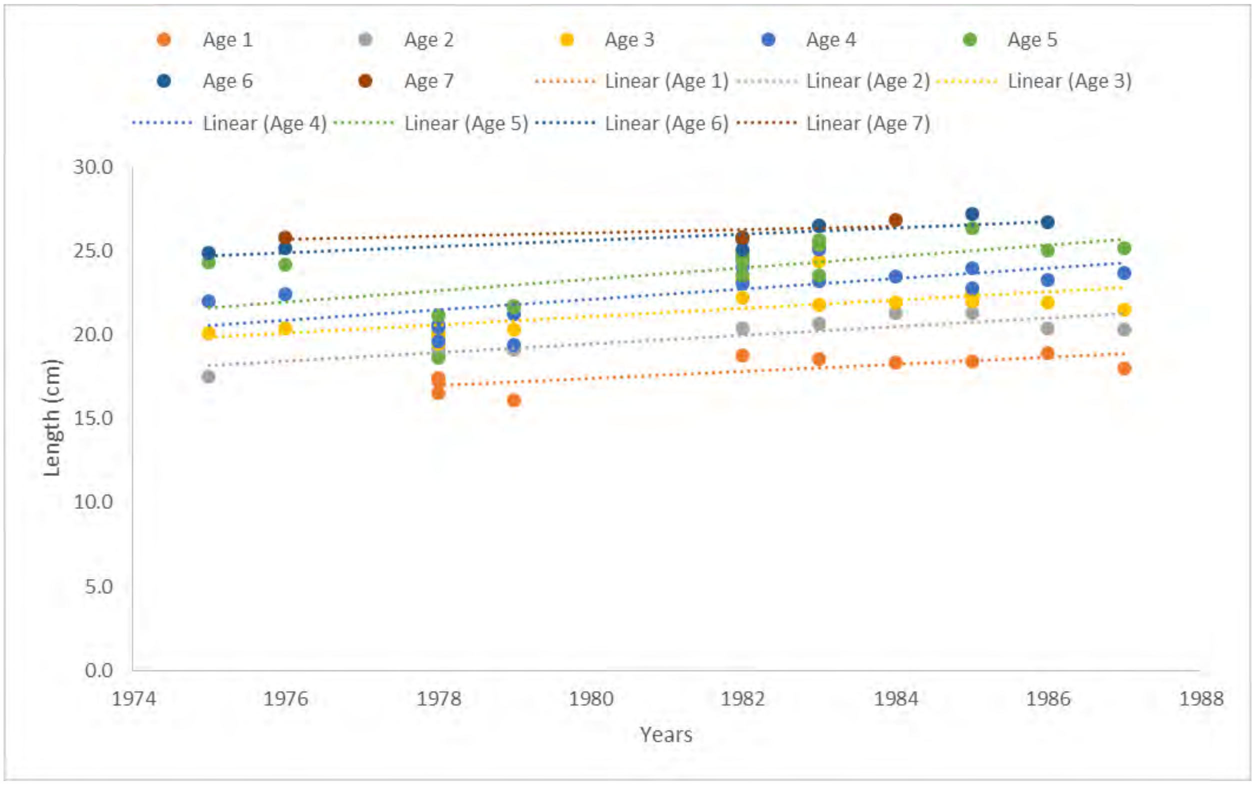

Figure 6: Annual mean length at ages 1 to 7 against year for sardine *Sardinops sagax* (Namibian stock) from 1975 to 1987, for divisions 1.3, 1.4 and 1.5. Linear regression lines fitted for each age are represented by the dotted lines.

Table 5: Regression results of mean length at ages 1 to 7 against years 1975 to 1987 of sardine *Sardinops sagax* (Namibian stock), * denotes significant regressions at the 5% level, ** denotes significant slopes at the 1% level and *** denotes significant slopes at the 0.1% level.

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 9				
Intercept	0.94	5.24	0.18	0.86
Year	0.0006	0.0002	3.23	**0.01 ***
2-year, DF= 10				
Intercept	-1.53	3.87	-0.40	0.70
Year	0.0007	0.0001	5.52	**0.0004 *****
3-year, DF= 14				
Intercept	0.26	6.01	0.04	0.97
Year	0.0007	0.0002	3.53	**0.004 ****
4-year, DF= 16				
Intercept	-3.48	7.70	-0.45	0.66
Year	0.0009	0.0003	3.38	**0.004 ****
5-year, DF= 15				
Intercept	-5.26	10.42	-0.50	0.62
Year	0.001	0.0003	2.79	**0.01 ****
6-year, DF= 8				
Intercept	10.74	4.05	2.65	0.03
Year	0.0005	0.0001	3.77	**0.007 ****
7-year, DF= 2				
Intercept	18.97	9.24	2.05	0.29
Year	0.00024	0.0003	0.78	0.58

Engraulis encrasicolus (anchovy)

Regression results showed that there was a significant increase in mean length at age 3 for *E. encrasicolus* (Namibian stock) between 1974 and 1987, (t-stat=3.18, df=9, $P<0.05$) (Figure 7). (Table 6). Figure 8 shows the mean length at age for the South African *E. encrasicolus* and table 7 shows that there was no significant long-term change in mean length at any age in South African anchovy.

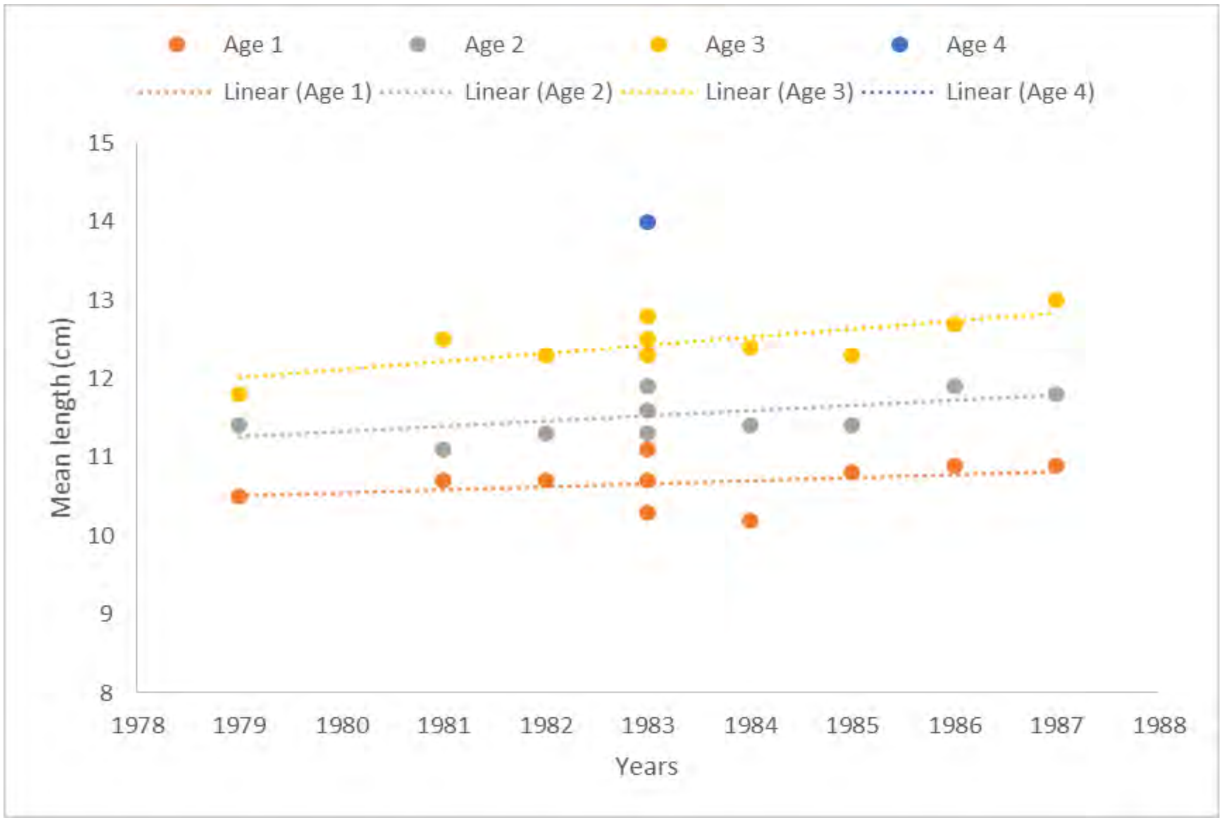

Figure 7: Annual mean length at ages 1 to 3 against year for anchovy *Engraulis encrasicolus* (Namibian stock) from 1974 to 1987, for divisions 1.3, 1.4 and 1.5. Linear regression lines fitted for each age are represented by the dotted lines.

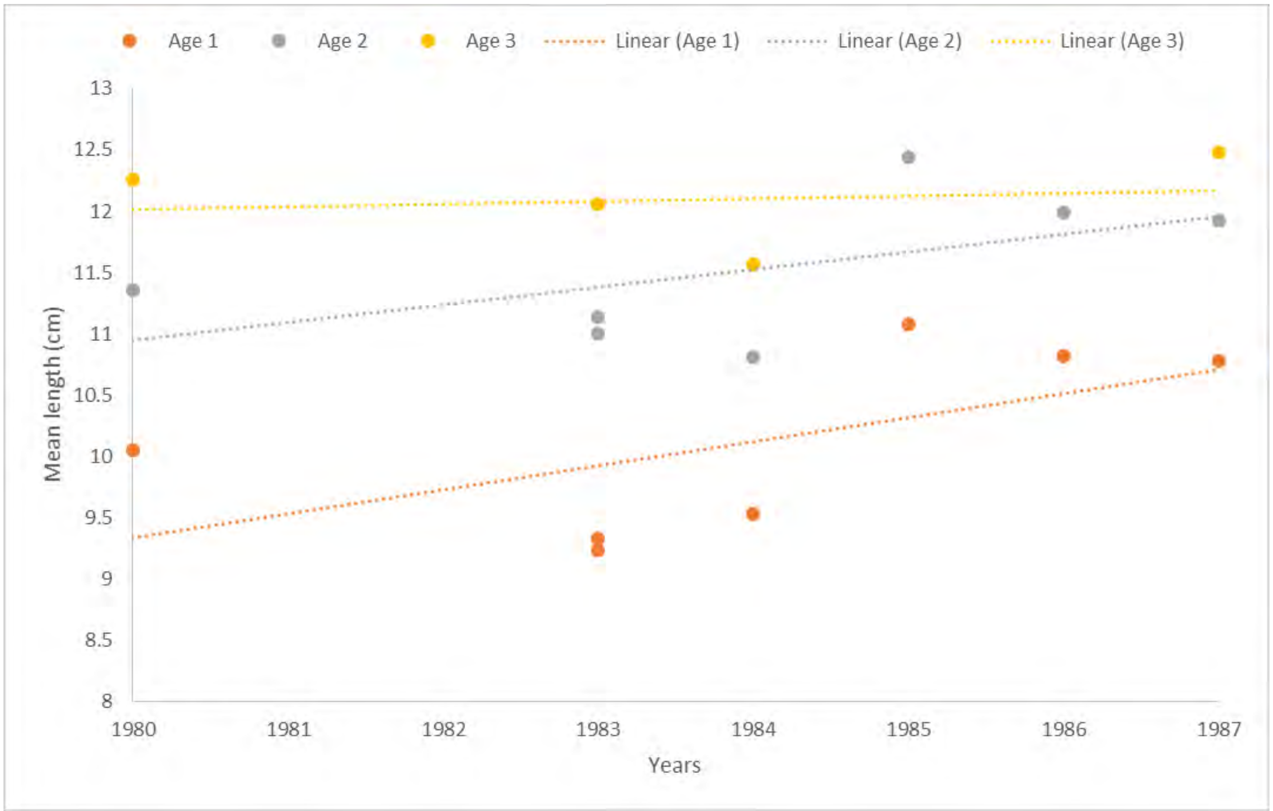

Figure 8: Annual mean length at ages 1 to 3 against years for anchovy *Engraulis encrasicolus* (South African stock) from 1980 to 1987. Linear regression lines fitted for each age are represented by the dotted lines.

Table 6: Regression results of mean length at ages 1 to 3 against years 1974 to 1987 for anchovy *Engraulis encrasicolus* (Namibian stock), * denotes significant regressions at the 5% level.

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 9				
Intercept	7.50	3.33	2.25	0.05
Year	0.0001	0.0001	1.00	0.37
2-year, DF= 10				
Intercept	5.96	3.09	1.93	0.09
Year	0.0002	0.0001	1.81	0.10
3-year, DF= 9				
Intercept	3.62	2.78	1.30	0.23
Year	0.0003	0.00009	3.18	**0.01 ***

Table 7: Regression results of mean length at ages 1 to 3 against years 1980 to 1987 for anchovy *Engraulis encrasicolus* (South African stock).

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 6				
Intercept	-4.42	10.36	-0.43	0.69
Year	0.0005	0.0003	1.40	0.21
2-year, DF= 6				
Intercept	0.49	8.15	0.06	0.95
Year	0.0004	0.0003	1.35	0.23
3-year, DF= 3				
Intercept	10.76	7.55	1.42	0.29
Year	0.00004	0.0002	0.18	0.87

Etrumeus whiteheadi (round herring) (South Africa only)

Figure 9 shows the mean length at age for the South African *E. whiteheadi* and Table 8 shows that there was no significant change in mean length at any age between 1978 and 1987. What is notable though is that there was an abrupt increase in mean length at age 1 from 1982 to 1983.

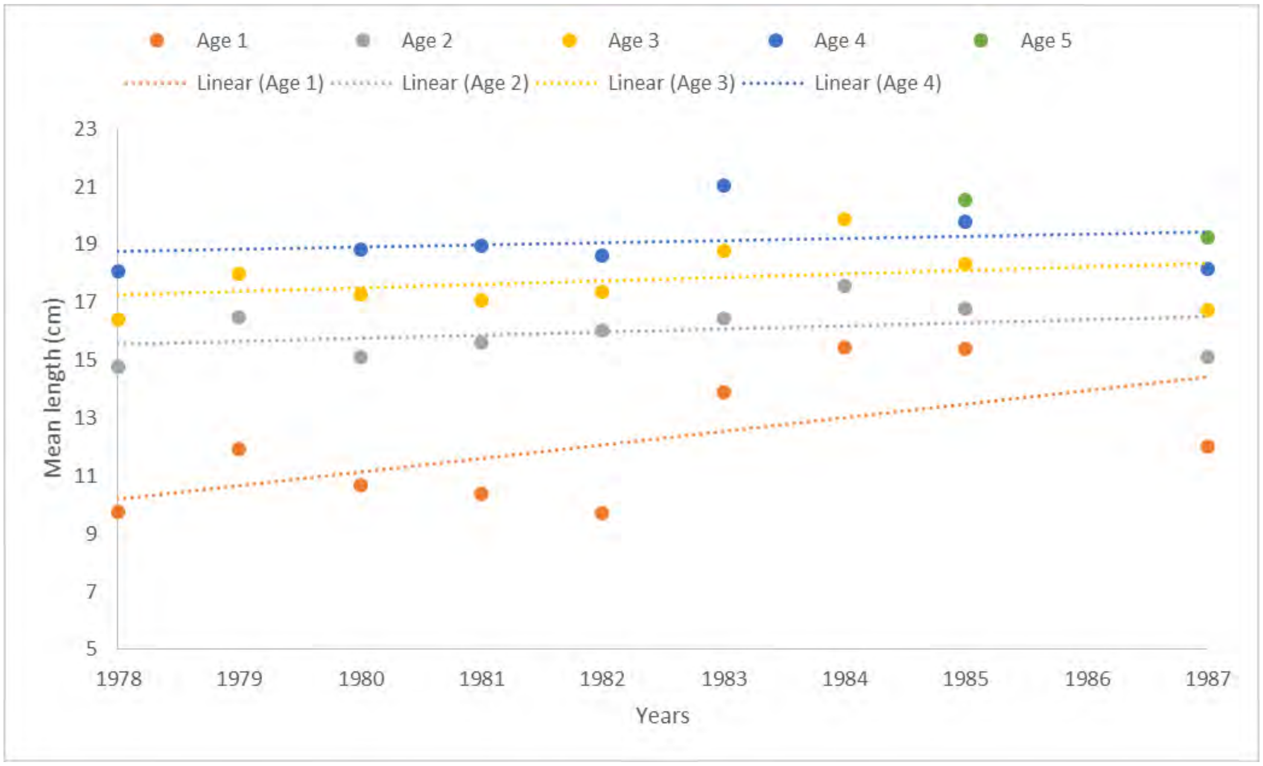

Figure 9: Annual mean length at ages 1 to 5 against year for round herring *Etrumeus whiteheadi* (South African stock) from 1978 to 1987. Linear regression lines fitted for each age are represented by the dotted lines.

Table 8: Regression results of mean length at ages 1 to 4 against years 1978 to 1987 for round herring *Etrumeus whiteheadi* (South African stock).

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 8				
Intercept	-27.40	18.89	-1.45	0.19
Year	0.001	0.0006	2.09	0.07
2-year, DF= 8				
Intercept	7.12	9.14	0.78	0.46
Year	0.0003	0.0003	0.97	0.36
3-year, DF= 8				
Intercept	7.87	10.96	0.72	0.50
Year	0.0003	0.0004	0.90	0.40
4-year, DF= 6				
Intercept	13,64	12.35	1.10	0.32
Year	0.0002	0.0004	0.44	0.68

Scomber japonicus (chub mackerel)

Figure 10 shows the mean length at age for the Namibian *S. scomber* and Table 9 shows that there was no significant long-term change in mean length at any age between 1981 and 1987.

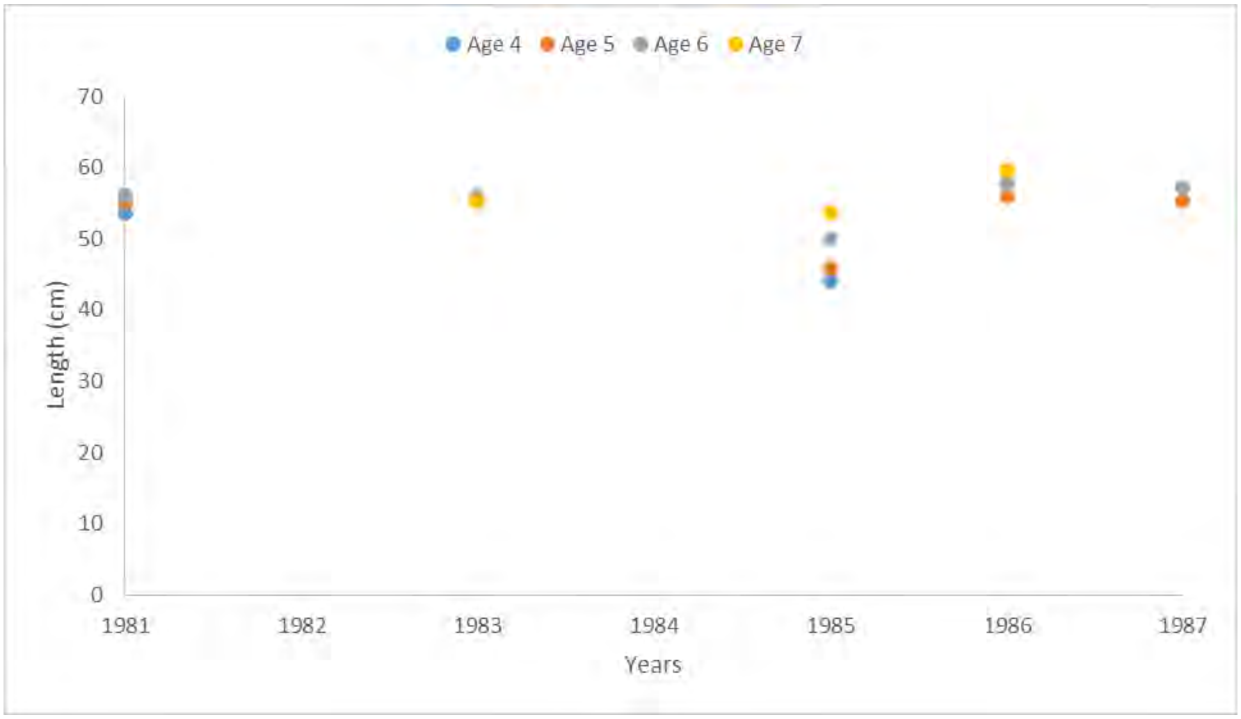

Figure 10: Annual mean length at ages 4 to 7 against year for chub mackerel *Scomber japonicus* (Namibian stock) from 1981 to 1987, for divisions 1.3, 1.4 and 1.5.

Table 9: Regression results of mean length at ages 4 to 7 against years 1981 to 1987 for chub mackerel *Scomber japonicus* (Namibian stock).

Coefficient	Estimate	Standard error	t-value	p-value
5-year, DF= 4				
Intercept	79.00	92.66	0.85	0.46
Year	-0.00082	0.003	-0.27	0.80
6-year, DF= 4				
Intercept	58.57	76.30	0.77	0.50
Year	-0.0001	0.002	-0.04	0.97
7-year, DF= 4				
Intercept	-142.50	119.29	-1.19	0.32
Year	0.006	0.004	1.65	0.20

Lampanyctodes hectoris (lanternfish) (South Africa only)

Figure 11 shows the mean length at ages for the South African *L. hectoris* and Table 10 shows that there was no significant long-term change in mean length at any age between 1978 and 1985.

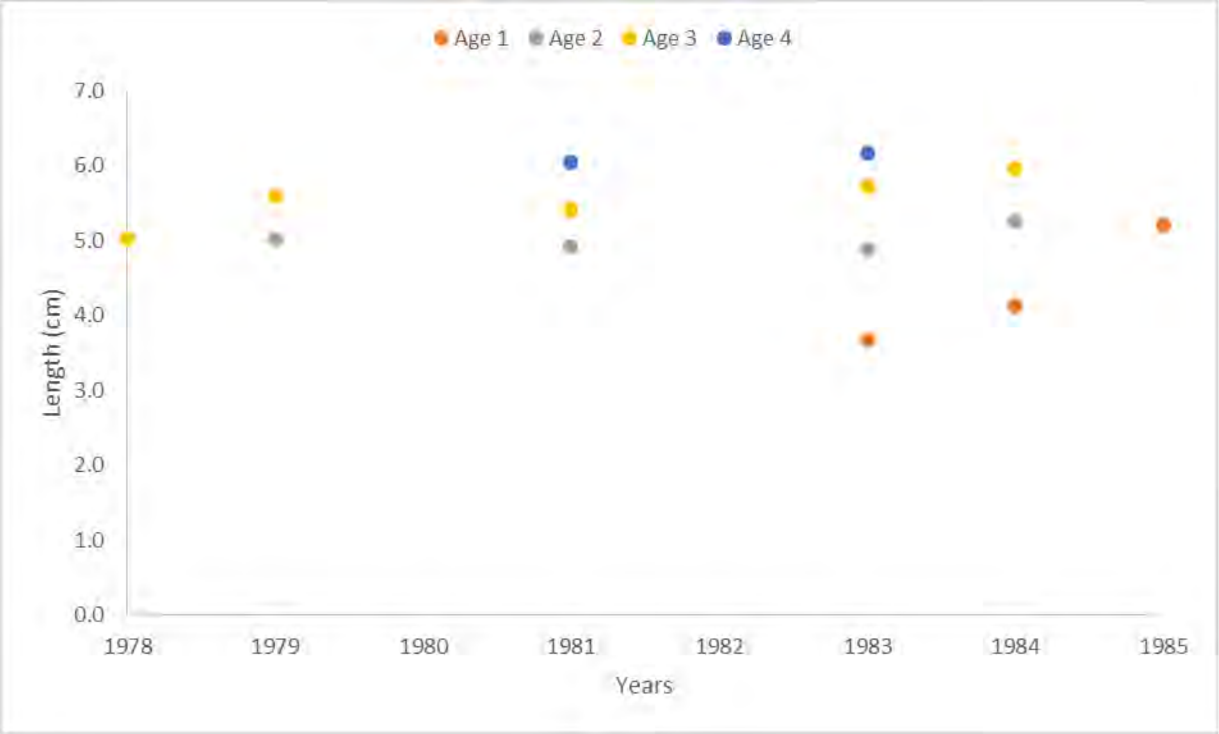

Figure 11: Annual mean length at ages 1 to 4 against year for lanternfish *Lampanyctodes hectoris* (South African stock) from 1978 to 1985. Linear regression lines fitted for each age are represented by the dotted lines.

Table 10: Regression results of mean length at ages 1 to 3 against years 1978 to 1985 for lanternfish *Lampanyctodes hectoris* (South African stock).

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 2				
Intercept	-64.10	18.31	-3.50	0.18
Year	0.002	0.0006	3.74	0.17
2-year, DF= 3				
Intercept	2.27	4.03	0.56	0.63
Year	0.00009	0.0001	0.68	0.57
3-year, DF= 4				
Intercept	-4.19	3.24	-1.29	0.29
Year	0.0003	0.0001	3.01	0.06

Dentex macrophthalmus (large eye dentex) (Namibia only)

The Regression analysis in Figure 12 shows a decrease in mean length at age 2 for *D. macrophthalmus* (Namibian stock) from 1976 to 1987 (t-stat=-1.04, df=23, P<0.05) (Table 11).

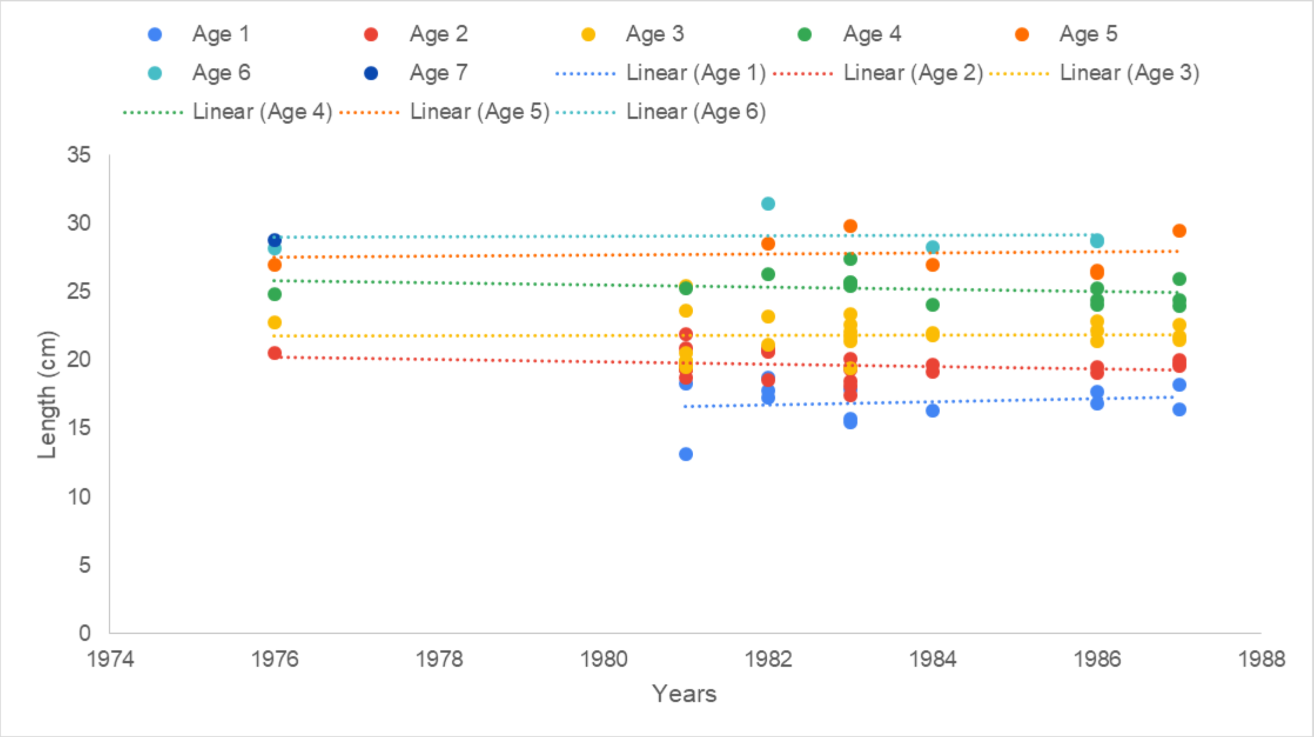

Figure 12: Annual mean length at ages 1 to 7 against years for large eye dentex *D. macrophthalmus* (Namibian stock) from 1976 to 1987, for divisions 1.3 and 1.4. Linear regression lines fitted for each age are represented by the dotted lines.

Table 11: Regression results of mean length at ages 1 to 7 against years 1976 to 1987 for large eye dentex *Dentex macrophthalmus* (Namibian stock), * denotes significant regressions at the 5% level.

Coefficient	Estimate	Standard error	t-value	p-value
1-year, DF= 12				
Intercept	5.95	18.00	0.33	0.75
Year	0.0004	0.0006	0.61	0.56
2-year, DF= 23				
Intercept	27.08	7.15	3.79	0.001
Year	-0.0002	0.0002	-1.04	**0.03 ***
3-year, DF= 22				
Intercept	20.16	10.20	1.98	0.06
Year	0.00005	0.0003	0.17	0.87
4-year, DF= 13				
Intercept	31.50	7.85	4.01	0.002
Year	-0.0002	0.0003	-0.80	0.44
5-year, DF= 6				
Intercept	23.80	14.57	1.63	0.16
Year	0.0001	0.0005	0.28	0.80
6-year, DF= 6				
Intercept	26.31	16.78	1.57	0.21
Year	0.00009	0,0006	0.17	0.88

3.2. Mean length of the catch

Merluccius capensis (shallow-water Cape hake)

The regression analyses in Table 12 indicated that there was a significant overall decrease in mean length of the catch for the Namibian *M. capensis* from 1968 to 1987 (t-value=-3.63, $P<0.05$). Figure 14 shows that the mean length of the catch for the South African *M. capensis* was between 29 cm and 62 cm and Table 13 shows that there was no significant change in mean length of the catch from 1972 to 1981.

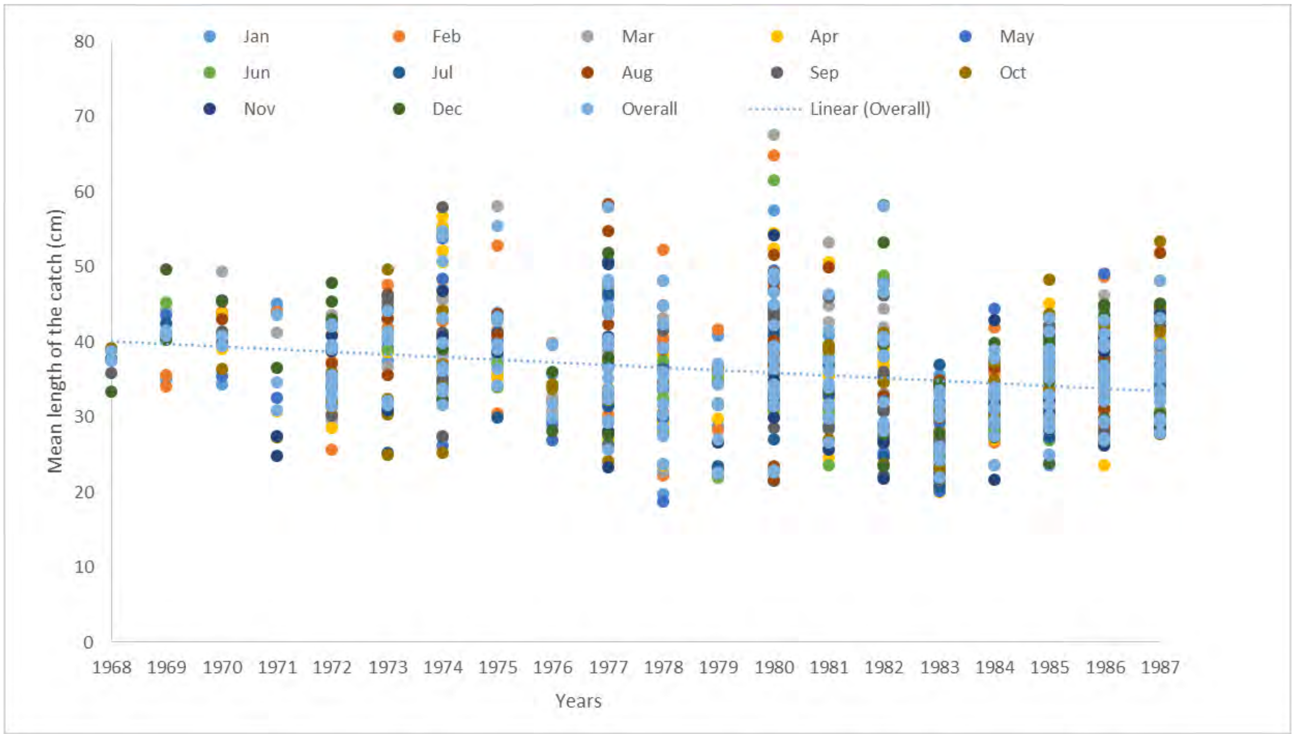

Figure 13: Monthly mean length of the catch against year for shallow-water Cape hake *Merluccius capensis* (Namibian stock) from 1968 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

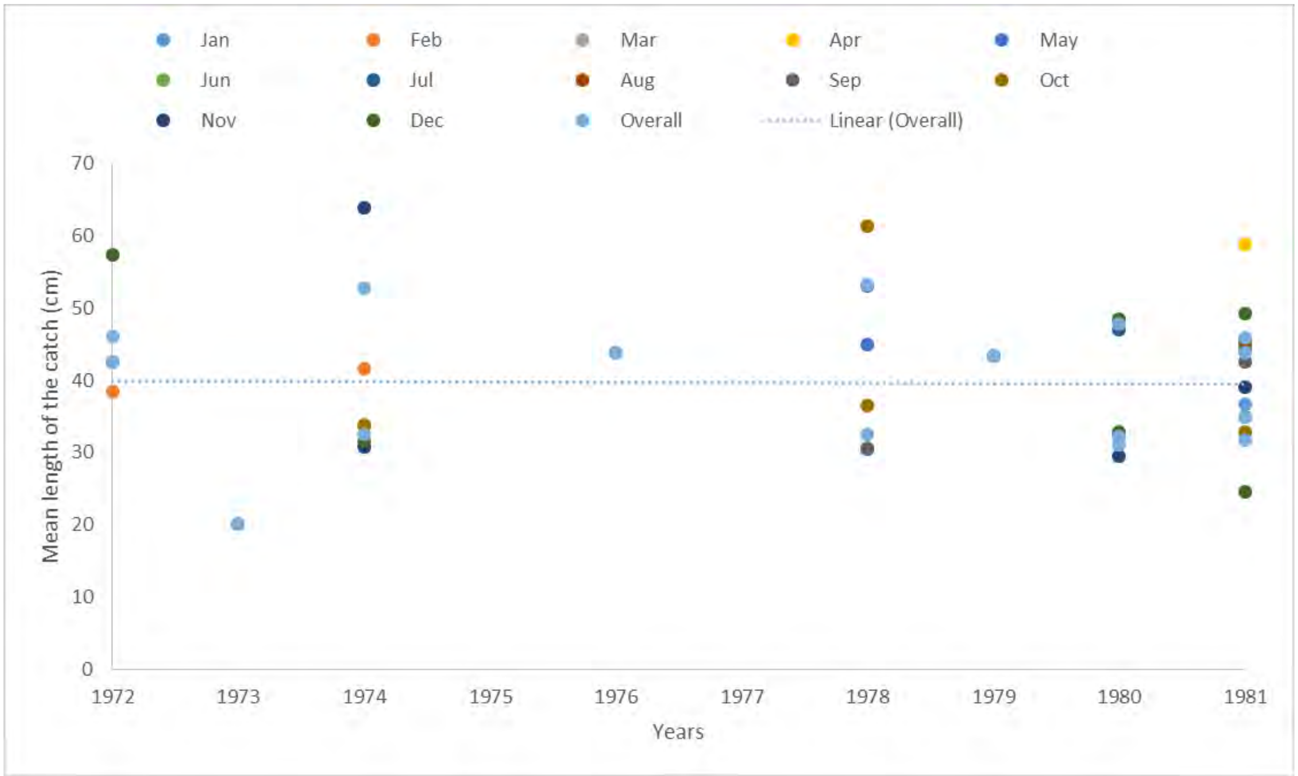

Figure 14: Monthly mean catch at length against year for shallow-water Cape hake *Merluccius capensis* (South African stock) from 1972 to 1981. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 12: Regression results of mean length of the catch against year of shallow-water Cape hake *Merluccius capensis* (Namibian stock), from 1968 to 1987, *** denotes a significant slope at the 0.1% level.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 191				
Intercept	725.39	189.8	3.82	0.0002
Year	-0.35	0.10	-3.63	**0.0004 *** **

Table 13: Regression results of mean length of the catch against year of shallow-water Cape hake *Merluccius capensis* (South African stock), from 1972 to 1981.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 15				
Intercept	146.58	1403.45	0.10	0.92
Year	-0.05	0.71	-0.08	0.94

Merluccius paradoxus (deep-water Cape hake)

Figure 15 shows that the mean length of the catch for the Namibian *M. paradoxus* was between 19 cm and 60 cm and Table 14 shows that there was no significant change in mean length of the catch from 1969 to 1987. Figure 16 shows that the mean length of the catch for the South African *M. paradoxus* was between 25 cm and 63 cm and Table 15 shows that there was no significant change in mean length of the catch from 1969 to 1981.

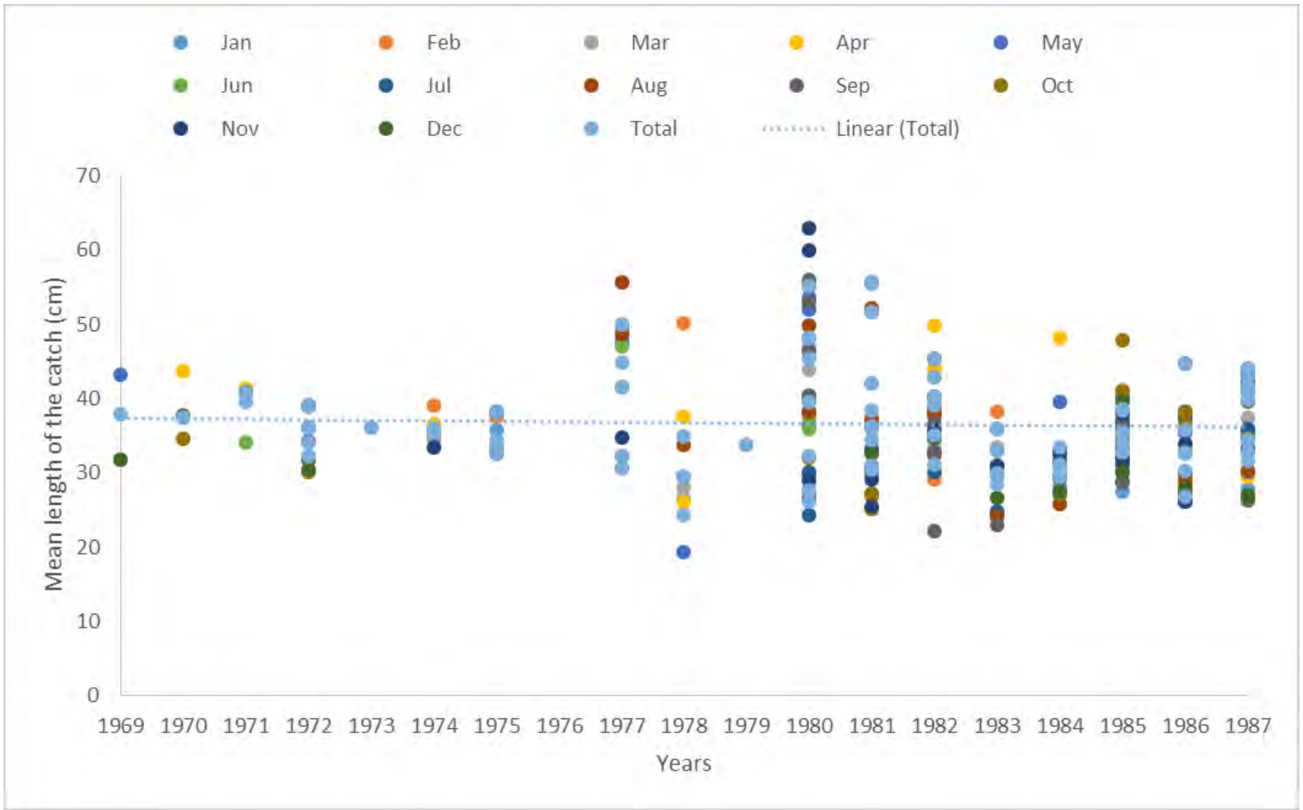

Figure 15: Monthly mean length of the catch against year for deep-water Cape hake *Merluccius paradoxus* (Namibian stock) from 1969 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

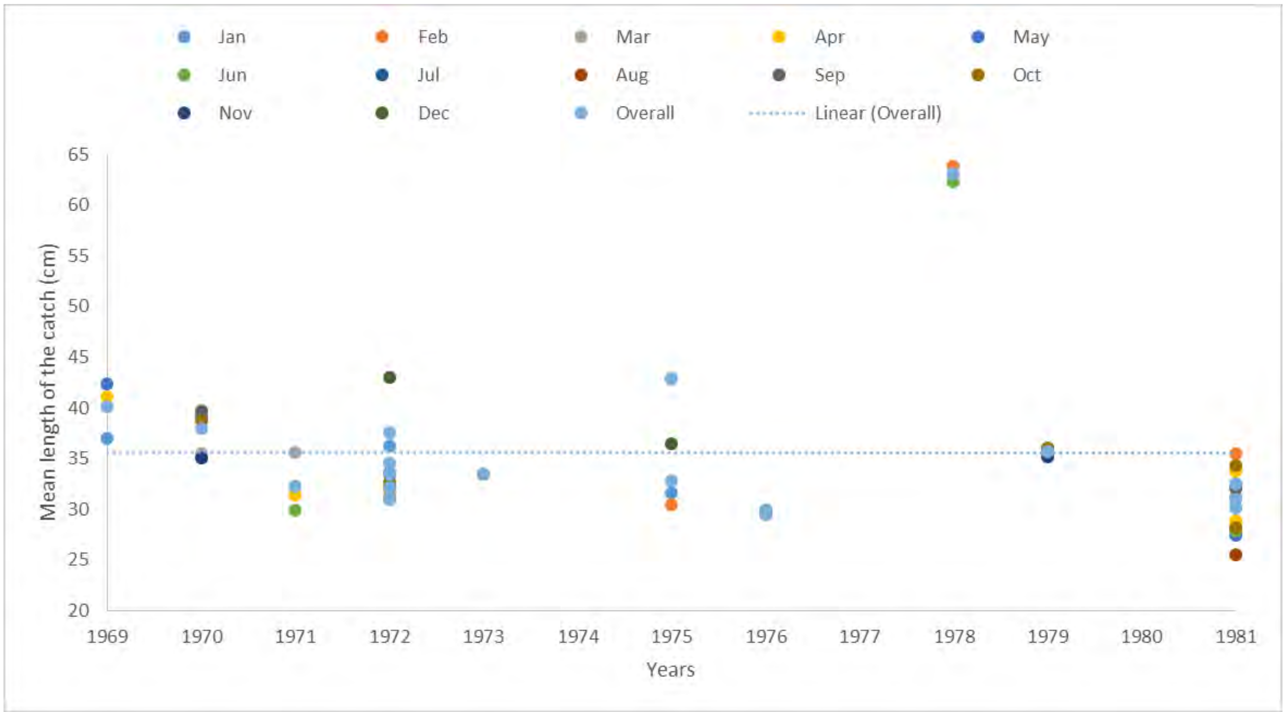

Figure 16: Monthly mean length of the catch against year for deep-water Cape hake *Merluccius paradoxus* (South African stock) from 1969 to 1981. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 14: Regression results of mean length of the catch against year of deep-water Cape hake *Merluccius paradoxus* (Namibian stock), from 1969 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 73				
Intercept	148.44	291.77	0.51	0.61
Year	-0.06	0.15	-0.38	0.70

Table 15: Regression results of mean length of the catch against year of deep-water Cape hake *Merluccius paradoxus* (South African stock) from 1969 to 1981.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 17				
Intercept	51.58	982.94	0.05	0.96
Year	-0.008	0.50	-0.02	0.99

Trachurus capensis (horse mackerel)

Figure 17 shows that the mean length of the catch for the Namibian *T. capensis* ranged between 14 cm and 43 cm and Table 16 shows that there was no significant change in mean length of the catch from 1972 to 1987. Figure 18 shows that the mean length of the catch for the South African *T. capensis* demersal stock ranged between 11 cm and 44 cm and Table 17 shows that there was no significant change in mean length of the catch from 1975 to 1987. Figure 19 shows that the mean length of the catch for the South African *T. capensis* the pelagic stock ranged between 2 cm and 16 cm and Table 18 shows that there was no significant change in mean length of the catch from 1975 to 1987.

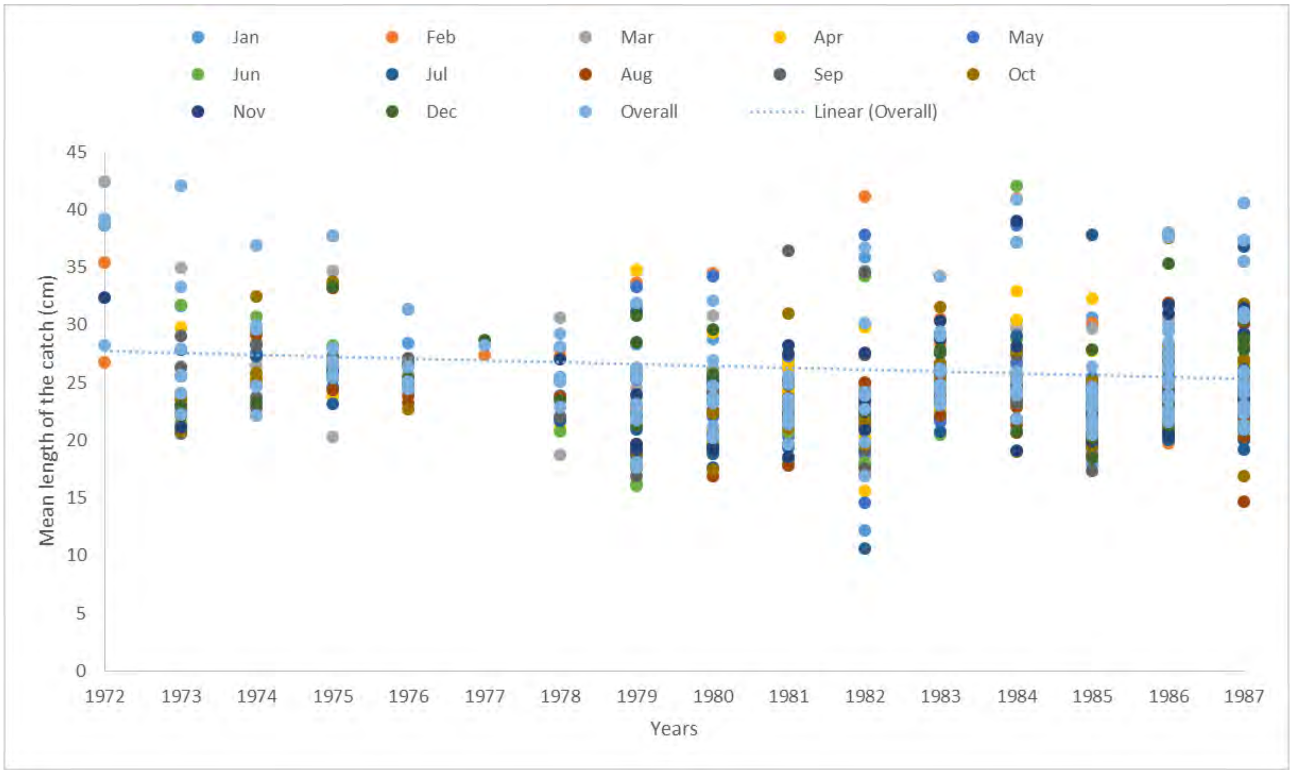

Figure 17: Monthly mean length of the catch against year for horse mackerel *Trachurus capensis* (Namibian stock) from 1972 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

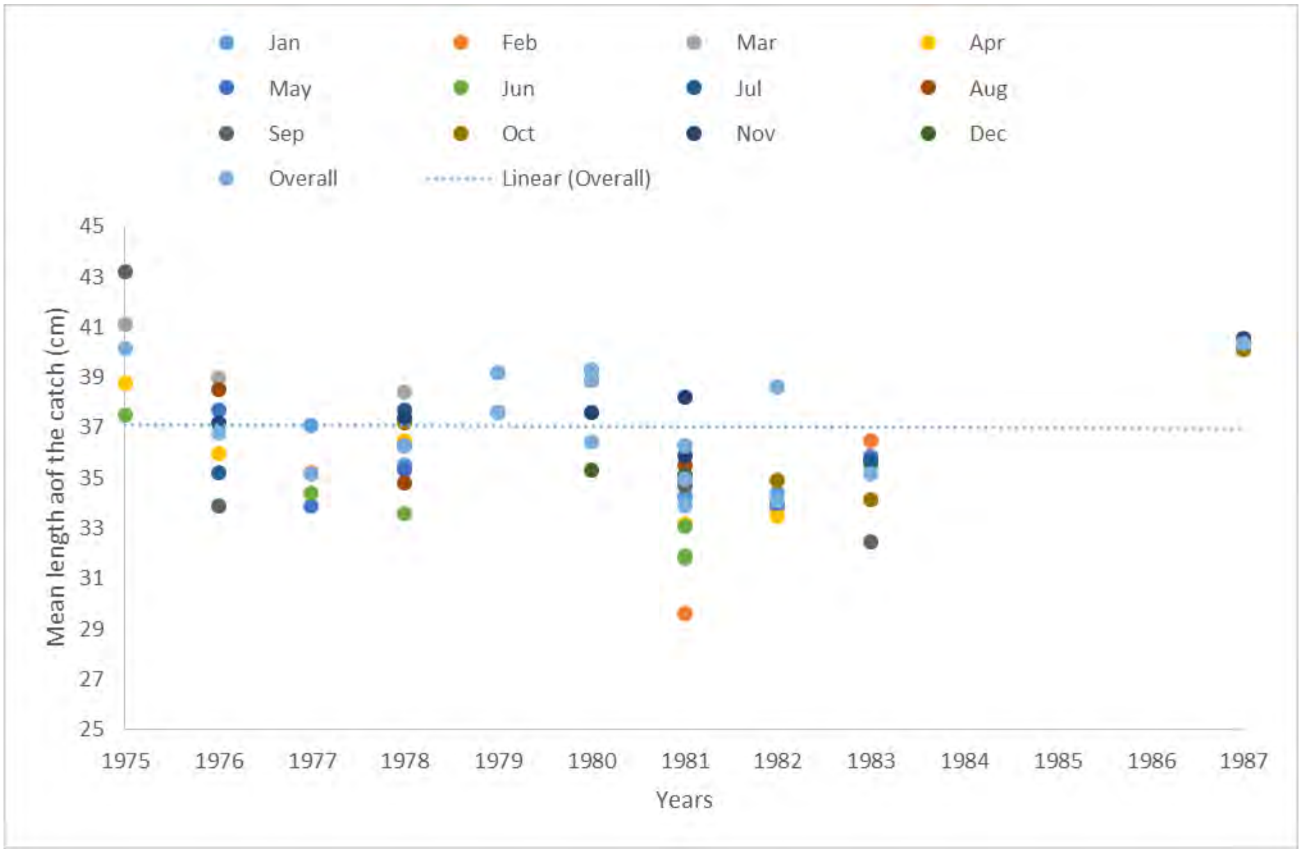

Figure 18: Monthly mean length of the catch against years for horse mackerel *Trachurus capensis* (South African demersal stock) from 1975 to 1987. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

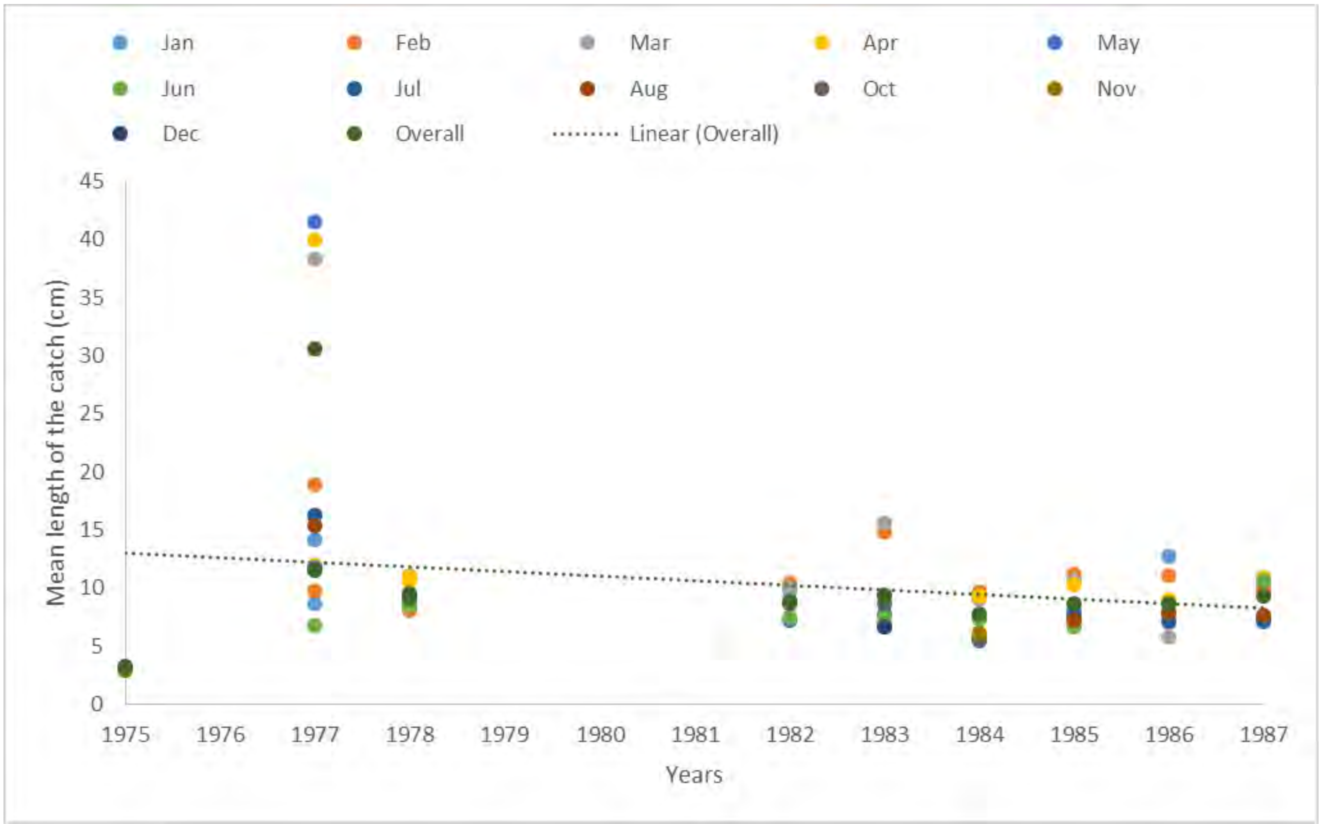

Figure 19: Monthly mean length of the catch against year for horse mackerel *Trachurus capensis* (South African pelagic stock) from 1975 to 1987. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 16: Regression results of mean length of the catch against year of horse mackerel *Trachurus capensis* (Namibian stock), from 1973 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 133				
Intercept	344.96	188.36	1.83	0.07
Year	-0.16	0.10	-1.69	0.09

Table 17: Regression results of mean length of the catch against year of horse mackerel *Trachurus capensis* (South African demersal stock), from 1975 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 15				
Intercept	60.38	391.07	0.15	0.88
Year	-0.01	0.20	-0.06	0.95

Table 18: Regression results of mean length of the catch against year of horse mackerel *Trachurus capensis* (South African pelagic stock), from 1975 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 10				
Intercept	789.92	1056.60	0.75	0.47
Year	-0.39	0.53	-0.74	0.48

Sardinops sagax (sardine)

Figure 20 shows that the mean length of the catch for the Namibian *S. sagax* was between 5 cm and 27 cm and Table 19 shows that there was no significant change in mean length of the catch from 1973 to 1987. Figure 21 shows that the mean length of the catch for the South African *S. sagax* was between 7 cm and 19 cm and Table 20 shows that there was no significant change in mean length of the catch in the summer (Jan-April) and winter (May-Dec) months.

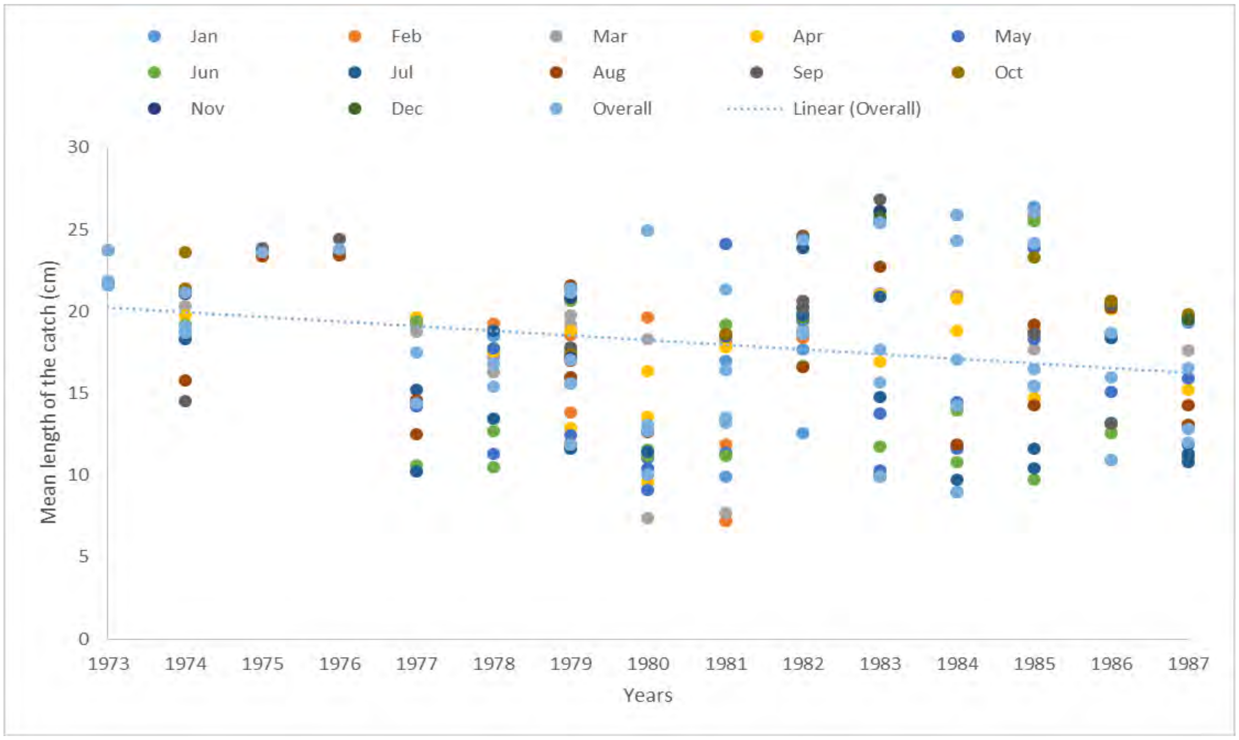

Figure 20: Monthly mean length of the catch against years for sardine *Sardinops sagax* (Namibian stock) from 1973 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

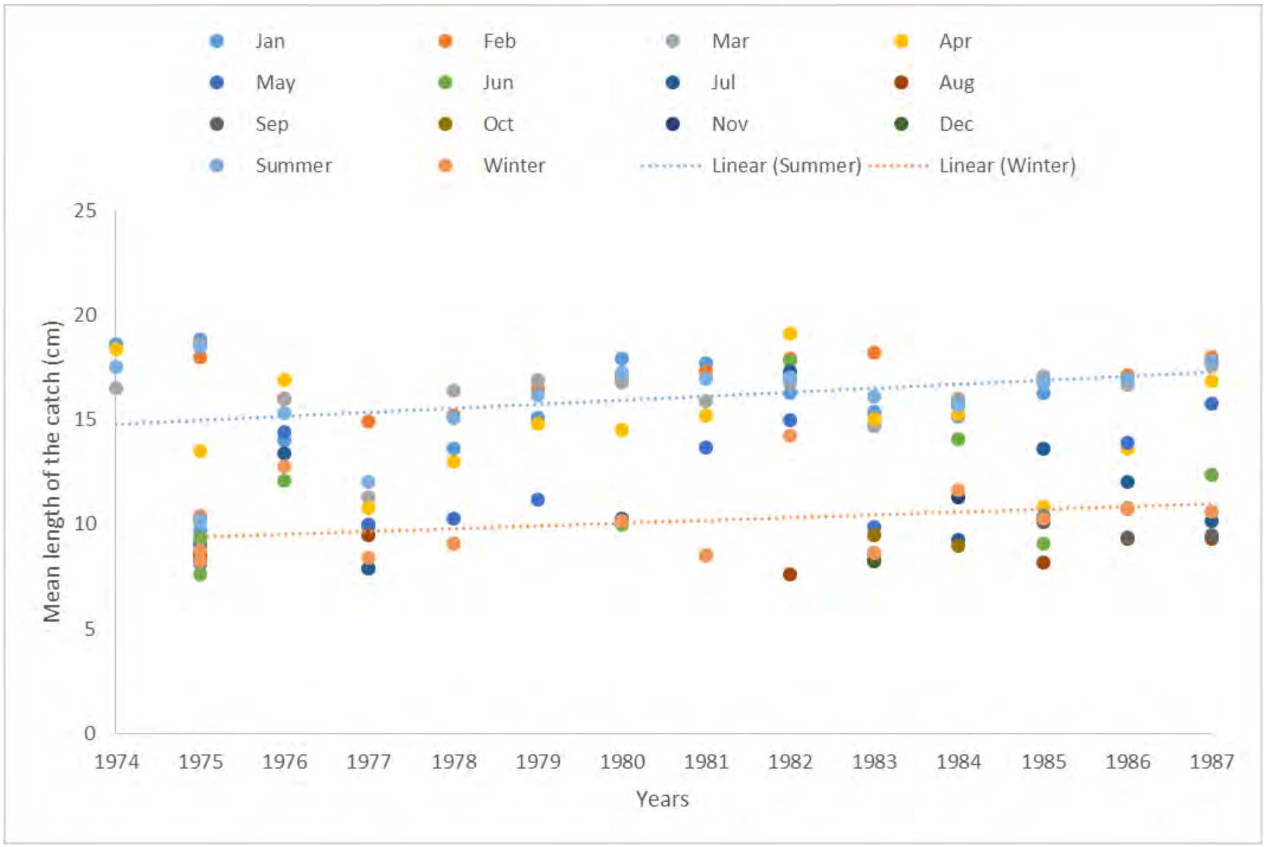

Figure 21: Monthly mean length of the catch against year for sardine *Sardinops sagax* (South African stock) from 1974 to 1987. A linear regression line fitted for average mean length of the catch for summer (Jan-April) and winter (other months) is represented by the dotted line.

Table 19: Regression results of mean length of the catch against year of sardine *Sardinops sagax* (Namibian stock), from 1973 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 48				
Intercept	577.32	328.69	1.76	0.09
Year	-0.28	0.17	-1.70	0.10

Table 20: Regression results of mean length of the catch against year of sardine *Sardinops sagax* (South African stock), from 1974 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Summer, DF= 14				
Intercept	-358.31	264.09	-1.36	0.20
Year	0.19	0.13	1.42	0.18
Winter, DF= 12				
Intercept	-257.19	249.13	-1.03	0.32
Year	0.13	0.13	1.07	0.31

Engraulis encrasicolus (anchovy)

Figure 22 shows that the mean length of the catch for the Namibian *E. encrasicolus* was between 5 cm and 12 cm and Table 21 shows that there was no significant change in mean length of the catch from 1974 to 1987. Figure 23 shows that the mean length of the catch for the South African *E. encrasicolus* was between 7 cm and 11 cm and Table 22 shows that there was no significant change in mean length of the catch over the years in the summer (Jan-April) and winter (May-Dec) months.

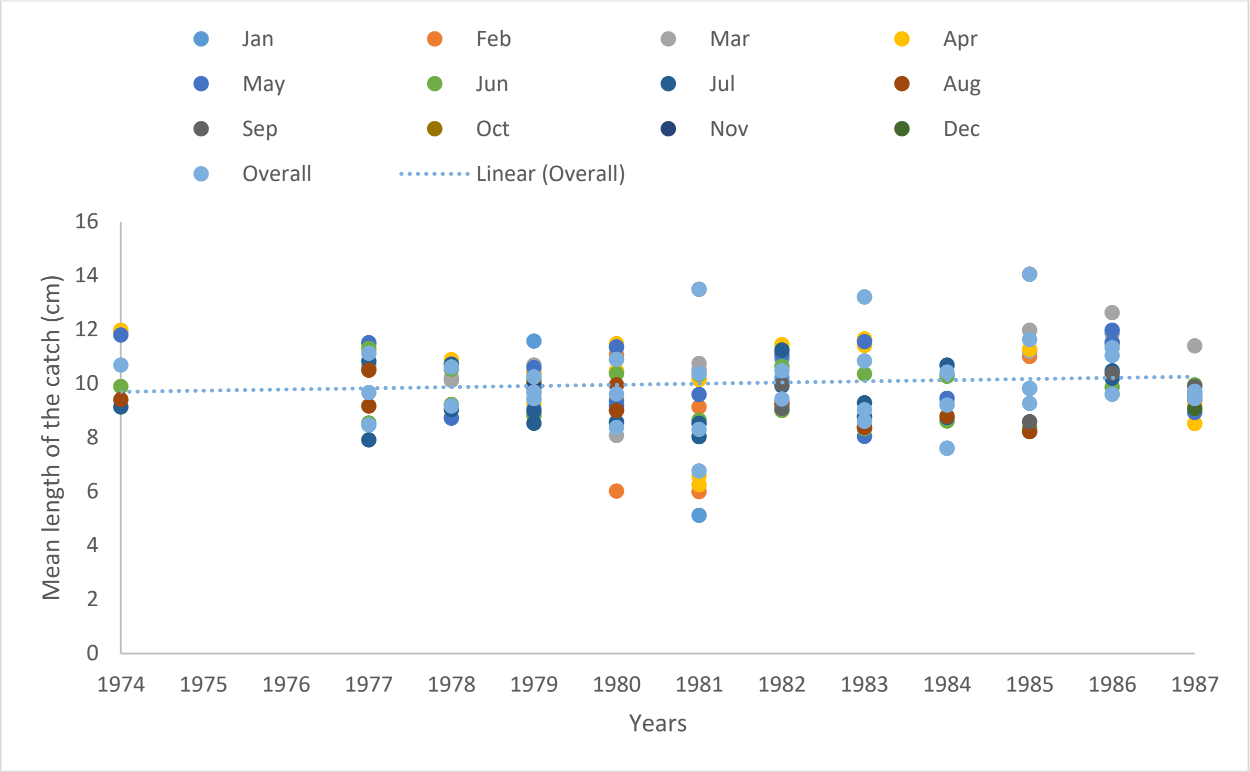

Figure 22: Monthly mean length of the catch against years for anchovy *Engraulis encrasicolus* (Namibian stock) from 1974 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

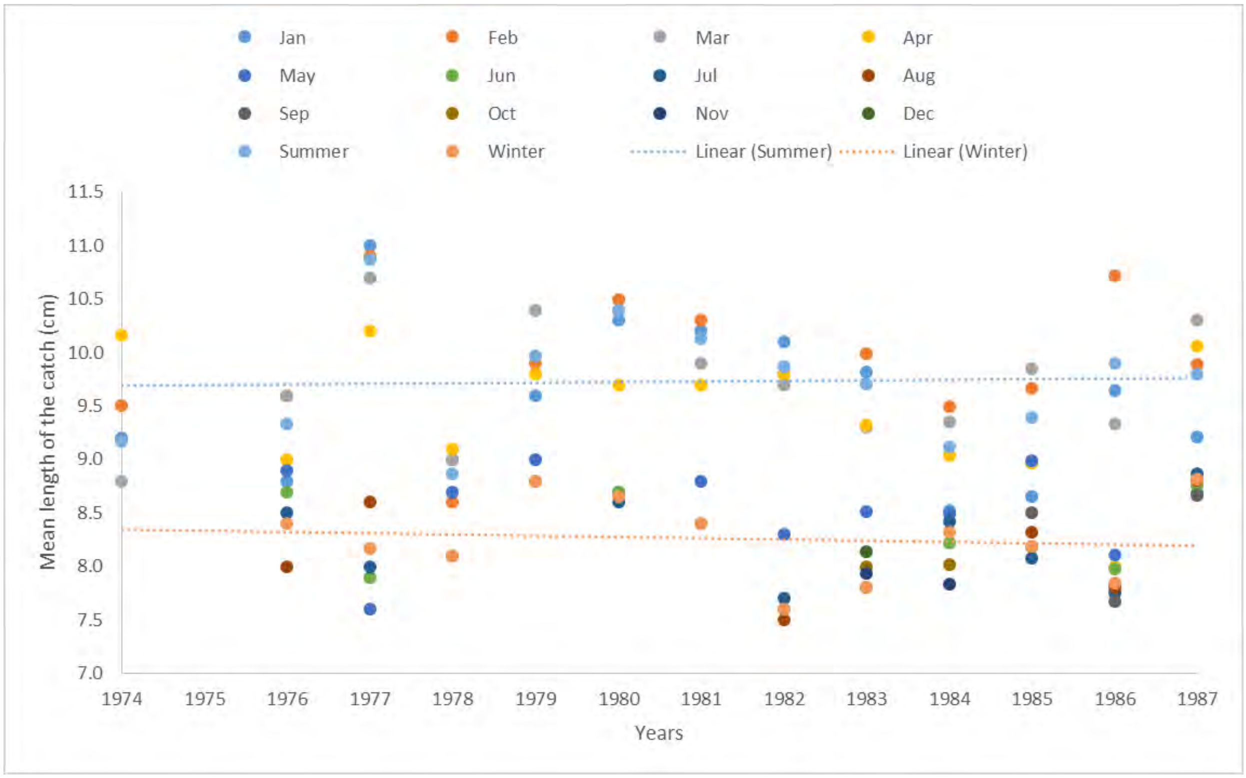

Figure 23: Monthly mean length of the catch against year for anchovy *Engraulis encrasicolus* (South African stock) from 1974 to 1987. A linear regression line fitted for average mean length of the catch for summer (Jan-April) and winter (other months) is represented by the dotted line.

Table 21: Regression results of mean length of the catch against year of anchovy *Engraulis encrasicolus* (Namibian stock), from 1974 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 34				
Intercept	-75.35	154.87	-0.49	0.63
Year	0.04	0.08	0.55	0.59

Table 22: Regression results of mean length of the catch against year of anchovy *Engraulis encrasicolus* (South African stock), from 1974 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Summer, DF= 12				
Intercept	-0.35	82.46	-0.004	1.00
Year	0.005	0.04	0.12	0.90
Winter, DF= 11				
Intercept	32.33	66.92	0.48	0.64
Year	-0.01	0.03	-0.36	0.73

Etrumeus whiteheadi (round herring)

There was no regression done of mean length of the catch for *E. whiteheadi* (Namibian stock) from 1980 to 1983 (Figure 24). Figure 25 shows that the mean length of the catch for the South African *E. whiteheadi* was between 5 cm and 19 cm and Table 23 shows that there was no significant change in mean length of the catch over the years in the summer (Jan-April) and winter months (May-Dec).

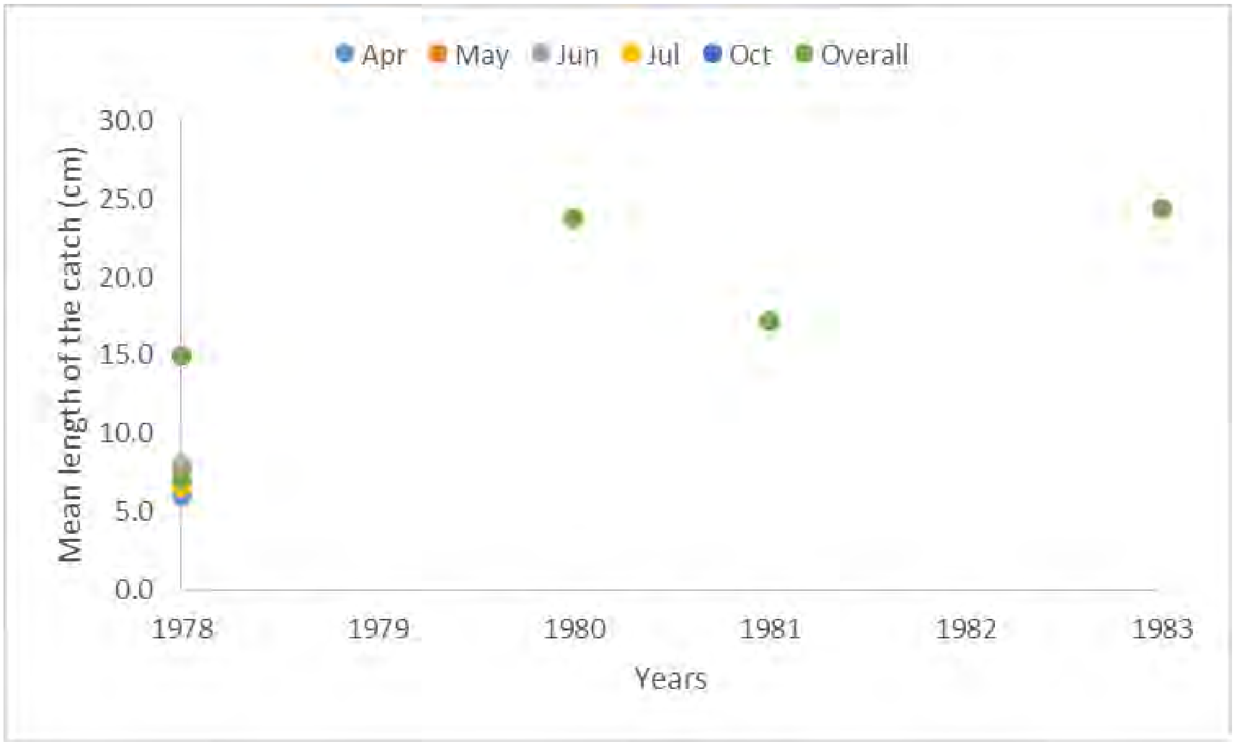

Figure 24: Monthly mean length of the catch against year for round herring *Etrumeus whiteheadi* (Namibian stock) from 1978 to 1987, for division 1.3, 1.4 and 1.5.

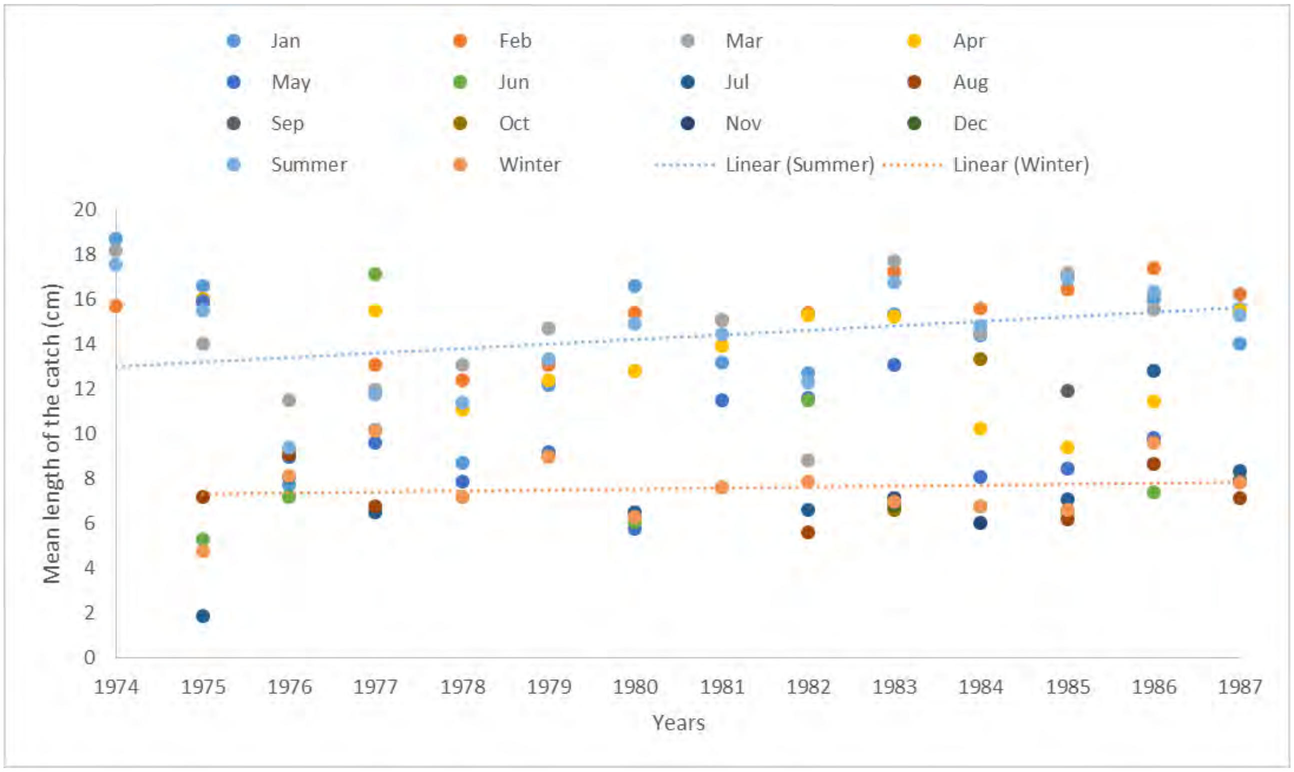

Figure 25: Monthly mean length of the catch against year for round herring *Etrumeus whiteheadi* (South African stock) from 1974 to 1987. A linear regression line fitted for average mean length of the catch for summer (Jan-April) and winter (other months) is represented by the dotted line.

Table 23: Regression results of mean of the catch against year of round herring *Etrumeus whiteheadi* (South African stock), from 1974 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Summer, DF= 13				
Intercept	-386.07	305.60	-1.26	0.23
Year	0.20	0.15	1.31	0.21
Winter, DF= 12				
Intercept	76.50	218.43	-0.35	0.73
Year	0.04	0.11	0.39	0.71

Scomber japonicus (chub mackerel)

Figure 26 shows that the mean length of the catch for the Namibian *S. japonicus* was between 20 cm and 60 cm and Table 24 shows that there was no significant change in mean length of the catch from 1972 to 1987. Figure 27 shows that the mean length of the catch for the South African *S. japonicus* was between 8 cm and 50 cm and Table 25 shows that there was no significant change in mean length of the catch from 1974 to 1987.

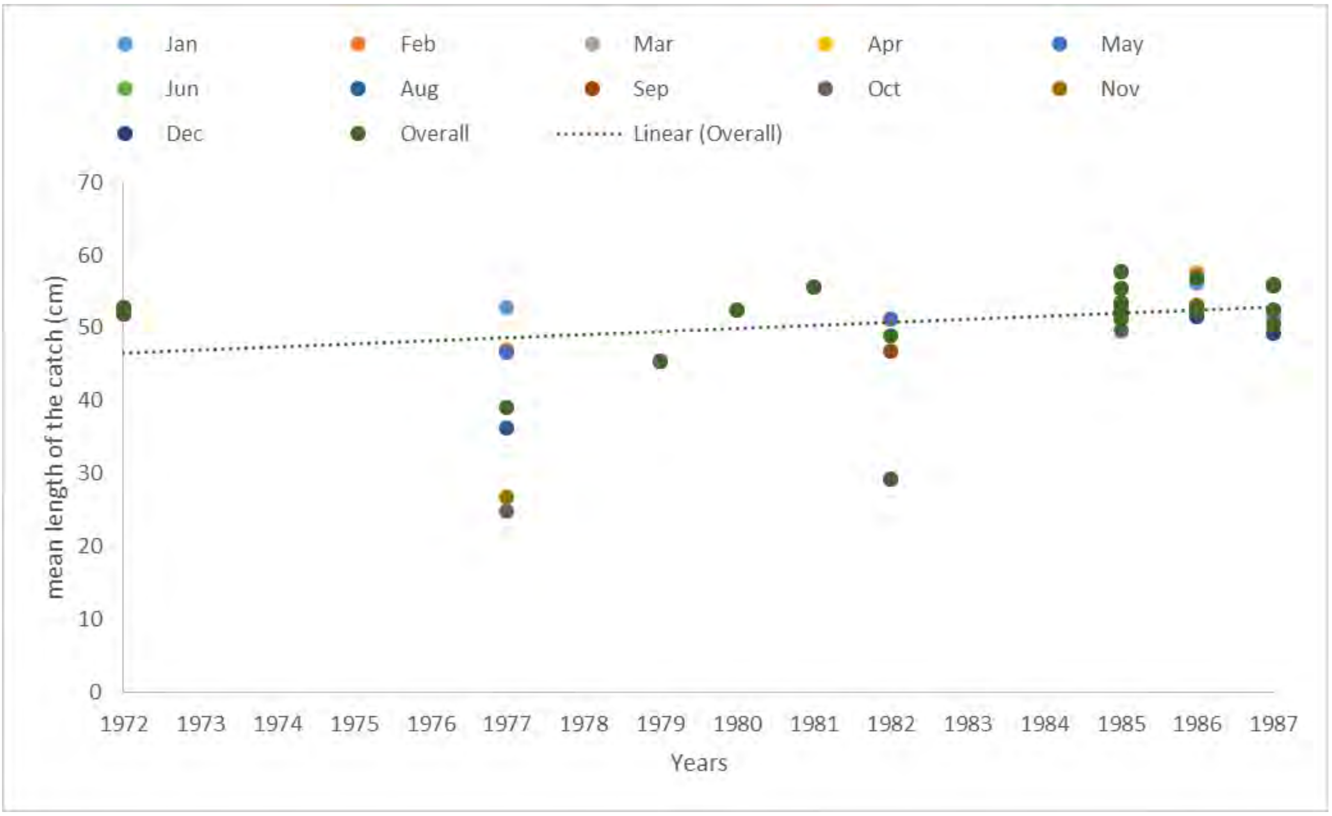

Figure 26: Monthly mean length of the catch against year for chub mackerel *Scomber japonicus* (Namibian stock) from 1972 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

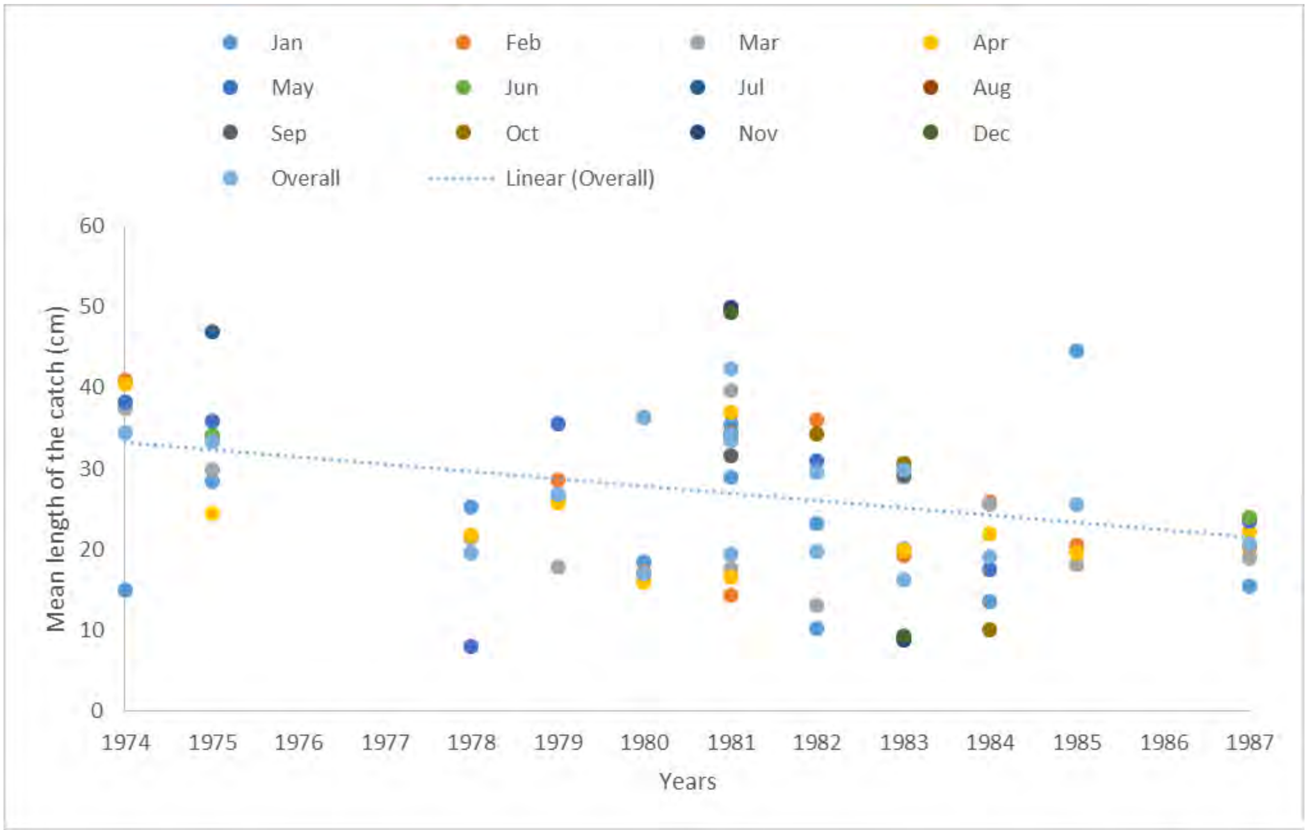

Figure 27: Monthly mean length of the catch against year for chub mackerel *Scomber japonicus* (South African stock) from 1974 to 1987. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 24: Regression results of mean length of the catch against year of chub mackerel *Scomber japonicus* (Namibian stock), from 1974 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 19				
Intercept	-783.56	631.62	-1.24	0.23
Year	0.42	0.32	1.32	0.20

Table 25: Regression results of mean length of the catch against year of chub mackerel *Scomber japonicus* (South African stock), from 1974 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 16				
Intercept	1810.79	1154.15	1.57	0.14
Year	-0.90	0.58	-1.54	0.14

Lampanyctodes hectoris (lanternfish) (South Africa only)

Figure 28 shows that the mean length of the catch for the South African *L. hectoris* was between 3.3 cm and 5.5 cm and Table 26 shows that there was no significant change in mean length of the catch from 1976 to 1986.

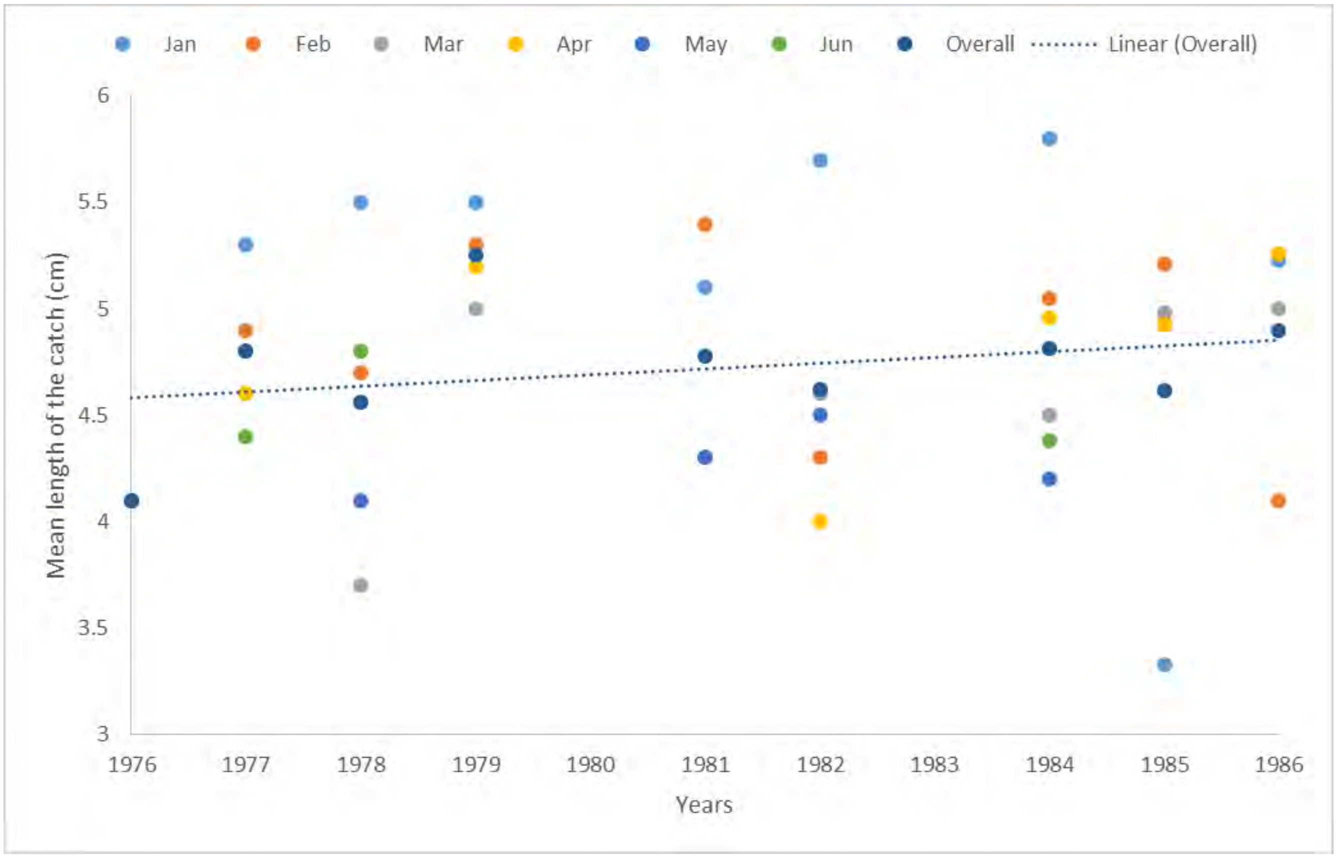

Figure 28: Monthly mean length of the catch against year for lanternfish *Lampancytodes hectoris* (South African stock) from 1976 to 1986. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 26: Regression results of mean length of the catch against year of lanternfish *Lampancytodes hectoris* (South African stock), from 1976 to 1986.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 8				
Intercept	-48.86	60.52	-0.81	0.45
Year	0.03	0.03	0.89	0.41

Genypterus capensis (kingklip)

Figure 29 shows that the mean length of the catch for the Namibian *G. capensis* was between 43.2 cm and 88.2 cm and Table 27 shows that there was no significant change in mean length of the catch from 1972 to 1987. Figure 30 shows that the mean length of the catch for the South African *G. capensis* was between 41 cm and 92.1 cm and Table 28 shows that there was no significant change in mean length of the catch from 1972 to 1986.

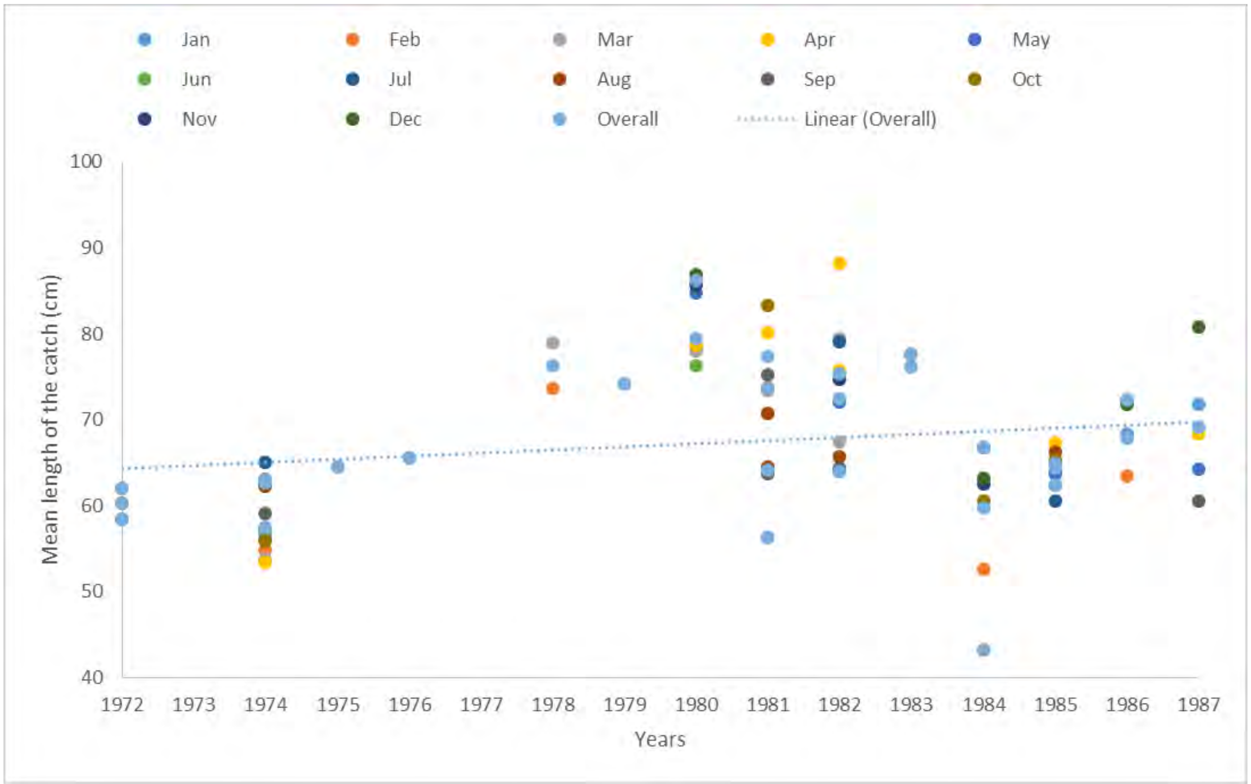

Figure 29: Monthly mean length of the catch against year for kingklip *Genypterus capensis* (Namibian stock) from 1972 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

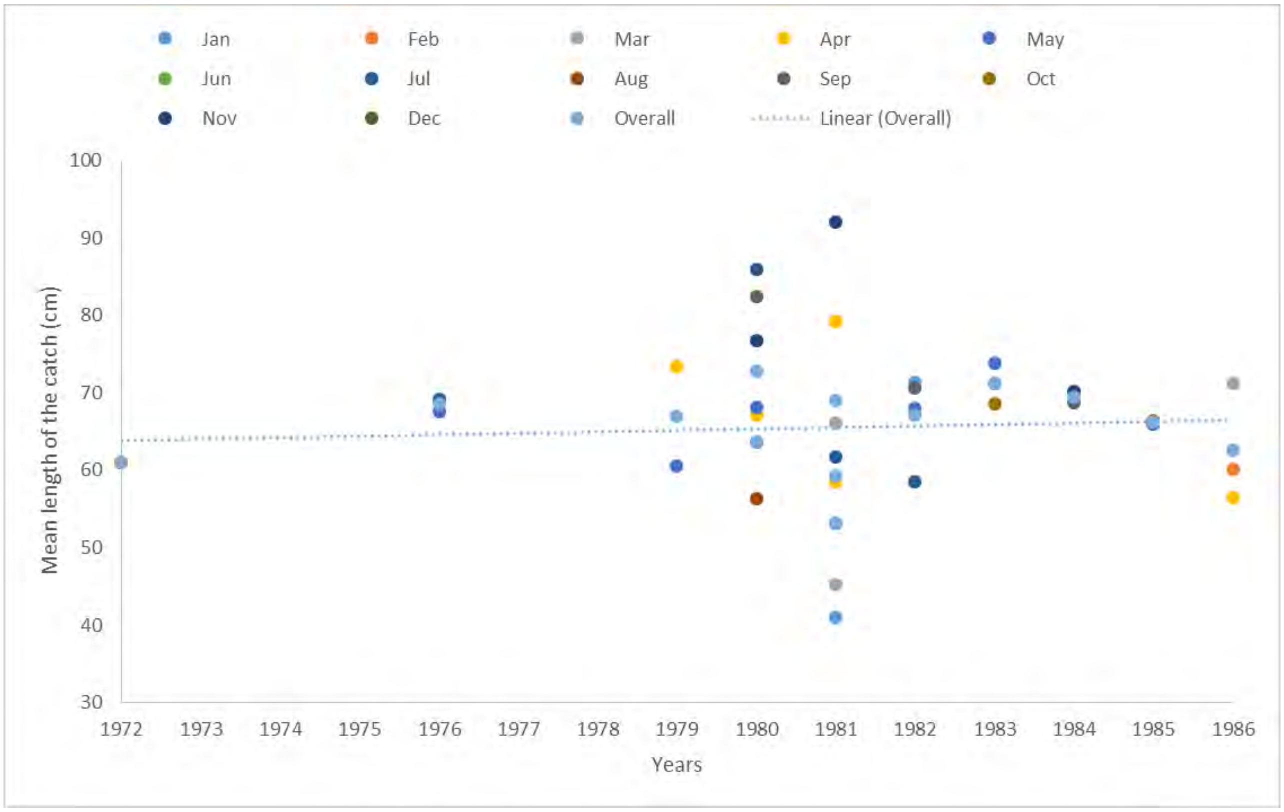

Figure 30: Monthly mean length of the catch against year for kingklip *Genypterus capensis* (South African stock) from 1972 to 1986. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 27: Regression results of mean length of the catch against year of kingklip *Genypterus capensis* (Namibian stock), from 1974 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 29				
Intercept	-646.59	692.04	-0.93	0.36
Year	0.36	0.35	1.03	0.31

Table 28: Regression results of mean length of the catch against year of kingklip *Genypterus capensis* (South African stock), from 1972 to 1986.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 12				
Intercept	-290.90	865.44	-0.34	0.74
Year	0.18	0.44	0.41	0.69

Loligo reynaudi chokka squid (South Africa only)

No regression on mean length of the catch was done on *L. reynaudi* (South African stock) because only a few points were available and Figure 31 shows that the mean length of the catch for the South African *L. reynaudi* was between 12.4 cm and 17.6 cm.

Figure 31: Monthly mean length of the catch against year for chokka squid *Loligo reynaudi* (South African stock) from 1980 to 1982.

Helicolenus dactylopterus (jacopever) (Namibia only)

Regression analysis in Table 29 indicated that there was a significant overall decrease in mean length of the catch for the Namibian *H. dactylopterus* from 1978 to 1987 (t-value=-3.00, P<0.05).

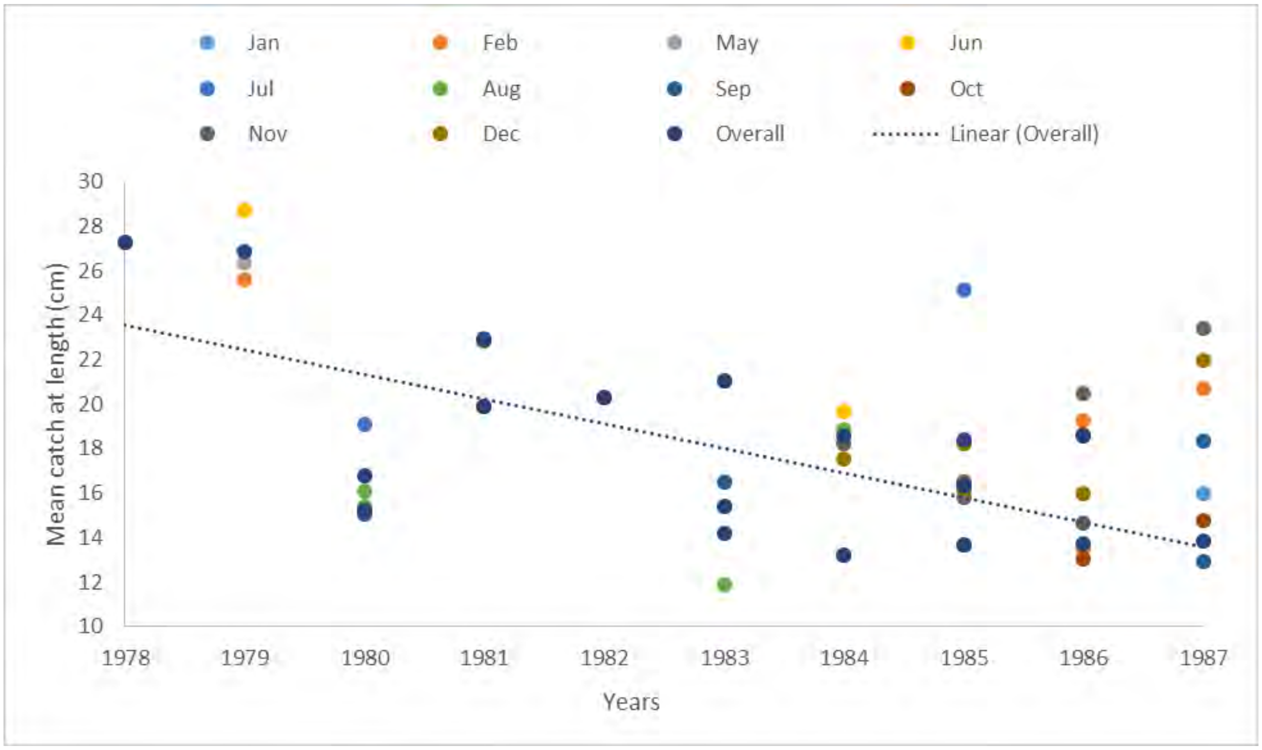

Figure 32: Monthly mean length of the catch against years for jacopever *Helicolenus dactylopterus* (Namibian stock) from 1978 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 29: Regression results of mean length of the catch against year of jacopever *Helicolenus dactylopterus* (Namibian stock), from 1978 to 1987, ** denotes a significant slope at the 1% level

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 18				
Intercept	1837.88	607.44	3.03	0.008
Year	-0.92	0.31	-3.00	**0.008 ****

Chelidonichthys capensis (Cape gurnard) (Namibian stock)

No regression on mean length of the catch was done on *Chelidonichthys capensis* (Namibian stock) because only a few points were available. Figure 33 shows that the mean length of the catch for the South African *C. capensis* was between 27.9 cm and 38.2 cm.

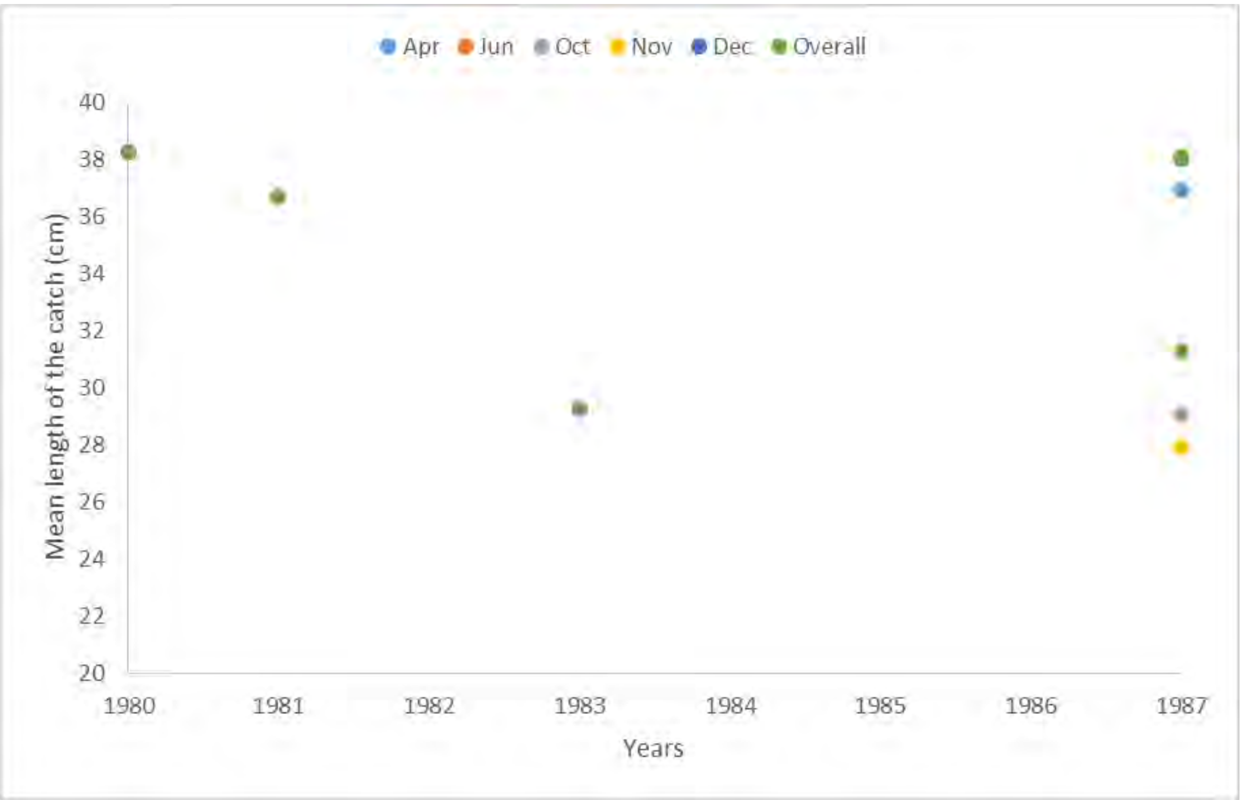

Figure 33: Monthly mean length of the catch against years for Cape gurnard *Chelidonichthys capensis* (Namibian stock) from 1980 to 1987, for divisions 1.3, 1.4 and 1.5.

Thyrsites atun (snoek)

Figure 34 shows that the mean length of the catch for the Namibian *T. atun* was between 52.3 cm and 94.3 cm and Table 30 shows that there was no significant change in mean length of the catch from 1976 to 1987. Figure 35 shows that the mean length of the catch for the South African *T. atun* was between 78.4 cm and 91 cm and Table 31 shows that there was no significant change in mean length of the catch from 1978 to 1983.

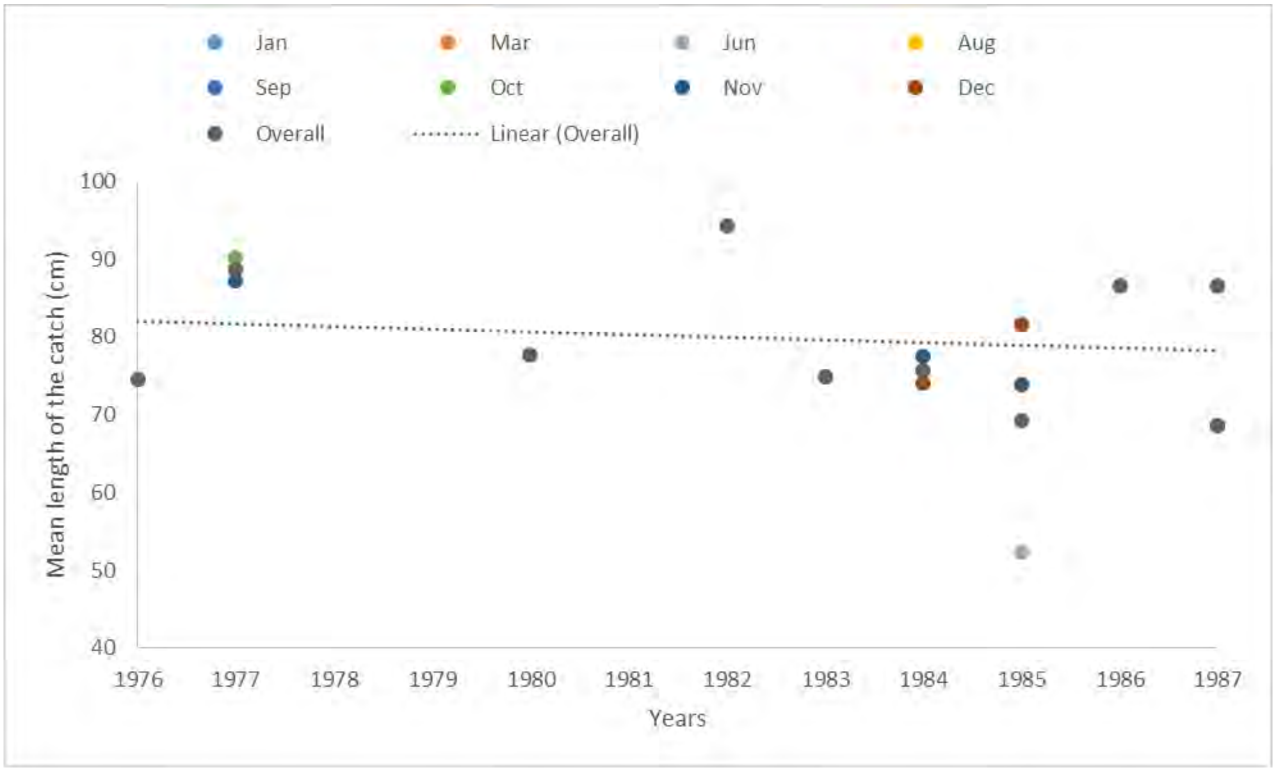

Figure 34: Monthly mean length of the catch against years for snoek *Thyrsites atun* (Namibian stock) from 1976 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

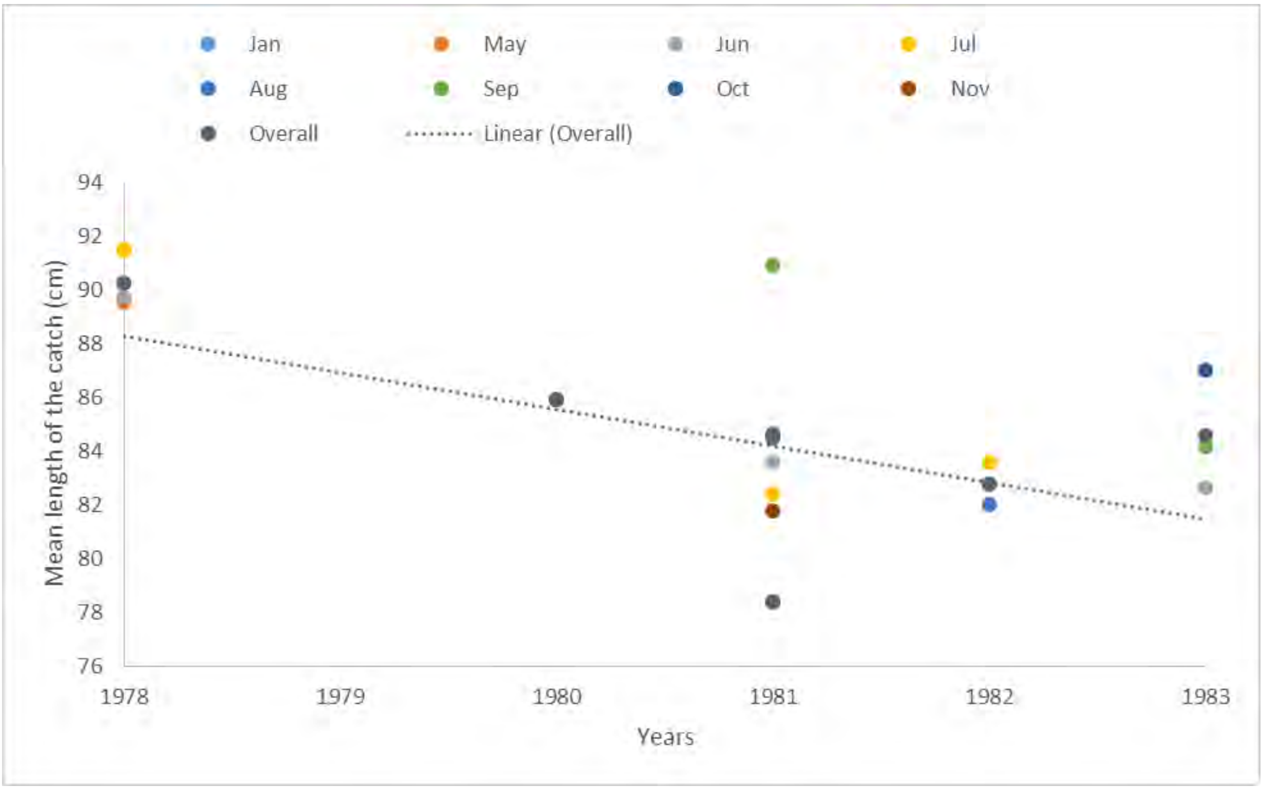

Figure 35: Monthly mean length of the catch against years for snoek *Thyrsites atun* (South African stock) from 1978 to 1983. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 30: Regression results of mean length of the catch against year of snoek *Thyrsites atun* (Namibian stock), from 1976 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 9				
Intercept	755.90	1532.88	0.49	0.64
Year	-0.34	0.77	-0.44	0.67

Table 31: Regression results of mean length of the catch against year of snoek *Thyrsites atun* (South African stock), from 1978 to 1983.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 5				
Intercept	2784.08	1772.93	1.57	0.19
Year	-1.36	0.90	-1.52	0.20

Dentex macrophthalmus (large eye dentex) (Namibia only)

Figure 36 shows that the mean length of the catch for the Namibian *D. macrophthalmus* was between 7.3 cm and 35.3 cm and Table 32 shows that there was no significant change in mean length of the catch from 1972 to 1987.

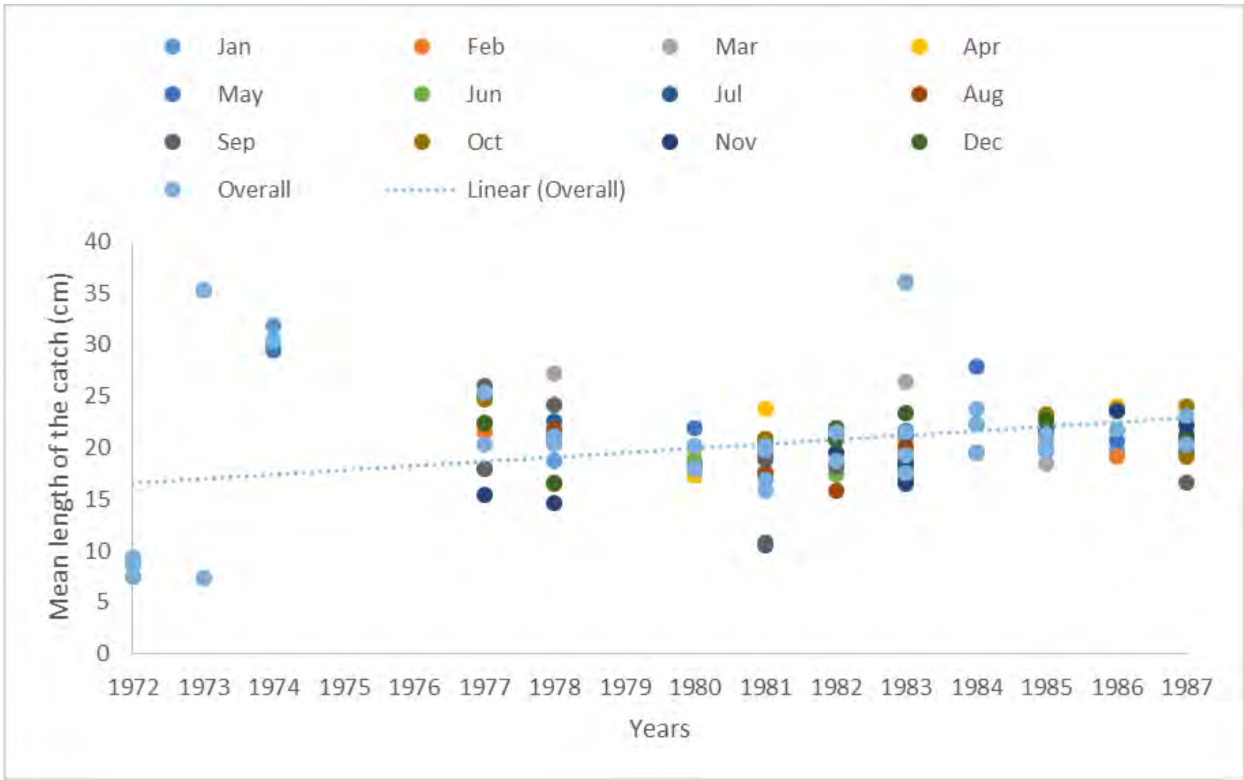

Figure 36: Monthly mean catch at length against years for large eye dentex *Dentex macrophthalmus* (Namibian stock) from 1972 to 1987, for division 1.3 and 1.4. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 32: Regression results of mean length of the catch against year of large eye dentex *Dentex macrophthalmus* (Namibian stock), from 1972 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 30				
Intercept	-808.81	488.89	-1.65	0.11
Year	0.42	0.25	1.70	0.10

Lophius vomerinus (monkfish)

Regression analysis in Table 33 indicated that there was a significant overall decrease in mean length of the catch for the Namibian *L. vomerinus* from 1978 to 1987 (t-value=-3.11, P<0.05).

Regression analysis in Table 34 indicated that there was a significant overall increase in mean length of the catch for the South African *L. vomerinus* from 1980 to 1987 (t-value=2.58, P<0.05).

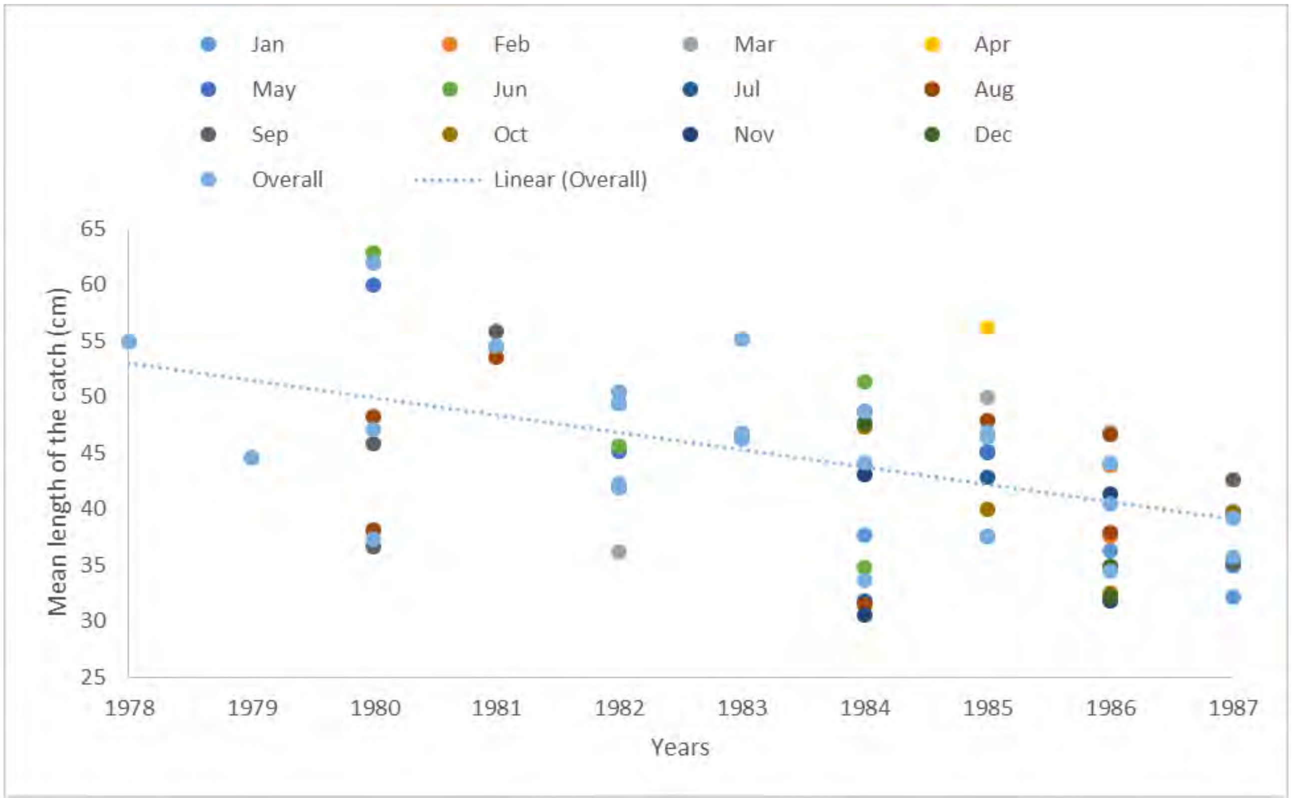

Figure 37: Annual mean length of the catch against years for monkfish *Lophuis vomerinus* (Namibian stock) from 1978 to 1987, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

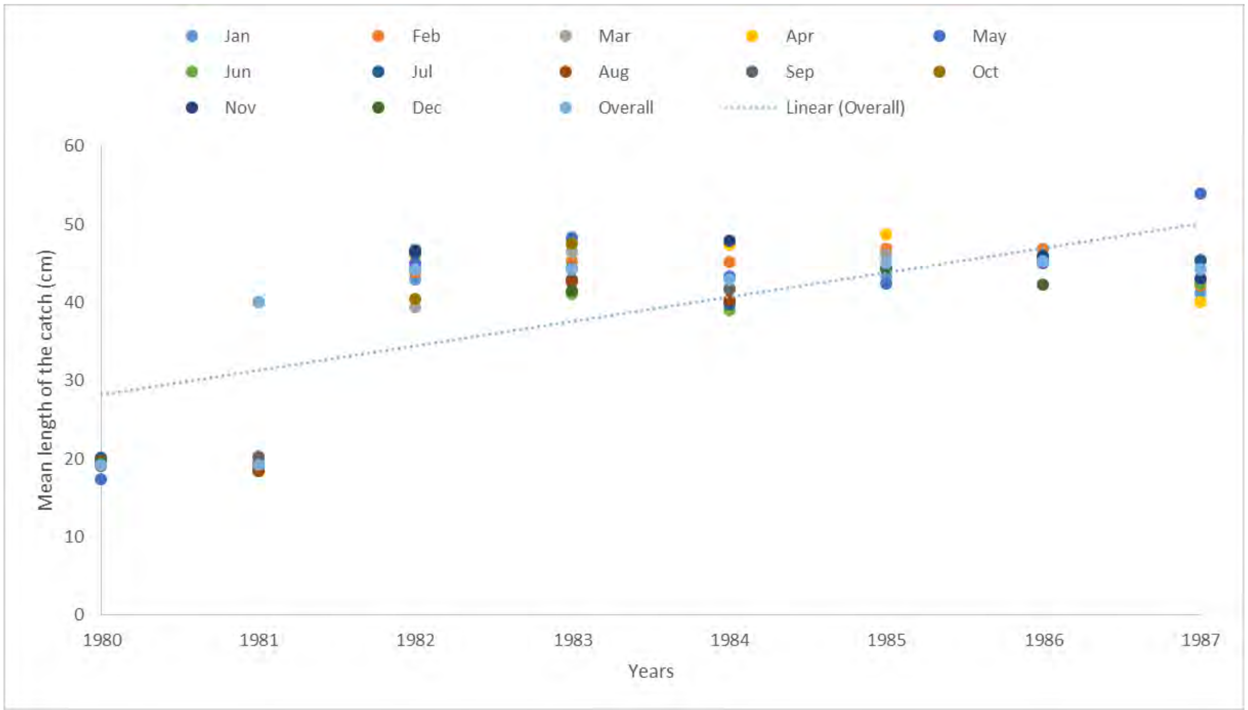

Figure 38: Annual mean length of the catch against years for monkfish *Lophius vomerinus* (South African stock) from 1980 to 1987. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 33: Regression results of mean length of the catch against year of monkfish *Lophius vomerinus* (Namibian stock), from 1978 to 1987, ** denotes a significant slope at the 1% level.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 23				
Intercept	3107.03	985.01	3.15	0.005
Year	-1.54	0.50	-3.11	**0.005 ** **

Table 34: Regression results of mean length of the catch against year of monkfish *Lophius vomerinus* (South African stock), from 1980 to 1987, * denotes a significant slope at the 5% level.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 8				
Intercept	-6165.40	2404.61	-2.56	0.04
Year	3.13	1.21	2.58	**0.04 * **

Austroglossus microlepis (West coast sole) (Namibia only)

Figure 39 shows that the mean length of the catch for the Namibian *A. microlepis* was between 31.1 cm and 45.1 cm and Table 35 shows that there was no significant change in mean length of the catch from 1974 to 1986.

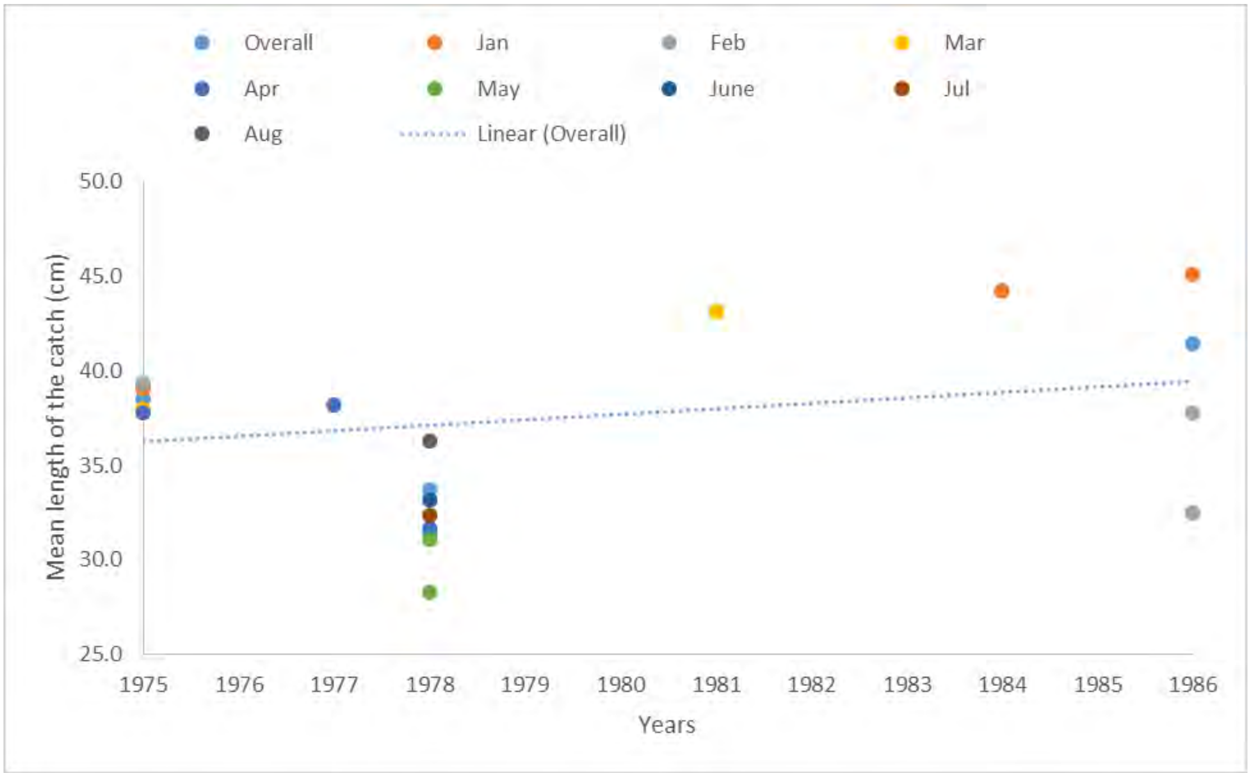

Figure 39: Monthly mean length of the catch against years for West coast sole *A. microlepis* (Namibian stock) from 1974 to 1986, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 35: Regression results of mean length of the catch against year of West coast sole *A. microlepis* (Namibian stock), from 1974 to 1986.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 7				
Intercept	-532.59	901.95	-0.59	0.58
Year	0.29	0.46	0.63	0.55

Jasus lalandii (West coast rock lobster)

Regression analysis in Table 36 indicated that there was a significant overall increase in mean length of the catch for the Namibian *J. lalandii* from 1977 to 1987 (t-value=3.87, $P<0.05$). Figure 41 shows that the mean length of the catch for the South African *J. lalandii* was between 7.2 cm and 11.2 cm and Table 37 shows that there was no significant change in mean length of the catch from 1977 to 1987.

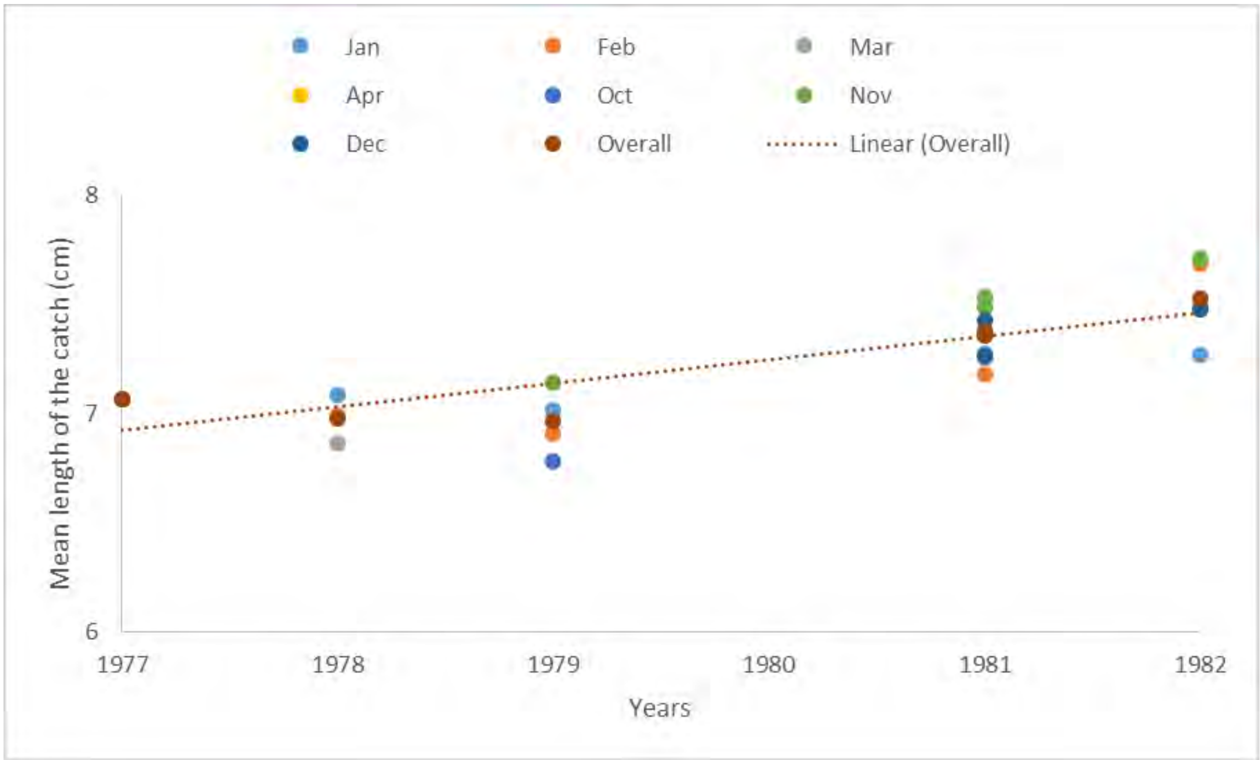

Figure 40: Monthly mean length of the catch against years for West coast rock lobster *Jasus lalandii* (Namibian stock) from 1977 to 1982, for divisions 1.3, 1.4 and 1.5. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

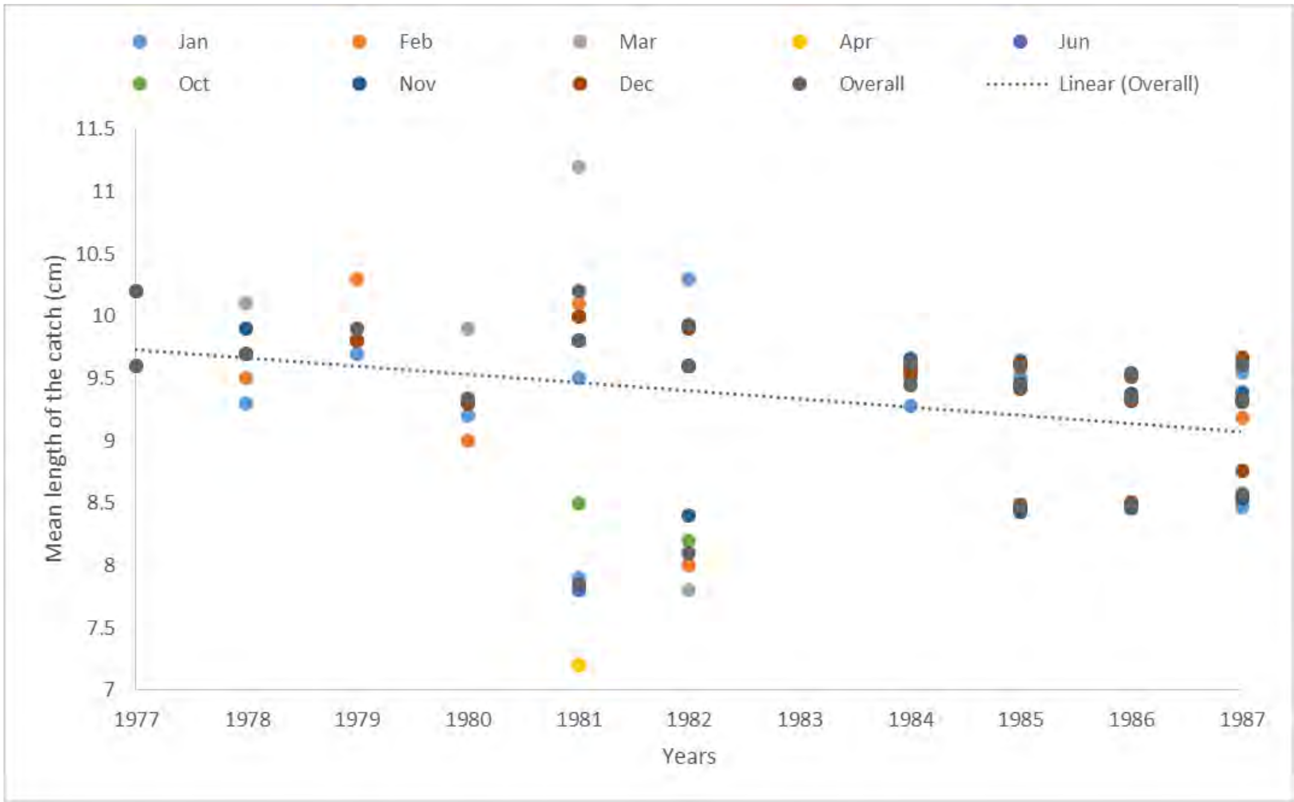

Figure 41: Monthly mean length of the catch against years for West coast rock lobster *Jasus lalandii* (South African stock) from 1977 to 1987. A linear regression line fitted for the average mean length of the catch for the year (Overall) is represented by the dotted line.

Table 36: Regression results of mean length of the catch against year of West coast rock lobster *Jasus lalandii* (Namibian stock), from 1977 to 1982, * denotes a significant slope at the 5% level.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 5				
Intercept	-206.91	55.34	-3.74	0.02
Year	0.11	0.03	3.87	**0.02 ***

Table 37: Regression results of mean catch at length against year of West coast rock lobster *Jasus lalandii* (South African stock), from 1977 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Average, DF= 21				
Intercept	139.57	82.25	1.70	0.11
Year	-0.07	0.04	-1.58	0.13

3.3. Fish condition

Merluccius capensis (shallow-water Cape hake) (Namibia stock only)

Figure 42 shows the mean weight at length 35 (g) for *M. capensis* over the years 1975 to 2020 for January and February (divisions 1.3, 1.4 and 1.5). Table 38 shows that there was no significant change in mean weight (g) at length 35 cm for *M. capensis* over the years 1975 to 2020. Fish worse conditions were found in the year 1983 and fish with best conditions were found in the year 1987 (Figure 42).

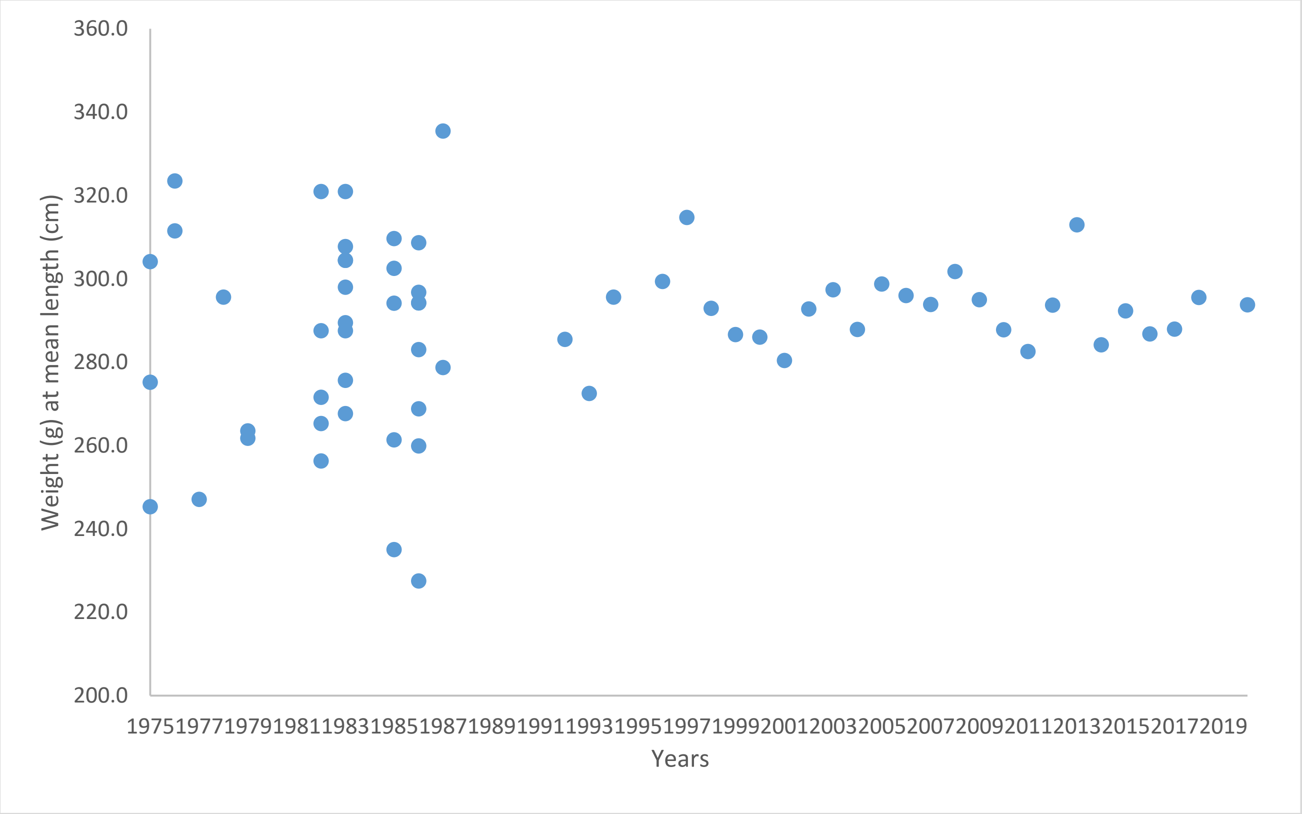

Figure 42: Annual mean weight (g) at length 35 cm against years for shallow-water Cape hake *M. capensis* (Namibian stock) from 1975 to 2020, for January and February.

Table 38: Regression results of mean weight (g) at length 35 cm against years for shallow-water Cape hake *M. capensis* from 1975 to 2020.

Coefficients	Estimate	Standard error	t-value	p-value
Overall, DF= 64				
Intercept	-260.47	390.41	-0.67	0.51
Year	0.28	0.20	1.41	0.16

Merluccius paradoxus (deep-water Cape hake) (Namibia stock only)

Figure 43 shows the mean weight (g) at length 35 cm for *M. paradoxus* over the years 1976 to 2013 for January and February (divisions 1.3, 1.4 and 1.5). Table 39 shows that there was no significant change in mean weight (g) at length 35 cm for *M. paradoxus* over the years 1976 to 2013. Fish worst conditions were found in the year 1982 and fish with best conditions were found in the year 1979 (Figure 43).

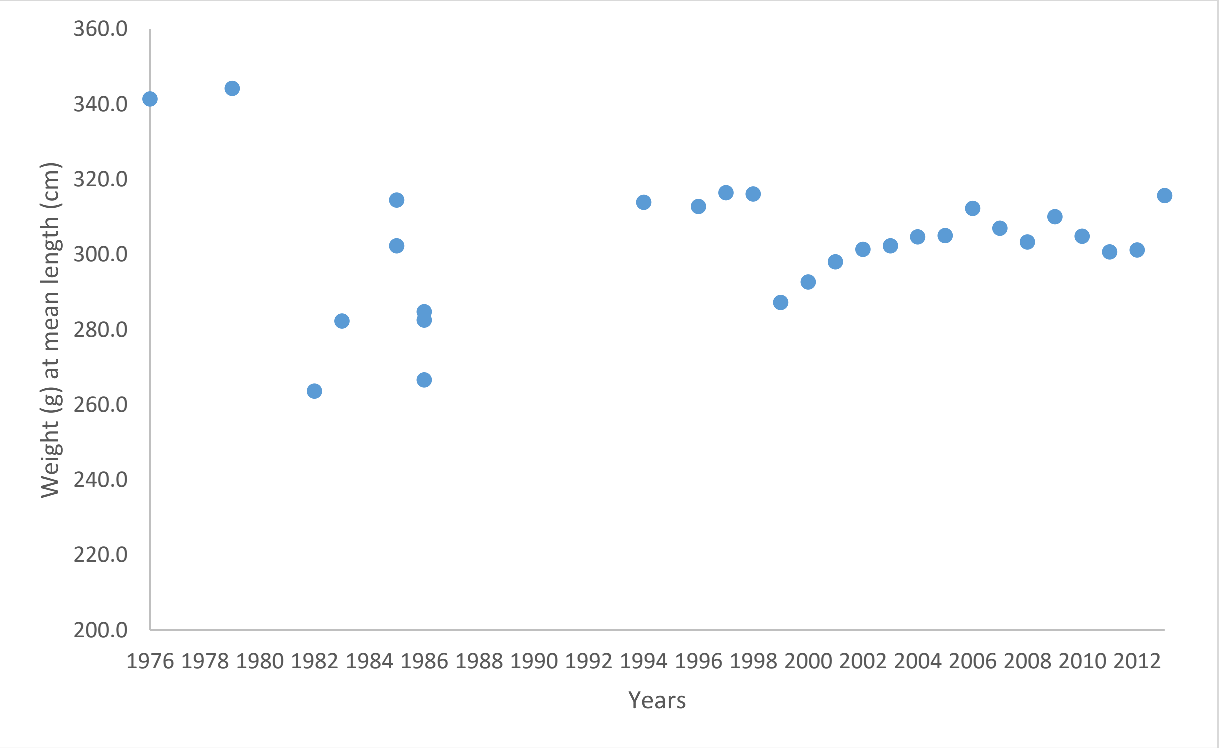

Figure 43: Annual mean weight (g) at length 35 cm against years for deep-water Cape hake *M. paradoxus* (Namibian stock) from 1976 to 2013, for January and February.

Table 39: Regression results of mean weight (g) at length 35 cm against years for deep-water Cape hake *M. paradoxus* from 1976 to 2013.

Coefficients	Estimate	Standard error	t-value	p-value
Overall, DF= 27				
Intercept	117.85	628.60	0.19	0.85
Year	0.09	0.31	0.29	0.77

Trachurus capensis (horse mackerel) (Namibian stock only)

Figure 44 shows the mean weight (g) at length 35 cm for *T. capensis* over the years 1976 to 1987 for January, February and March (divisions 1.3, 1.4 and 1.5). Table 40 shows that there was no significant change in mean weight (g) at length 35 cm for *T. capensis* over the years 1976 to 1987. Fish worst conditions were found in the year 1980 and fish with best conditions were found in the year 1986 (Figure 44).

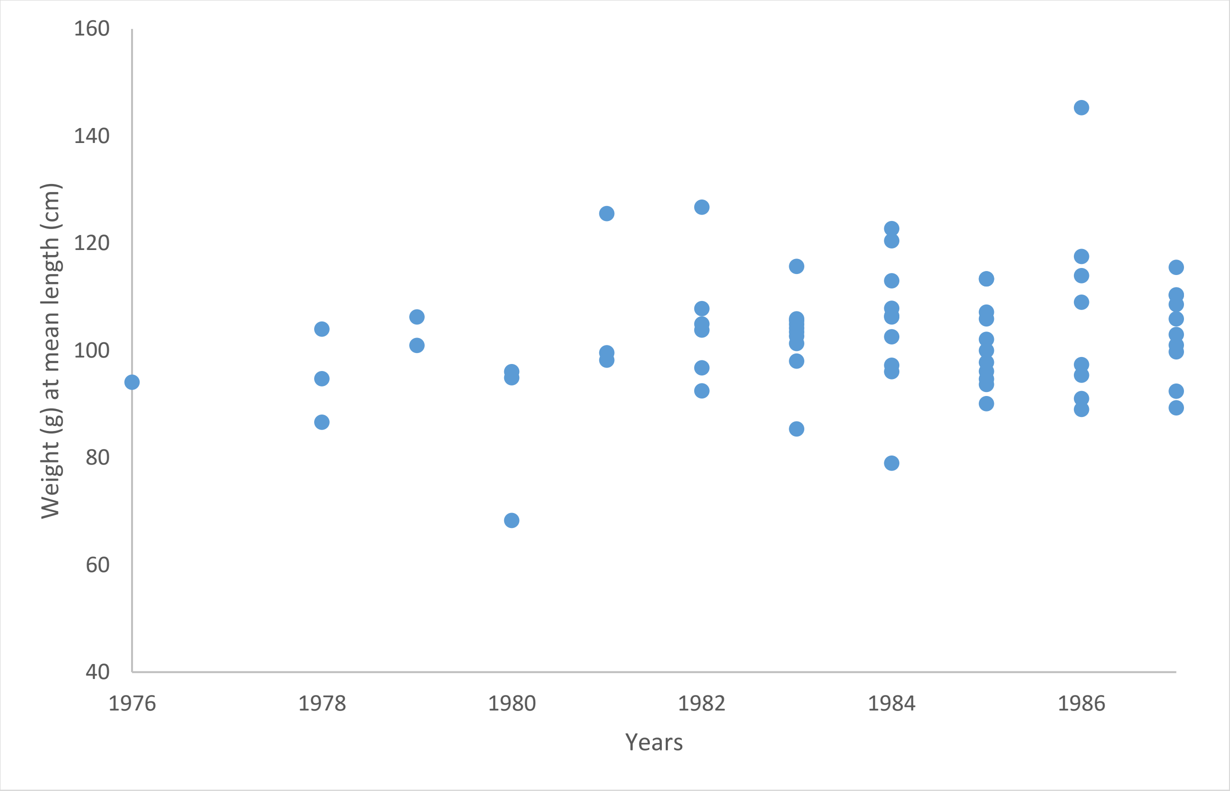

Figure 44: Annual mean weight (g) at length 23 cm against years for horse mackerel *T. capensis* (Namibian stock) from 1976 to 1987, for January, February and March.

Table 40: Regression results of mean weight (g) at length 23 cm against years for horse mackerel *T. capensis* from 1976 to 1987.

Coefficients	Estimate	Standard error	t-value	p-value
Overall, DF= 66				
Intercept	-1640.93	1064.11	-1.54	0.13
Year	0.88	0.54	1.64	0.11

3.4. Correlation between SST and mean length at age

Merluccius capensis (shallow-water Cape hake) (Namibian stock only)

There was a significant negative correlation between mean length of *M. capensis* at age 3 and SST of the previous year for North: 17° to 20°S in July (Figure 45, Appendix Figure A1), Centre: 20° to 24°S in September (Figure 46, Appendix Figure A2), South 24° to 28°S in January (Figure 47, Appendix Table A3). Appendix Figure A4 shows that there was no significant correlation between mean length of *M. capensis* at age 3 and SST of the previous year for South Africa 28° to 31°S (December).

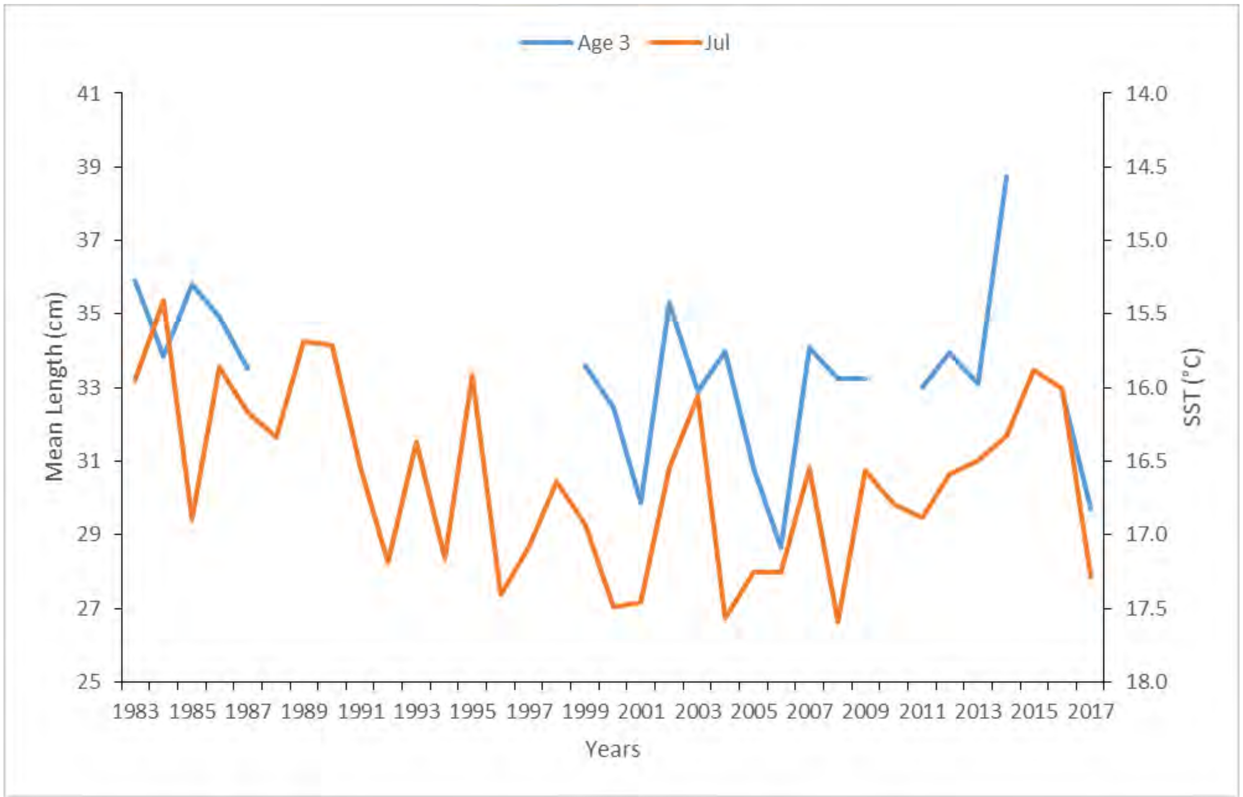

Figure 45: Annual mean length at age 3 for shallow-water Cape hake *M. capensis* (Namibian stock) and SST for July the previous year in North: 17° to 20°S and 10° to 12°E plotted against year. Note that SST is plotted in reverse order to demonstrate the (absolute) correlation.

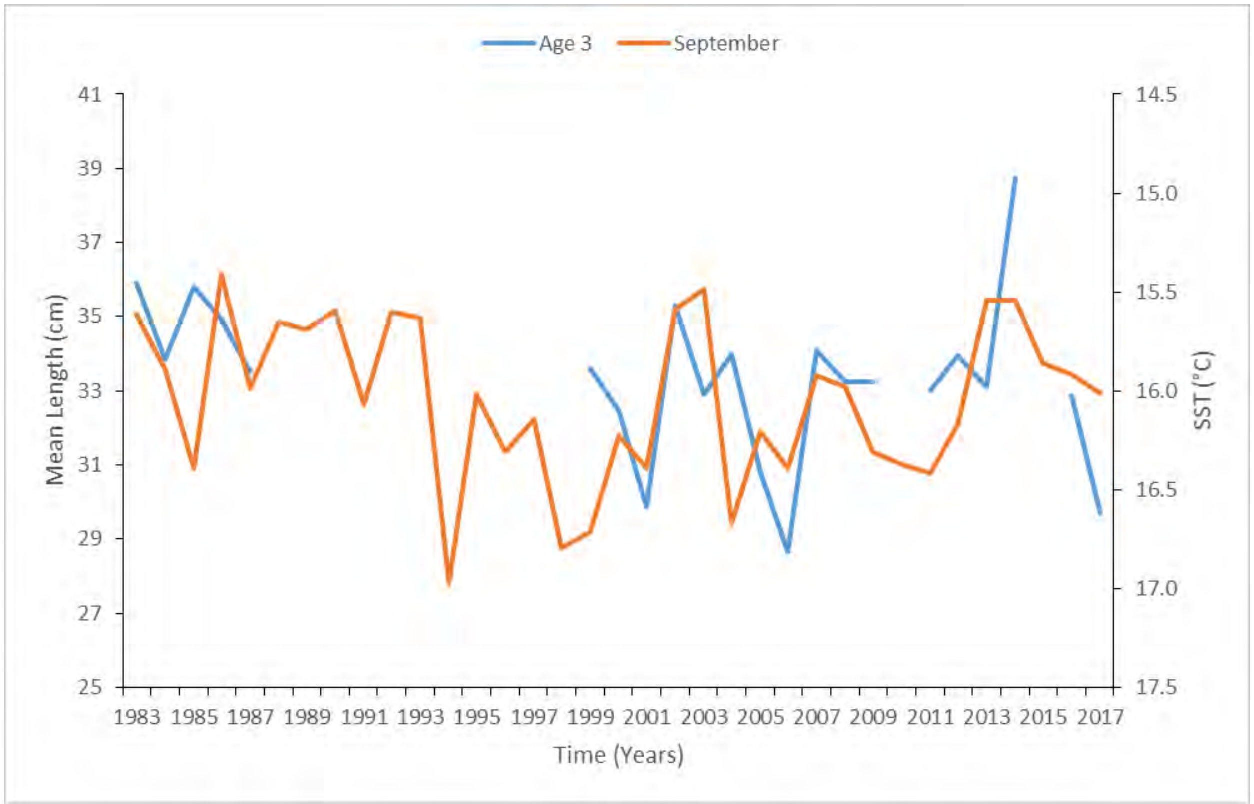

Figure 46: Annual mean length at age 3 for shallow-water Cape hake *M. capensis* (Namibian stock) and SST for September the previous year in Centre: 20° to 24° S and 12° to 14° E plotted against year. Note that SST is plotted in reverse order to demonstrate the (absolute) correlation.

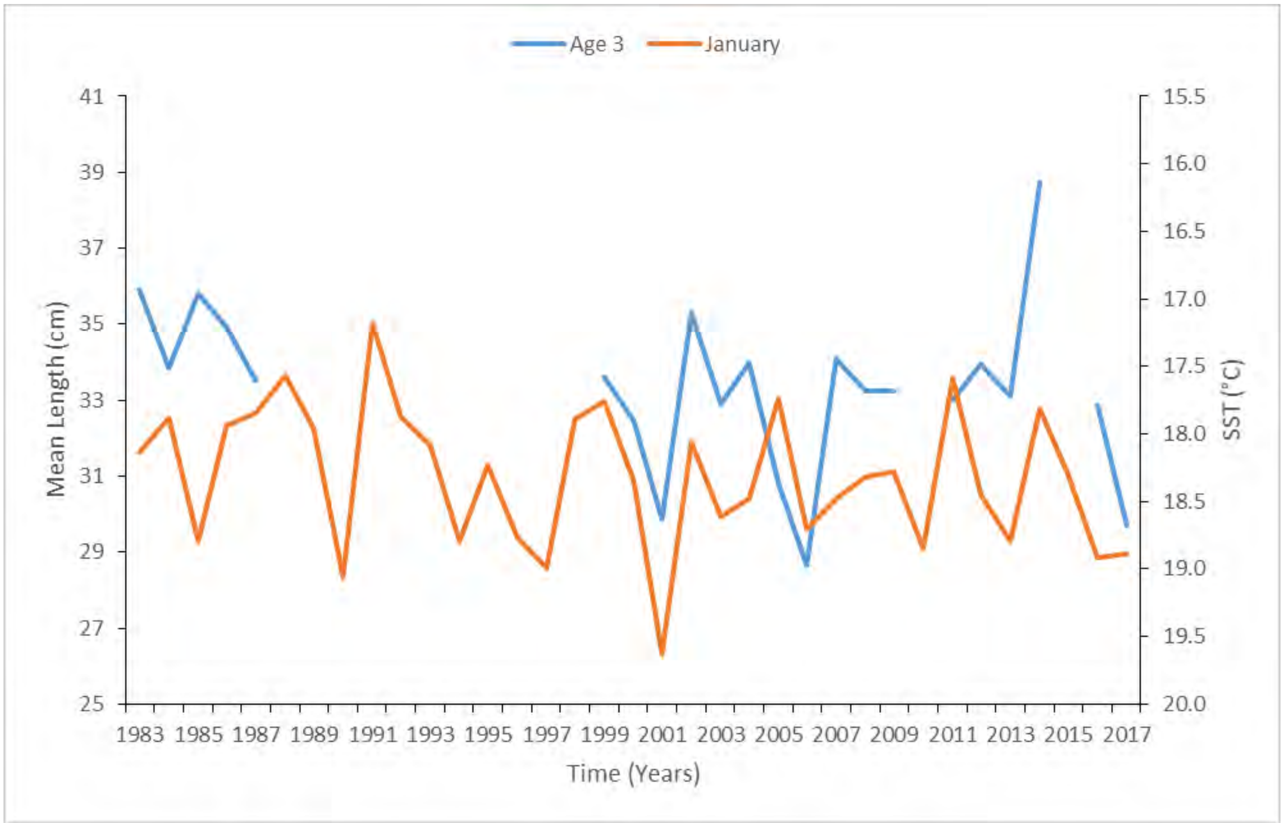

Figure 47: Annual mean length at age 3 for shallow-water Cape hake *M. capensis* (Namibian stock) and SST for January the previous year in South 24° to 28°S and 13° to 15°E plotted against year. Note that SST is plotted in reverse order to demonstrate the (absolute) correlation.

Trachurus capensis (horse mackerel) (Namibian stock only)

There was no significant correlation between the mean length of *T. capensis* at age 3 and SST in any month of the previous year in either area (Appendix A7, A9, A11 and A13).

4. Discussion

4.1. Annual changes in lengths at age

The first objective of this study was to determine the long-term trends in mean length at age for Namibia and South Africa's exploited resources and bycatch resources. This study demonstrated that there were long-term changes in annual mean-length at age of some stocks. Most species experienced an increase in mean length at age over the last few decades from the start of fishing.

The results demonstrated a significant decrease in mean length at age 7 for Namibian shallow-water Cape hake from 1968 to 2017 (see Figure 2, Table 1). Mean length decreasing at older age groups happens because fishing is size selective and selects for the larger and older fish (Shin et al. 2005). The stock was overfished (collapsed at the end of the 1980s) and the mean length at age 7 decreased from 1968 to 2017 despite several management measures put in place after Namibia's independence to reduce fishing such as the 200 m depth restriction, a closed season during October and a TAC that varied from year to year (Wilkinson and Japp 2020). The implications of overfishing the shallow-water Cape hake stock was a decline in mean length at age 7 and an increase in smaller fish abundance.

Larger fish usually have a higher market value and are more targeted than smaller ones and a shift in the size structure of the stock could lead to more stock being discarded (Heino et al. 2002, Hixon et al. 2014). Fishing selects against fast growing fish, leading to increased natural mortality of larger fish and this in turn causes growth to evolve towards a slower growth rate after maturity (Enberg et al. 2012). Such response towards fishing is known as fishing-induced evolution. The current 200 m depth restriction measure put in place for the management of the shallow-water Cape hake fishery may have influenced size selection, under-selecting juvenile shallow-water Cape hake causing this type of fisheries-induced evolution and contributing to the negative growth trend of large (age 6) shallow-water Cape hake.

The mesh size limit of 110 mm for hake trawls as well as the 200 m depth restriction was another management measure put into place in 1991 to protect undersized, younger fish (especially shallow-water Cape hake) (Jones et al. 2020). The current management measures evidently put an even greater target on larger individuals. Small individuals are less likely to be caught because and they evolve a slow growing trait to make them less targeted (Heino et al. 2002). Also, smaller individuals are able to through the mesh (110 mm in the case of Swch), Wolff et al. (2015), so they are captured in smaller numbers. Fishery selection may cause a change in the adult and offspring life history characteristic, thus, contributing to fishery induced evolution. An adaptive trait would be early maturation, which would make them smaller in size after maturity, because growth slows after maturation (Heino et al. 2002). Similarly, DeCelles and Vidal (2020) noticed a trend of early maturation and smaller sizes in the exploited *Limanda ferruginea* in the Gulf of Maine, after the regulations of mesh size and minimum landing sizes were set in 1980 and older and larger fish were preferred. The adaptive a slow-growing trait may explain the decline in mean length at age 7 for shallow-water Cape hake from 1968 to 2016.

There was a significant increase in mean length ages 3 to 7 for the South African shallow-water Cape hake from 1968 to 2008 (see Figure 3) and a significant increase at ages 2 to 6 for South African deep-water Cape hake from 1976 to 2008 (see Figure 4). The observed changes may have also been the effects of fishery-induced evolutionary changes. In the South African case the exploitation and selection of the stock led to early maturation, and therefore increased growth before maturation (Enberg et al. 2021). The different sizes at a given age may be influenced by the timing of maturation and variation in reproductive investment. Hence, fishery-induced evolution may be the reason for the increase in mean length in the early ages of hake may be due to fishing selectivity favouring earlier maturation, increased reproductive investment, increased resource acquirement and faster growth before maturity (Enberg et al. 2012). These findings are consistent with other studies, for example, Ohlberger et al. (2019) found that the west coast North American chinook salmon matured at younger ages and size at age is increased for younger ages and decreased for older ages after the onset of fishing. Wilhelm et al. (2020) demonstrated increased mean length at ages 2 and 3 and decreased mean lengths at ages 7 and 8 in the Namibian deep-water Cape hake (Wilhelm et al. 2020).

Similar to the fishing effects on growth demonstrated for South African shallow-water Cape hake and deep-water Cape hake there was an increase in mean length at age 1, 2, 3, 4, 5 and 6 for sardine in Namibian waters from 1975 to 1987 (see figure 6). The Namibian sardine stock has not been able to recover fully since it was depleted since before 1990 due to its collapse in the early 1970s due to overfishing and it is currently severely depleted and under a moratorium (Wilkinson and Japp 2020). The stock had a very low biomass between 1975 and 1987 due to overfishing, as a result, their increased growth rate fishery-induced evolution and this probably led to earlier maturation and faster fish growth rate. Hence, the increase in mean length at age 1 to 6 for sardine.

The results also demonstrated a significant increase in mean length at age 6 for Namibian horse mackerel from 1972 to 2018 (see Figure 5). According to Williamson and Japp (2018), the stock was overexploited in 2017 and the total biomass has decreased significantly since 1961. The decline in biomass, could have led to reduced intraspecific competition, allowing for more resources available to the stock, as well as fisheries-induced changes similar to those explained for Namibian *M. capensis* previously. Food availability is known to affect fish growth and higher food availability means fish have sufficient food available to enable faster growth (Hazlerrig et al. 2012). Hence, the increase in mean length for horse mackerel could have been a result of easing up of density-dependent effects when the growth rate of a population increases as its density declines (Aubier 2020). Similarly, Eikeset et al. (2016) found that northeast Arctic cod (*Gadus morhua*) increased in phenotypic growth and this was likely that growth was density-dependent, where a decline in biomass from fishing led to faster growth. However, the study did not test the correlation between mean length at age and stock biomass. The determination of the correlation between mean length and age is recommended for future studies.

A significant increase was demonstrated in the early ages (age 3) of anchovy (Namibian stock) from 1974 to 1987 (see Figure 7). The increase in catches of anchovies between the mid-1970s and mid1980s and a peak in 1987 led to a decline in the stock by the 1990s (David 2012). As we have mentioned before fish growth rate of stock usually increases when the abundance of the stock decreases. The size of smaller fish increase and tend to outgrow some of their predators, thus, decreasing natural mortalities (Heino et al. 2002). Total juvenile mortalities rates decrease with an increase in growth rate, anchovies are exposed to the mortality risk for a shorter time and have a higher chance at survival (Heino et al. 2002).

Similarly, low fishing intensity in the Scottish western shelf sea contributed to the reduction of the severity of truncations in length distributions allowing more fast-growing fish to survive and pass on their fast growing traits (Hunter et al. 2016). A study by Howard et al. (2007) found that anchovy decreased in mean length after a successful recruitment throughout the mid-1980s.

However, this study did not have sufficient data of the older ages for anchovy. Older age classes may either be absent or greatly reduced due to the stock being exploited (Coggins et al. 2013).

Figure 9 shows that there was a regime shift in mean length at age 1 for round herring in South Africa where there was an abrupt increase in mean length at age from 1982 to 1983. The abrupt increase in mean length at age 1 may have been caused by increased temperatures. The years 1982 and 1983 are known as the cooler years in the Benguela region, Hardman-Mountford et al. (2003), at colder temperatures fish spend less on metabolism so more consumed energy is going for growth. However, this is different for the years of the regime shifts years identified in the 1970s and the 1980s for northern Benguela (Van der Lingen et al. 2006a). This study's observation does support the regime shifts that occurred in the southern Benguela during the mid-1960s and mid-1990s, (Cury and Shannon 2004). Similar observations were shown in, mangrove jack when it had higher growth rates, however, this was during the La Nina events where there were conditions of warm and low salinity waters (Ong et al. 2015). During the 1920s and 1930s, the North Atlantic underwent increased warming, which led to environmental and ecosystem changes (Denechaud et al. 2020). In addition to the changes in environmental conditions, cod growth underwent shifts of an abrupt decrease in growth rates between 1993 and 1999 and this was linked to the warming phase of the Barents Sea (Denechaud et al. 2020).

Similarly, temperature-at-depth and large-scale climate variability in the Northeast Atlantic appeared to be the cause of the abrupt decline in the rosefish somatic growth and low abundance causing a regime shift (Tanner et al. 2019). Fish are able to adapt to environmental variability because they have phenotypic plasticity and it allows them to produce different phenotypes that allow them to adapt to different environmental conditions. The phenotypic variability can then result in an evolutionary change of the population (Heino et al. 2002) and this is known as a regime shift.

The opposite trend to the five above-mentioned stocks was demonstrated for Namibian large eye dentex showing a significant decrease in mean length at age 2 f from 1976 to 1987 (see figure 11). The high density of the stock at the end of the time period (late 1980s), Kirchner (2011), may have led to increased intraspecific competition and reduced food availability. Intraspecific competition for food resources may have caused the decrease in mean length at age 2 a process known as negative density dependence. Negative density dependence was demonstrated in a study that investigated the impact of density-dependence on fish growth of stream salmonid populations when an increase in density of the population brought about a significant decrease in fish growth rate of stream salmonid populations (Grant and Imre 2005). Similarly, there was an increase in abundance and followed by a decline in growth rates of *Galaxias maculatus* observed in fresh water protected areas (Watson et al. 2022).

Recruitment of the large eye dentex is usually at approximately 160mm FL, which is the length-at-50% maturity of the species and this allows for some of the population to at least reproduce once (Potts et al. 2010). Knowledge on the current fish growth rate of the species determines the current recruitment size. Hence, future research of large eye dentex should focus on stock identification and include otolith morphometric studies (Potts et al. 2010).

4.2. Mean length of the catch

The second objective of this study was to determine the long-term trends in mean length of the catch for Namibia and South Africa's exploited targeted resources and bycatch. The study showed significant positive and negative trend in mean catch at length in both Namibia's and South Africa's exploited resources and bycatch from the start of the fishery to current.

The introduction of management measures from Namibian independence in 1990 onwards, might have contributed to the significant decrease in mean length of the catch for Namibian shallow-water Cape hake observed between 1968 and 1987 (see Figure 13), Namibia monkfish from 1978 to 1987 (see Figure 37), Namibian jacopever between 1978 and 1987 (see Figure 32) before Namibia's independence. Prior to independence, shallow-water Cape hake was mostly exploited between 50 to 300 m depth contours and juveniles were mostly found in depths shallower than 100 m (Kirchner 2011). After independence the management measures set was not allowing hake trawling in less than 200 m depth water. Fish were caught at all sizes and catch at length decreased as a result of recruitment overfishing without the 200 m depth restriction (David 2012). Pet-Soede et al. (2001) found that fishers caught more fish at less intense fishing areas and the mean length at capture of the fish decreases with an increase in fishing intensity. However, the decrease in mean catch at length might have also been due to high SST. Similarly, a study on the Senegalese sardine also found that temperature played a factor in their growth variability and that their mean length peaked at low temperatures (Sabaly et al. 2019).

Monkfish was an important bycatch of the hake fishery before it became a targeted fishery in 2001. There was an excessive peak of approximately 14 000 t then declining to about 6 000 t in 1989 in the catch of monkfish as bycatch in Namibia (Maartens and Booth 2001). The high catch rates observed in the early 1980s may have contributed to the decrease in mean length of the catch for monkfish in Namibia between 1978 and 1987. Recruitment overfishing occurred when smaller fish were caught along with the larger older fish according to Maartens and Booth (2001) analysis of monkfish size category data.

Jacopever are demersal species and are also caught as bycatch in the Namibian hake fishery (Kainge et al. 2015). The decrease in mean length of the catch of jacopever may have also been caused by an increase in bycatch rates due to high hake catches in the 1980s. Most of the larger adult fish might have been caught as bycatch. Hence, leaving behind an abundance of smaller fish and causing a decrease in mean catch at length of jacopever in Namibia.

There was a significant increase in mean length of the catch for the South African monkfish from 1980 to 1987 (see Figure 38). Monkfish are long-lived fish that can live approximately up to 17 years and is a bycatch of the hake fishery (DEFF 2020). Before an increase in annual catches of monkfish in the hake fishery of over 10 000 t in 2001, it varied around 4 700 t between 1974 and 1994 (DEFF 2020). This means that the stock was still underexploited before 1994, despite the hake stock being depleted by 1990. The under exploitation of this stock allowed it to increase in mean length of the catch from 1980 to 1987. The reason for this is that they were able to grow to a larger size before they were caught. Since monkfish live up to at least 10 years, a time series longer than 10 years would be ideal to determine more informative trends and obtain more meaningful results (Maartens and Booth 2001).

There was a significant increase in mean length of the catch for the Namibian West coast rock lobster from 1977 to 1982 (see Figure 40). The stock had consistently remained heavily exploited between 1977 and 1982 and subsequently collapsed in 1996 t (David 2012). This led to the management measures that included minimum legal size limits of 65 mm and prevention of landing of egg bearing females (Kirchner 2011). West coast rock lobster is sensitive to environmental variability. Therefore, changes in lobster productivity in Namibia was due to oxygen fluctuations in bottom waters, intensified by overfishing (Kirchner 2011). There is little longshore migration of rock lobster in Namibia and fishing might have impacted all areas simultaneously (Kirchner 2011). Since rock lobsters migrate to new areas to avoid oxygen depleted water, it leads to overcrowding in the newly occupied areas and the feeding of juveniles declines, thus, leading to a decrease in their growth rate (Pollock and Shannon 1987). The increase in mean length of the catch observed for West coast rock lobster between 1977 and 1982 may have been due to favourable oxygen fluctuation. Rock lobsters rely on the uptake of oxygen from water to drive their metabolic processes that lead to growth (Crear and Forteath 2000). It is important to continue the time series from 1982 to after 1996 when the new Namibian fisheries management measures became effective.

4.3. Fish condition and correlations of mean length with temperature

Fish condition is an important indicator of environmental conditions of fish, as fat fish represent favourable environmental conditions, whereas, thin fish represent unfavourable environmental conditions (Blackwell et al. 2000). Mean fish conditions did not change significantly from 1975 to 2020 for Namibian shallow-water Cape hake, deep-water Cape hake or horse mackerel. Fish condition indicates whether there is a balance between prey and predators (Ramses et al. 2019). Hence, the third objective of this study was to determine the fish condition of Namibia and South Africa commercially exploited resources, targeted and bycatch. The overall results of this study found that there were significant differences in fish condition between years.

This study demonstrated that there were annual and monthly fluctuations in the fish condition of Namibian shallow-water Cape hake from 1975 to 2020 (see Figure 42). Fish with the best condition were found in 1987 and fish with the worst condition were found in 1983. The fish condition was calculated for the summer months (January and February) because fish condition changes with season (Efitre & Chapman 2009, Wilhelm et al. 2020). Blackwell et al. (2000) found that female spring spawners generally have a higher condition in spring before spawning and then it reduces after spawning, before increasing again in summer and winter. Shallow-water Cape hake spawns from July to November and the study focused on the fish condition for January and February, which implied that the fish condition reduced after spawning and increased again in the summer months (January and February).

Mean length of shallow-water Cape hake and SST in summer (January) were negatively correlated (see Figure 47). Shallow-water Cape hake growth rate increased in the cooler summer temperatures and decreased in the warmer summer temperatures. The warmest spring and summer SSTs could be seen in 1990, 1994 and 2001 (see Figures 46 and 47). Upwelling intensity decreases with higher temperatures and leads to low phytoplankton biomass in summer (Shelton et al. 1985; Demarcq et al. 2007). Primary productivity supports the prey species that are targeted by shallow-water Cape hake. Therefore, less food was probably available due to less upwelling coinciding with higher temperatures in 1994 and 2001 which could have been the reason for these relatively poor summer conditions of shallow-water Cape hake (see Figure 47) as well as small mean lengths at age 3. In another instance, there was a variation in condition of plaice in the Kattegat and this may have been due to the variation in prey availability and this shows that condition of predator fish is affected by prey availability (Hiddink et al. 2016).

In Namibia, deep-water Cape hake best condition were found in 1976, 1978 and 1979 and deep-water Cape hake worst condition were found in 1982, 1986 and 1998 (see Figure 43). The latter did not correspond with warm summer conditions in southern Namibia (see Figure 47), but corresponds with warm summer SSTs in the northern part of South Africa (data not shown). Since young deep-water Cape hake are likely to be found in the southern part of Division 1.5, their prey and therefore growth and condition is therefore likely to be driven by upwelling in this area. This was confirmed by Wilhelm et al (2020).

Horse mackerel showed a relatively even conditions from 1976 to 1986 (see Figure 44). Horse mackerel in Namibia spawn all year, but there is a spawning peak between December and March (Ndjaula et al. 2013b). Since the fish condition was analysed for the summer months (January to March), the stock invested more into gonad development rather than feeding, hence, the worst conditions observed in in summer months.

Fish condition knowledge helps in understanding the spacio-temporal population dynamics of the species in order to identify absent or present stocks for fisheries management (Ndjaula et al. 2013a). For example, there was a study done on the fish condition of *L. niloticus* in Epe lagoon and the results emphasised the need to conserve in the Epe lagoon (Olopade et al. 2015). Such information is helpful in the management of fisheries, as it will give an insight on the stocks are in favourable or unfavourable conditions. It will determine whether the exploitation of stocks will increase or decrease fish condition (Hindink et al. 2016).

4.4. Correlation between SST and mean length at age

The fourth objective of this study was to determine whether the annual growth rates of three species was related to environmental changes (SST). The results of this study showed that mean length-at-age of shallow-water Cape hake does correlate negatively to spring and summer SST (see figure 45, 46 and 47).

This means that shallow-water Cape hake growth rate responded positively to cold summers. Similarly, Wilhelm et al. (2020) found that the annual growth of *M. paradoxus* off Namibia correlated positively with the SST in the colder springs (October). Environmental impacts are also noticeable in cephalopods populations found in areas with seasonal differences between summer and winter. The positive results of cephalopods in cooler temperatures confirmed (Villanueva 1992) findings that *T. angolensis* (oceanic squid) responded positively to cooler conditions in the Benguela system.

With cessation of upwelling in the years when spring and summer temperatures were high (1984) (see figure 47) or during a Benguela Nino event in 1984. Shallow-water Cape hake would have had lack in food and relatively slow growth rates. For example, in the North Sea, three different species namely; *Melanogrammus aeglefinus* (haddock), *Clupea harengus* (herring), and *Pleuronectes platessa* (plaice) decreased in body sizes along with an increase in water temperatures (Baudron et al. 2014). Conner and Booth (2021) found that increased water temperatures had a negative impact on the growth rate of *Acanthaluteres spilomelanurus*. However, because the negative impact on the fish growth rate could be because *A. spilomelanurus* resides in cooler temperate regions and was caught in a region with higher temperatures (Conner and Booth 2021).

This is also similar to a study on horse mackerel where they found a positive relationship between SST and length of horse mackerel in all age groups and higher temperatures in summer and spring lead to an increase in growth of horse mackerel (Tanner et al. 2019). Results in the study by (Vieira et al. 2020), showed that the fish growth rate of the European hake species responded to variations in winter and spring temperatures. In higher SST in winter and spring, there was decrease in growth in the younger fish (age 2 to 5) and a decrease in the growth of the older fish (age 6 to 10) (Vieira et al. 2020).

Extensive occurrence of warm conditions in the main spring upwelling period could then severely limit plankton production and concentrate fish in a restricted environment where density-dependent population responses may be intensified (Shelton et al. 1985). The decrease in the growth rates of shallow-water Cape hake in the warmer temperatures in summer may have been due to the increase in energy supply caused by warmer temperatures not being compensated by an increase in food supplies (van der Sleen et al. 2018).

In winter, growth rate of shallow-water Cape hake decreased in the warmer winter temperatures and an increased in cooler water temperatures (see Figure 45). SST in winter is moderately isothermal and chlorophyll concentrations are low Shelton et al. (1985), because wind mixing is weakest during winter throughout the Benguela (Shannon and O'Toole 1999). Chlorophyll concentration contribute to the plankton production in the surface waters and affects the abundance and biomass of prey species. The highest value of Chlorophyll index was observed in winter (June to August) in the northern part of northern Benguela and this corresponded with the winter cooling SST (Demarcq et al. 2007). The high chlorophyll index might have contributed to the increase in mean lengths of shallow-water Cape hake observed in the cooler winter.

Despite upwelling contributing to a high abundance of food, it sometimes leads to the dispersal of food resources. These summer and winter patterns in the Benguela have contributed to the favourable and unfavourable environment for the fish growth rate of shallow-water Cape hake in summer and winter. Plankton is consumed by primary consumers such as crustaceans, zooplankton and small fish such as sardine and anchovy. High abundance of plankton promotes increased abundance of primary consumers. Younger shallow-water Cape hake feed on zooplankton such as euphausiids and anchovy, when they become older they prefer horse mackerel and hake (Pillar and Wilkinson 1995). Increased abundance of prey species may lead to an increase in fish growth rate of shallow-water Cape hake as seen in cooler winter and a decrease may negatively affect fish growth rate as seen in warmer summer.

The results of this study also showed that horse mackerel mean length at age 3 and SST had no significant correlation between 1983 and 2017 perhaps implying that the growth response of this species (significant increase in mean length at age 6) may not be as a result of environmental variability but rather fishery-induced evolution (as discussed above). Alternatively, their growth responses to environmental conditions are not detectable at the scale investigated here.

4.5. Limitations and recommendations

This study has noted how important it is to obtain age and growth information. However, obtaining age and growth information is quite expensive and data collection mainly focuses on fish stocks that are more economically important (Kathena et al. 2018). Furthermore, to obtain samples needed to estimate fish growth rate has proven to be difficult because some sampling methods are size selective which may cause bias. Whereas, scientific surveys are less selective and more consistent (Enberg et al. 2012). Finally, in this study there were difficulties in determining the results for stocks with fewer data sets. However, stocks that were analysed showed very informative trends over the years, such as regime shifts, increases and decreases in mean lengths at age, and correlations between weight and mean length and sea surface temperature.

The mechanisms driving the changes is attributed to fishery-induced evolution. Since data for some species was outdated, it is recommended to update biological variables and assessment for future work. Other impacts on fish growth rate might have also included density-dependence and environmental (SST) variability. Although this study did not include the impact of density-dependence, the results demonstrate the need to determine the impacts associated with density on fish growth rates. This study analysed the historic mean catch at length and it is recommended that future studies determine the current mean catch at length to be able to ascertain an improvement or a decline in mean catch at length of the stocks.

According to (Ndjaula et al. 2013a) length-weight data are mostly available for commercial species. However, for this study we were unable to obtain length-weight data for all Namibian and South African commercial species. It is recommended that future studies should determine the fish condition of all exploited commercial species and catch of the recent years. Since this study found that there was a correlation between SST and fish growth rate, it is recommended that future studies should determine the effects of other environmental factors such as chlorophyll concentrations, upwelling intensity and bottom temperatures.

5. Conclusion

Determination of age and growth of fish populations are important for the management of fisheries because they impact stock productivity. In this study fishery-induced evolution was the main factor that led to a decrease in fish growth rate in shallow-water Cape hake. Fishery-induced evolution was caused by the overexploitation and overfishing of the stock. Hence, greater emphasis should be placed on the importance of reducing fishing pressure on overfished stocks. Fishery-induced evolution could potentially have some irreversible consequences, hence, more effort should be put into analysing existing data in order to attract more attention on the issue (Heino et al. 2002).

In this study, overfishing and unlimited access to exploited stocks demonstrated the impacted trends in mean catch at length of stocks. Knowledge of the long-term trends of mean catch at length of exploited resources is needed for the sustainable management of these fisheries. Sustainable management aims at having resources that have a biomass and fishing mortalities at optimal levels, which can be achieved by reducing fishing pressure on exploited resources (DEFF 2020). Mean catch at length can be used as an indicator of growth of the stocks on all monthly basis.

Fish condition has been largely overlooked in the monitoring and management of fishing on marine resources (Ndjaula et al. 2013a). Changes in energy reserves affects population dynamics and the productivity of the system (Ndjaula et al. 2013a). This study analysed the years in which stocks underwent good or poor condition and postulated food availability may have been a contributing factor to fish condition. It is also important to model small changes in fish condition in order to inform management of diseases, or other physiological stresses before high levels of mortality strike (Jones et al. 1999).

In order to accurately predict how fish respond to climate change, it is important to understand how fish growth responds to environmental changes (Huang et al. 2021). However, such research has not received adequate attention and has only been done on a limited number of species (Pankhurst et al. 2011; Huang et al. 2021). This study demonstrated that some stocks were correlated to SST, such as for shallow-water Cape hake with a negative correlation in summer, spring and winter and this may have been related to upwelling and plankton production. There are other environmental stressors such as biological invasions, pollution and flow alterations that may contribute to alterations in fish growth rate. Hence, it is important to understand the impacts of climate change on fish growth rate and other stressors in order to reliably predict how fish respond to climate change (Huang et al. 2021).

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7. Appendices

Table A1: Age-length data available from the ICSEAF sampling bulletins from 1968 to 1987 for Namibia, Divisions (Div) 1.3, 1.4 and 1.5 (see Fig 1), sometimes combined, sometimes separate. The reporting countries were: Bulgaria (BGR), the Soviet Union (SUN), Spain (ESP), Poland (POL), Portugal (PRT), Romania (ROM), South Africa (ZAF), German Democratic Republic (DDR), Cuba (CUB), Japan (JPN), Angola (ANG) and Union of Soviet Socialist Republics (USSR).

Stock		Months												Country
Years	Div	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Merluccius capensis (shallow-water Cape hake)														
1968	1.3-1.4										1			USSR
	1.5	1												USSR
1969	1.3-1.4						1							USSR
1970	1.3-1.4	1												USSR
	1.5	1												USSR
1971	1.3-1.4	1												USSR
1972	1.3-1.4	1												USSR
	1.5	1												USSR
	1.3		1									1		POL
	1.4		2	1								1		POL
	1.5			1	1						1			POL
1973	1.3			1	1		1							USSR
	1.4			1	1									USSR
	1.5	1												POL
	1.5								1					USSR

1974	1.3			1										USSR
	1.4				1									ESP
	1.4		1			1								POL
	1.4	1	1		1									USSR
	1.4			1										ESP
	1.5		2											POL
1975	1.3		1											CUBA
	1.3										1			DDR
	1.3	1												SUN
	1.4		1											SUN
	1.5			1										POL
	1.5			1										SUN
1976	1.3	1												SUN
	1.4	1												SUN
	1.5		2											POL
	1.5								1					ZAF
1977	1.3											1	1	ESP
	1.3		1								1			SUN
	1.4												1	DDR
	1.4										1			JPN
	1.4											1		POL
	1.4							1	1	1		1	2	ESP
	1.5				1									DEU
	1.5						1							ZAF
1978	1.3			1										DDR
	1.3			2	2									ROM
	1.3	1												ESP
	1.3	1												SUN
	1.4												1	DDR
	1.5						1							DEU

	1.5		1	1		1					1			ESP
1979	1.3							1						ROM
	1.3	1												SUN
	1.4											1		ESP
	1.4	1												SUN
	1.5		1		1	1	1							ESP
1980	1.3				1	1	1	1	1		1	1		ROM
	1.3												1	POL
	1.3			1								1		SUN
	1.4							1	1					ROM
	1.4				1								1	SUN
	1.5			1	1	1	1					1		ESP
1981	1.3		1		1									POL
	1.3				2	2				1	1	1		ROM
	1.3					1		1						SUN
	1.4								1					ESP
	1.4						1							SUN
	1.5				1	1				1				ESP
1982	1.3			1	1									POL
	1.3		1			1			1					ROM
	1.3										1	1		ESP
	1.3	1					1					1		SUN
	1.4									1				ESP
	1.4		1			1			1			1		SUN
	1.5		1		1									PRT
	1.5			1				1	1					ESP
1983	1.3					1						1		BGR
	1.3		1		1							1		POL
	1.3		1			2	1		2			2		ROM
	1.3								1					ESP

	1.3									1				ESP
	1.3										1			ESP
	1.3		1			1		1				1		SUN
	1.4	1	1											BGR
	1.4	1			1								1	POL
	1.4						1	2						ESP
	1.4		1				1		1			1		SUN
	1.5		1		1									PRT
	1.5						1	3						ESP
1984	1.3		1											BGR
	1.3			1							1			DDR
	1.3		1											POL
	1.3					1		1				1		ROM
	1.3		1		1					1	1			SUN
	1.4			1										BGR
	1.4									1				DDR
	1.4												1	POL
	1.4		1		1								1	ROM
	1.4						1					1		ESP
	1.4		1						1				2	SUN
	1.4	1												BGR
	1.5				1	1	1							PRT
	1.5	1												ZAF
	1.5					1	1	1	1		1		1	ESP
1985	1.3						1							BGR
	1.3										1			DDR
	1.3		1		1									POL
	1.3		1			1		1				1		ROM
	1.3			1		1			1			1		SUN
	1.4					1								DDR

	1.4	1			1									POL
	1.4	1						1				1		ROM
	1.4							1				1		ESP
	1.4		1			1			1			1		SUN
	1.5			1		1							1	POL
	1.5											1		PRT
	1.5			1	1	2		1			1	1	1	ESP
	1.5												1	SUN
1986	1.3		1		1							1		ROM
	1.3					1						1		ESP
	1.3		1			1			1		1			SUN
	1.4		2						1					ROM
	1.4					2			1			1		ESP
	1.4		1		1				1				1	SUN
	1.5	1												POL
	1.5		1											ROM
	1.5	1												ZAF
	1.5	1				1			1		1			ESP
	1.5	1							1			1		SUN
1987	1.3		1		1								1	ROM
	1.3		1											ESP
	1.3				1					1	1			SUN
	1.4		1			1			1			1		ESP
	1.4		1			1		1				1		SUN
	1.5									1		1		PRT
	1.5	1						1						ZAF
	1.5		1			1			1			1		ESP
	1.5			1		1			1			1		SUN
Trachurus capensis (Cape horse mackerel)														
1972	1.3			1										POL

	1.4		1											POL
1973	1.3-1.4										1			CUBA
	1.4	1												POL
	1.4			1		1								USSR
1974	1.4		1											POL
1975	1.3								1	1				POL
	1.3	1												SUN
	1.4									1	1			POL
	1.4			1										SUN
1976	1.3									1	1			DDR
1977	1.3											1		POL
	1.3		1					1				1		SUN
	1.4												1	DDR
	1.4											1		POL
1978	1.3			1										DDR
	1.3	1												POL
	1.3			2	2									ROM
	1.3	1												SUN
	1.4											1		DDR
	1.4	1												SUN
1979	1.3						1		1		1			ROM
	1.3	1				1			1			1		SUN
	1.3		1				2	1		1		2		DDR
	1.4											1		ESP
	1.4						1		1					ROM
	1.4	1			1									SUN
	1.4						1					1		DDR
1980	1.3				1	1		1						DDR
	1.3				1	1	1	1	1	1	1	1	1	ROM

	1.3		1						1			1		SUN
	1.4					1	1	1	1	1		1		ROM
	1.4				1								1	SUN
1981	1.3		1											POL
	1.3		1	1	1	1	1	1	1	1	1	1		ROM
	1.3					1	2	1					1	SUN
	1.4				1									POL
	1.4								1					ROM
	1.4			1										SUN
	1.5			1										ESP
1982	1.3	1			1					1	1			BGR
	1.3			1							1			DDR
	1.3			1	1									POL
	1.3		1			1		1			1			ROM
	1.3	1				1		1				1		SUN
	1.4			1		1						1		SUN
	1.5								1					ESP
1983	1.3		1			1			1		1			BGR
	1.3					1					1			DDR
	1.3		1		1							1		POL
	1.3		1			1			1			1		ROM
	1.3		1			1		1				1		SUN
	1.4				1								1	POL
	1.4		1				1					1		SUN
	1.4		1	1										ZAF
1984	1.3-1.4		1				1							BGR
	1.3					1			1			1		BGR
	1.3			1							1			DDR
	1.3	1				1		1				1		ROM

	1.3		1		1					1		1		SUN
	1.4										1			DDR
	1.4												1	POL
	1.4		1			1			1					ROM
	1.4	1			1				1		1			SUN
1985	1.3		1			1			1			1		BGR
	1.3					1					1			DDR
	1.3					1								POL
	1.3		1			1			1			1		ROM
	1.3			1	1				1			1		ZAF
	1.3		1	1		1		1						SUN
	1.4						1							BGR
	1.4					1						1		DDR
	1.4	1			1									POL
	1.4	1						1				1		ROM
	1.4				1	1	1	1	1	1				ZAF
	1.4					1		1						SUN
1986	1.3		1			1			1			1		BGR
	1.3				1						1			DDR
	1.3		1			1		1				1		ROM
	1.3		1		1				1		1			SUN
	1.4					1						1		DDR
	1.4								1			1		ROM
	1.4		1		1				1			1		SUN
	1.4		1											POL
1987	1.3		1			1			1			1		BGR
	1.3				1	1				1	1			DDR
	1.3								1		1			POL
	1.3		1			1			1			1		ROM
	1.3		1			1			1			1		SUN

	1.4				1	1								DDR
	1.4	1									1			ROM
	1.4		2			1			1					SUN
Sardinops sagax (sardine)														
1974	1.4-1.5					1								ZAF
1975	1.4								1					POL
1976	1.4								1					POL
1978	1.3-1.5		1			1		1						ZAF
	1.3					1				1				ROM
	1.4						1		1					ROM
1980	1.3-1.5					1								ZAF
1981	1.3					1								ROM
1982	1.3						1		1				1	ROM
	1.3-1.5					1								ZAF
1983	1.3											1		POL
	1.3							1						ROM
	1.3-1.4						1							ZAF
1984	1.3					1								ROM
	1.4												1	POL
	1.3-1.4						1							ZAF
1985	1.4	1												POL
	1.3-1.5						1							ZAF

1986	1.3-1.5				1									ZAF
1987	1.3-1.5					1								ZAF
Engraulis encrasicolus (anchovy)														
1979	1.3					1								ZAF
1981	1.3										1			ROM
	1.3-1.5						1							ZAF
1982	1.3-1.5					1								ZAF
1983	1.3						1							ROM
	1.3				1									ZAF
	1.4						1							ZAF
	1.3-1.4						1							ZAF
1984	1.3-1.4					1								ZAF
1985	1.3-1.5						1							ZAF
1986	1.3-1.5				1									ZAF
1987	1.3-1.5					1								ZAF
Etrumeus whiteheadi (round herring)														
1981	1.3										1			ROM
1983	1.3						1							ROM
Scomber japonicus (chub mackerel)														
1981	1.3						1							ROM
1983	1.3		1	1	1		1					1		POL

1985	1.3			1										POL
	1.4	1												POL
	1.5					1								POL
1986	1.3	1												ROM
1987	1.3		1											ROM
Genypterus capensis (kingklip)														
1976	1.5								1					ZAF
1978	1.5		1	1										ESP
1979	1.4											1		ESP
1980	1.5			1	1	1						1		ESP
1982	1.5						1							ESP
1985	1.5				1								1	POL
Helicolenus dactylopterus (jacopever)														
1978	1.5		1			1	1				1			ESP
1979	1.4											1		ESP
	1.5		1			1								ESP
1980	1.4								1					ESP
	1.5			1	1									ESP
1982	1.5								1					ESP
Chelidonichthys capensis (Cape gurnard)														
1981	1.3											1		ROM
1983	1.3						2							ROM
Dentex macrophthalmus (large-eye dentex)														
1976	1.3										1			DDR
1980	1.4								1					ESP
1981	1.3				1	1	1	1	1	1	1			ROM
1982	1.3						1		1			1		ROM
	1.3												1	SUN
1983	1.3					1			1			1		ROM
	1.3		1			1			1			1		SUN

1984	1.3					1		1						ROM
	1.4				1									ROM
1986	1.3		1		1							1		ROM
1987	1.3			1	1				1			1		ROM
Lophius vomerinus (monkfish)														
1979	1.4											1		ESP

Data available from ICSEAF (1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987).

Table A2: Age-length data available from the ICSEAF sampling bulletins from 1968 to 1987 for South Africa, Division 1.6 (see Fig 1), sometimes combined, sometimes separate. The reporting countries were: Poland (POL), South Africa (ZAF) and Union of Soviet Socialist Republics (USSR).

	Months												Country
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Merluccius capensis (shallow-water Cape hake)													
1968												1	USSR
1970					1								USSR
1972		2	1									1	POL
1975			1		1								POL
1976		1							1				ZAF
1977				1		1				1			ZAF
1978					1	1		1					ZAF
1979										1			ZAF
1980			1				1		1			1	ZAF
1981		1		1	1			1		1		1	ZAF
1982	1				1				1		1		ZAF
1983	2		1		1				1				ZAF
1984	1	1		1			1	1			1		ZAF
1985	2			1			1	1			1		ZAF

1986	1	1			1		1				1		ZAF
1987	1	1		1			2				1		ZAF
M. paradoxus (deep-water hake)													
1976			1						1				ZAF
1977				1		1			1	2			ZAF
1978					1	1		1	1	1			ZAF
1980			1				1		1			1	ZAF
1981		1		1	1			1		1		1	ZAF
1982	1				1				1		1		ZAF
1983					1		2		1				ZAF
1984	1	1			1		1	1			1		ZAF
1985	1		1	1			1	1		1			ZAF
1986	2	1			1		1				1		ZAF
1987	1	1			1		1	1			1		ZAF
Trachurus capensis (Cape horse mackerel)													
1972			1										ZAF
1975			1										ZAF
1979						1							ZAF
1981			1										ZAF
1984						1							ZAF
1985					1								ZAF
1986		1											ZAF
Sardinops sagax (sardine)													
1976				1									ZAF
1978						1							ZAF
1979						1							ZAF
1980	1												ZAF
1986					1								ZAF
Engraulis encrasicolus (anchovy)													
1974		1											ZAF

1980	1												ZAF
1981	1												ZAF
1983											1		ZAF
1984						1							ZAF
1985					1								ZAF
1986					1								ZAF
1987					1								ZAF
Etrumeus whiteheadi (round herring)													
1978						1							ZAF
1979						1							ZAF
1980	1												ZAF
1981	1												ZAF
1982			1										ZAF
1983											1		ZAF
1984						1							ZAF
1985					1								ZAF
1987					1								ZAF
Scomber japonicus (chub mackerel)													
1978						1							ZAF
1980	1												ZAF
1981			1										ZAF
1982				1									ZAF
1983			1								1		ZAF
1984						1							ZAF
1985					1								ZAF
1987					1								ZAF
Lampanyctodes hectoris (lanternfish)													
1978						1							ZAF
1979						1							ZAF
1981			1										ZAF

1983			1							1		ZAF
1984						1						ZAF
1985					1							ZAF

Data available from ICSEAF (1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987).

Table A3: Length frequency distribution of commercial catch data available from the ICSEAF sampling bulletins from 1968 to 1987 for Namibia, Divisions 1.3, 1.4 and 1.5. (see Fig 1), sometimes combined data, sometimes seperate. The reporting countries were: Bulgaria (BGR), the Soviet Union (SUN), Spain (ESP), Poland (POL), Portugal (PRT), Romania (ROM), South Africa (ZAF), German Democratic Republic (DDR), Cuba (CUB), Japan (JPN), Angola (ANG), Italy (ITA), Germany (DEU) and Union of Soviet Socialist Republics (USSR).

		Months												Country
Years	Div	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Merluccius capensis (shallow-water Cape hake)														
1968	1.3-1.4									1	1	1	1	USSR
	1.5										1	1		USSR
1969	1.3-1.4	1	1	1		1	1	1				1	1	USSR
	1.5		1			1							1	USSR
1970	1.3-1.4	1	1	1	1	1			1	1	1	1	1	USSR
	1.5				1					1				USSR
1971	1.3-1.4	1	1	1										USSR
	1.3				1	1					1	1	1	CUBA
	1.4	1										1		CUBA
1972	1.3		2	1								1		POL
	1.4		3	1								3		POL
	1.4							1	1	1	1	1		CUBA

	1.3- 1.4	1	1	1	1	1	1			1	1	1	1	USSR
	1.5	1		2							1	2	2	POL
	1.5		1	1										USSR
1973	1.3	1	1	1	1	1	1	1	1	1	2			CUBA
	1.3		1	1	1	1	1	1	1	1	1			USSR
	1.4	1	1											POL
	1.4			1	1	1	1	1	1	1	1			USSR
	1.5								1	1	1			USSR
1974	1.3									1	1			DDR
	1.3	1	1	2	2					1	1	1	1	USSR
	1.4	1	1		1	1								POL
	1.4			1	1	1								ESP
	1.4	1	2	1	2	1				2	1	1	1	USSR
	1.5		1	1	1	1								POL
	1.5							1						ESP
	1.5		1										1	USSR
1975	1.3	1	1	1	1	1	1	1	1	1	1	1	1	SUN
	1.4		1	1										ESP
	1.4			1								1	1	POL
	1.4		1	1	1		1	1	1					SUN
	1.5	1	1	1										ESP
	1.5								1	1	1			USSR
	1.5	1	1	1								1	1	POL
1976	1.3	1	1								1		1	SUN
	1.4	1	1	1	1	1					1		1	SUN
	1.4	1	1	1	1	1								BGR
1977	1.3					2		1						ITA
	1.3											1	1	ESP
	1.3		1	1				1	1	1				SUN

	1.4	1	1	1	1						1	1	1	BGR
	1.4										1	1	1	POL
	1.4	1	1											DDR
	1.4						1		1		1			JPN
	1.4										1		1	POL
	1.4							1	1	1		1	1	ESP
	1.5	1	1											DDR
	1.5			1	1									DEU
	1.5					1	1		1		1	1		JPN
	1.5						1							ZAF
	1.5											1	1	ESP
1978	1.3			1								1		DDR
	1.3	1	1	1										JPN
	1.3			1	1	1								ROM
	1.3	1												ESP
	1.3	1	1	1	1	1	1	1	1	1				SUN
	1.4	1	1	1	1	1	1							BGR
	1.4	1	1	1			1	1						JPN
	1.4					1								ESP
	1.4	1	1	1	1			1		1				SUN
	1.5						1							DEU
	1.5	1		1						1				JPN
	1.5	1	1			1	1							ESP
1980	1.3	2	3	2	2	2		1	2	1		2		JPN
	1.3												1	POL
	1.3				1	1	1	1	1		1	1		ROM
	1.3							2	2	1				ESP
	1.3		1									1	1	SUN
	1.4	2			1	2	1		1	1		2		JPN
	1.4							1	1					ROM

	1.4								2	2				ESP
	1.4					1							1	SUN
	1.5	1			1	2	1		2	1		1		JPN
	1.5			1	1	1	1							ESP
1981	1.3	1		1										JPN
	1.3	1	1	1	1	1								POL
	1.3				1	1	1	1						ROM
	1.3			1	1									ESP
	1.3	1				1	1	1					1	SUN
	1.3									1	1	1		ROM
	1.4	1	1											JPN
	1.4			1	1				1		1			ESP
	1.4				1	1	1			1				SUN
	1.5			1	1				1	1	1			ESP
1982	1.3												1	JPN
	1.3			1	1									POL
	1.3		1	1	1		1	1	1	1		1	1	ROM
	1.3			1							1	1		ESP
	1.3	1		1		1	1	1		1	1	1	1	SUN
	1.4												1	JPN
	1.4			1		1	1						1	ESP
	1.4	1		1		1	1	1	1	1	1	1	1	SUN
	1.5												1	JPN
	1.5			1	1			1		1				ESP
1983	1.3					1				1				BGR
	1.3	1	1	1	1							1	1	POL
	1.3	1	1	1	1	1	1	1		1	1	1	1	ROM
	1.3								1	1	1			ESP
	1.3	1	1	1	1	1	1	1	1		1	1	1	SUN
	1.4	1	1											BGR

	1.4	1			1									POL
	1.4				1				1			1		ESP
	1.4	1	1	1		1	1	1	1	1		1	1	SUN
	1.5	1	1	1	1	1								PRT
	1.5		1	1	1	1		1	1			1	1	ESP
1984	1.3	1	1	1	1									BGR
	1.3			1							1			DDR
	1.3		1											POL
	1.3	1	1	1	1	1				1	1	1		SUN
	1.3				1	1	1	1				1	1	ROM
	1.4	1	1											BGR
	1.4										1			DDR
	1.4												1	POL
	1.4	1	1	1	1	1							1	ROM
	1.4	1					1	1				1		ESP
	1.4	1	1		1	1	1	1	1	1	1	1	1	SUN
	1.5				1	1	1							PRT
	1.5		1			1	1		1		1	1	1	ESP
	1.5							1	1					SUN
1985	1.3	1					1							BGR
	1.3										1			DDR
	1.3		1		1									POL
	1.3		1	1	1	1	1	1			1	1	1	ROM
	1.3			1	1	1	1	1	1	1	1	1	1	SUN
	1.4						1							CUBA
	1.4					1								DDR
	1.4	1			1									POL
	1.4	1						1			1	1		ROM
	1.4							1						ESP
	1.4		1	1	1	1	1	1	1		1	1	1	SUN

	1.5			1	1	1	1						1	POL
	1.5										3	2		PRT
	1.5			1	1	1		1		1	1	1	1	ESP
	1.5					1	1				1	1	1	SUN
1986	1.3	1	1	1	1							1	1	ROM
	1.3												1	EPS
	1.3	2	2	1	1	2			1	1	1	1	1	SUN
	1.4								1					CUBA
	1.4		1							1	1	1	1	ROM
	1.4		1			1			1		1	1	1	ESP
	1.4	3	3	1	1				1	1	1		1	SUN
	1.5				1									CUBA
	1.5	1	1											POL
	1.5		1											ROM
	1.5	1	1			1	1	1	1		1	1	1	ESP
	1.5	2	2						2					SUN
1987	1.3	1		1	1								1	ROM
	1.3	1		1										ESP
	1.3			1	1					1	1	2		SUN
	1.4					1								JPN
	1.4	2		1		2	2	1	1	1	2			ESP
	1.4				1						1		1	SUN
	1.4									1	1	1	1	PRT
	1.5	1		1	1	1		1		1		1	1	ESP
	1.5			1	1	1	1	1	1			1	1	SUN
M. paradoxus (deep-water hake)														
1969	1.5				1								1	USSR
1970	1.5				1					1	1			USSR
1971	1.5			1										POL
	1.5				1	1	1							USSR

1972	1.4		1									1		POL
	1.5			1							2	2	3	POL
	1.5											1		USSR
1973	1.3	1												POL
1974	1.4		1	1	1									POL
	1.5		2									1		ESP
1975	1.5	2	1	1				1				1	1	POL
1977	1.4					1	2		2			1		JPN
	1.5			1			1							DEU
	1.5						1							ZAF
1978	1.3			1	1	1								ROM
	1.5					1								DEU
	1.5	1	1		1				1					JPN
1979	1.5		1											DEU
1980	1.3	1			1	2	1	1	1	2		1		JPN
	1.3				1	1	1	1	1		1	1		ROM
	1.4							1	1					ROM
	1.4								1	1				ESP
	1.5	1	1	1	1	2	1		1	1		1		JPN
1981	1.3			1										JPN
	1.3				1	1	1	1		1	1	1		ROM
	1.4	1												JPN
	1.3				1				1					ESP
	1.5	1	1											JPN
	1.5								1	1	1	1	1	PRT
	1.5			1	1	1			1	1	1			ESP
1982	1.3				1				1					JPN
	1.3		1	1	1			1	1	1		1	1	ROM
	1.3											1		ESP
	1.4								1					JPN

	1.5			1	1	1		1	1	1			1	JPN
	1.5			1	1	1		1	1	1				ESP
1983	1.3	1					1	1		1	1	1	1	ROM
	1.3					1								ESP
	1.4				1									ESP
	1.5		1	1	1				1					ESP
1984	1.3				1	1	1	1				1	1	ROM
	1.4	1	1	1	1	1							1	ROM
	1.5				1	1	1							PRT
	1.5	1				1	1		1		1	1	1	ESP
1985	1.3		1	1	1	1	1	1			1	1	1	ROM
	1.4	1						1			1	1		ROM
	1.4							1						ESP
	1.5									1	1	1	1	PRT
	1.5			1	1	1		1		1	1	1	1	ESP
1986	1.3	1	1	1	1							1		ROM
	1.4		1						1	1	1	1		ROM
	1.5													ESP
	1.5							1	1	1	1			PRT
	1.5		1											ROM
	1.5	1	1		1	1	1	1	1		1	1	1	ESP
	1.5			1								1		ZAF
1987	1.3			1	1									ROM
	1.3						1	1		1				ESP
	1.4							1					1	SUN
	1.4					1								JPN
	1.5	1			1	1	1	1	1	1		1	1	ESP
	1.5					1		1			1		1	SUN
Trachurus capensis (Cape horse mackerel)														
1972	1.3		1									1		POL

	1.4		1	1										POL
	1.5											1		POL
1973	1.3									1	1	1		CUBA
	1.3										1			POL
	1.3		1	1	1	1	1	1	1	1	1			USSR
	1.4	1												POL
	1.4	1		1										BGR
	1.4									1			1	CUBA
	1.4		1				1	1	1	1				POL
	1.4			1	1	1	1	1	1	1	1			USSR
	1.4-1.5				1	1	1	1	1					ZAF
1974	1.3						1	1	1	1	1	1		ANG
	1.3									1	1			DDR
	1.3	1	1	1	1					1	1		1	USSR
	1.4										1			DDR
	1.4		1	1	1	1				1	1			USSR
1975	1.3	1	1	1										CUBA
	1.3								1	1				POL
	1.3	1	1	1	1	1	1	1	1			1		SUN
	1.4								1					ZAF
	1.4									1	1			POL
	1.4		1	1	1	1	1	1	1		1		1	SUN
1976	1.3							1	1	1				POL
	1.3	1		1						1	1		1	SUN
	1.3										1			DDR
	1.4							1	1	1	1			POL
1977	1.4		1										1	DDR
1978	1.3		1	1	1	1	1	1	1	1	1	1	1	BGR
	1.3	1	1	1	1	1	1	1	1	1	1	1	1	CUBA

	1.3			1										DDR
	1.3	1	1											JPN
	1.4											1		DDR
	1.4	1		1										JPN
1979	1.3	1	1	1	1	1	1	1	1	1	1	1	1	SUN
	1.3	1	1	1	1	1	1	1		1	1	1	1	BGR
	1.3						1	1		1	1	1	1	DDR
	1.3				1							1	1	POL
	1.4						2	1	2	1	1	1	2	ROM
	1.4	1	1	1	1	1							1	SUN
	1.4						1					1		DDR
	1.4				1									POL
1980	1.3	1	1	1	1	1		1	1					BGR
	1.3				1									DDR
	1.3					1	1	1	1					DDR
	1.3	1	1	1	1	1								JPN
	1.3				1	1	1	1	1	1	1	1	1	ROM
	1.3	1	1	1	1	1	1							ZAF
	1.3	1	1	1	1	1		1	1	1	1	1	1	SUN
	1.4					1	1	1	1	1		1		ROM
	1.4	1	1	1	1	1	1	1	1	1				ZAF
	1.4		1		1	1							1	SUN
	1.5			1	1			1						ZAF
1981	1.3-1.4			1	1	1	1	1	1	1		1	1	BGR
	1.3										1	1		DDR
	1.3	1	1	1	1	1								POL
	1.3		1	1	1	1	1	1	1					ROM
	1.3									1	1	1		ROM
	1.3	1	1	1	1	1		1						ZAF

	1.3	1	1	1	1	1	1	1	1	1	1	1	1	SUN
	1.4	1		1	1	1								POL
	1.4						1			1				ROM
	1.4	1	1	1	1	1	1							ZAF
	1.4			1	1	1	1		1	1	1	1		SUN
1982	1.3	1	1		1	1	1			1	1	1		BGR
	1.3			1	1						1	1		DDR
	1.3								1	1				JPN
	1.3		1	1										POL
	1.3	1	1	1	1	1	1	1	1	1	1	1	1	ROM
	1.3	1	1	1	1	1	1	1	1	1				SUN
	1.4	1	1							1				JPN
	1.4	1	1	1		1	1	1	1					ZAF
	1.4			1		1	1			1		1	1	SUN
	1.3-1.4	1	1	1	1	1	1	1	1	1	1	1	1	BGR
	1.3					1	1			1	1	1		DDR
	1.3	1	1	1	1	1						1	1	POL
	1.3	1	1	1	1	1	1	1		1	1	1	1	ROM
	1.3			1	1	1	1	1						ZAF
	1.3									1	1			ESP
	1.3	1	1	1	1	1	1	1	1		1	1	1	SUN
	1.4				1								1	POL
	1.4				1	1	1	1	1					ZAF
	1.4								1					ESP
	1.4		1			1	1	1			1	1	1	SUN
	1.5								1					ZAF
1984	1.3			1							1			DDR
	1.3	1	1											POL
	1.3	1				1	1	1	1			1	1	ROM

	1.3				1									ZAF
	1.3	1	1	1	1				1	1	1	1	1	SUN
	1.4										1			DDR
	1.4												1	POL
	1.4		1	1	1		1		1	1		1		ROM
	1.4			1	1	1	1							ZAF
	1.4						1							ESP
	1.4	1	1		1		1	1		1	1	1		SUN
	1.3-1.4	1	1	1	1	1	1	1	1	1	1	1	1	BGR
	1.5												1	ESP
1985	1.3					1	1							CUBA
	1.3					1				1	1	1	1	DDR
	1.3		1	1										POL
	1.3	1	1	1	1	1	1	1		1	1	1	1	ROM
	1.3			1	1				1	1				ZAF
	1.3			1	1	1	1	1	1	1	2	3	1	SUN
	1.4					1						1		DDR
	1.4	1	1		1									POL
	1.4	1						1				1		ROM
	1.4			1	1	1	1	1	1	1				ZAF
	1.4					1	1							CUBA
	1.4	2	2	2	2	2	2	2	2	2	2	2	2	SUN
	1.3-1.4	1	1	1	1	1	1	1	1	1	1	1	1	BGR
1986	1.3	1	1	1	1	1	1	1	1	1	1	1	1	BGR
	1.3	1	1	1	1	1	1	1			1	1	1	ROM
	1.3										1	1	1	CUBA
	1.3	3	2	2	1	1			3	3	2	2	1	SUN
	1.3					1							1	ESP

	1.3			1	1	1								ZAF
	1.3				1	1					1	1		DDR
	1.4								1	1	1	1		ROM
	1.4					1						1		DDR
	1.4										1	1	1	ESP
	1.4	3	3	2	2	1			1	2	1	1		SUN
	1.4	1	1	1	1	1			1	1		1	1	SUN
	1.4	1	1	1	1	1	1	1	1					ZAF
	1.4		1											POL
	1.4		1											SUN
1987	1.3	1	1	1	1	1	1	1	1	1	1	1	1	BGR
	1.3			1	1					1	1			DDR
	1.3					1	1							JPN
	1.3								1	1	1			POL
	1.3	1	1	1	1	1	1	1	1	1	1	1	1	ROM
	1.3		1	1	1	1								ZAF
	1.3	1		1										ESP
	1.3	2	1	2	1	1	1		1	1	2	2	2	SUN
	1.4				1	1								DDR
	1.4						1							JPN
	1.4	1						1	1		1			ROM
	1.4			1	1	1	1	1						ZAF
	1.4	1												ESP
	1.4	2	1	1	1	1	1		1		2	1	2	SUN
	1.5											1		ESP
	1.5								1			1	1	SUN
Sardinops sagax (sardine)														
1973	1.4									1	1			BGR
	1.4							1	1					POL
1974	1.3									1	1			POL

	1.4-1.5			1	1	1	1	1	1					ZAF
	1.3								1	1	1	1		ANG
1975	1.4							1	2	2				POL
1977	1.4				1	1	1							BGR
	1.4			1	1	1	1	1	1					ZAF
1978	1.3	1		1	1	1	1	1						ZAF
1979	1.3									1				ROM
	1.3	1	1	1	1	1	1	1	1	1	1	1		ZAF
	1.4						1		1					ROM
	1.4		1	1	1	1	1	1	1	1		1		ZAF
	1.5								1					ZAF
1980	1.3					1								ROM
	1.3		1	1	1	1	1		1					ZAF
	1.4			1	1	1	1	1	1					ZAF
	1.5				1	1								ZAF
1981	1.3					1					1			ROM
	1.3	1	1	1	1									ZAF
	1.4	1	1	1	1	1	1	1						ZAF
	1.5		1				1							ZAF
1982	1.3	1	1	1	1	1	1	1	1	1				ZAF
	1.3						1	1	1	1				ROM
	1.4	1		1	1		1	1	1	1				ZAF
1983	1.3							1	1	1	1	1	1	POL
	1.3							1						ROM
	1.3		J	1		1	1	1						ZAF
	1.4		1	1	1	1	1	1	1					ZAF
	1.5								1					ZAF
1985	1.3					1								ROM
	1.3			1		1	1	1						ZAF

	1.4												1	POL
	1.4			1	1	1	1	1	1					ZAF
	1.5							1						ZAF
1985	1.3					1	1				1			ROM
	1.3				1	1								ZAF
	1.4	1	1											POL
	1.4			1	1	1	1	1	1	1				ZAF
	1.5							1						ZAF
1986	1.3			1	1	1		1		1				ZAF
	1.4	1	1	1	1	1	1	1	1	1	1			ZAF
	1.5						1							ZAF
1987	1.3			1	1	1		1						ZAF
	1.4	1	1	1	1	1	1	1	1		1	1	1	ZAF
	1.5							1	1					ZAF
Engraulis encrasicolus (anchovy)														
1974	1.4-1.5			1	1	1	1	1	1					ZAF
1977	1.3			1		1	1	1	1					ZAF
	1.4			1	1	1	1	1	1					ZAF
	1.5					1								ZAF
1978	1.3			1	1	1	1	1						ZAF
	1.4			1	1	1	1	1						ZAF
1979	1.5				1			1	1					ZAF
	1.4	1	1	1	1	1	1	1	1		1	1		ZAF
	1.3	1		1	1	1	1	1	1	1	1	1	1	ZAF
1980	1.3		1	1	1	1	1		1					ZAF
	1.4		1	1	1	1	1	1	1					ZAF
	1.5		1	1	1	1		1						ZAF
1981	1.3										1			ROM
	1.3	1	1	1	1		1							ZAF

	1.4	1	1	1	1	1	1	1						ZAF
	1.5		1		1			1						ZAF
1982	1.3	1		1	1	1	1	1	1	1				ZAF
	1.4	1		1			1	1	1	1				ZAF
1983	1.3						1							ROM
	1.3			1	1	1	1	1						ZAF
	1.4				1	1	1	1	1					ZAF
	1.5						1		1					ZAF
1984	1.3					1	1	1						ZAF
	1.4			1	1	1	1	1	1					ZAF
	1.5							1						ZAF
1985	1.3										1			ROM
	1.3			1	1									ZAF
	1.4		1	1			1	1	1	1				ZAF
	1.5							1						ZAF
1986	1.3			1	1	1		1		1				ZAF
	1.4			1	1	1	1	1						ZAF
	1.5						1							ZAF
1987	1.3			1	1	1		1						ZAF
	1.4			1	1	1	1	1	1	1				ZAF
	1.5							1	1					ZAF
Scomber japonicus (chub mackerel)														
1972	1.4											1		POL
	1.5											1	1	POL
1977	1.4	1	1			1			1		1	1		BGR
1979	1.5					1								ESP
1980	1.4						1							ROM
1981	1.3						1							ROM
1982	1.5					2								ESP
1983	1.3			1	1	1						1	1	POL

	1.3						1							ROM
	1.3		1											POL
1984	1.4											1		ESP
	1.5										1	1	1	ESP
1985	1.3			1			1	1						BGR
	1.3			1										POL
	1.3				1									ROM
	1.4	1												POL
	1.4											1		ROM
	1.5									1	1			ESP
1986	1.3	1	1											ROM
	1.4											1	1	ESP
	1.5											1	1	ESP
1987	1.3		1											ROM
	1.4	1											1	ESP
	1.4												1	SUN
Genypterus capensis (kingklip)														
1972	1.4		1										1	POL
	1.5												1	POL
1974	1.4		1											POL
	1.4	1	1	1	1	1	1	1	1	1	1			ZAF
	1.5		1		1									POL
1975	1.5	1												ESP
1976	1.5		1											POL
1978	1.5		1	1										ESP
1979	1.5		1											ESP
1980	1.5			1	1	1	1					1	1	ESP
1981	1.4	1												JPN
	1.4								1	1				ESP
	1.5		1	1										JPN

	1.5				1				1	1	1			ESP
1982	1.4			1		1	1					1		ESP
	1.5					1								ZAF
	1.5			1	1			1	1	1				ESP
1983	1.4								1					ESP
	1.5					1								ZAF
1984	1.4	1												ESP
	1.5											1		ZAF
	1.5		1								1	1	1	ESP
1985	1.5												1	POL
	1.5					1			1					ZAF
	1.5			1	1	1		1			1			ESP
1986	1.5			1										ZAF
	1.5	1	1										1	ESP
1987	1.5	1			1	1				1			1	ESP
Loligo reynaudi (chokka squid)														
1981	1.4								1					ESP
	1.5				1				1	1	1			ESP
1982	1.5									1				ESP
Helicolenus dactylopterus (jacopever)														
1978	1.5		1											ESP
1980	1.3							1	1	1				ESP
	1.4									1	1			ESP
1981	1.4								1					ESP
	1.5								1	1				ESP
1982	1.3			1										ESP
1983	1.5								1					ESP
	1.4								1					ESP
	1.3								1	1				ESP
1984	1.4											1		ESP

	1.5						1		1			1	1	ESP
1985	1.3											1	1	ROM
	1.4							1						ESP
	1.5							1		1	1	1	1	ESP
1986	1.3			1	1									ROM
	1.4		1								1	1		ESP
	1.5		1								1	1	1	ESP
1987	1.4									1	1			ESP
	1.5	1	1							1		1	1	ESP
Chelidonichthys capensis (Cape gurnard)														
1981	1.3											1		ROM
1983	1.3						1							ROM
1986	1.3		1											ROM
	1.4										1			ESP
1987	1.3				1					1	1			ROM
	1.3											1	1	ROM
Thyrsites atun (snoek)														
1976	1.3								1					POL
1977	1.3										1	1	1	POL
1978	1.3			1										ROM
1980	1.3						1							ROM
1982	1.5									1				ESP
1983	1.3									1				ROM
1984	1.5											1	1	ESP
1985	1.3						1					1	1	ROM
1986	1.5												1	ESP
1987	1.3												1	ROM
	1.5	1												ESP
	1.5					1								JPN
Dentex macrophthalmus (large-eye dentex)														

1972	1.3		1									1		POL
	1.4			1										POL
1973	1.4		1											POL
	1.4					1								BGR
1974	1.4	1	1			1								POL
1977	1.4		1			1			1	1	1	1	1	SUN
1978	1.3										1			CUBA
	1.3	1	1	1				1	1	1	1	1	1	SUN
1980	1.3				1	1								POL
	1.3				1	1	1							ROM
1981	1.3				1	1	1	1	1	2	2			ROM
	1.3				1	1	1	1						SUN
1982	1.3						2	1	1	1		2	2	ROM
1983	1.3	1	1	1	1							1	1	POL
	1.3		1	1	1	1	1	1		1		1		ROM
	1.3									1				ESP
	1.3	1	1	1	1	1	1	1	1			1	1	SUN
1984	1.3		1											POL
	1.3					2		1						ROM
1985	1.3	1				1	1							BGR
	1.3		1											POL
	1.3	1	1	1	1	1	1	1			1	1	1	ROM
1986	1.3	1	1	1	1	1						1		ROM
1987	1.3			1	1	1				1	1	1	1	ROM
	1.3										1	1		SUN
Lophius vomerinus (monkfish)														
1978	1.5		1											ESP
1979	1.4					1								ESP
1980	1.3								1	1				ESP
	1.4								1	1				ESP

	1.5				1	1	1							ESP
1981	1.5								1	1				ESP
1982	1.3											1		ESP
	1.4			1		1	1							ESP
	1.5					1								ZAF
	1.5									1				ESP
1983	1.5								1					ESP
	1.5					1								ZAF
1984	1.4	1					1	1				1		ESP
	1.5											1		ZAF
	1.5		1				1		1		1	1	1	ESP
1985	1.4							1						ESP
	1.5					1			1					ZAF
	1.5			1	1	1		1			1			ESP
1986	1.4		1						1		1	1	1	ESP
	1.5			1								1		ZAF
	1.5	1	1						1				1	ESP
1987	1.4	1								1	1			ESP
	1.5	1				1				1				ESP
Austroglossus microlepis (West coast sole)														
1977	1.4				1									BGR
1978	1.4				1	1	2	1		1				ZAF
1984	1.5	1												ESP
1986	1.4		1											ESP
	1.5	1	1											ESP
1987	1.4-1.5									1				ESP
Jasus lalandii (West coast rock lobster)														
1977	1.5											1	1	ZAF
1978	1.5	1	1	1										ZAF

1979	1.5	1	1									1	1	ZAF
1981	1.5	1	1	1	1							2	2	ZAF
1982	1.5	1	1	1								1	1	ZAF

Data available from ICSEAF (1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987).

Table A4: Length frequency distribution of commercial catch data available from the ICSEAF sampling bulletins from 1968 to 1987 for South Africa, Division 1.6. (see Fig 1). The reporting countries were: Bulgaria (BGR), the Soviet Union (SUN), Spain (ESP), Poland (POL), South Africa (ZAF), Japan (JPN) and Union of Soviet Socialist Republics (USSR).

	Months												Country
Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Merluccius capensis (shallow-water Cape hake)													
1972		1	1									1	POL
1973										1			POL
1974		3								1	1	1	USSR
1976									1				ZAF
1977	1	1	1	1	1					1	1		BGR
1978		1				1							JPN
					1								ESP
					1				1				ZAF
1979											1	1	ZAF
1980											1	2	JPN
							1					1	ZAF
1981											1	1	JPN
	1			1	1	1		1	1	1		2	ZAF
M. paradoxus (deep-water hake)													
1969	1			1	1								USSR
1970			1	1	1				1	1	1		USSR
1971			1	1		1							USSR

1972			1										POL
										1			POL
	1	1	1							1	1		USSR
			1									1	POL
										1			POL
1973										1			USSR
1975					1								POL
	1		1									1	SUN
1976								1					SUN
								1					ZAF
1978					1			1	1				ZAF
1979						1				1	1		ZAF
1981	1	1	1	2	1	1		1	1	2		2	ZAF
Trachurus capensis (Cape horse mackerel)													
1975			1	1		1			1				ZAF
			1								1	1	SUN
1976			1	1	1		1	1	1		1		ZAF
1977	3	3	2	2	3	2	1	1					ZAF
1978	2	1	2	2	2	2	1	1	1	1	1		ZAF
1979	1	1	1	1	2								ZAF
1980											1	3	JPN
1981	2	1	1	1	1	2	1	1				1	ZAF
1982	2	2	2	1	2	1	1	1		2			ZAF
1983	2	2	1	1	2	2	1		1	2	1	1	ZAF
1984	1	1	1	1	1	1				1	1		ZAF
1985	1	1	1	1	1	1	1	1					ZAF
1986	1	1	1	1	1	1	1	1					ZAF
1987	1	1	1	1	1	1	1	1	1	1	1		ZAF
Sardinops sagax (sardine)													
1974	1		1	1									ZAF

1975	1	1	1	1	1	1	1	1					ZAF
1976	1	1	1	1	1	1	1						ZAF
1978	2	2	2	2	2	2	1						ZAF
1979	1	1	1	1	1								ZAF
1980	1	1	1	1	1	1	1						ZAF
1981	1	1	1	1	1	1							ZAF
1982	1	1	1	1	1	1	1	1					ZAF
1983	1	1	1	1	1	1				1	1	1	ZAF
1984	1	1	1	1	1	1	1			1	1	1	ZAF
1985	1	1	1	1	1	1	1	1	1				ZAF
1986	1	1	1	1	1	1	1	1	1				ZAF
1987	1	1	1	1	1	1	1	1	1				ZAF
Engraulis encrasicolus (anchovy)													
1974	1	1	1	1									ZAF
1975	1	1	1	1	1	1	1	1					ZAF
1976	1	1	1	1	1	1	1	1					ZAF
1978	1	1	1	1	1	1							ZAF
1979	1	1	1	1	1	1							ZAF
1980	1	1	1	1	1	1	1						ZAF
1981	1	1	1	1	1	1							ZAF
1982	1	1	1	1	1	1	1	1					ZAF
1983	1	1	1	1	1	1				1	1	1	ZAF
1984	1	1	1	1	1	1	1			1	1		ZAF
1985	1	1	1	1	1	1	1	1	1				ZAF
1986	1	1	1	1	1	1	1	1	1				ZAF
1987	1	1	1	1	1	1	1	1	1				ZAF
Etrumeus whiteheadi (round herring)													
1974		1	1										ZAF
1975	1	1	1	1	1	1	1						ZAF
1977	1	1	1	1	1	1	1	1					ZAF

1978	1	1	1	1	1	1						ZAF
1979	1	1	1	1	1	1						ZAF
1980	1	1	1	1	1	1	1					ZAF
1981	1	1	1	1	1	1						ZAF
1982	1	1	1	1	1	1	1	1				ZAF
1983	1	1	1	1	1	1				1	1	1	ZAF
1984	1	1	1	1	1	1				1	1	1	ZAF
1985	2	2	2	2	2	2	2	2	2				ZAF
1986	1	1	1	1	1	1	1	1					ZAF
1987	1	1	1	1	1	1	1	1	1				ZAF
Scomber japonicus (chub mackerel)													
1974	1	1	1	1	1								ZAF
1975	1	1	1	1	1	1	1						ZAF
1976	1	1	1	1	1	1	1	1					ZAF
1978	1	1	1	1	1								ZAF
1979	1	1	1	1	1								ZAF
1980	1	1	1	1				1					ZAF
1982		1		1						1			ZAF
1983	1	1	1	1					1	1	1	1	ZAF
1984											1	1	ZAF
1985	1	1	1	1									ZAF
1987	1	1	1	1	1	1							ZAF
Lampanyctodes hectoris (lanternfish)													
1976	1												ZAF
1977	1	1	1	1		1							ZAF
1978	1	1	1		1	1							ZAF
1979	1	1	1	1									ZAF
1981	1	1	1		1								ZAF
1982	1	1	1	1	1								ZAF
1984	1	1	1	1	1	1							ZAF

1985	1	1	1	1									ZAF
1986	1	1	1	1									ZAF
Genypterus capensis (kingklip)													
1972												1	POL
1976					1	1	1						ZAF
1979				2	2								ZAF
1980											1		JPN
				1	1		1	1	1		1		ZAF
1981	1		2	2			1				1	1	ZAF
1982	1			1		1		1					ZAF
1983				1		1				1			ZAF
1984									1		1		ZAF
1985			1		1			1					ZAF
1986		1	1	1									ZAF
Loligo reynaudi (chokka squid)													
1980												2	JPN
1981											1	1	JPN
1982						1							JPN
Helicolenus dactylopterus (jacopever)													
1979				1	1								ZAF
Thyrsites atun (snoek)													
1978					1	1	1						ZAF
1980								1					ZAF
1981						1	1	2	1		1		ZAF
1982	1						1	1					ZAF
1983						1			1	1			ZAF
Lophius vomerinus (monkfish)													
1980					1		1	1	1		1	1	ZAF
1981	2	2	2	2	2	2	2	2	2		2	1	ZAF
1982	1	1	1	1	1	1	1		1	1	1	1	ZAF

1983		1	1	1	1	1	1	1	1	1		1	ZAF
1984		1	1	1	1	1	1	1	1		1		ZAF
1985		1	1	1	1	1	1	1				1	ZAF
1986		1	1	1	1				1		1	1	ZAF
1987	1	1	1	1	1	1	1				1		ZAF
Austroglossus microlepis (West coast sole)													
1975	1	1	1	1									ZAF
Jasus lalandii (West coast rock lobster)													
1976												1	ZAF
1977	1	1											ZAF
1978	1	1	1								1	1	ZAF
1979	1	1									1	1	ZAF
1980	1	1	1								1	1	ZAF
1981	2	1	1	1		1				1	1	1	ZAF
1982											2	2	ZAF
1983		1	1							1	1		ZAF
1984											2	2	ZAF
1985	2										3	13	ZAF
1986	2	1									3	3	ZAF
1987	3	2									3	3	ZAF

Data available from ICSEAF (1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987).

Table A5: Weight-length data available from the ICSEAF sampling bulletins from 1968 to 1987 for Namibia, Divisions 1.3, 1.4 and 1.5. (see Fig 1). The reporting countries were: the Soviet Union (SUN), Spain (ESP), Poland (POL), Portugal (PRT), Romania (ROM), German Democratic Republic (DDR), Germany (DEU) and Union of Soviet Socialist Republics (USSR).

		Months												Country
Years	Div	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Merluccius capensis (shallow-water Cape hake)														
1975	1.3	1	1											SUN

	1.4		1											SUN
	1.5			1										SUN
1976	1.3	1												SUN
	1.4	1												SUN
1977	1.5				1			1						DEU
	1.4										1			JPN
	1.3		1								1			SUN
1978	1.3			1										DDR
	1.3	1												SUN
	1.5						1							DEU
1979	1.3												1	ROM
	1.3	1												SUN
	1.4	1												SUN
1980	1.3				1	1	1	1	1		1	1		ROM
	1.3			1								1		SUN
	1.4							1	1					ROM
	1.4				1	1								SUN
1981	1.3				1	1	1	1		1	1	1		ROM
	1.3					1		1						SUN
	1.4					1	1							SUN
1982	1.3	1	1	1	1	1	1	1	1	1	1	1	1	ROM
	1.3			1										ESP
	1.3	1					1				1	1	1	SUN
	1.4			1		1	1							ESP
	1.4	1		1		1	1	1	1	1				SUN
	1.5	1	1	1	1	1								PRT
	1.5			1	1			1	1	1				ESP
1983	1.5	1	1	1	1	1								PRT
	1.3	1	1	1	1							1	1	POL
	1.3	1	1	1	1	1	1	1		1	1	1	1	ROM

	1.3	1	1	1	1	1	1	1	1		1	1	1	SUN
	1.4	1			1								1	POL
	1.4	1	1	1			1	1		1		1	1	SUN
1985	1.3		1											POL
	1.3		1	1	1	1	1	1			1	1	1	ROM
	1.3			1	1	1	1		1	1	1	1	1	SUN
	1.4	1												POL
	1.4	1						1			1	1		ROM
	1.4		1	1	1		1		1		1	1	1	SUN
	1.5											1		PRT
	1.5												1	SUN
1986	1.3	1	1	1	1							1	1	ROM
	1.3	1	1	1	1	1	1		1	1	1			SUN
	1.4		1						1	1	1	1		ROM
	1.4	1	1	1					1				1	SUN
	1.5		1											ROM
	1.5											1		ESP
	1.5								1			1		SUN
1987	1.3	1		1	1								1	ROM
	1.3			1	1						1	1		SUN
	1.4	1			1	1	1	1	1				1	SUN
	1.5									1	1	1	1	PRT
	1.5			1	1	1	1	1		1		1	1	SUN
M. paradoxus (deep-water hake)														
1976	1.4	1												SUN
1977	1.5						1				1			DEU
1978	1.5					1								DEU
1979	1.5		1		1									DEU
1980	1.3				1	1	1	1	1		1	1		ROM
	1.4							1	1					ROM

1981	1.3				1	1	1	1		1	1	1		ROM
	1.5							1						PRT
1982	1.3		1	1	1		1	1	1			1	1	ROM
	1.3			1	1			1	1	1				ESP
1983	1.3	1					1	1		1	1	1	1	ROM
1985	1.3		1	1	1	1	1	1			1	1	1	ROM
	1.4		1					1						ROM
	1.5									1	1	1	1	PRT
1986	1.3	1	1	1	1							1		ROM
	1.4		1						1	1	1	1		ROM
	1.5							1	1	1	1			PRT
	1.5		1											ROM
1987	1.3			1	1								1	ROM
Trachurus capensis (Cape horse mackerel)														
1976	1.3								1					POL
	1.3									1	1			SUN
	1.3									1	1			DDR
	1.4	1									1		1	SUN
1977	1.3		1									1	1	SUN
1978	1.3			1										DDR
	1.3	1												SUN
	1.4											2		DDR
	1.4	1												SUN
1979	1.3						1	1	1	1	1	1		ROM
	1.3	1			1		1							SUN
	1.3											2		DDR
	1.4						1		1					ROM
	1.4	1									1			SUN
1980	1.3				1	1	1	1	1					DDR
	1.3				1	1	1	1	1	1	1	1	1	ROM

	1.3	1	1	1					1		1			SUN
	1.3											1	1	SUN
	1.4					1	1	1	1	1		1		ROM
	1.4				1									SUN
1981	1.3-1.4			1			1	1					1	BGR
	1.3		1	1	1	1	1	1	1	1	1	1		ROM
	1.3						1	1						SUN
	1.4						1		1					ROM
	1.4				1		1							SUN
1982	1.3			1							1	1		DDR
	1.3	1	1	1	1	1	1	1	1	1	1	1	1	ROM
	1.3	1		1		2	2	1	1	1	1	2	1	SUN
1983	1.3					1					1	1		DDR
	1.3	1	1	1	1	1						1	1	POL
	1.3	1	1	1	1	1	1	1		1	1	1	1	ROM
	1.3	1	1	1	1	1	1	1	1		1	1	1	SUN
	1.4				1								1	POL
	1.4		1				1					1	1	SUN
1984	1.3			1							1			DDR
	1.3	1	1											POL
	1.3	1			1	1	1	1	1			1	1	ROM
	1.3	1	1	1	1	1				1	1		1	SUN
	1.4										1			DDR
	1.4												1	POL
	1.4		1	1	1		1		1	1				ROM
	1.4				1	1		1	1	1	1	1		SUN
1985	1.3					1					1			DDR
	1.3		1	1										POL
	1.3	1	1	1	1	1	1	1		1	1	1	1	ROM

	1.3			1	1	1	1	1	1					SUN
	1.4					1						1		DDR
	1.4	1	1											POL
	1.4	1						1				1		ROM
	1.4		1	1	1	1	1	1	1					SUN
	1.3-1.4					1								BGR
1986	1.3					1								DDR
	1.3	1	1	1	1	1	1	1			1	1	1	ROM
	1.3	1	1	1	1	1			1	1	1	1		SUN
	1.3					1						1		DDR
	1.3								1	1	1	1		ROM
	1.4	1	1			1			1	1		1	1	SUN
1987	1.3			1	1									DDR
	1.3								1	1	1			POL
	1.3	1	1	1	1	1	1	1	1	1	1	1	1	ROM
	1.3	1	1	1	1	1	1		1	1	1	1	1	SUN
	1.4				1	1								DDR
	1.4										1			ROM
	1.4	1	1	1	1	1	1		1		1	1	1	SUN
Sardinops sagax (sardine)														
1976	1.4								1					POL
1979	1.3						1		1	1				ROM
1981	1.3					1					1			ROM
1982	1.3						1	1	1	1			1	ROM
1983	1.3											1		POL
	1.3							1						ROM
1984	1.3					1								ROM
1985	1.4		1											POL
1987	1.3		1											ROM

Dentex macrophthalmus (large-eye dentex)														
1976	1.3									1				DDR
1981	1.3				1	1	1	1	1	1	1			ROM
1982	1.3						1	1	1	1		1	2	ROM
1983	1.3				1	1	1	1		1		1		ROM
	1.3	1	1	1	1	1	1	1	1			1	1	SUN
1984	1.3				1	1		1						ROM
1986	1.3	1	1	1	1	1								ROM
1987	1.3			1	1	1				1	1	1	1	ROM
Scomber japonicus (chub mackerel)														
1981	1.3						1							ROM
1983	1.3			1	1	1						1	1	POL
	1.3						1							ROM
	1.4		1											POL
1985	1.3			1										POL
	1.4	1												POL
1986	1.3	1	1											ROM
Engraulis encrasicolus (anchovy)														
1981	1.3										1			ROM
Etrumeus whiteheadi (round herring)														
1981	1.3										1			ROM
1983	1.3						1							ROM

Data available from ICSEAF (1972, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1987).

Table A6: One-way ANOVA results of comparisons of mean length at age 3 by countries, for shallow-water hake *M. capensis* (Namibian stock) from 1968 to 1987, *** denotes significant regressions at the 0.1% level

	Df	**Sum Square**	**Mean Square**	**f-value**	**p-value**
Country	11	369.7	33.61	3.92	**<0.001 *****
Residuals	196	1682.7	8.59		

Table A7: One-way ANOVA results of comparisons of mean length at age 3 by divisions, for shallow-water hake *M. capensis* (Namibian stock) from 1968 to 1987.

	Df	Sum Square	Mean Square	f-value	p-value
Division	3	2.60	0.85	0.09	0.97
Residuals	204	2049.90	10.05		

Table A8: One-way ANOVA results of comparisons of mean length at age 3 by months, for shallow-water hake *M. capensis* (Namibian stock) from 1968 to 1987.

	Df	Sum Square	Mean Square	f-value	p-value
Month	11	114.2	10.38	1.05	0.40
Residuals	196	1938.2	9.89		

Table A9: ANOVA post hoc test of mean length at age 3 for the different countries, for shallow-water hake *M. capensis* (Namibian stock) from 1968 to 1987.

Countries	Diff	Lower Bound	Upper bound	p-value
CUBA-BGR	-3.20	-14.4	7.98	1.00
DDR-BGR	1.04	-6.36	8.44	1.00
DEU-BGR	-0.23	-9.08	8.61	1.00
ESP-BGR	0.01	-5.71	5.74	1.00
JPN-BGR	-4.83	-16.03	6.36	0.96
POL-BGR	1.84	-4.10	7.78	1.00
PRT-BGR	1.52	-5.05	8.08	1.00
ROM-BGR	-1.63	-7.45	4.19	1.00
SUN-BGR	1.82	-3.95	7.59	1.00
USSR-BGR	1.18	-5.02	7.39	1.00
ZAF-BGR	-0.28	-9.13	8.56	1.00
DDR-CUBA	4.25	-6.59	15.08	0.97
DEU-CUBA	2.97	-8.90	14.84	1.00
ESP-CUBA	3.21	-6.55	12.98	0.99
JPN-CUBA	-1.63	-15.34	12.08	1.00
POL-CUBA	5.04	-4.85	14.94	0.87
PRT-CUBA	4.72	-5.56	15.00	0.93
ROM-CUBA	1.58	-8.25	11.40	1.00
SUN-CUBA	5.02	-4.77	14.81	0.87
USSR-CUBA	4.39	-5.67	14.45	0.95
ZAF-CUBA	2.92	-8.95	14.79	1.00
DEU-DDR	-1.28	-9.67	7.12	1.00
ESP-DDR	-1.03	-6.02	3.96	1.00
JPN-DDR	-5.88	-16.71	4.96	0.82

POL-DDR	0.80	-4.44	6.03	1.00
PRT-DDR	0.48	-5.46	6.41	1.00
ROM-DDR	-2.67	-7.77	2.43	0.85
SUN-DDR	0.78	-4.27	5.82	1.00
USSR-DDR	0.14	5.40	5.69	1.00
ZAF-DDR	-1.33	-9.72	7.07	1.00
ESP-DEU	0.24	-6.71	7.20	1.00
JPN-DEU	-4.60	-16.47	7.27	0.98
POL-DEU	2.07	-5.06	9.21	1.00
PRT-DEU	1.75	-5.91	9.41	1.00
ROM-DEU	-1.39	-8.43	5.64	1.00
SUN-DEU	2.05	-4.95	9.05	1.00
USSR-DEU	1.42	-5.94	8.78	1.00
ZAF-DEU	-0.05	-9.74	9.64	1.00
JPN-ESP	-4.84	-14.61	4.92	0.89
POL-ESP	1.83	-0.49	4.14	0.28
PRT-ESP	1.51	-2.13	5.14	0.97
ROM-ESP	-1.64	-3.64	0.36	0.23
SUN-ESP	1.81	-0.04	3.65	0.06
USSR-ESP	1.17	-1.77	4.12	0.98
ZAF-ESP	-0.29	-7.25	6.66	1.00
POL-JPN	6.67	-3.22	16.57	0.53
PRT-JPN	6.35	-3.93	16.63	0.66
ROM-JPN	3.21	-6.62	13.03	1.00
SUN-JPN	6.65	-3.14	16.44	0.52
USSR-JPN	6.02	-4.04	16.08	0.71
ZAF-JPN	4.55	-7.32	16.42	0.98
PRT-POL	-0.32	-4.28	3.63	1.00
ROM-POL	-3.47	-6.01	-0.92	**0.0006 *****
SUN-POL	-0.02	-2.45	2.40	1.00
USSR-POL	-0.66	-3.99	2.68	1.00
ZAF-POL	-2.12	-9.26	5.01	1.00
ROM-PRT	-3.14	-6.92	0.63	0.21
SUN-PRT	0.30	-3.40	4.00	1.00
USSR-PRT	-0.33	-4.69	4.02	1.00
ZAF-PRT	-1.80	-9.46	5.86	1.00
SUN-ROM	3.44	1.32	5.57	**0.00001 *****
USSR-ROM	2.81	-0.31	5.94	0.12
ZAF-ROM	1.34	-5.69	8.38	1.00
USSR-SUN	-0.63	-3.66	2.40	1.00
ZAF-SUN	-2.10	-9.10	4.90	1.00

ZAF-USSR	-1.47	-8.83	5.89	1.00

Table A10: One-way ANOVA results of comparisons of mean length at age 3 by countries, for horse mackerel *Trachurus capensis* (Namibian stock) from 1975 to 1987, *** denotes significant regressions at the 0.1% level

	Df	**Sum Square**	**Mean Square**	**f-value**	**p-value**
Country	9	725.4	80.60	80.75	**<0.001 *** **
Residuals	159	158.7	1.00		

Table A11: One-way ANOVA results of comparisons of mean length at age 3 by divisions, for horse mackerel *Trachurus capensis* (Namibian stock) from 1975 to 1987.

	Df	**Sum Square**	**Mean Square**	**f-value**	**p-value**
Division	4	55.4	13.85	1.48	0.21
Residuals	182	1708.1	9.39		

Table A12: One-way ANOVA results of comparisons of mean length at age 3 by months, for horse mackerel *Trachurus capensis* (Namibian stock) from 1975 to 1987.

	Df	**Sum Square**	**Mean Square**	**f-value**	**p-value**
Month	11	100.7	9.15	0.80	0.64
Residuals	113	1290.3	11.42		

Table A13: ANOVA post hoc test of mean length at age 3 for the different countries, for horse mackerel *T. capensis* (Namibian stock) from 1968 to 1987.

BRG-BGR	0.91	-7.25	9.07	1.00
CUB-BGR	-2.22	-8.09	3.65	0.97
DDR-BGR	3.74	1.66	5.82	**<0.001 *** **
ESP-BGR	-3.89	-12.05	4.27	0.88
POL-BGR	-0.76	-3.03	1.52	0.99
ROM-BGR	-1.07	-2.91	0.76	0.69
SUN-BGR	0.22	-1.66	2.09	1.00
USSR-BGR	-0.24	-6.11	5.63	1.00
ZAF-BGR	-7.03	-11.90	-2.15	**0.00 *** **
CUB-BRG	-3.13	-12.94	6.68	0.99

DDR-BRG	2.84	-5.30	10.97	0.98
ESP-BRG	-4.80	-16.13	6.53	0.94
POL-BRG	-1.66	-9.85	6.52	1.00
ROM-BRG	-1.98	-10.05	6.09	1.00
SUN-BRG	-0.69	-8.77	7.39	1.00
USSR-BRG	-1.14	-10.96	8.67	1.00
ZAF-BRG	-7.93	-17.18	1.32	0.16
DDR-CUB	5.96	0.13	11.80	**0.04 ***
ESP-CUB	-1.67	-11.48	8.14	1.00
POL-CUB	1.46	-4.44	7.37	1.00
ROM-CUB	1.15	-4.60	6.90	1.00
SUN-CUB	2.44	-3.33	8.20	0.94
USSR-CUB	1.98	-6.03	10.00	1.00
ZAF-CUB	-4.80	-12.12	2.51	0.53
ESP-DDR	-7.64	-15.77	0.50	0.09
POL-DDR	-4.50	-6.68	-2.32	**0.00 *****
ROM-DDR	-4.82	-6.53	-3.10	**0.00 *****
SUN-DDR	-3.53	-5.28	-1.77	**0.00 *****
USSR-DDR	-3.98	-9.81	1.85	0.47
ZAF-DDR	-10.77	-15.60	-5.94	**0.00 *****
POL-ESP	3.14	-5.05	11.32	0.97
ROM-ESP	2.82	-5.25	10.89	0.98
SUN-ESP	4.11	-3.97	12.19	0.83
USSR-ESP	3.66	-6.16	13.47	0.97
ZAF-ESP	-3.13	-12.38	6.12	0.99
ROM-POL	-0.32	-2.26	1.63	1.00
SUN-POL	0.97	-1.01	2.95	0.86
USSR-POL	0.52	-5.39	6.43	1.00

ZAF-POL	-6.27	-11.19	-1.35	**0.00 *****
SUN-ROM	1.29	-0.16	2.74	0.13
USSR-ROM	0.84	-4.91	6.59	1.00
ZAF-ROM	-5.95	-10.68	-1.22	**0.00 *****
USSR-SUN	-0.45	-6.22	5.31	1.00
ZAF-SUN	-7.24	-11.99	-2.50	**<0.001 *****
ZAF-USSR	-6.79	-14.10	0.52	0.09

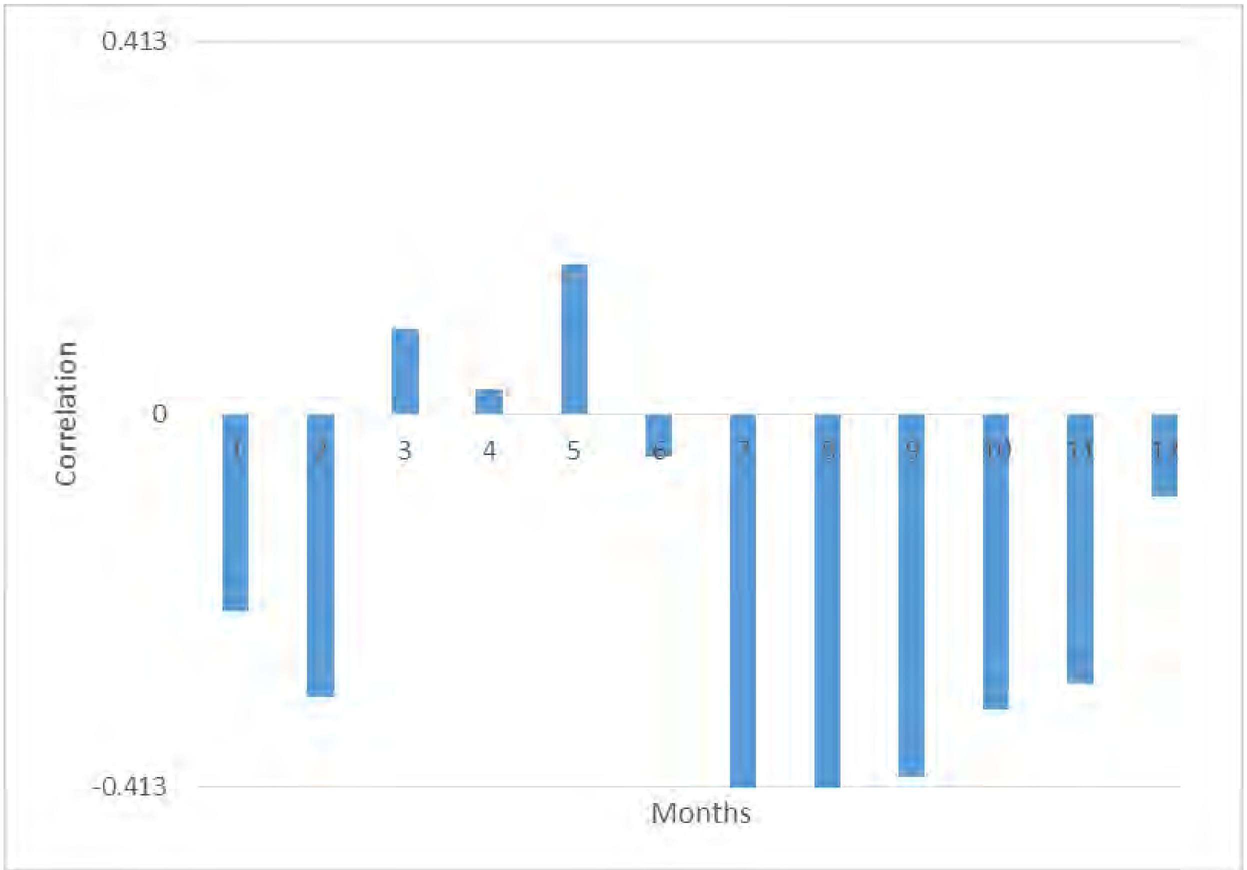

Figure A1: Correlation of annual mean length at age 3 for shallow-water Cape hake *M. capensis* (Namibian stock) from 1983 to 2017 and SST for all the months from the previous year in North: 17° to 20°S and 10° to 12° E from 1982 to 2016.

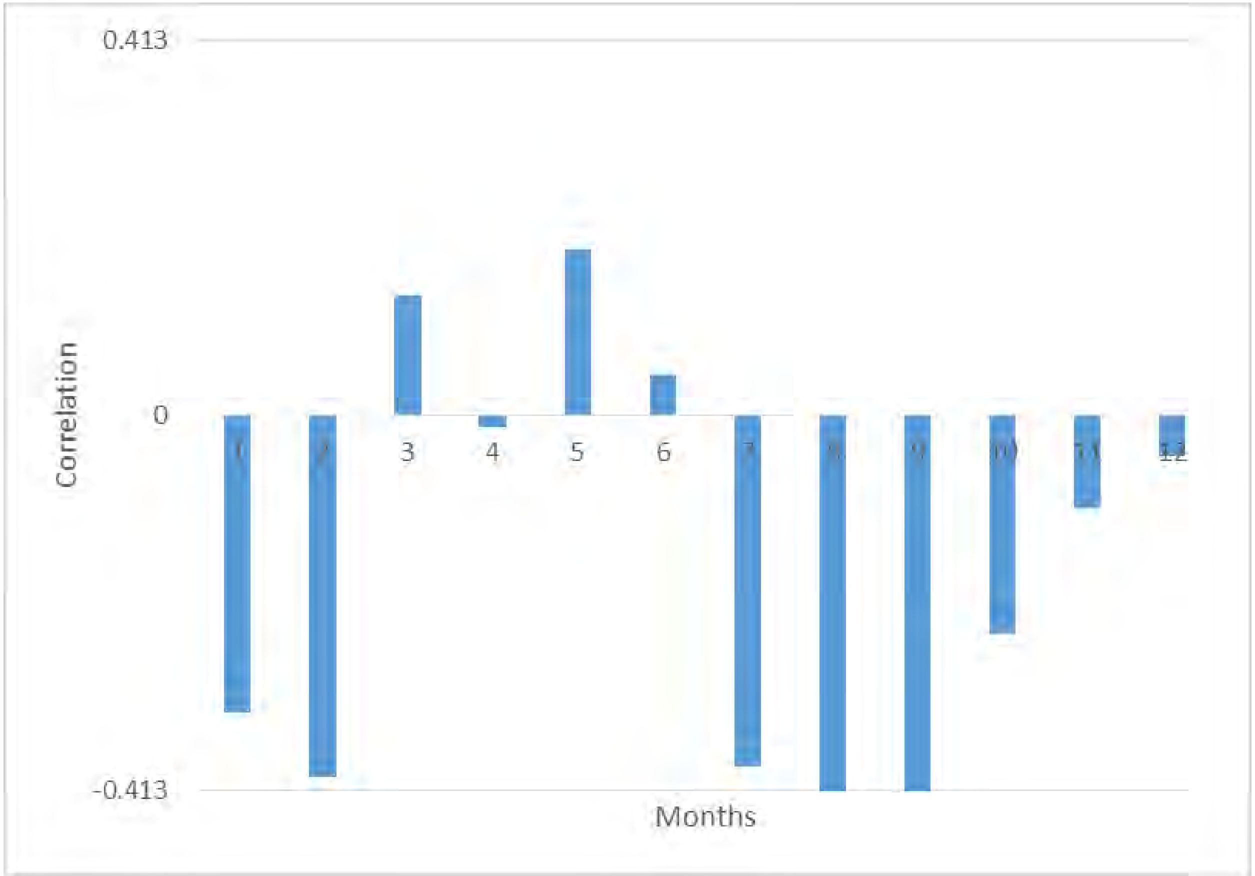

Figure A2: Correlation of annual mean length at age 3 for shallow-water Cape hake *M. capensis* (Namibian stock) from 1983 to 2017 and SST for all the months from the previous year in Centre: 20° to 24° S and 12° to 14° E from 1982 to 2016.

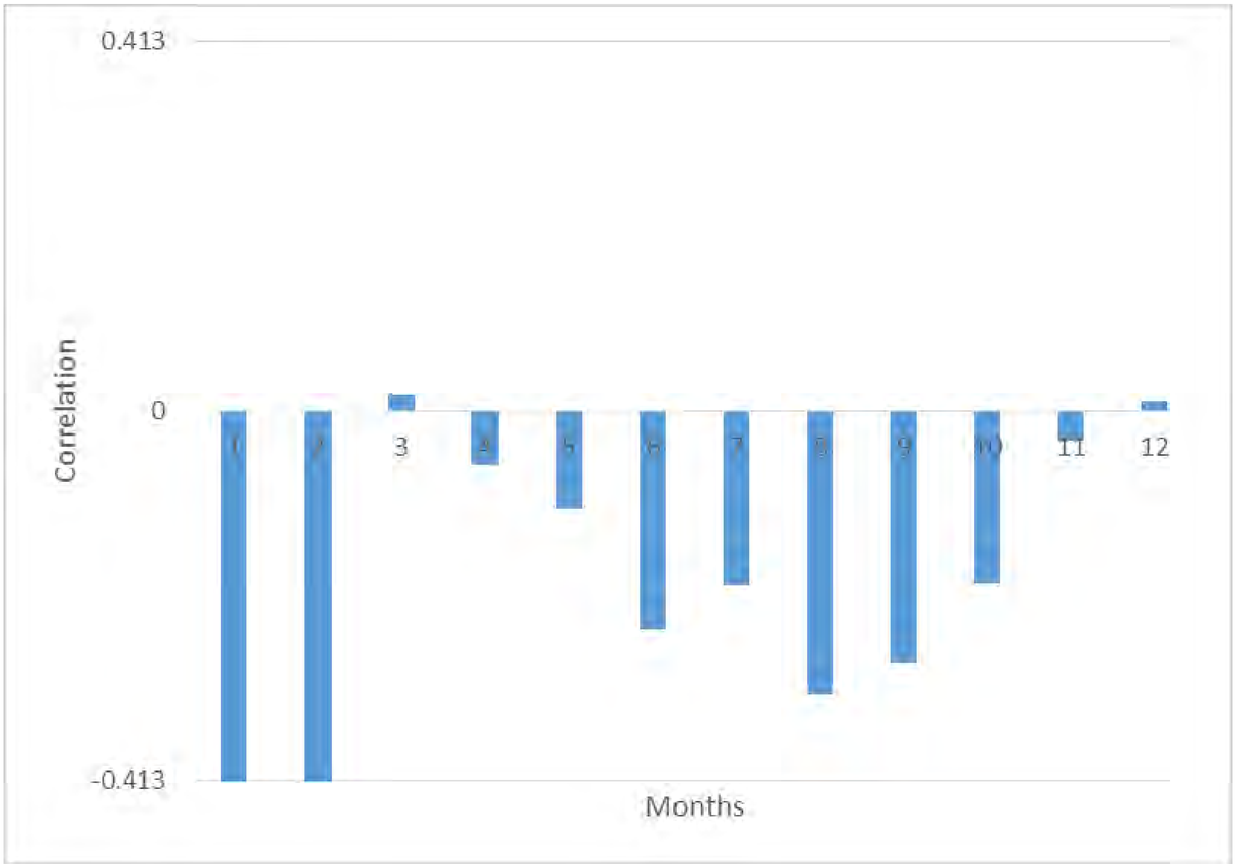

Figure A3: Correlation of annual mean length at age 3 for shallow-water Cape hake *M. capensis* (Namibian stock) from 1983 to 2017 and SST for all the months from the previous year in South 24° to 28° S and 13° to 15° E from 1982 to 2016.

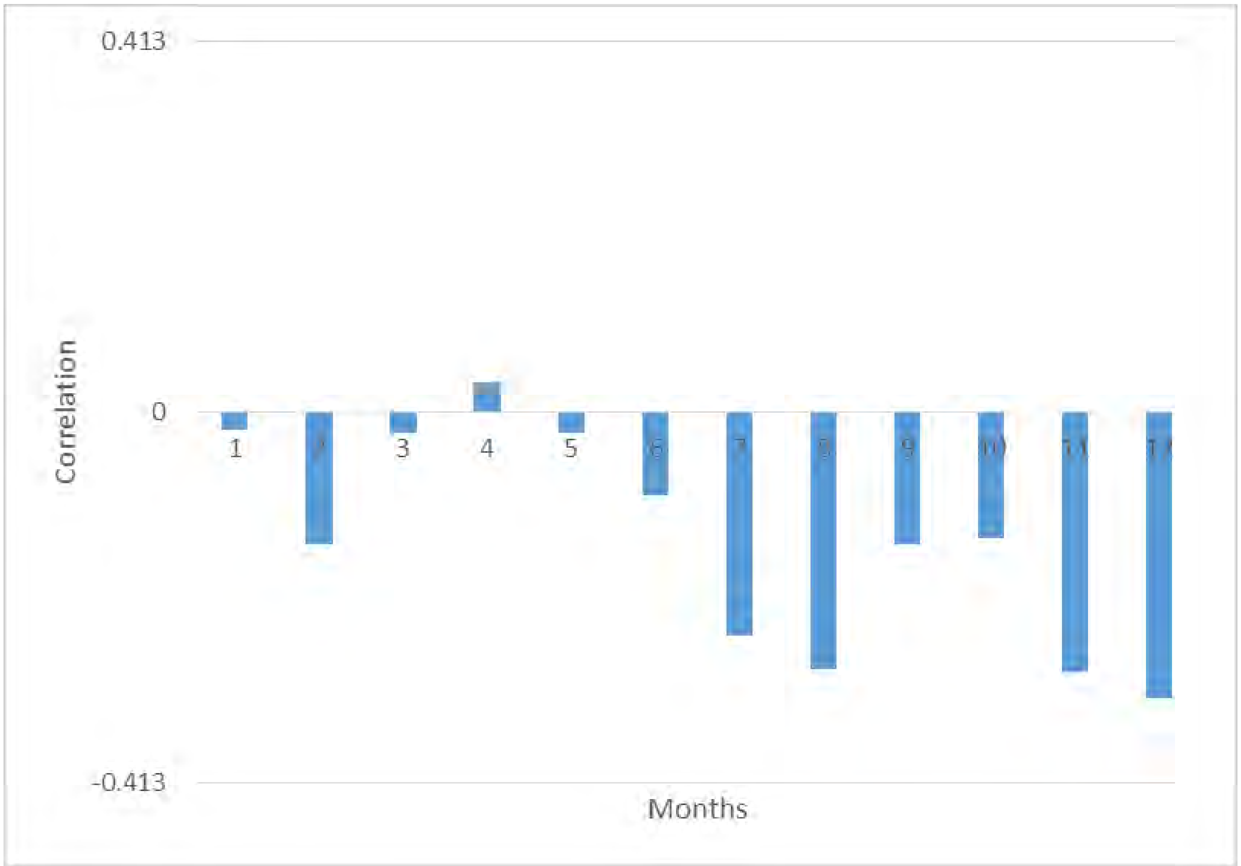

Figure A4: Correlation of annual mean length at age 3 for shallow-water Cape hake *M. capensis* (Namibian stock) from 1983 to 2017 and SST for all the months from the previous year in South Africa 28° to 31°S and 14° to 16° E from 1982 to 2016.

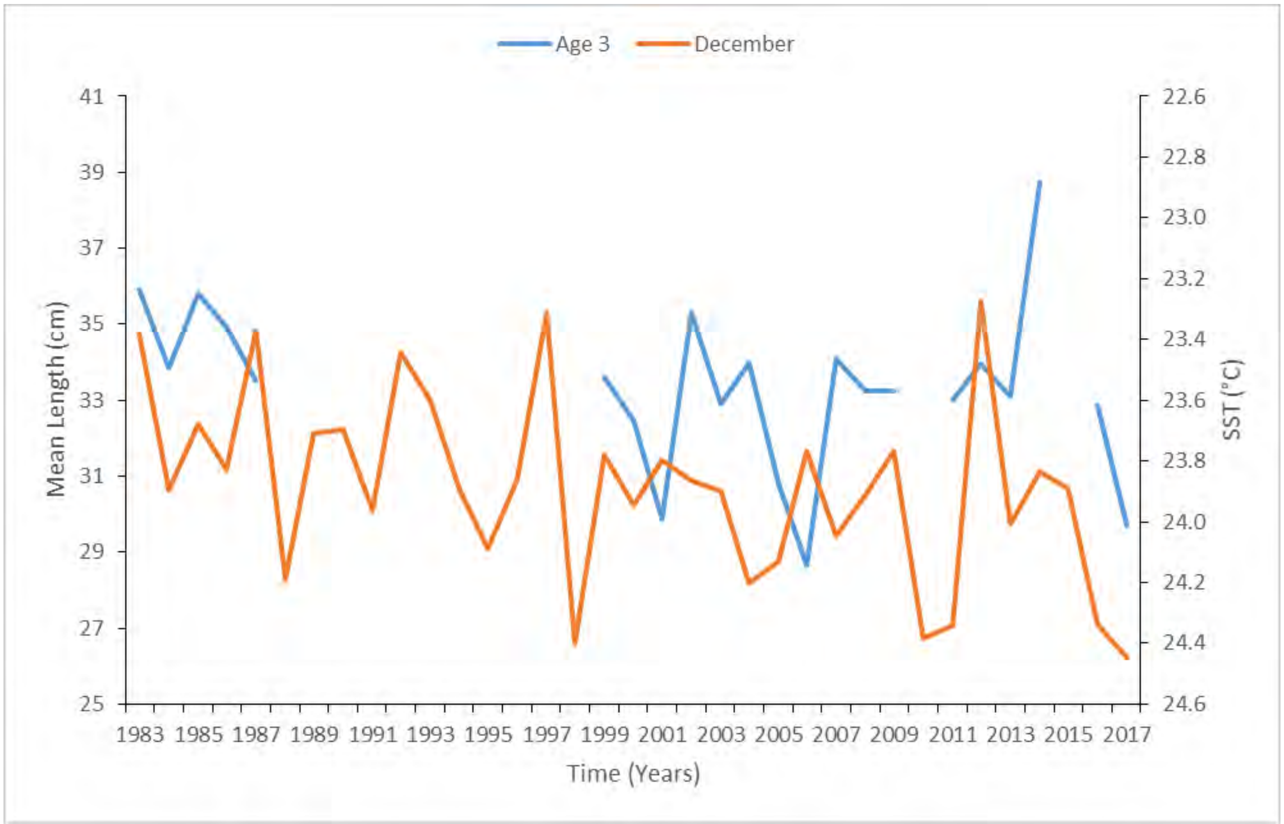

Figure A5: Annual mean length at age 3 for shallow-water Cape hake *M. capensis* (Namibian stock) from 1983 to 2017 and SST for December the previous year in South Africa 28° to 31°S and 14° to 16° E from 1982 to 2016.

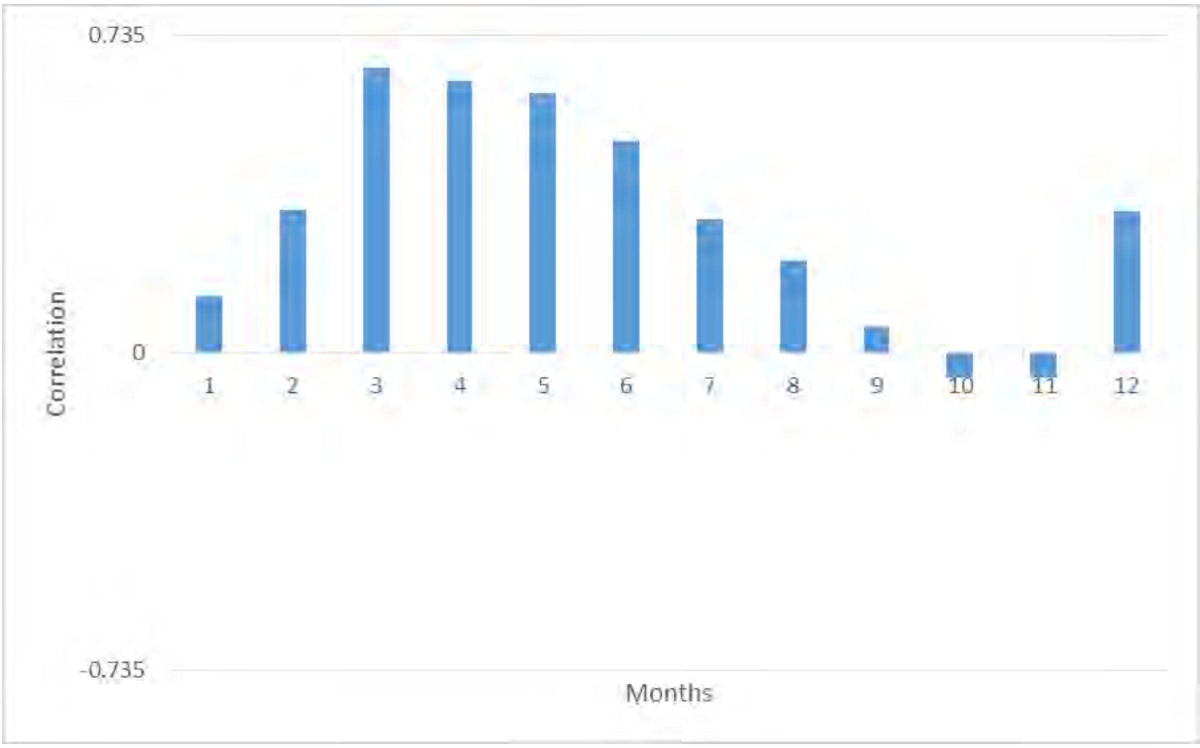

Figure A6: Correlation of annual mean length at age 3 for horse mackerel *T. capensis* (Namibian stock) from 1983 to 2017 and SST for all the months from the previous year in North: 17° to 20°S and 10° to 12° E from 1982 to 2017.

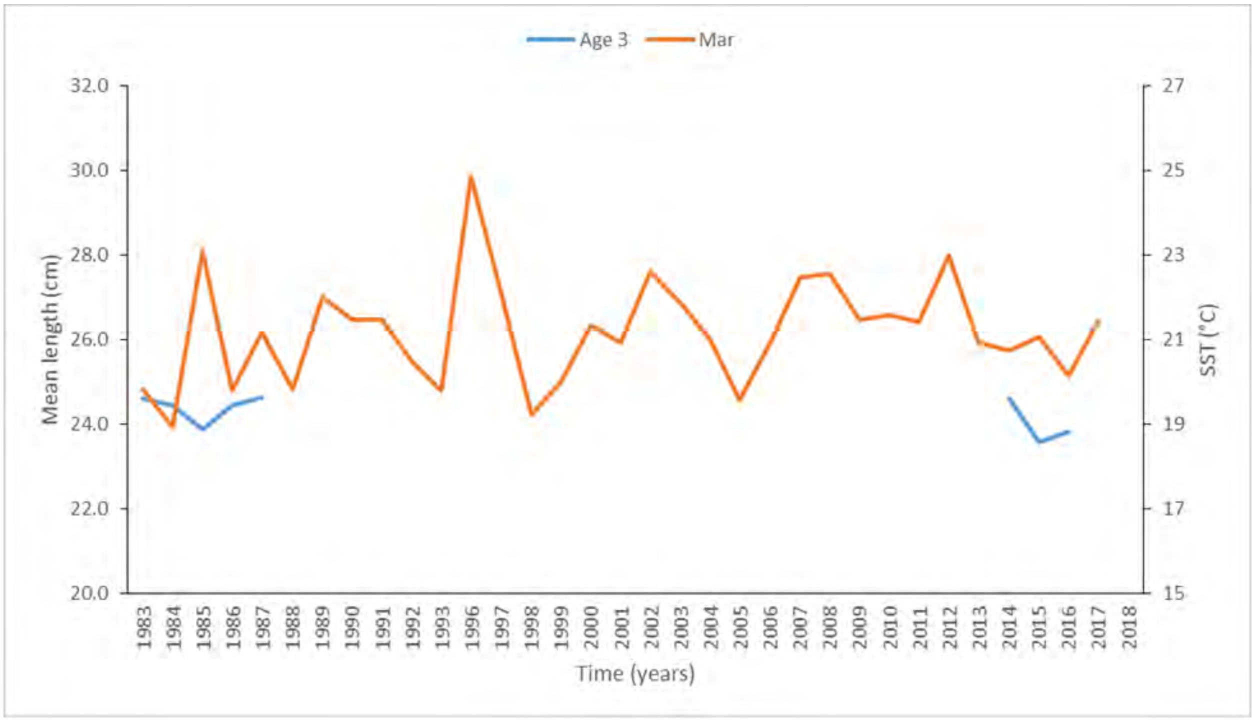

Figure A7: Annual mean length at age 3 for horse mackerel *T. capensis* (Namibian stock) and SST for March the previous year in North: 17° to 20°S and 10° to 12° E plotted against year.

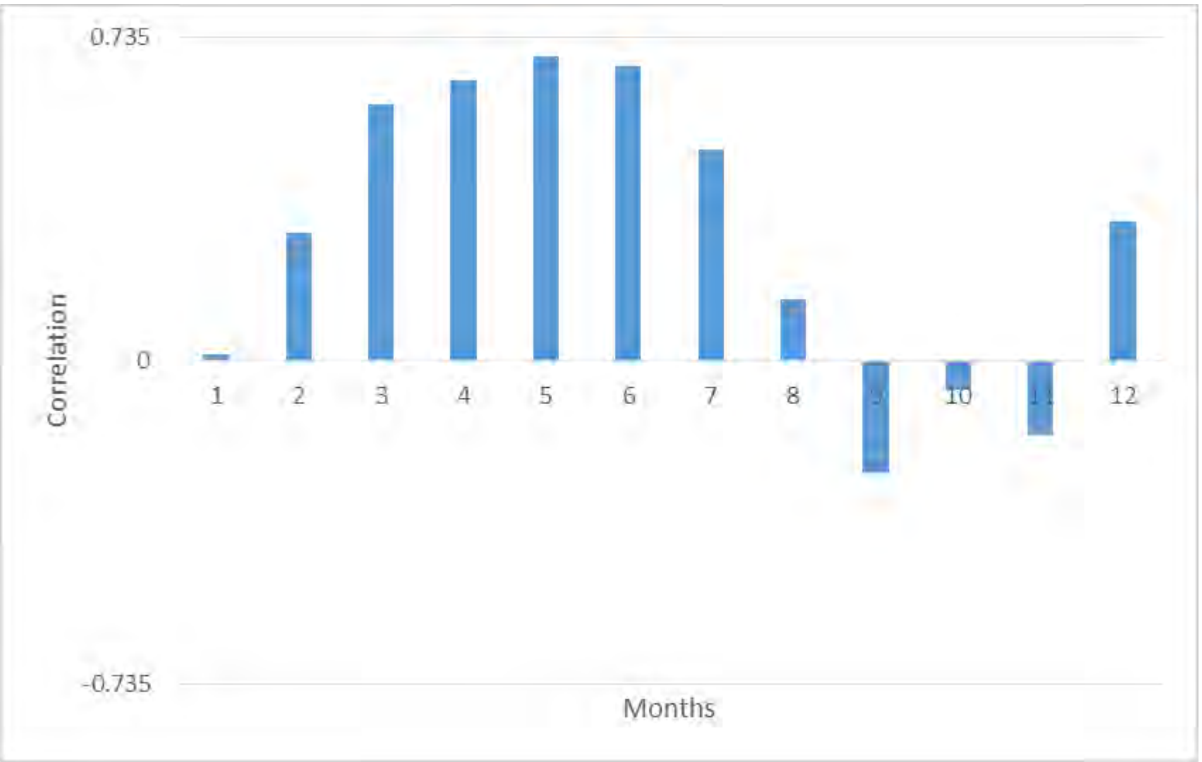

Figure A8: Correlation of annual mean length at age 3 for horse mackerel *T. capensis* (Namibian stock) from 1983 to 2017 and SST for all the months from the previous year in Centre: 20° to 24° S and 12° to 14° E from 1982 to 2017.

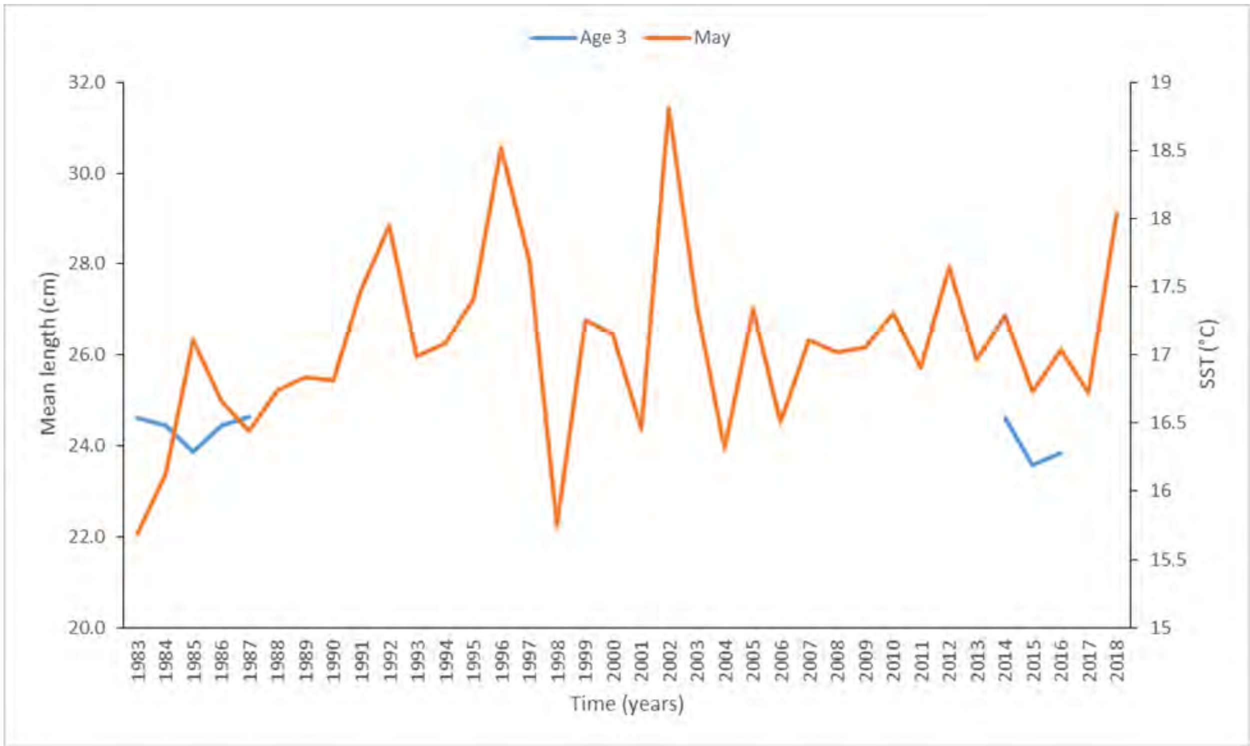

Figure A9: Annual mean length at age 3 for horse mackerel *T. capensis* (Namibian stock) and SST for May the previous year in Centre: 20° to 24° S and 12° to 14° E plotted against year.

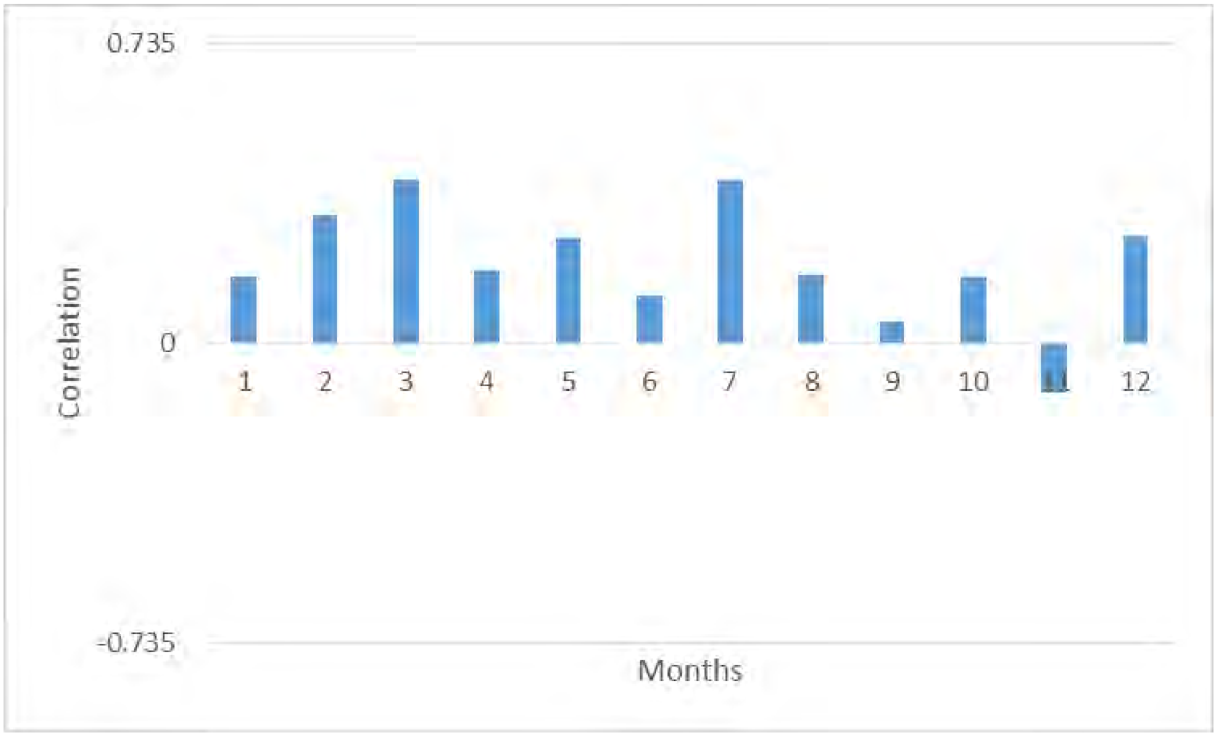

Figure A10: Correlation of annual mean length at age 3 for horse mackerel *T. capensis* (Namibian stock) from 1983 to 2017 and SST for all the months from the previous year in South 24° to 28° S and 13° to 15° E from 1982 to 2017.

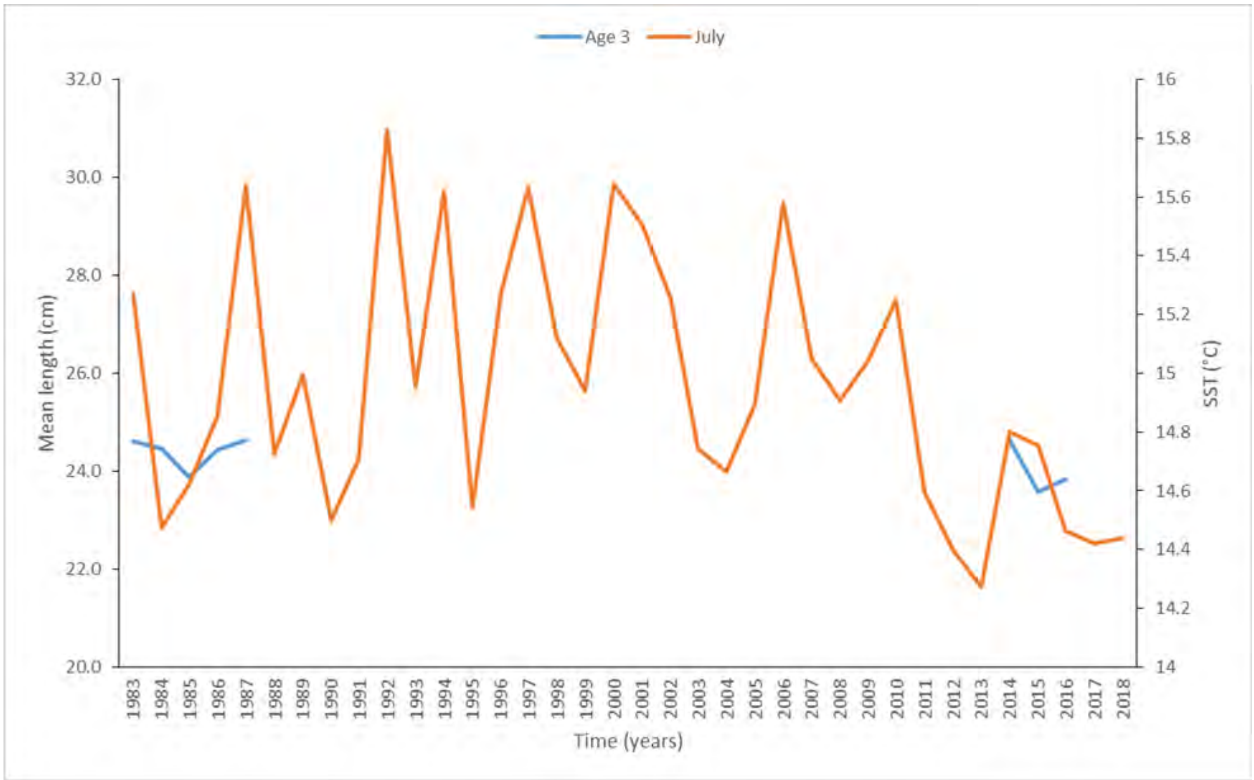

Figure A11: Annual mean length at age 3 for horse mackerel *T. capensis* (Namibian stock) and SST for July the previous year in South 24° to 28° S and 13° to 15° E plotted against year.

Figure A12: Correlation of annual mean length at age 3 for horse mackerel *T. capensis* (Namibian stock) from 1983 to 2017 and SST for all the months from the previous year in South Africa 28° to 31°S and 14° to 16° E from 1982 to 2017.

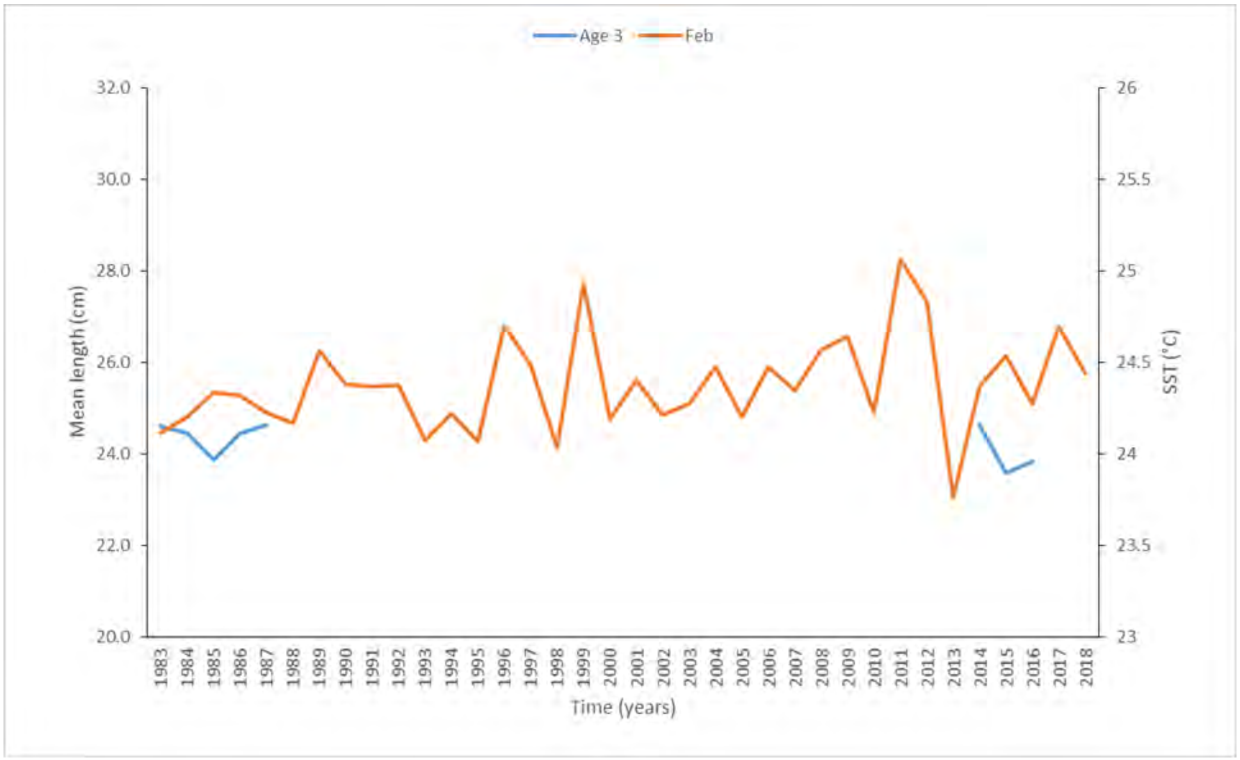

Figure A13: Annual mean length at age 3 for horse mackerel *T. capensis* (Namibian stock) and SST for February the previous year in South Africa 28° to 31°S and 14° to 16° E plotted against year.