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Assessment of some variables affecting demersal assemblages of the Angolan coast

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IMRs research vessel Dr. Fridtjof Nansen (Photo: Institute of Marine Research)

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Abstract

The globe is facing major problems with anthropogenic impacts such as human induced climate changes, a growing human population and a growing food and hunger problem. Since fish is of such a commercial importance, studies on functioning and monitoring of marine ecosystems are of great interest. In this study, I have assessed some variables that could affect the demersal assemblages and result in observable changes in demersal trawl catches off the continental shelf and upper slope of Angola, comparing catch data collected in 1989 and 2010.

Based on findings from an earlier study on trawl performance, it is assumed that both number per unit effort and weight per unit effort is likely to be influenced to some degree by upgrades in gear and more systematic methods that took place between 1989 and 2010.

Increase in number of species might be a result of spatial migrations, which can be caused by global warming. As well as more experienced taxonomists combined with improved gear on the research vessel RV Dr. Fridtjof Nansen probably have contributed to the increase.

Single-species analyses indicate southward shifts from 1989 to 2010 for many of the species.

Oil activity, in terms of oil installations, seem to have a positive effect on number of demersal species in deep waters (>550 m) off the continental shelf and upper slope of Angola. On depths shallower than 550 m number of species is highest in areas without oil activity.

Abstrakt

Kloden vår er sterkt preget av antropogene påvirkninger, som menneskeskapte klimatiske endringer, høy populasjonsvekst og en økende mat- og sultkrise. Siden fisk er av så stor kommersiell betydning globalt, øker interessen for å studere marine økosystemers funksjon og endringer over tid. I denne oppgaven har jeg prøvd å finne noen variabler som kan påvirke den bunn-levene faunaen utenfor kysten av Angola og gi merkbare endringer ved å sammenlikne fangst-data fra 1989 og 2010.

Basert på funn fra tidligere studier så konkluderes det med at antall per innsats og endringer i vekt per innsats, i noen grad, er en effekt av endringer trålingsutstyr og mer systematiserte metoder som fant sted mellom 1989 og 2010.

Den økte diversiteten i arter, med et høyere antall arter i 2010, kan være en effekt av migrasjoner fra lavere breddegrader mot høyere breddegrader som følge av klimaendringer. Samt at økt erfaring og høyere kunnskap hos taxonomene med tanke på artsbestemmelse, kan ha bidratt til noe økning av antall arter som fanges i bunntrålen.

Enkeltartanalysene indikerer at flere av artene har migrert sørover fra 1989 til 2010.

På dypt vann (>550 m) kan det se ut som oljeinstallasjoner har en positiv effekt på bunnlevende marine arter ved kysten av Angola. På grunnere vann (<550 m) er antall bunnlevende arter høyest i områder uten oljeinstallasjoner.

Glossary and abbreviations

Anthropogenic: Human made/resulting from human activity

Fluorescence: Emission of light by a light-absorbing substance. Here used for chlorophyll fluorescence, used as indication for concentration of phytoplankton in water

IMR: Institute of Marine Research

IPCC: Intergovernmental Panel on Climate Change

NA: Not Available

NPUE: Number per unit effort, i.e., number of fish per trawl hour. Not to be confused with number of species

Number of species: Measure for biodiversity in terms of species richness, in this case biodiversity of demersal assemblages of the continental shelf and upper Angolan slope

Oil activity: Oil activity in this study is refers to oil installations (Oil rigs), and no other activity associated with oil industry

UNEP: United Nations Environment Programme

WPUE: Weight per unit effort, i.e., total weight of fish per trawl hour

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Introduction

Ecosystems are the cornerstones of all life on earth, and they are essential to us because we rely on harvesting a great deal of resources from them, as well as we rely on other ecosystem services they provide (UNEP, 2005). The globe is facing major changes and challenges due to a variety of anthropogenic impacts threatening many of the world's ecosystems (UNEP, 2005). The marine ecosystems constitutes an invaluable part of these, and are crucial for life on earth (Hoegh-Guldberg and Bruno, 2010). Several variables affect marine ecosystems in different ways. Oceanographic processes such as ocean currents are important for composition of marine assemblages. Great faunal shifts may occur where currents with different chemical and physical properties meet (Bianchi, 1992). Salinity, depth/pressure, bottom type, and latitudinal gradients affect marine assemblages (Bianchi, 1992), as could temperature and concentration of dissolved oxygen (Koranteng, 2001). Light can also affect marine assemblages, both in terms of day-night variations (Carpentieri et al., 2005) and in terms of solar UV radiation and fluorescence (Häder et al., 2007).

In addition to natural occurring differences, anthropogenic impacts are of growing concern. Such impacts are altering marine ecosystems worldwide, and we know little about the long-term changes in the oceans compared to terrestrial ecosystems (Rosenzweig et al., 2008). According to the Fifth Assessment Report (AR5) several studies addressing anthropogenic climate changes within the last 45 years concludes that biotic and abiotic factors has increased greatly in their relation to regional climate changes (IPCC, 2014). Climate changes such as global warming seem to cause spatial shifts in marine ecosystems which is predicted to lead to higher extinction-rates and decreased species richness in tropic systems (IPCC, 2014). As a result marine fisheries are projected to get decreased catch potential in the tropics (IPCC, 2014). In addition, the growing human population is facing an increasing food and hunger problem (Cribb, 2010, FAO, 2012, Paul, 2010). Today fish is one of the most important sources of export by developing countries, and the European Union (EU) is the largest single-marked for imported fish and fishery products on a global scale (FAO, 2014b), accounting for 40% of the total fish import in 2010 (FAO, 2012). Still, capture fisheries does not satisfy the increasing global demand for fish (Casal, 2006). Some scientists predict that the global fisheries can experience collapse within the next 50 years if they are not made more sustainable (Worm et al., 2006). Overexploitation by humans have significant effects on global fish populations both from commercial harvest (Costello et al., 2008, Gordon, 1954), and recreational harvest (Cooke and Cowx, 2004). Overfishing seem to be the main reason for ecological extinction in coastal ecosystems caused by anthropogenic disturbances, even preceding climate changes (Jackson et al., 2001). Another important source of anthropogenic impact to marine ecosystems are the petroleum industry. Each year millions of gallons of oil reach marine and coastal ecosystems from different sources (Islam and Tanaka, 2004). Oil spills, ballast water from ships, and contaminated water from oil purification processes is released into marine ecosystems where much of it sinks to the bottom where it is deposited (Islam and Tanaka, 2004). After oil spills there have been found petroleum-related contaminants in fish bile 1 year after the spill (Krahn et al., 1993). On the other hand, different oil installations are also found to have positive environmental effects on some marine species as they can serve as artificial habitat and thus gives an increased abundance of certain fish species (Martin and Lowe, 2010, Scarcella et al., 2011). In Angola the exploitation of oil started in Cabinda in 1966 (Serigstad, 2009). However, the Angolan oil industry was in a structuring phase from 1974-1995, and the National Society of Fuels of Angola (SONANGOL) divided the Angolan continental shelf in Blocks from 1979 (Serigstad, 2009).

Because of the high pressure on marine ecosystems from anthropogenic impacts it is important to study and monitor fish populations around the globe. To monitor anthropogenic impacts on marine assemblages, it is important to have some basic information about the natural variables that could affect these assemblages. In general, number of studies on observed trends in different environments in relation to regional climate changes has increased greatly over the last years (IPCC, 2007). However, developing countries show a marked scarcity on data and literature on observable changes in physical and biological environments (IPCC, 2007). Because of this, further studies and monitoring of fish populations is important for a better understanding of anthropogenic effects on global fish communities and their ecology. Single-species analyses are also important for a better understanding off species ecology and how a species respond to changes, as well as to monitor temporal changes in abundance. Because of the scarcity on data and literature on observable changes in different environments, these types of studies should be especially important in developing countries.

Exploitation of commercial fisheries started in Angola in the 1950s, and had a stable growth until the Angolan independence in 1975 (ITC, 2003). The independence resulted in a great relapse of fish catches, until 1987 when Angola resorted to foreign fleet (ITC, 2003). Along the Angolan coast the commercial fishing used to be concentrated mainly in the South-western parts of Namibe, Tombua and Lucira, as well as port of Lobito in the Benguela province (ITC, 2003). Today this is still the case for pelagic commercial fisheries, while the demersal trawl fisheries are localized along the coast. There have been conducted fisheries-independent trawl surveys on the continental shelf and upper slope to monitor demersal fish, shrimp and cephalopod assemblages since the 1980s (Axelsen and Johnsen, 2014). Angolan coastal waters are part of the large Benguela current system, which is rich in biomass because of its nutrient-rich water with high primary productivity (Hutchings et al., 2009, Shannon and Nelson, 1996, Shannon and Pillar, 1986). In recent years there have been found regime shifts in the system (Cury and Shannon, 2004), but it is not well known what effects climate changes will have on the system (Hays et al., 2005). Also, the demand for fish products, along with other animal products in developing countries are expected to increase with increasing populations and income, together with urbanization and dietary diversification (FAO, 2014b). This could mean increased fishing pressure in Angola, which has already been under high pressure for several years (Bianchi, 1992). In this study, I have analyzed and tried to assess some variables that could affect the demersal assemblages and result in observable changes in demersal trawl catches off the continental shelf and upper slope of Angola, comparing catch data collected in 1989 and 2010.

Materials and methods

Description of study area

The study area, is located off the continental shelf and upper slope of the Angolan coast (Figure 1). This area covers about 800 nautical miles of the Angolan coastline and stretches between Congo River in the North (S06°00') and to Cunene River in the South (S17°14'). There was little trawling in the area between Tombua (S16°00') and Benguela (S12°40') because of the steep shelf edge that makes bottom trawling difficult.

Several oceanographic features impacts Angolan waters all year round. From the north flows the Angola current, which is an extension of the Guinea Current that flows southeast along the West African coast from Guinea. The Guinea Current is situated off the Angolan shelf (Figure 2). The coast of Guinea experience two warming events of varying year-to-year intensity during the year, a strong warming around austral fall and winter (April-July) and a weaker warming around late austral spring and early summer (November-December) (Richardson and Walsh, 1986, Yamagata and Iizuka, 1995). Seasonal winds favor an accumulation of the warm water in the eastern end of the Gulf of Guinea, which then flows southward along the West African coast, intensifying the meridional temperature gradient in the northern parts of the Angolan coast (around 10°S) (Yamagata and Iizuka, 1995). The southern parts of the Angola current always meets the northward flowing Benguela current (Figure 2),and makes up a frontal zone (the Angola-Benguela front) between Tombua and Cunene (Lass et al., 2000). The Angola-Benguela frontal zone extend westward into the Atlantic ocean with an average width of 200 km during most of the year, normally with higher fluctuations during the austral fall (Lass et al., 2000). Though the Angola-Benguela front have normally been situated at about 15°S in recent years (Lass et al., 2000), so called Benguela Niños causes abnormal climate conditions and force the front southward from its normal position, it has been observed as far south as 23°S (Shannon et al., 1986). The front experience a great variability in interannual and seasonal features, and also in a smaller scale, both in temporal and spatial variations (Lass et al., 2000), for more detailed information see Lass et al. (2000). And it is especially prominent during the austral spring, when warm equatorial water from the Angola current moves southwards (Yamagata and Iizuka, 1995). The front is also usually located further south during the austral summer (Shannon et al., 1987).

Cold surface water from the Benguela current extends northwards all through the year, but is somewhat diluted in the northern areas of the West African coast during the boreal fall and winter, as the warm equatorial water from the Angola current flows further south in this period (Yamagata and Iizuka, 1995), for more detailed information see Yamagata and Iizuka (1995). In the upper 50 m of the Angola-Benguela front there is clear differences in the temperature and salinity gradients (Lass et al., 2000). Most of the Angolan coast, from the north and all the way to Tombua have a seasonal upwelling, while the Benguela current gives an almost permanent upwelling to the area south of Tombua (Bianchi, 1992). After a weak seasonal upwelling starting in December-January, the emergence of the first seasonal downwelling finds place at the Angolan coast around March, before a new upwelling emerge in July-August followed by a another downwelling around October (Ostrowski et al., 2009). The water masses from the Benguela current is rich in nutrients (Lass et al., 2000) and thus contributes to nutrient enrichment in Angolan waters. The Angola gyre (also known as the Angola Dome) which lies off the Angolan coast, normally located around 10°S (Yamagata and Iizuka, 1995), is also a source of nutrient enrichment to Angolan waters. The Angola gyre contains South Atlantic Central Water which is high in nutrients and has a low level of oxygen, these water masses undergo upwelling to the Angolan shelf, and moves southward during the austral summer (Mohrholz et al., 2008). This contributes to nutrient enrichment and thus high productivity in this area (Ostrowski et al., 2009). There is a shift of water flow in the southern areas of the Angolan coast during the austral winter, as the Angola dome ceases (Yamagata and Iizuka, 1995), and oxygen rich Eastern South Atlantic Central Water starts moving northwards in this period (Mohrholz et al., 2008). During the period March- August the dome is cooled (Yamagata and Iizuka, 1995). Near the Equator and in major parts of the tropical south Atlantic, surface waters are warmest around March-April and coldest around August (Hirst and Hastenrath, 1983). In the period March-April there is an appearance of negative sea surface temperature anomalies of the Angolan coast (Nobre and Srukla, 1996). Bottom temperatures south of Tombua are normally lower than 20°C (Shannon et al., 1987).

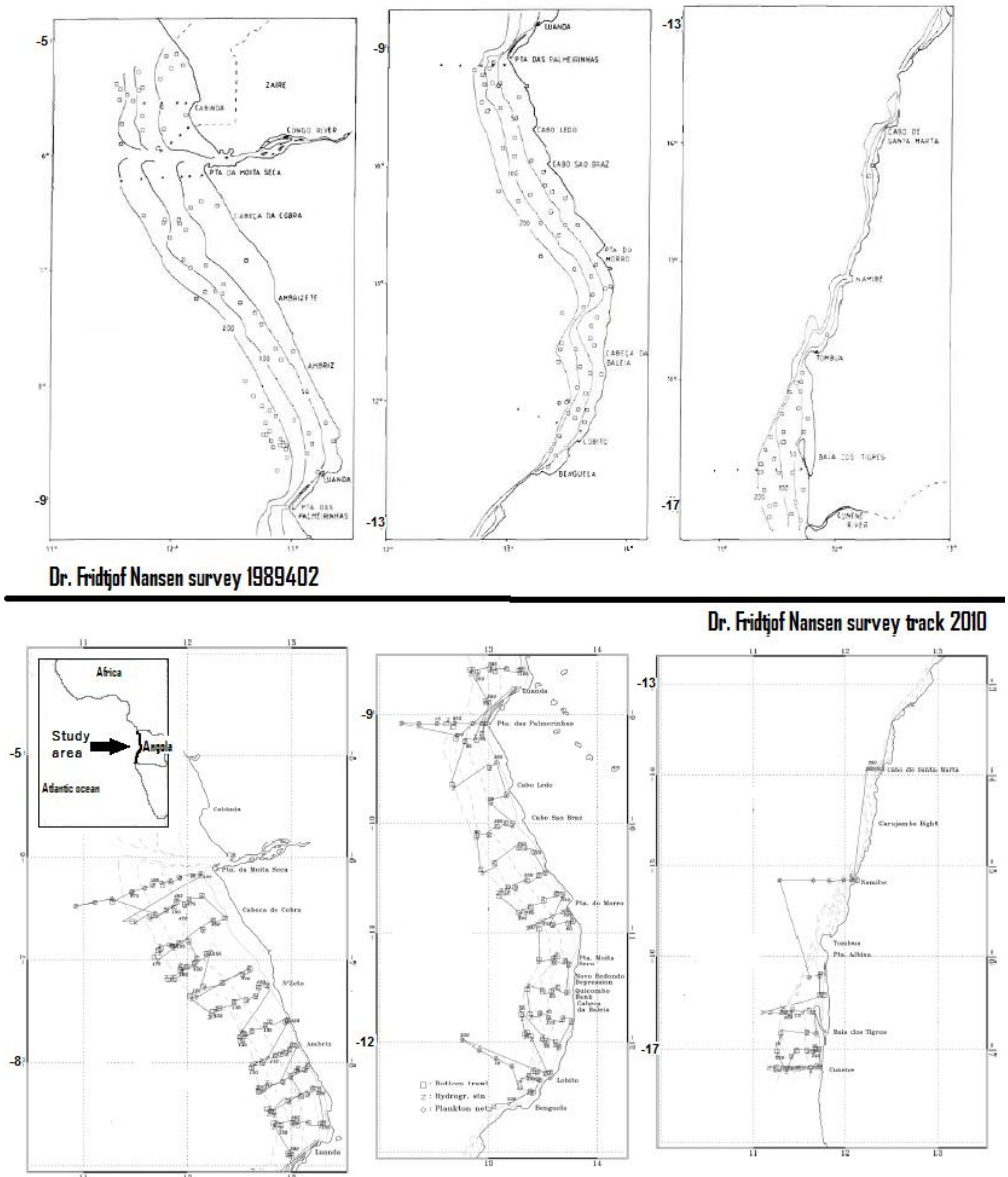


Figure 1. Map over study area with Congo River in the North (S06°00') and Cunene River in the South (S17°14'). The top three maps show the trawl track with towing stations for the 2010 survey. The bottom three maps show the towing stations for the 1989402 survey. Left maps = northern area, middle maps = central area, right maps = southern area (Map: 1989: Bianchi (1992), map 2010: Krakstad et al., (2010)).

Surface currents and sea surface temperatures play a major role for the precipitation patterns off the Angolan coast (Reason and Rouault, 2006, Yamagata and Iizuka, 1995). The annual wind cycles shows less wind stress from September-November until February-March (Hirst and Hastenrath, 1983). There is a concentration of precipitation in Angola around March-April (Hirst and Hastenrath, 1983, Shannon et al., 1986). Several months with heavy rainfall, as well as the continuous rain causes the rivers to deposit larger amounts of fresh water into the sea, causes the sea surface salinity in these areas to fall around this period (UNEP, 1984). As the northernmost parts of Angola lies close to the equator these areas have a tropical climate and enjoy rain most of the year. Because of this, as well as increased runoff with fresh water from the Congo river, there is a sharp halocline in the northern areas to Punta das Palmeirinhas (Bianchi, 1992). There are several rivers running into the Atlantic Ocean along the coast of Angola (Figure 3), particularly important because of their size is the Congo River in the north, the Cuanza River situated just south of Luanda and the Cunene River situated on the southern Angolan border to Namibia. These rivers are important because they have an effect on salinity and sea surface temperature (Carton, 1991).

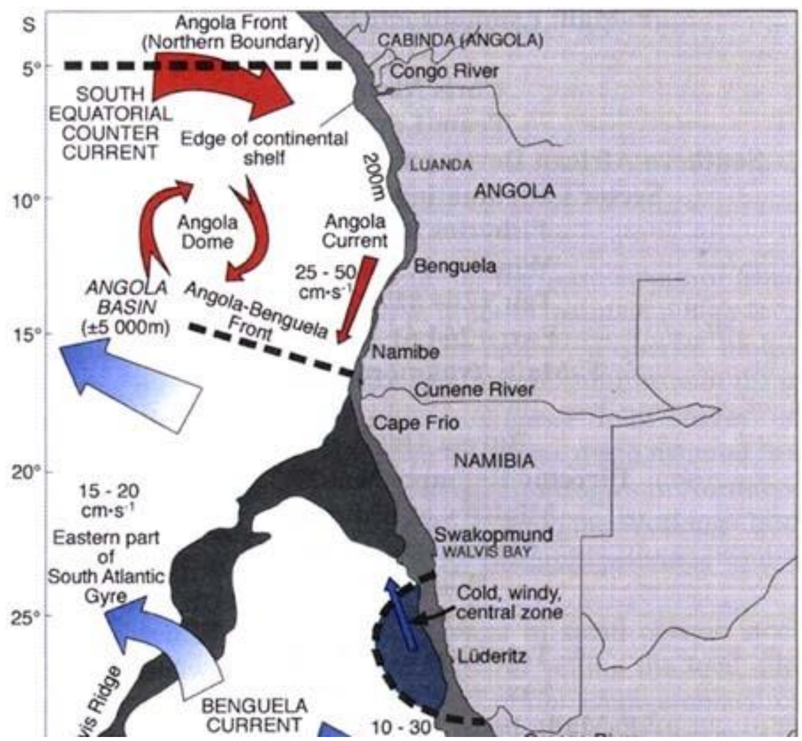


Figure 2. Currents off the continental shelf and upper slope off Angola. The cold Benguela current moves northwards from South Africa and along Namibia before it meet the hot Equatorial waters in the Angola current. (Map: Sumalia et al., FAO)

As seen in Figure 3, there are several towns and cities along the Angolan coast. There are national regulations prohibiting the large national and international fishing vessels to fish within 12 nautical miles from the coastline (Lankester, 2002). However, it is uncertain whether this requirements are met or not (Lankester, 2002). The area closest to the coast is reserved for artisanal fishing, while the coastal zone beyond this area is open for large-scale industrial and semi-industrial fishing from both national and international actors (Lankester, 2002).

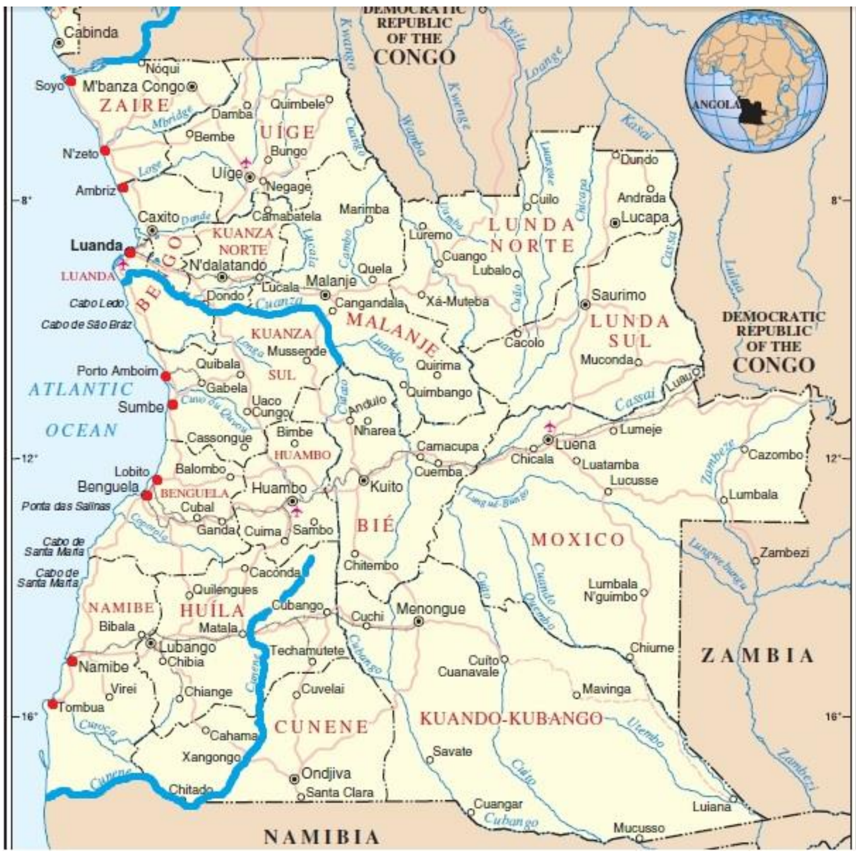


Figure 3. United Nations map of Angola showing the rivers that run off in the Atlantic, and the three major rivers Congo River, Cuanza River and Cunene River is highlighted with blue lines. Cities and towns at the coast are highlighted with red dots (Map: UN).

There is a concentration of oil fields north of Ambriz (around 08°00’). Most of the petroleum activities at sea are located in these northern areas, as the oil fields around Luanda are on land (Figure 4).

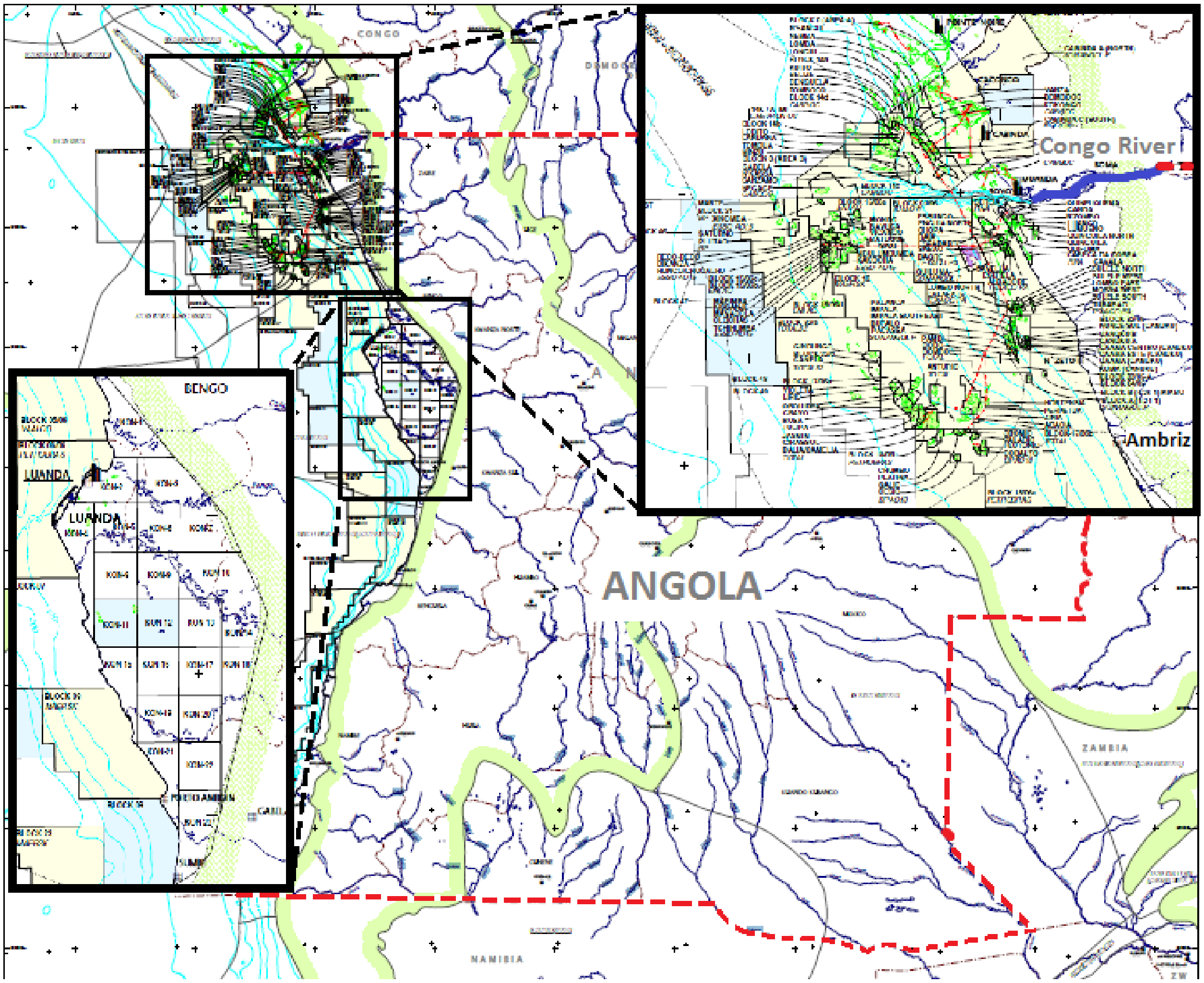


Figure 4. The major petroleum sites in Angola (highlighted areas), shows a clear concentration of petroleum activity in the northern parts of the coast, north of Ambriz. There is also some petroleum activity in the areas around Luanda, but these are on land (Map: IHS).

Data collection, gear and data (pre)processing

Depth and area were used as stratifying variables in a stratified semi-random survey design, i.e. the distance between transects is relatively fixed and stations are depth stratified. Stations that were not trusted to give a valid reflection of the true density of demersal assemblages were recorded as unsuccessful. (Krakstad et al., 2010). The species of interest are the marine assemblages caught in bottom trawl within the study area during two surveys in 1989 and one survey in 2010.

Collection of biological data

The trawl data from 1989 was collected during the austral summer season, in the period 13.02.1989-29.05.1989 (1989402: 13.02.1989-16.03.1989, and 1989403: 23.04.1989-29.05.1989). In total, 418 stations were conducted in the same region as in 2010, from which at least 4 were considered unsuccessful because of damage to the trawl gear. The average tow duration for each of the two surveys in 1989 was 35 min, ranging from 3 min to 67 min. The shrimp and fish trawl used was a Gisund super 2-panel bottom trawl (Sætersdal et al., 1999). While the trawl doors were Waco combi type (Axelsen and Johnsen, 2014). Otherwise the method and gear used during the two surveys in 1989 was similar to that used in 2010 (see below), only somewhat less standardized in 1989. For more detailed information see Bianchi (1992).

The biological data from 2010 was collected by a new vessel also called Dr. Fridtjof Nansen during the wet season in the period 03.03.10-30.03.10. In total, 191 trawl stations were conducted, in which 188 were successful and three were considered unsuccessful. The same type of trawl as in 1989, Gisund super bottom trawl, was used, however the doors were of the Thyborøn' combi type (see figure 1 and 2 in appendix). To allow catch of smaller fish, a fine meshed (10 mm mesh size) inner lining was used inside the cod-end. The distance between the front parts of the wings during towing was estimated to 18.5 m at a speed of 3 knots. To keep a more constant distance between trawl doors in deeper waters a 9 m constraining rope was attached 120 m in front of the trawl doors at stations deeper than 80 m, and at stations deeper than 300 m it was used a 44 m long tickler chain on the foot rope to improve the catches of shrimp. Door and trawl height sensors logged data for all tows. The standard duration time for all tows was, as in all earlier cruises, 30 min. However some towing stations had a diverging duration time due to interruptions by either too high catches, or due to unsuitable bottom conditions, resulting in a range of tow duration from 3 min – 32 min with an average duration time of 27.8 min for all tows in 2010. SCANMAR sensors were used to control the trawling start time by detecting when the trawl hit the bottom, and the stop time was defined as the time the net was lifted off the bottom.

Trawl stations shallower than 300 m were usually conducted during daytime, while deeper stations were conducted after dark to reduce the effect of dial migration on the catches. Samples from the catches were taken for species composition by numbers and weight. The specimen body length was measured to the nearest whole cm. Each of the specimen caught was identified to the lowest taxonomic level possible by experienced taxonomists, and then counted and weighed separately. When congeneric species where hard to separate they were pooled together. For species identification the FAO species identification sheets for fishery purposes, Fishing Areas 34/47 (Fischer and Scott, 1981), the WoRMS database (WoRMS Ed. Board, 2000), the Eschmeyer database (Eschmeyer and Fricke, 2000) and the FishBase (Froese and Pauly 2000) were used. For more detailed information of gear and methods see the cruise report from 2010 (Krakstad et al., 2010) or Sætersdal et al. (1999).

Collection of hydrographical data

In 2010, the CTD data were collected by use of a seabird 911 plus CTD probe which was equipped with a temperature sensor (SBE 3plus), an fluorimeter (Aqua tracka MK 111), a conductivity sensor (SBE 4C) and a oxygen sensor (SBE 43). CTD data contains measurements of temperature, fluorescence, salinity and oxygen. Samples were taken at standard depths, a few meters above the bottom, and along fixed transects. A Seabird Seasave software was used for real time plotting and logging of this data. For more details see Krakstad et al. (2010).

In 1989 the hydrographic data were collected by use of Nansen bottles. The hydrographic data contains measurements of salinity, temperature, oxygen and depth. These samples were taken at standard depths, and along fixed transects. For more details see Bianchi (1992) or Sætersdal et al. (1999)

Species used in single-species analyses

Single-species analyses were performed on three different groups of species. These were commercially important pelagic species, commercially important demersal species and non-commercial common species. A list of all species used in single-species analyses is provided in appendix.

Commercial pelagic species:

Note that the species referred to as pelagic in this study are not necessarily pelagic per se, rather they have ecological traits such as a life-cycles or seasonal migrations that naturally interfere with their appearance in demersal trawl.

Figure 5. *B. auritus* (Photo: O. Alvheim. IMR)

The bigeye grunt *Brachydeuterus auritus* is around 23 cm long (Bianchi, 1986). This species is common and abundant in coastal areas and from 10-100 m of depth and it is of commercial importance (Bianchi, 1986). The species typically have a semi-pelagic schooling pattern in shallow, intermediate water depths (20-50m).

Figure 6. *C. atlanticus* (Photo: O. Alvheim. IMR)

The Atlantic greeneye, *Chlorophthalmus atlanticus*, is a small pelagic marine fish (size: around 25 cm) affiliated with deep water as well as in the surface layers on the continental shelf (Bianchi, 1986). *C. atlanticus* is commercially fished by trawlers off the Angolan coast (Bianchi, 1986).

Figure 7. *C. chrysurus* (Photo: O. Alvheim. IMR)

The Atlantic bumper, *Chloroscombrus chrysurus* is a small (size: around 20 cm) pelagic species found widespread on the shelf, both in marine and brackish waters (Bianchi, 1986).
C. chrysurus is a shoaling species, which is commercially fished by the use of different towing gear and gill nets (Bianchi, 1986).

Figure 8. *S. officinalis* (Photo: O. Alvheim. IMR)

Common cuttlefish, *Sepia officialis* is found from the surface waters to around 200 m depth (mantle rarely exeeds 40 cm) (Bianchi, 1986). This species is occasionally caught by trawlers off the Angolan coast (Bianchi, 1986). There have been found seasonal migrations in all stocks, mainly between deeper and shallower waters (Roper et al., 1984).

Figure 9. *S. orbignyana* (Photo: Arias M. A.)

Pink cuttlefish, *Sepia orbignyana* has a mantle around 12 cm, it is common in waters of 50-450 m depth (Bianchi, 1986). The species is mainly caught by the use of bottom trawl (Bianchi, 1986). *S. orbignyana* uses a wide bathymetric depth range (Barratt and Allcock, 2012).

Figure 10. *T. trecae* (Photo: O. Alvheim. IMR)

The Cunene horse mackerel, *Trachurus trecae,* is a commercially very important species (around 35 cm long), it is a pelagic species that is affiliated with coastal waters and the shelf break (Bianchi, 1986). *T. trecae* is abundant along all of the Angolan coast, and it is found from the surface waters to the bottom (Bianchi, 1986).

Commercial demersal species:

Figure 11. *B. barbata* (Photo: O. Alvheim. IMR)

The adult bearded brotula, *Brotula barbata*, is a bentopelagic species living down to 650 m depth on the continental shelf and slope (Nielsen and R, 1999), while the juveniles are pelagic

(Bianchi, 1986). *B. barbata* is a common species, and is often fished by trawlers between 50 to 300 m depth (Bianchi, 1986).

Figure 12. *D. angolensis* (Photo: O. Alvheim. IMR)

The Angola dentex, *Dentex angolensis*, is a common species of the Angolan coast, and it can reach a size of 35 cm, more normal around 25 cm (Bianchi, 1986). Normal range is from 15-300 m of depth, and it is often fished by trawlers between 70-250 m (Bianchi, 1986). *D. angolensis* feeds on other fish, crustaceans, worms and molluscs (Bianchi, 1986).

Figure 13. *D. macrophthalmus* (Photo: O. Alvheim. IMR)

The large-eyed dentex, *Dentex macrophthalmus*, is a very common species of the coast of Angola, normally around 24 cm (Bianchi, 1986). The species is affiliated with sandy or rocky bottoms, where adults feed on fish and crustaceans, while the young feed on plankton (FAO, 2014a). *D. macrophthalmus* follows a seasonal migration according to hydrographic conditions in certain areas and to their stages of life (FAO, 2014a).

Figure 14. *G. decadactylus* (Photo: Frans Noyelle)

The lesser African threadfin, *Galeoides decadactylus*, is a demersal species, normally around 30 cm (Bianchi, 1986). It normally ranges from 10-70 m of depth and its distribution ranges from Morocco to Angola, as well as it sporadically occurs in Namibia (Daget and Njock, 1986). *G. decadactylus* is common in brackish waters and close to river mouths (Bianchi, 1986).

Figure 15. *M. polli* (Photo: O. Alvheim. IMR)

The benguela hake, *Merluccius polli*, is a bathydemersal species, normally around 40 cm long (Cohen et al., 1990). It feeds on small fishes, squids and shrimps. The species is commonly found from 50-550 m of depth , but it has been discovered on depths around 900 m (Lloris et al., 2005). *M. polli* is fished between 50-450 m of depth, and 200-400 m of depth like juveniles and adults respectively (Bianchi, 1986).

Figure 16. *P. bellottii* (Photo: O. Alvheim. IMR)

The red Pandora, *Pagellus bellottii* is a schooling species, its size ranges from around 25-42 cm, and it is abundant along the Angolan coast (Bianchi, 1986). *P. bellottii* normally ranges down to 250 m depth, and it is often fished in depths between 25-100 m (Bianchi, 1986).

Figure 17. *U. canariensis* (Photo: O. Alvheim. IMR)

The canary drum, *Umbrina canariensis* is an abundant species, they are commonly around 40 cm long (Bianchi, 1986). It lives on sandy and muddy bottoms, from 15-300 m depth where it feeds on small invertebrates, worms and shrimps (Bianchi, 1986). *U. canariensis* is often fished with trawl gear and other traditional fishing gear, normally between 25-200 m depth (Bianchi, 1986).

Common non-commercial demersal species:

Figure 18. *C. linguatula* (Photo: O. Alvheim. IMR)

The spotted flounder, *Citharus linguatula* is a common species of the Angolan coast. It is normally around 20 cm long, and it is found on soft bottoms all the way from the shoreline until around 300 m of depth (Bianchi, 1986).

Figure 19. *N. africanus* (Photo: O. Alvheim. IMR)

The African spider shrimp, *Nematocarcinus africanus* can reach a maximum size of 10.4 cm, and is common in depth ranges from 200-700 m (Bianchi, 1986).

Figure 20. *R. miraletus* (Photo: O. Alvheim. IMR)

The brown ray, *Raja miraletus* (also known as the twineye skate) is a common species along the Angolan coast (Bianchi, 1986). Its size is around 60 cm, and it is found in sandy and muddy bottoms in the depth range of 50-150 m where it feeds on different kinds of benthic animals (Bianchi, 1986).

Figure 21. *S. microlepis* (Photo: O. Alvheim. IMR)

The thinlip splitfin, *Synagrops microlepis* is a common and abundant species of the Angolan coast (Bianchi, 1986). It is around 16 cm, and it is normally found in the depth range of 100-500 m (Bianchi, 1986).

Figure 22. *Y. blackfordi* (photo: Matsuura K.)

Yarrella Blackfordi is a bathypelagic species, which is normally under 33 cm long (Quéro et al., 2004). Depth range is around 350-1000 m (Quéro et al., 2004). The species lives on or near the bottom, and is mainly associated with rocky and sandy bottoms (Quéro et al., 2004).

Statistical analysis

The main research aims in this study was to quantify effects from spatial (latitude and bottom depth), temporal (1986 VS 2010) and environmental factors (temperature and salinity) on some selected species' (mentioned above) Number Per Unit Effort (mean number of individuals in catch per hour), and Weight Per Unit Effort (mean catch-weight in kg, per hour) – and to quantify effects from petroleum installations. In addition to analyses on aggregated data (i.e., total NPUE and WPUE, number of species).

Because the catchability coefficient is unknown, it was assumed that all the fish within the path of the trawl is caught. This gives a catchability coefficient (q) that equals 1. Between surveys the catchability coefficient is assumed to be constant, and therefore changes in population abundance between surveys will be reflected by the swept-area estimates. It is assumed for the purpose of this study that there is no day-night effect on catches. Trawl catches were conducted during all hours a day in all three surveys.

Aggregated data was analyzed by fitting ordinary linear models to the data with ln-transformed response variables if needed, to secure variance homoscedasticity. These models followed the same Akaike Information Criterion (AIC) (Akaike, 1974) -based model selection routes as described for ZIP-modelling (see below). AIC-values serves as a tool in model selection, they provide measures of the balance between model precision and model bias – aiming at favoring models with few parameters (the principle of parsimony). In model selection the model with the lowest AIC-value is the most supported among the candidate models. While the lm-procedure in R was used to fit linear models. I used Analysis of variance (ANOVA) to compare NPUE, WPUE and number of species for all three surveys. When performing one-way ANOVA tests on survey effects on NPUE, WPUE and number of species, a Welsh-ANOVA approach was undertaken as it allows for unequal variances among compared groups (Sokal and Rohlf, 1995). Tukey's Honest Significant Difference post hoc tests (Tukeys HSD) were performed to explore pairwise between-survey differences (Sokal and Rohlf, 1995). Tukeys HSD, allows multiple comparison of data, and was the tool used to test for significance between surveys. These tests were performed using the oneway.test-procedure in R.

In order to secure variance homogeneity both values of NPUE and WPUE along with some of the predictor variables were ln-transformed (Sokal and Rohlf, 1995). Because oxygen and fluorescence is just relative measurements, they do not necessarily reflect the actual oxygen and fluorescence values. Because of this, I have not included these variables in the oil-effect analyses.

Because occurrence of zero-catches was larger than expected, a zero-inflate Poisson (ZIP) modelling approach was undertaken (Lambert, 1992, Zuur et al., 2012). Since catch processes inevitably involve count data the underlying response distribution is a Poisson distribution. There are many reasons why a given trawl haul ends up with no catches of a given species, e.g., patchy distributions of schools or migrations, and because of this the data often ends up with more zeros than expected from true Poisson processes (Lecomte et al., 2013). Technically, species-specific deviations from Poisson distributions were assessed by testing whether plain intercept Poisson models explained less variation than similar-structured ZIP models using a Vuong test (Vuong, 1989). The ZIP approach always came out as superior in these tests (p<0.0001). ZIP models explicitly model factors affecting zero-observations as a probability process (i.e., logit-linked generalized linear models, GLM) and non-zero observations as a Poisson process (i.e., log-linked GLM). Therefore, ZIP models include two sub-models where the count data are made conditional on the probability of not observing zero values. The applied ZIP approach produced the following likelihood function (i.e., the likelihood of a single observation):

$$l(y|\mathrm{x},\mathrm{z},\beta,\gamma) = P(\mathrm{z}'\gamma)I(y=0) + [1-P(\mathrm{z}'\gamma)]\, f(y|\mathrm{x}'\beta)$$

, where z represents the vector of zero-observation covariates, γ represents the corresponding coefficients; x is the count covariate vector and β the corresponding coefficients. *P* represents the cumulative distribution function, fitted to specify the $y>0$ outcome, and *f* represent the probability mass function corresponding to the count model (here the Poisson distribution).

Model selection was undertaken by using AIC-values. After finding the most supported predictor variables to include in the model, backwards selection was used to find the detailed model structure (Zuur A. F. et al., 2009). Model selection was considered to be reflected by the zero-inflation model, and was performed in two steps where the capture process was modeled prior to the count data modelling. This was motivated by recommendations in the mark-recapture modelling literature (Lebreton et al., 1992). The most supported zero-inflation model structure was sought by fitting candidate models under a fully year*latitude*bottom depth count model part. After establishing the most supported zero-inflation model structure, the previously described model selection route was followed for the Poisson model part. The ZIP-modelling was performed using the zero-inflation-procedure in the pscl-library in R (Team, 2013).

In single-species oil analyses I also used model selection by means of AIC. The most supported model for each species used in analyses were corrected for salinity and temperature. Salinity and temperature were corrected for by fitting different variations of the most supported model, adding salinity and temperature. I did not correct for oxygen and fluorescence, because measurements of these variables were not considered accurate enough. I also removed depths where oil and no-oil activities were not registered, so it would not affect the models range. As well as I customized the model predictions to each species' depth-range.

To determine what areas along the Angolan coast there have or have not been petroleum activities I used an IHS map for global exploration & production service which contains the status of Carto Data and IRIS21 databases on 16 Oct 2007. First, I marked the areas where it was petroleum installations only in 1989, and then the areas where it was only/also petroleum installations in 2010. I did this by using different colors for both years, determining it by overlapping maps in the same map scale. In these analyses I have assumed that all petroleum installations without a given year is from the same year as the first mentioned year above in the IHS map year row. Except the ones where year is not available (NA). Trawl sites from areas where year is not available is excluded from the analyses. As there was a severe lack of stations in areas which were considered as areas with petroleum activity from 1989, I decided to exclude 1989 from the oil analyses. Areas south of S07°55’ were also excluded from the oil analyses, as there is no petroleum installations off the Angolan coats south of this latitude. Note that petroleum installation and no petroleum installation sites are referred to as oil activity and no oil activity respectively from now on.

Results

NPUE

Analysis of variation among transects shows that NPUE varied between 0 and 1 941 000 (62 560±212 245.5, mean±SD) in 2010, between 2 and 757 400 (28 130±80 414.28) in the 1989402 survey and between 5 and 1 437 000 (34 210±109 692.5) in the 1989403 survey. A one-way ANOVA and a corresponding post-hoc contrast test (Tukey HSD) suggests there is no significant difference in NPUE among any of the three surveys (ANOVA: $F_{2,598}=2.189$, $p=0.113$, Figure 23).

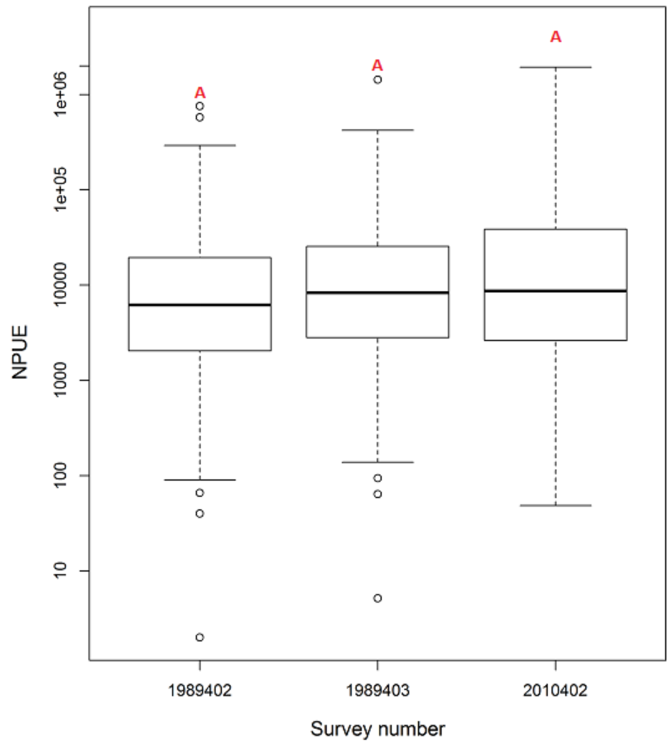


Figure 23. Boxplot of survey-specific number of species per station with corresponding one-way ANOVA test statistics and Tukey HSD statistics (indicated as letters). Surveys with the same letter are not statistically different, suggesting there is a significant effect of survey number on number of species caught in 1989 and 2010. Note that the y-axis is log transformed.

WPUE

WPUE varied between 8.4 kg and 40 000 kg (792.1± 3 235, mean±SD) in the 1989402 survey, between 0 kg and 15 999.4 kg (706.3±1 351.2) in the 1989403 survey, and 0 kg and 62 325.2 kg (1 480±5 337.2) in the 2010402 survey. A multiple comparison test (Tukey HSD) indicates the 1989402 survey and the 2010402 survey differs significantly in WPUE, while neither of the two surveys differ significantly from the 1989403 survey (Figure 24). These results are illustrated in a boxplot of survey-specific WPUE with corresponding one-way ANOVA test statistics (ANOVA-test $p < 0.005$, see Figure 24).

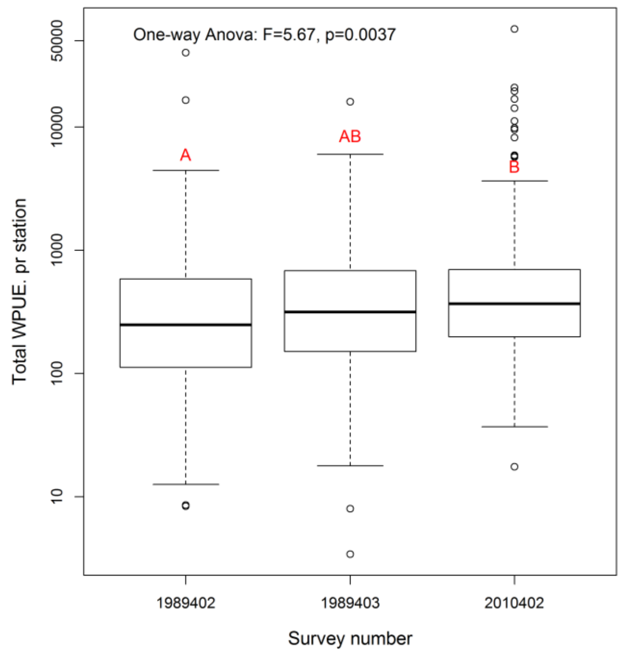


Figure 24. Boxplot of survey-specific number of species per station with corresponding one-way ANOVA test statistics and Tukey HSD statistics (indicated as letters). Surveys with the same letter are not statistically different, suggesting there is a significant difference between the 1989402 survey and the 2010402 survey. Note that the y-axis is log-transformed.

Number of species

Catches from both surveys in 1989 (1989402 and 1989403) resulted in a total catch of 387 different species. While the total number of species caught in 2010 was 397. Analysis of variation among transects shows that the number of species caught per station varied between 1 and 30 (13.54±5.09) in the 1989402 survey, between 1 and 30 (14.11±5.20) in the 1989403 survey, between 7 and 39 (24.11±6.90) in the 2010 survey. A one-way ANOVA and a corresponding post-hoc contrast test (Tukey HSD) suggests there is a significant difference in number of species between the 1989-surveys (1989402 and 1989403) and the 2010402 survey (ANOVA: $F_{2,596}$=204.65, p<0.0001, Figure 25).

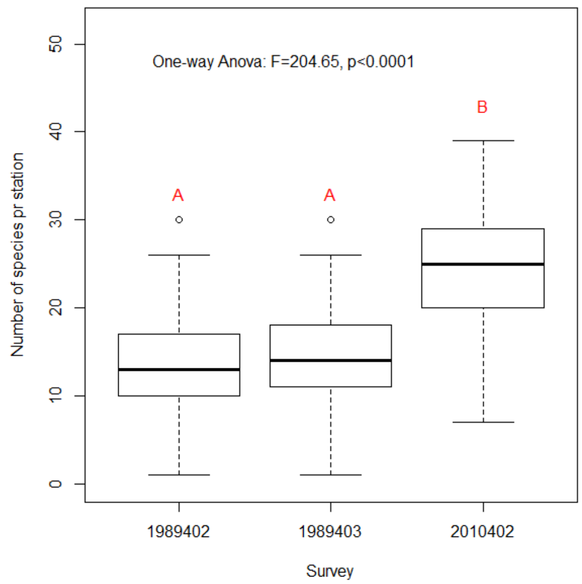


Figure 25. Boxplot of survey-specific number of species per station with corresponding one-way ANOVA test statistics and Tukey HSD statistics (indicated as letters). Surveys with the same letter are not statistically different, suggesting there is a significant effect of survey number on number of species caught in 1989 and 2010.

Latitude effect on number of species

Results from model selection of latitude effect indicate that the favored model has marginal lower AIC-values than the second most supported model (Table 1). A multiple comparison test for number of species indicates no significant difference between the two surveys in 1989 (Figure 25). Since the second most supported model gives an effect of survey instead of year, I have only included the results for the most supported model, despite the marginal difference in AIC-values from the second most supported model. The most supported model included a significant year*latitude effect ($p_{year*latitude}<0.0001$, Table 2). An ANOVA of the most supported model indicates the effect of latitude is statistical significantly different between years (Table 2). Further, a prediction plot with year*latitude effect indicates that number of species increases corresponding to lower latitudes (Figure 26A), meaning number of species increases from Cunene in South (S17°14') to Congo River in North (06°00'). The random pattern of residuals support a linear relationship of bottom depth effect (Figure 26B).

Table 1. AIC-ranking for the best ZIP-models used to explore if number of species is affected by latitude off the continental shelf and upper slope of the Angolan coast. All models are probided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Model	df	AIC	∆AIC
Year * Latitude	5	3739.102	0
Latitude * Survey number	7	3739.249	0.147
Latitude + Survey number	5	3765.097	25.995
Survey number	4	3802.202	63.1
Latitude	3	4082.670	343.568
1	2	4111.357	372.255

Table 2. Parameter estimates and explanatory level of Latitude effect and effect of year for the most supported model from model selection. (Intercept) = year 1989, Latitude = Latidude 1989. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 Residual standard error: 5.459 on 595 degrees of freedom Multiple R-squared: 0.4682, Adjusted R-squared: 0.4655 F-statistic: 174.6 on 3 and 595 DF, p-value: < 2.2e-16.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	15.99543	0.86665	18.457	< 2e-16 ***
Year 2010	17.85217	1.55653	11.469	< 2e-16 ***
Latitude	0.20660	0.07975	2.591	0.00981 **
Year 2010:Latitude	0.76834	0.14669	5.238	2.26e-07 ***

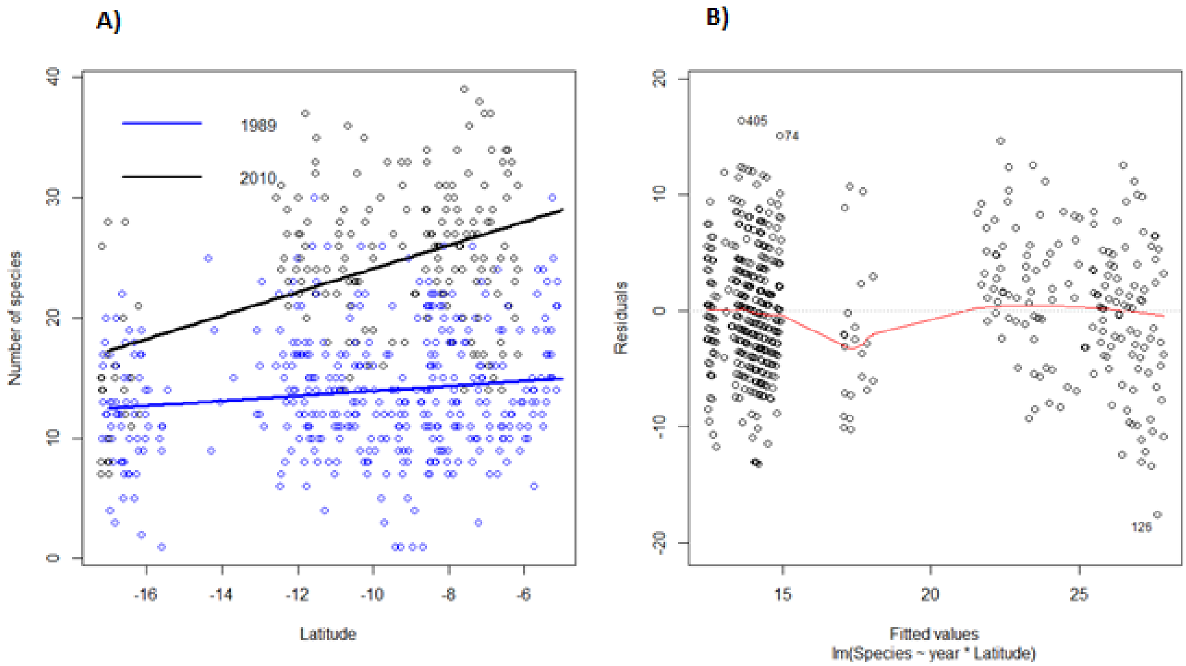


Figure 26 A) Prediction plot of the favored model from model selection suggests an increasing linear relationship of number of species with decreasing latitude for both years, the effect is clearly strongest in 2010. Lines represent the estimated number of species in relation to latitude, while dots represents the actual number of species in each trawl station for both years. Blue = 1989, black = 2010. **B)** Corresponding residuals with fitted values for prediction for Figure 26 A) suggests a linear relationship between year and latitude.

Bottom depth effect on number of species

Overall bottom depth differed from 9-800m (157.4±176.5). Results from model selection indicates the favored model includes a year*bottom depth effect (Table 3), this effect is significant ($p_{year*bottom\ depth}$=0.0185, Table 4). An ANOVA of the favored model shows that the effect of bottom depth is statistically significant different between years ($p<0.05$, Table 4). Prediction plot and parameter estimates of the most supported model shows that number of species increases corresponding to greater bottom depths (Figure 27A), further, they indicate a steeper slope and thus a greater effect of bottom depth in 2010 compared to 1989. The random pattern of residuals support a linear relationship of bottom depth effect (Figure 27B). The second most supported model gives an effect of surveys instead of year (Table 3).

Table 3. AIC-ranking for the most supported ZIP-models used to explore if number of species is affected by bottom depth off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Model	df	AIC	Δ AIC
Year * Bottom depth	5	3779.418	0
Bottom depth * Survey number	7	3782.244	2.826
Bottom depth + Survey number	5	3783.689	4.271
Survey number	4	3802.202	22.784
Bottom depth	3	4061.882	282.464
1	2	4111.357	331.939

Table 4. Parameter estimates and explanatory level of Bottom depth effect and effect of year for the favored model in model selection. (Intercept) = year 1989, Bottom depth = Bottom depth 1989. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 Residual standard error: 5.645 on 595 degrees of freedom. Multiple R-squared: 0.4283. F-statistic: 150.3 on 3 and 595 DF, p-value: < 2.2e-16.

	Estimate	Std.Error	t value	Pr(>|t|)
(Intercept)	13.525613	0.380448	35.552	<2e-16 ***
Year 2010	8.611491	0.687446	12.527	<2e-16 ***
Bottom Depth	0.002598	0.002006	1.295	0.1958
Year 2010: Bottom depth	0.006393	0.002706	2.362	0.0185 *

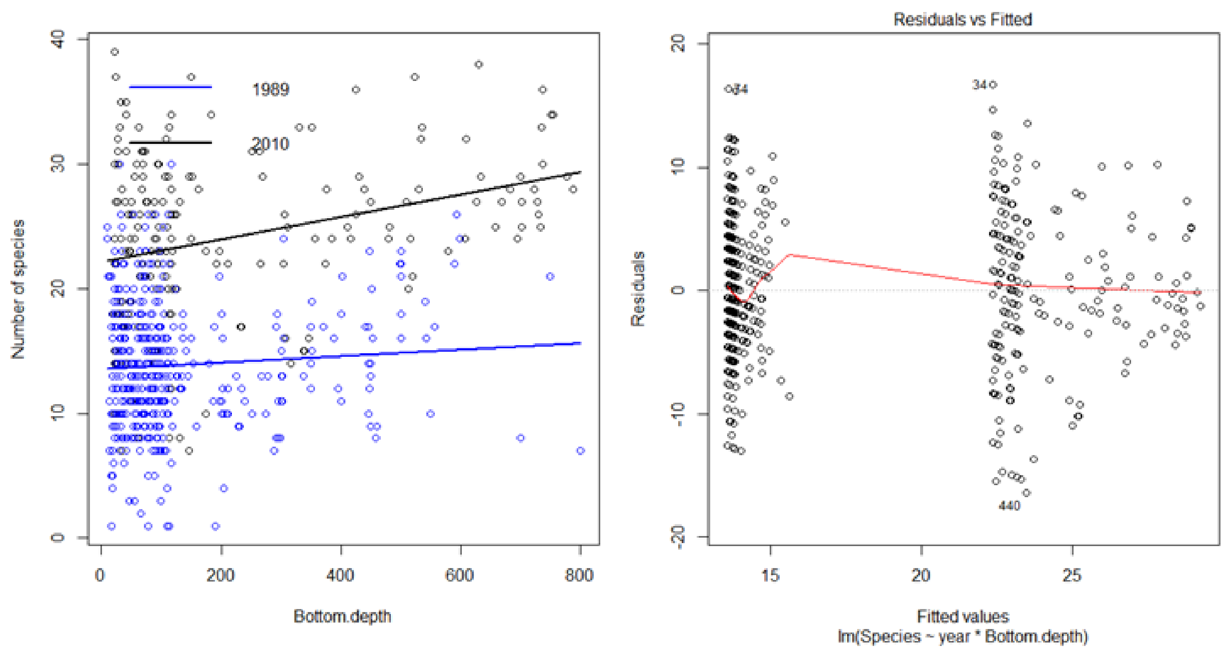


Figure 27 A) Prediction plot of the favored model suggests an increasing linear relationship of number of species with increasing bottom depth for both years. Lines represent the estimated number of species in relation to bottom depth, while dots represent the actual number of species in each trawl station for both years. Blue = 1989, black = 2010. **B)** Corresponding residuals with fitted values suggests a linear relationship between year and bottom depth.

Single-species analyses

Commercial pelagic species:

Because pelagic species might not be caught representatively in a demersal trawl as a result of them mainly being caught in shallow waters, results for these species are provided in the appendix. Results from model selection favored a model with significant interaction between latitude^2, bottom depth and year on NPUE for most species (see appendix). The *C. chrysurus* were the exception, where despite the same model favored in model selection, would not give any parameter estimates because the given model for *C. chrysurus* received an error. The cause of error is unknown. For scatter plots and prediction plots for these species, see appendix.

Commercial demersal species:

Brotula barbata

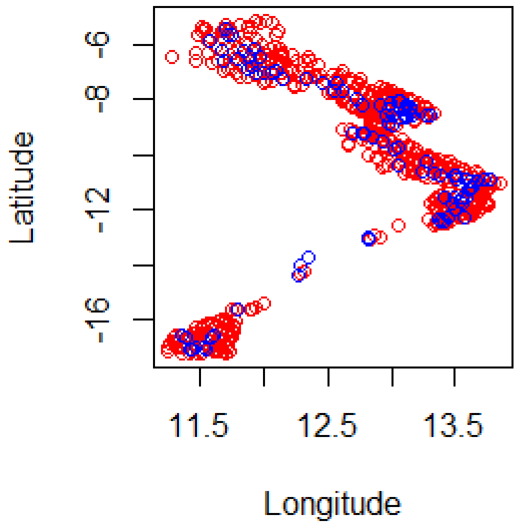


Figure 28. Scatter plot showing overall catch distribution of *B. barbata* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *B. barbata* is caught in patches in semi-deep waters all the way from Congo River in the north (06°00') to Cunene River in the South (S17°14') (Figure 28). *B. barbata* was not caught in trawl at greater bottom depths than 300 m. There is a small area a bit north of 16°00' where *B. barbata* is absent from trawl catch, before it is caught again close to the borders of Namibia and Cunene River. *B. barbata* is not caught in trawl at greater bottom depths than 400 m.

Model selection favored a model with a significant interaction effect between latitude^2, bottom depth and year ($p_{latitude^2*year*bottom\ depth}<0.0001$, table 13 in appendix) on NPUE of *B. barbata* (Table 5, full table with all fitted models and corresponding AIC-values for all single-species analyses are provided in appendix), for parameter estimates of favored model see table 13 in appendix. The interaction effect between latitude and bottom depth on NPUE of *B. barbata* is different between 1989 and 2010 (table 13 in appendix). A prediction plot for this model is provided in showing that the NPUE of *B. barbata* in 1989 increase from 1 to 100 towards deeper waters in a small area in the northcentral parts of the study area, between 09°00'-10°00'and in bottom depths greater than 250 m (Figure 29). South of 11°00' there is a shift in trends where *B. barbata* shows a clear decrease in NPUE towards deeper waters while NPUE increases towards shallow waters in 1989. The tendency increases south of 14°00' and in bottom depths shallower than 80 m. In 2010 there is a decrease in NPUE of *B. barbata* towards deeper waters along the whole study area, from 06°00' to 13°00' NPUE of *B. barbata* is totally absent (Figure 29). In the southern parts of the study area, south of 14°00', there is still an increase of NPUE of *B. barbata* in bottom depths shallower than 80 m in 2010 in the same way as in 1989.

Table 5. AIC-ranking for the 5 most supported ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *B. barbata* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values.
df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
$Latitude^2$ * Bottom depth * Year	Year	14	3878.304	0
$Latitude^2$ * Bottom depth	Year	8	4452.802	574.498
$Latitude^2$ * Bottom depth + Year	Year	9	4454.465	576.161
$Latitude^2$ * Bottom depth	1	7	4493.834	615.53
$Latitude^2$ * Bottom depth	Latitude	8	4495.809	617.505

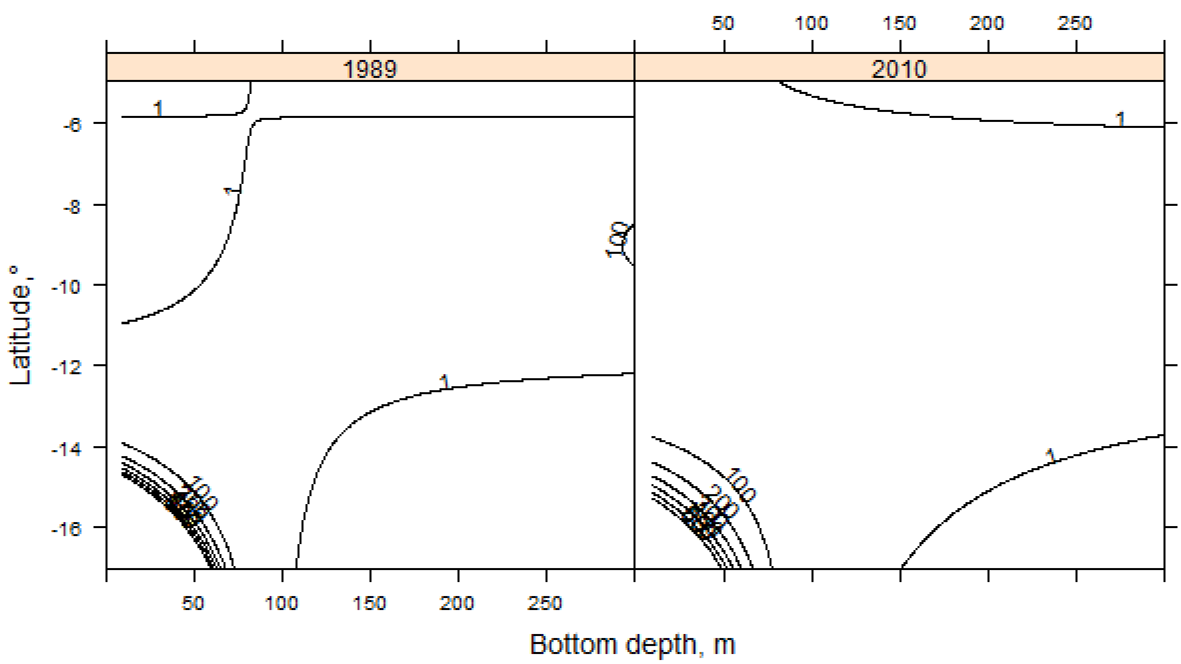


Figure 29. Predictions of NPUE for *B. barbata* as function of latitude and bottom depth for 1989 and 2010. NPUE is illustrated with contours and numbers. The model predictions were retrieved from parameter estimates provided in table 13 in appendix.

Dentex Angolensis

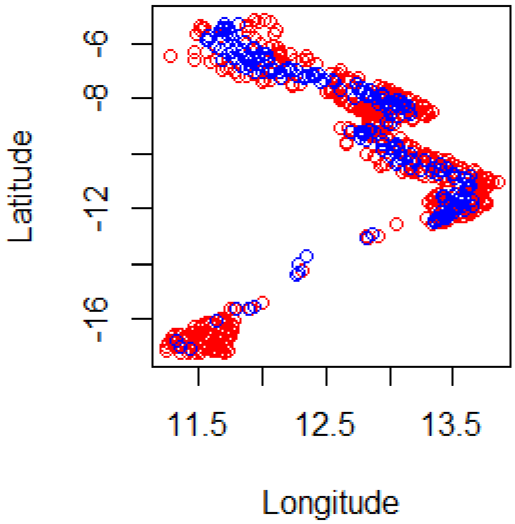


Figure 30. Scatter plot showing overall catch distribution of *D. angolensis* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *D. angolensis* is caught in high abundance between the deepest and the shallowest waters from the north to the central parts of the study area (Figure 30). There seem to be a decrease in catch rate of *D. angolensis* in south from the central parts of the study area. In the southernmost parts of the study area there is a small area where *D. angolensis* is absent from trawl (Figure 30). *D. angolensis* is not caught in trawl at greater bottom depths than 300 m.

Model selection favored a model with a significant interaction effect between latitude^2, bottom depth and year ($p_{latitude^2*year*bottom\ depth}<0.5$, table 15 in appendix) on NPUE of *D. angolensis* (table 14 in appendix). The interaction effect between latitude and bottom depth on NPUE of *D. angolensis* is different between 1989 and 2010 (table 15 appendix). A prediction plot for this model is provided in (Figure 31), showing that the NPUE of *D. angolensis* in 1989 increase towards deeper waters in the northern parts of the study area, in bottom depths greater than 140 m (Figure 31). In the southern parts of the study area and on bottom depths shallower than 90 m, *D. angolensis* shows an increase in NPUE towards shallower bottom depths and towards Cunene River in the south. NPUE of *D. angolensis* is moderate on bottom depths greater than 140 m. In 2010 there increase in NPUE of *D. angolensis* in the north is low and concentrated to a narrower latitudinal limit compared to 1989 (Figure 31). Also, NPUE of *D. angolensis* increases towards north and shallower bottom depths in the northernmost parts of the study area. There is still an increase of NPUE of *D. angolensis* towards shallower bottom depths in the southern parts of the study area in 2010, however this tendency starts on shallower bottom depths and stretches further north compared to in 1989 (Figure 31).

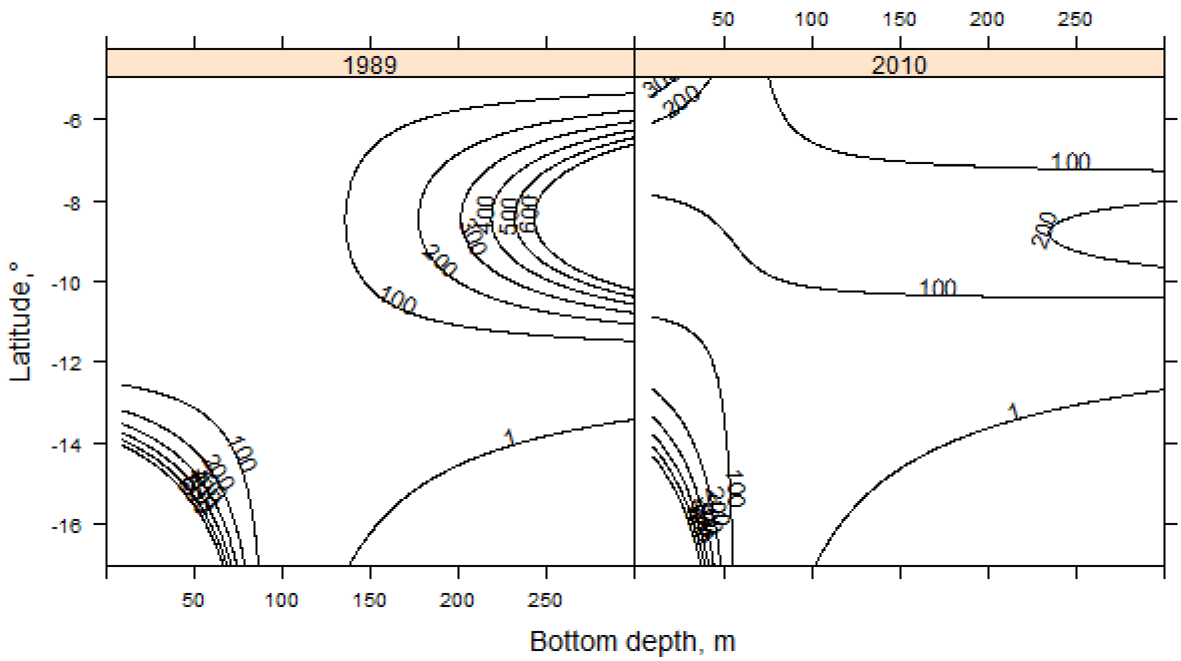


Figure 31. Predictions of NPUE for *D. angolensis* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model provided in appendix. Contours show estimated NPUE as number of *D. angolensis* individuals per trawl session. The model predictions were retrieved from parameter estimates provided in table 15 in appendix.

Dentex macrophthalmus

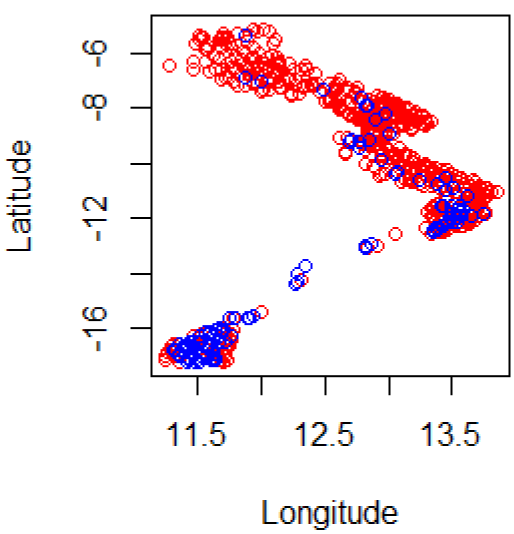


Figure 32. Scatter plot showing overall catch distribution of *D. macrophthalmus* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *D. macrophthalmus* has a low patchy catch rate in the northern parts of the study area (Figure 32). The catch of *D. macrophthalmus* shows a steady increase from the north to south in the study area, being almost completely absent from trawl catch in the northernmost parts of the study area to a high catch in the southernmost parts of the study area (Figure 32). *D. macrophthalmus* is not caught in trawl at greater bottom depths than 300 m.

Model selection favored a model with a significant interaction effect between latitude^2, bottom depth and year ($p_{latitude^2 * year * bottom\ depth} < 0.0001$, table 17 in appendix) on NPUE of *D. macrophthalmus* (table 16 in appendix). For parameter estimates of favored model see table 17 in appendix. The interaction effect between latitude and bottom depth on NPUE of *D. macropthalmus* is different between 1989 and 2010 (table 17 in appendix). A prediction plot for this model is provided in Figure 33, showing that the NPUE of *D. macrophthalmus* increases from the central parts of the study area and towards south in 1989. This increase in NPUE seems to be slightly shifted towards the deeper bottom depths compared to shallower bottom depths of *D. macrophthalmus* catch limit (Figure 33). In 2010 this tendency remains, only relocated further south compared to in 1989. In addition, the NPUE of *D. macrophthalmus* increases in shallow bottom depths in the northernmost parts of the study area, while there is a modest occurrence in NPUE at greater depths in 2010 (Figure 33).

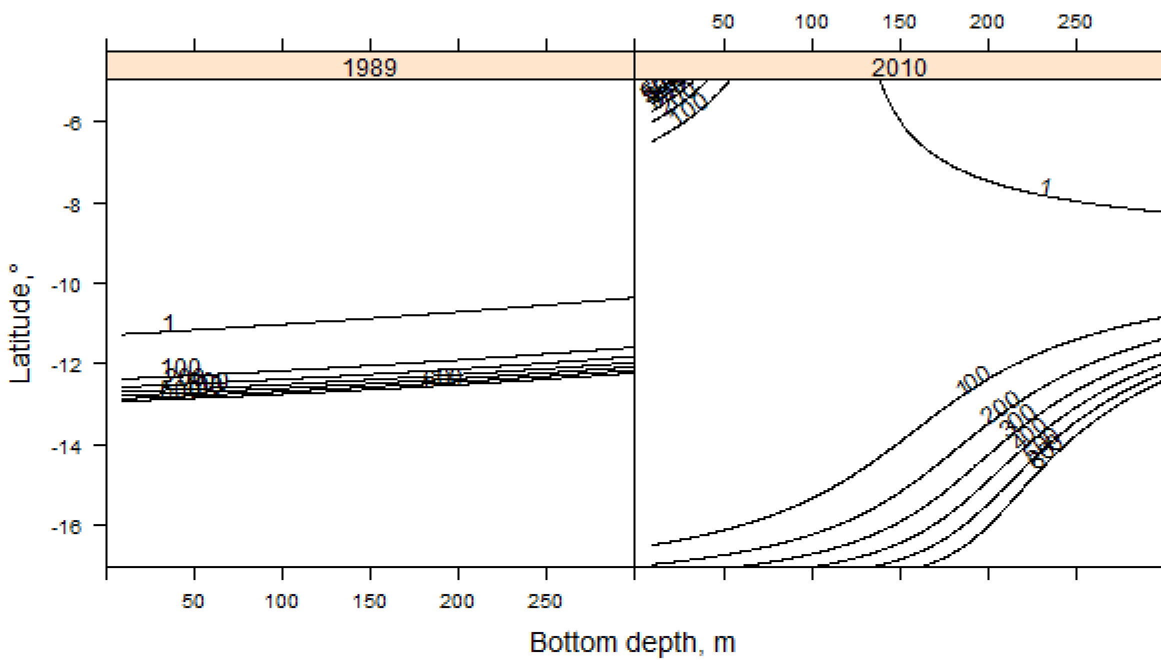


Figure 33. Predictions of NPUE for *D. macrophthalmus* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model provided in appendix. Contours show estimated NPUE as number of *D. macrophthalmus* individuals per trawl session. The model predictions were retrieved from parameter estimates provided in table 17 in appendix.

Galeoides decadactylus

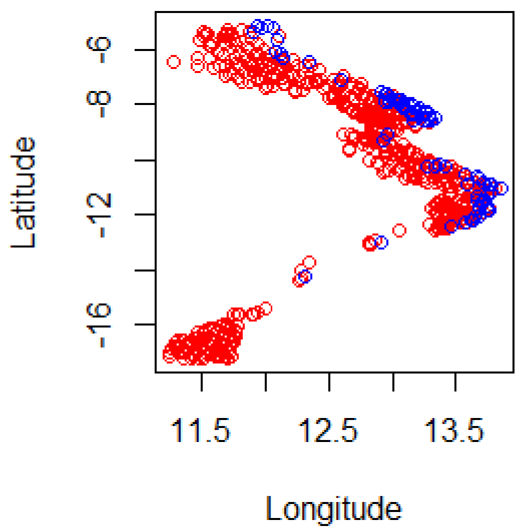


Figure 34. Scatter plot showing overall catch distribution of *G. decadactylus* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *G. decadactylus* is caught close to shore from the north towards south, where the catch ceases somewhat south of the central parts of the study area (Figure 34). *G. decadactylus* seem to have a patchy catch rate which seem to increase towards the north-central and central parts of the study area, and decrease in north and south (Figure 34). *G. decadactylus* is not caught in trawl at greater bottom depths than 100 m.

Model selection favored a model with an interaction effect between latitude^2, bottom depth and year on NPUE of *G. decadactylus* (table 18 in appendix). Because the model received some kind of error message, parameter estimates for the model could not be provided, and it is unknown whether or not the effects of the favored model are significant.

Merluccius polli

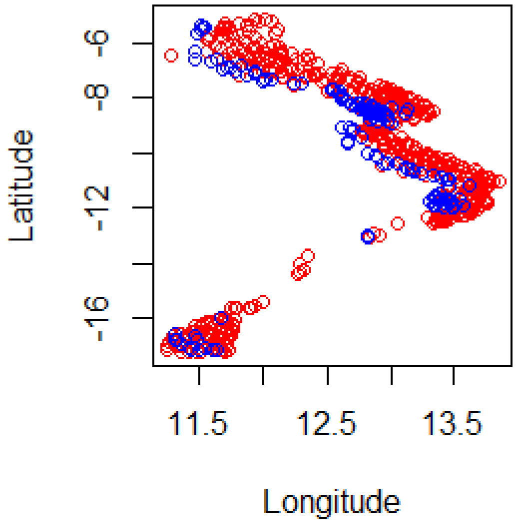


Figure 35. Scatter plot showing overall catch distribution of *M. polli* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *M. polli* is caught in waters with greater bottom depths from north to south in the study area (Figure 35). The catch rates of *M. polli* seem to be highest in the north central parts of the study area, while they have completely ceased in the south central parts of the study area. *M. polli* is caught again in the southernmost point of the study area (Figure 35). *M. polli* is caught in depths up to 800 m.

Model selection favored a model with a significant interaction effect between latitude^2, bottom depth and year ($p_{latitude^2 * year * bottom\ depth}$<0.0001, 20 in appendix) on NPUE of *M. polli* (table 19 in appendix). For parameter estimates of favored model see table 20 in appendix. The interaction effect between latitude and bottom depth on NPUE of *M. polli* is different between 1989 and 2010 (table 20 in appendix). A prediction plot for this model is provided in Figure 36, showing that the NPUE of *M. polli* increases towards shallower bottom depths and towards north in the northernmost point of the study area in 1989. There seem to be a similar tendency in the southernmost area in 1989, only weaker. In 2010 the increase in north seem to have shifted slightly towards the north central parts of the study area, while NPUE of *M. polli* shows no increase in the southern areas (Figure 36).

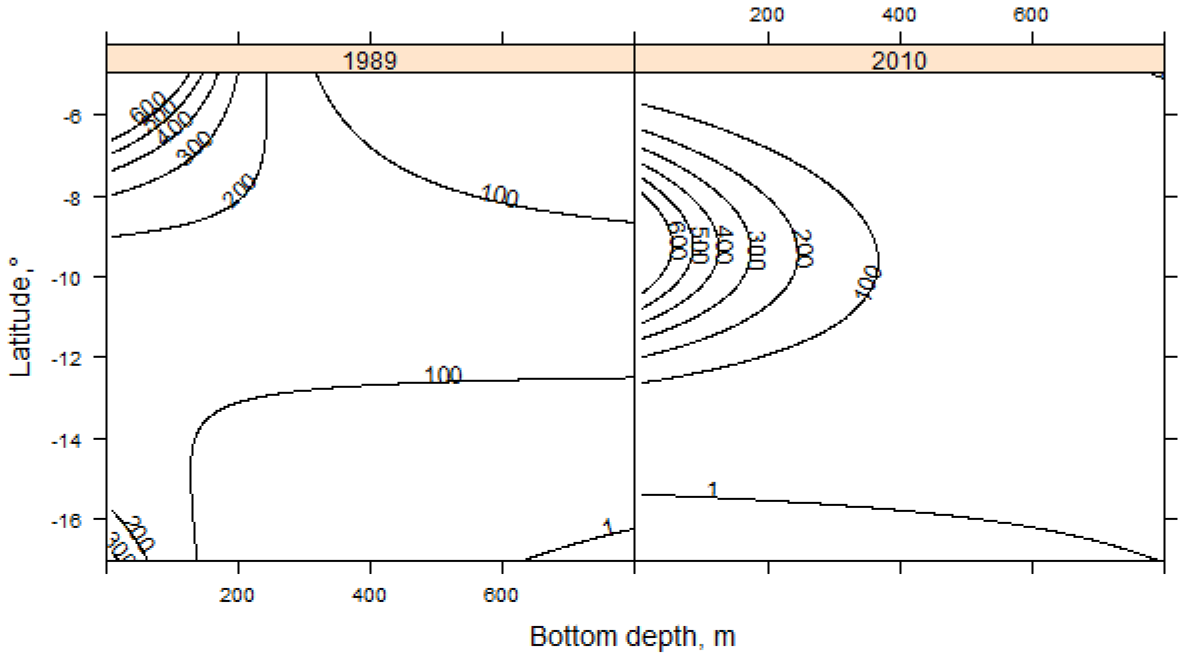


Figure 36. Predictions of NPUE for *M. polli* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model provided in appendix. Contours show estimated NPUE as number of *M. polli* individuals per trawl session. The model predictions were retrieved from parameter estimates provided in table 20 in appendix.

Pagellus bellottii

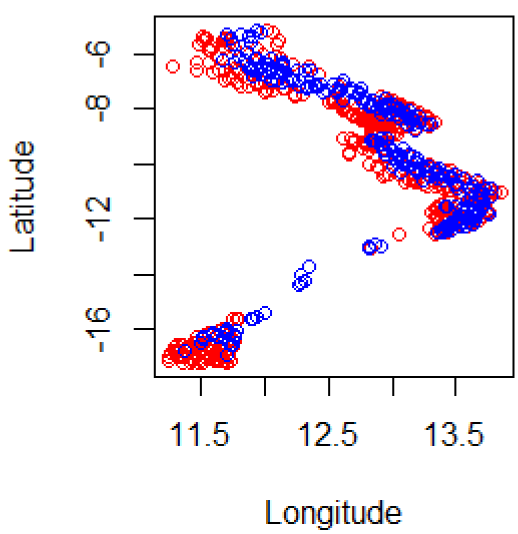


Figure 37. Scatter plot showing overall catch distribution of *P. bellottii* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *P. bellottii* is caught in semi shallow waters (Figure 37). *P. bellottii* seems to be caught in high abundance all the way from the northern parts of the study area and close to the southernmost parts of the study area (Figure 37). *P. bellottii* is not caught in trawl at greater bottom depths than 100 m.

Model selection favored a model with a significant interaction effect between latitude^2, bottom depth and year ($p_{latitude^2*year*bottom\ depth}<0.0001$, 22 in appendix) on NPUE of *P. bellottii* (table 21 in appendix). For parameter estimates of favored model see table 22 in appendix. The interaction effect between latitude and bottom depth on NPUE of *P. bellottii* is different between 1989 and 2010. A prediction plot for this model is provided in Figure 38, showing that the NPUE of *P. bellottii* increases towards the central parts of the study area in 1989. In 2010, NPUE of *P. bellottii* increases towards greater bottom depths and towards the south in the southernmost part of the study area. In addition NPUE of *P. bellottii* increases somewhat towards land in the southcentral parts of the study area (Figure 38).

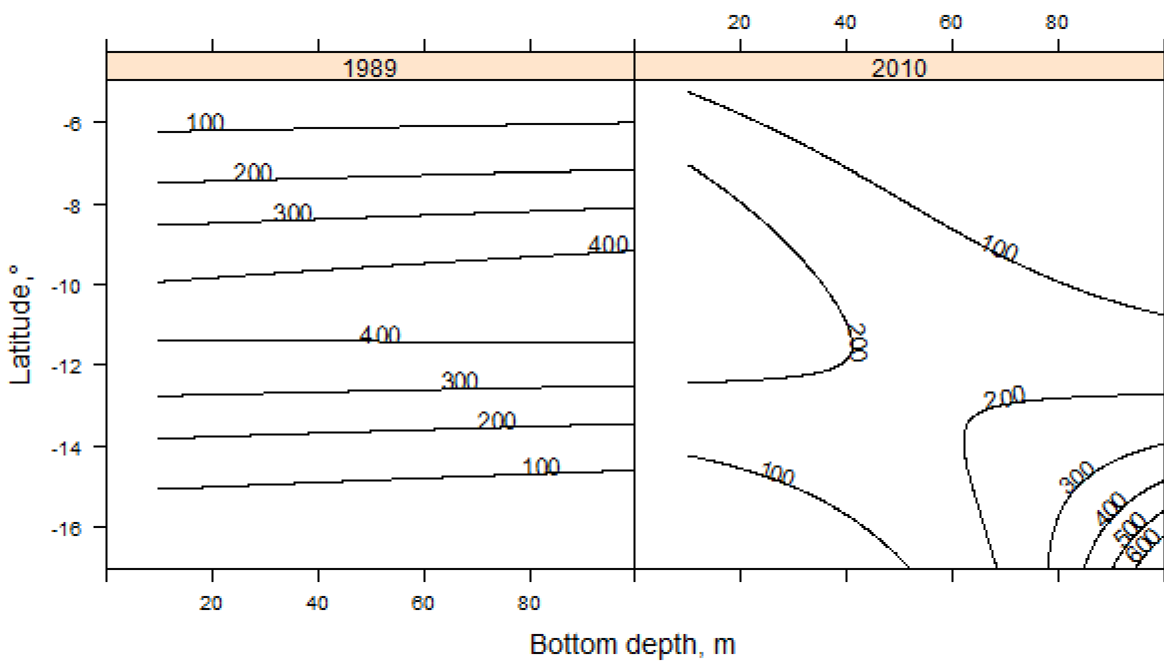


Figure 38. Predictions of NPUE for *P. bellottii* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model provided in appendix. Contours show estimated NPUE as number of *P. bellottii* individuals per trawl session. The model predictions were retrieved from parameter estimates provided in table 22 in appendix.

Umbrina canariensis

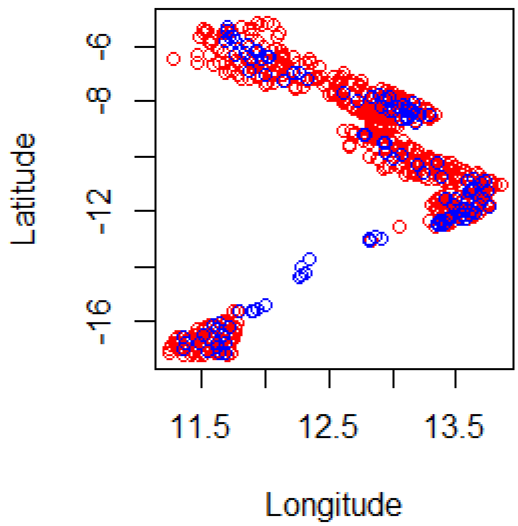


Figure 39. Scatter plot showing overall catch distribution of *U. canariensis* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *U. canariensis* are caught in patches all the way from north to south in the study area (Figure 39). *U. canariensis* is not caught in trawl at greater bottom depths than 200 m.

Model selection favored a model with a significant interaction effect between latitude^2, bottom depth and year ($p_{latitude^2 * year * bottom\ depth} < 0.0001$, 24 in appendix) on NPUE of *U. canariensis* (table 23 in appendix). For parameter estimates of favored model see table 24 in appendix. The interaction effect between latitude and bottom depth on NPUE of *U. canariensis* is different between 1989 and 2010 (table 24 in appendix). A prediction plot for this model is provided in Figure 40, showing that the NPUE of *U. canariensis* is modest in 1989. *U. canariensis* is only present towards the greater bottom depths in 1989, caught in the northernmost part of the study area and in depth greater than 170 m in the south central parts of the study area. In 2010, NPUE of *U. canariensis* shows an increase towards shallower bottom depths in the northernmost part of the study area, while the tendency shifts towards greater bottom depths in the southernmost part of the study area (Figure 40).

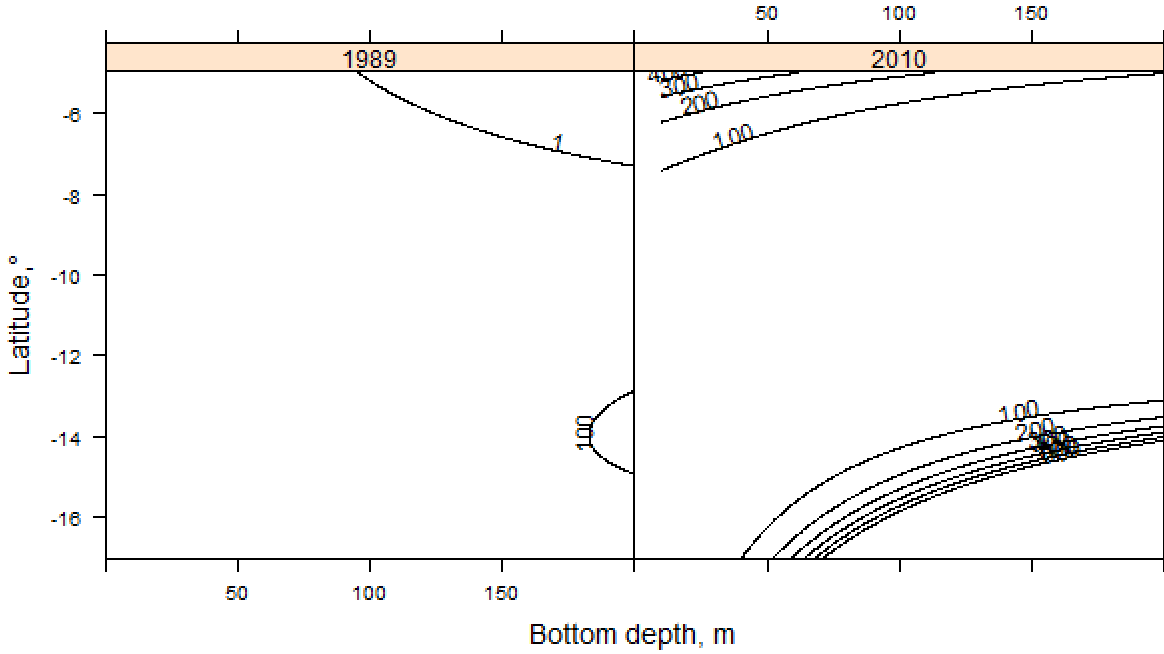


Figure 40. Predictions of NPUE for *U. canariensis* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model provided in appendix. Contours show estimated NPUE as number of *U. canariensis* individuals per trawl session. The model predictions were retrieved from parameter estimates provided in table 24 in appendix.

Common non-commercial demersal species

Citharus linguatula

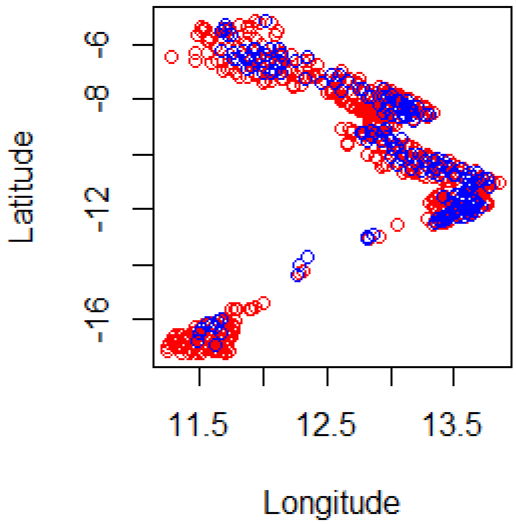


Figure 41. Scatter plot showing overall catch distribution of *C. linguatula* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *C. linguatula* is caught in semi-deep waters through most of the study area (Figure 41). The catch rate of *C. linguatula* seems to be highest in the central parts of the study area, whereas it is absent from trawl close to the southern borders of the study area (Figure 41). *C. linguatula* is caught down to 200 m depth.

Model selection favored a model with a significant interaction effect between latitude^2, bottom depth and year ($p_{latitude^2 * year * bottom\ depth} < 0.0001$, 26 in appendix) on NPUE of *C. linguatula* (table 25 in appendix). For parameter estimates of favored model see table 26 in appendix. The interaction effect between latitude and bottom depth on NPUE of *C. linguatula* is different between 1989 and 2010 (table 26 in appendix). A prediction plot for this model is provided in Figure 42, showing that the NPUE of *C. linguatula* is almost zero in 1989, only caught in trawl in the northernmost part of the study area where NPUE is 1. In 2010, NPUE of *C. linguatula* increases towards lower bottom depths in the southern parts of the study area, while it shifts and increases towards greater bottom depths in the north central parts of the study area (Figure 42).

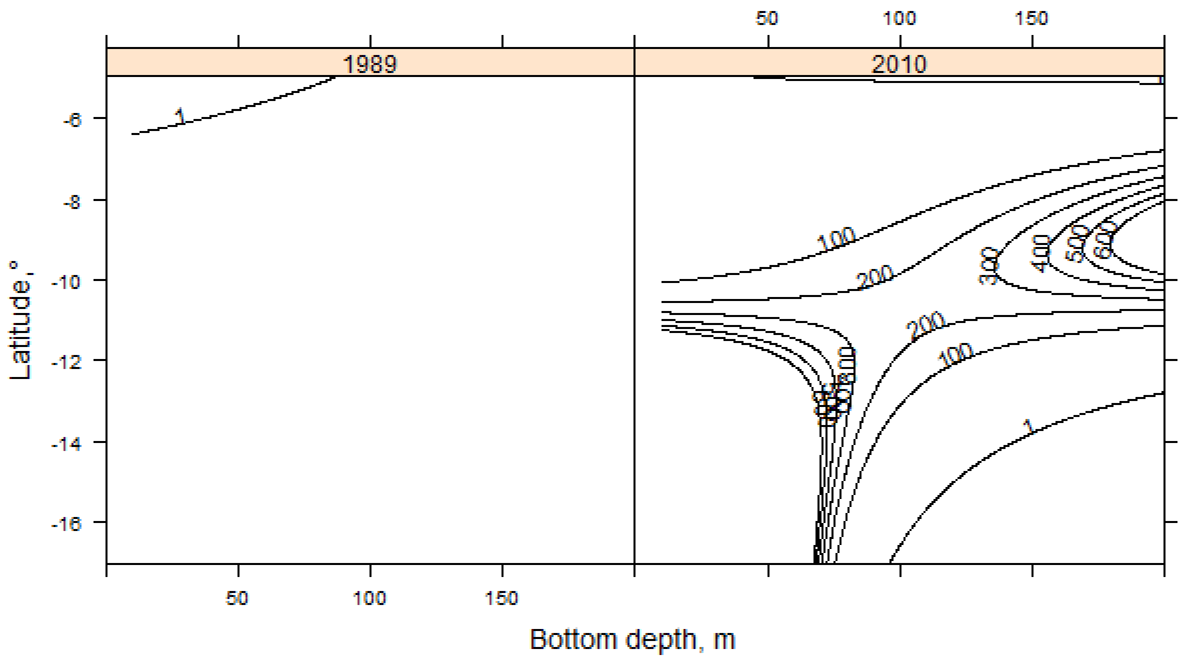


Figure 42. Predictions of NPUE for *C. linguatula* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model provided in appendix. Contours show estimated NPUE as number of *C. linguatula* individuals per trawl session. The model predictions were retrieved from parameter estimates provided in table 26 in appendix.

Nematocarcinus africanus

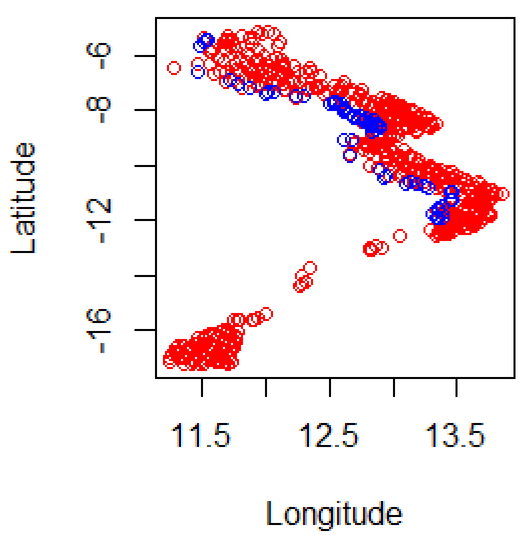


Figure 43. Scatter plot showing overall catch distribution of *N. africanus* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *N. africanus* is caught in patches from the northern parts of the study area to the central parts of the study area (Figure 43). From the central parts to the southern parts of the study area *N. africanus* is absent from trawl (Figure 43). *N. africanus* is caught between 300-800 m depth.

Model selection favored a model with an interaction effect between latitude^2, bottom depth and year on NPUE of *N. africanus* (table 27 in appendix). Because the model received some kind of error message, parameter estimates for the model could not be provided, and it is unknown whether or not the effects of the favored model are significant.

Raja miraletus

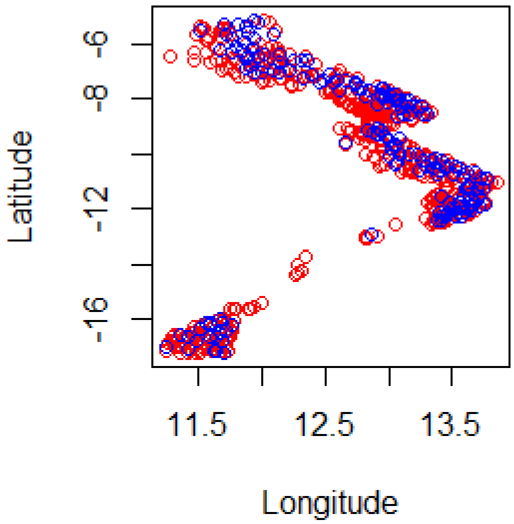


Figure 44. Scatter plot showing overall catch distribution of *R. miraletus* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *R. miraletus* is caught in shallow waters along most of the study area, except the southcentral parts of the study area (Figure 44). *R. miraletus* is caught down to 800 m depth.

Model selection favored a model with a significant interaction effect between latitude^2, bottom depth and year ($p_{\text{latitude}^2\text{*year*bottom depth}}$=0.009, table 29 in appendix) on NPUE of *R. miraletus* (table 28 in appendix). For parameter estimates of favored model see table 29 in appendix. The interaction effect between latitude and bottom depth on NPUE of *R. miraletus* is different between 1989 and 2010 (table 29 in appendix). A prediction plot for this model is provided in Figure 45, showing that the NPUE of *R. miraletus* is almost zero in 1989, only caught in trawl in the northern to central part of the study area where NPUE is 1. In 2010, NPUE of *R. miraletus* is very much similar to in 1989 (Figure 45).

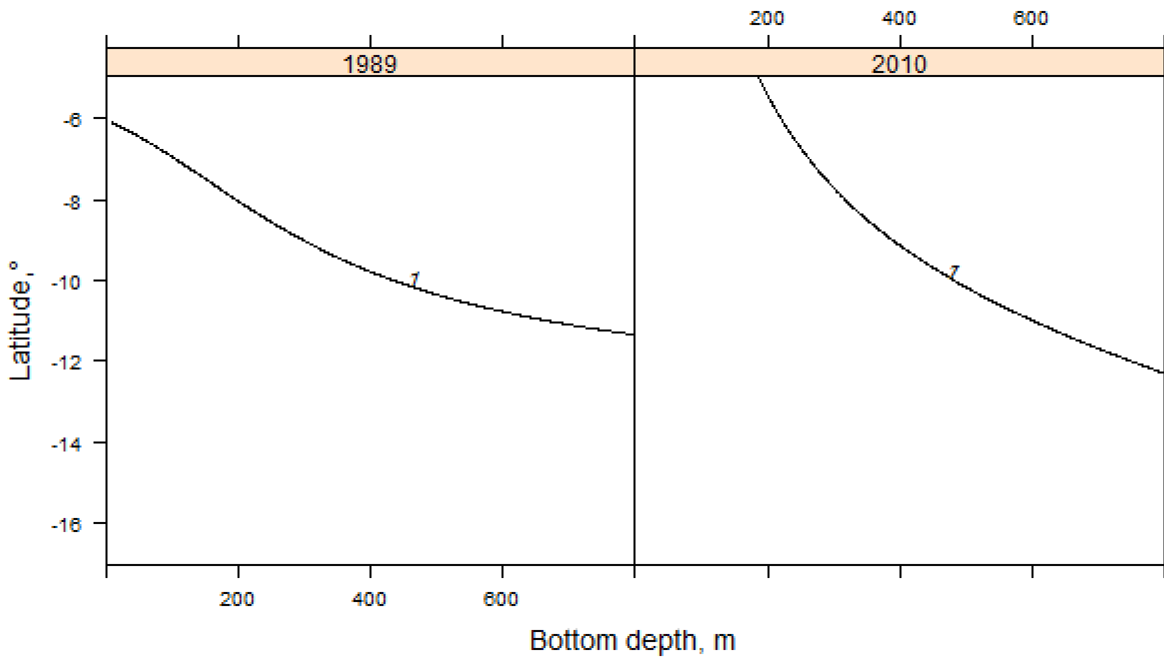


Figure 45. Predictions of NPUE for *R. miraletus* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model provided in appendix. Contours show estimated NPUE as number of *R. miraletus* individuals per trawl session. The model predictions were retrieved from parameter estimates provided in table 29 in appendix.

Synagrops microlepis

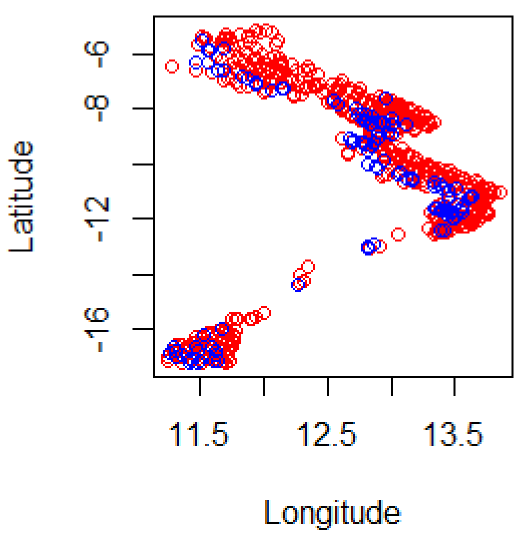


Figure 46. Scatter plot showing overall catch distribution of *S. microlepis* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *S. microlepis* are caught in patches all the way from north to south in the study area (Figure 46). *S. microlepis* is caught down to 400 m depth.

Model selection favored a model with a significant interaction effect between latitude^2, bottom depth and year ($p_{latitude^2*year*bottom\ depth}<0.05$, 31 in appendix) on NPUE of *S. microlepis* (table 30 in appendix). For parameter estimates of favored model see table 31 in appendix. The interaction effect between latitude and bottom depth on NPUE of *S. microlepis* is different between 1989 and 2010 (table 31 in appendix). A prediction plot for this model is provided in Figure 47, showing that the

NPUE of *S. microlepis* increases from lower bottom depths to greater bottom depths in the northernmost parts of the study area, while it increases from greater bottom depths towards lower bottom depths in the southernmost parts of the study area in 1989. In 2010, NPUE of *S. microlepis* increases from greater bottom depths towards lower bottom depths around the central to southcentral parts of the study area (Figure 47).

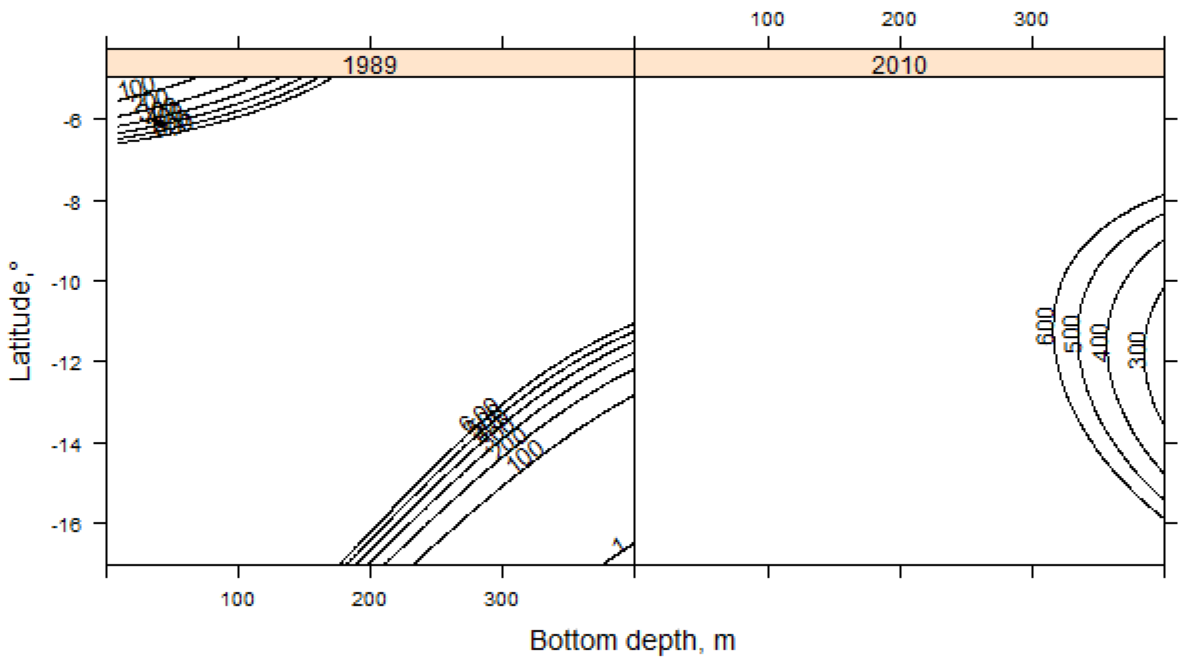


Figure 47. Predictions of NPUE for *S. microlepis* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model provided in appendix. Contours show estimated NPUE as number of *S. microlepis* individuals per trawl session. The model predictions were retrieved from parameter estimates provided in table 31 in appendix.

Yarrella blackfordi

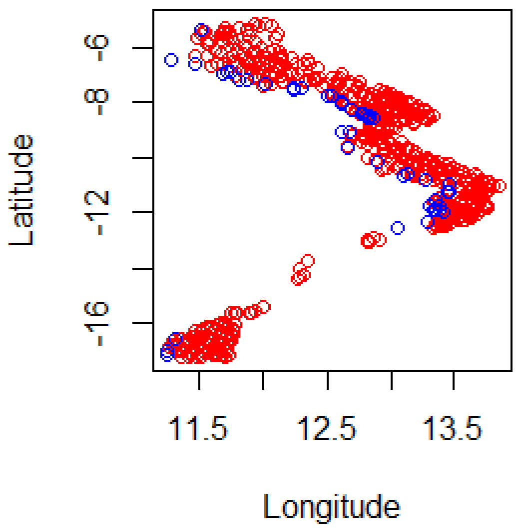


Figure 48. Scatter plot showing overall catch distribution of *Y. blackfordi* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Overall trawl catch shows that *Y. blackfordi* is caught from the northern parts of the study area to around the central parts of the study area (Figure 48). From the central parts of the study area *Y. blackfordi* is absent from trawl and is only caught again in the southernmost part of the study area, close to Cunene River (Figure 48). *Y. blackfordi* is caught in bottom depths between 300-800 m.

Model selection favored a model with an interaction effect between latitude^2, bottom depth and year on NPUE of *Y. blackfordi* (table 32 in appendix). Because the model received some kind of error message, parameter estimates for the model could not be provided, and it is unknown whether or not the effects of the favored model are significant.

Effects of oil activity on NPUE

Results from model selection indicates that the favored model includes an interaction effect between bottom depth, oil activity and latitude (Table 6). Parameter estimates indicate that the effect is significant ($p_{\text{bottom depth*oil activity*latitude}}$=0.0106, Table 7). Predictions indicates that NPUE increase southwards and towards greater bottom depths in areas with oil activity within the study area of oil activity effects (between S06°00’- S07°55’). Further, predictions indicates a more even NPUE in areas with no oil activity, with an increase in NPUE northwards and towards greater bottom depths, as well as there is an increase in NPUE towards shallower bottom depths in the southern parts of the study area (Figure 49).

Table 6. AIC-ranking of ZIP-models fitted to explore if NPUE is affected by oil activity off the continental shelf and upper slope of the Angolan coast. df = degrees of freedom.

Model	df	AIC	△AIC
Bottom depth * Oil activity * Latitude	9	152.9289	0
Bottom depth + Oil activity + Latitude	5	160.0014	7.0725
Bottom depth + Oil activity * Latitude	6	161.0048	8.0759
Bottom depth * Oil activity	5	161.3105	8.3816
Bottom depth + Oil activity	4	164.2902	11.3613
Bottom depth + Latitude	4	166.0900	13.1611
Bottom depth * Latitude	5	167.0239	14.095
Latitude + Oil activity	4	167.3941	14.4652
Latitude * Oil activity	5	169.1839	16.255
Oil activity	3	177.5253	24.5964
1	2	181.3141	28.3852

Table 7. Parameter estimates and explanatory level of bottom depth effect and oil activity effect on NPUE for the most supported model from model selection. (Intercept) = No oil activity, Bottom depth = No oil activity, Latitude = No oil activity, Bottom depth: Latitude = No oil activity, Oil activity = oil. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Residual standard error: 1.018 on 42 degrees of freedom. Multiple R-squared: 0.5716, Adjusted R-squared: 0.5002. F-statistic: 8.006 on 7 and 42 DF, p-value: 3.708e-06.

	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	-8.979856	6.918055	-1.298	0.2014
Bottom depth	0.047423	0.024771	1.914	0.0624 .
Oil activity	13.865701	8.196114	1.692	0.0981 .
Latitude	-2.554543	1.033731	-2.471	0.0176 *
Bottom depth: Oil activity	-0.072142	0.028199	-2.558	0.0142 *
Bottom depth: Latitude	0.006765	0.003581	1.889	0.0658 .
Oil activity: Latitude	2.291511	1.215621	1.885	0.0664 .
Bottom depth: Oil activity: Latitude	-0.010862	0.004061	-2.675	0.0106 *

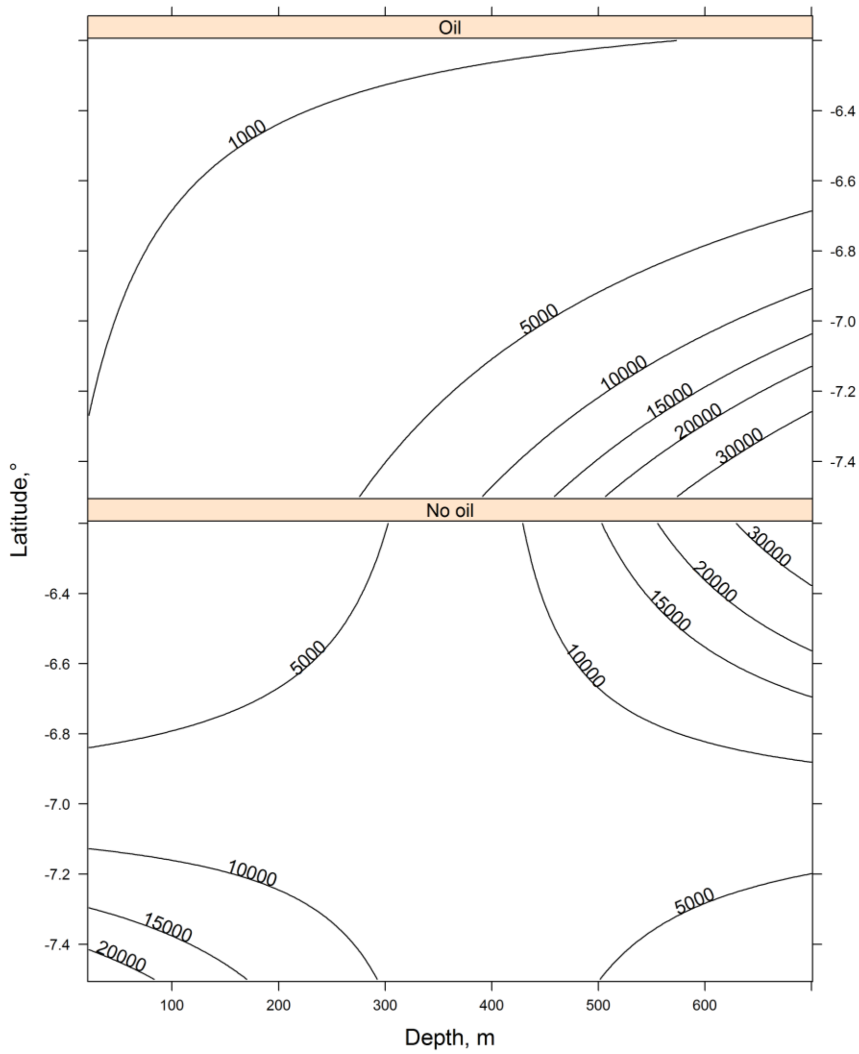


Figure 49. Contour plot of the favored model from model selection provides predicted NPUE of demersal assemblages in areas with and without oil activity in consideration of latitudinal gradient and bottom depth off the continental shelf and upper Angolan slope. Oil = areas in proximity to oil installations, No oil = areas not close to oil installations. Contours are provided with predicted NPUE. Note that the studied area only stretches from S06°00'- S07°55', and that oil activity only defines areas close to petroleum installations, and no other activity associated with petroleum industry.

Effects of oil activity on WPUE

Results from model selection indicates that the favored model includes an additive effect between latitude and oil activity (Table 8). Parameter estimates indicates that the oil effect is significant ($p_{oil\ activity}$ =0.0086, Table 9). Predictions suggests a decreasing linear relationship of WPUE northwards in the study area, with a higher overall WPUE in areas with no oil activity within the study area of oil activity effects (between S06°00'- S07°55') (Figure 50).

Table 8. AIC-ranking of ZIP-models used to explore if WPUE is affected by oil activity off the continental shelf and upper slope of the Angolan coast. df = degrees of freedom.

Model	df	AIC	△AIC
Latitude + Oil activity	4	115.2638	0
Latitude * Oil activity	5	115.9525	0.6887
Bottom depth + Oil activity + Latitude	5	116.0031	0.7393
Bottom depth + Oil activity * Latitude	6	117.0036	1.7398
Bottom depth * Oil activity * Latitude	9	119.0424	3.7786
Oil activity	3	120.2929	5.0291
Bottom depth * Oil activity	5	121.4491	6.1853
1	2	122.2401	6.9763
Bottom depth + Oil activity	4	122.2926	7.0288
Bottom depth + Latitude	4	122.6216	7.3578
Bottom depth * Latitude	5	124.1718	8.908

Table 9. Parameter estimates and explanatory level of Latitude effect and oil activity effect on WPUE for the most supported model from model selection. (Intercept) = No oil activity, Oil activity = oil. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Residual standard error: 0.7295 on 47 degrees of freedom. Multiple R-squared: 0.1971, Adjusted R-squared: 0.4655. F-statistic: 5.769 on 2 and 47 DF. P-value: 0.005748.

	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	0.6538	1.8089	0.361	0.71939
Latitude	-0.7118	0.2672	-2.664	0.01056 *
Oil activity	-0.5870	0.2141	-2.742	0.00862 **

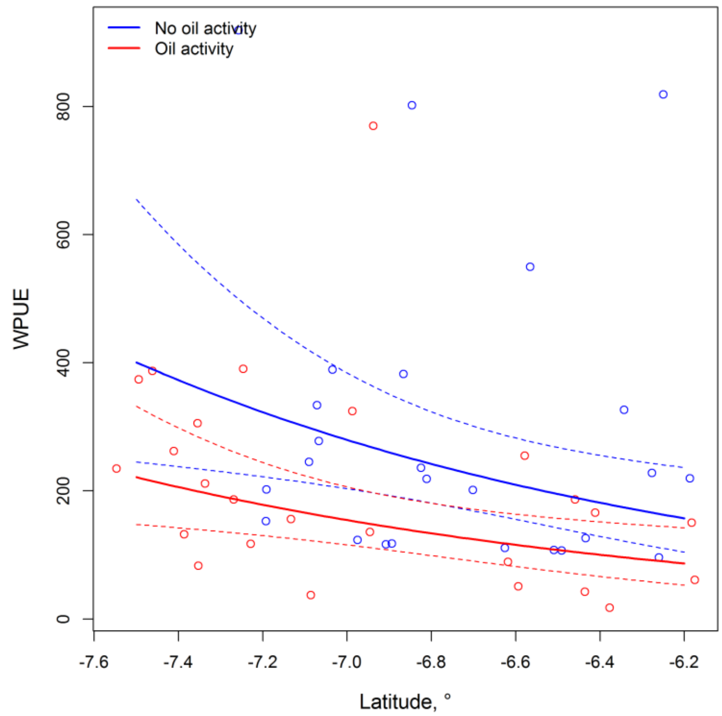


Figure 50. Prediction plot of the favored model from model selection provides predicted WPUE of demersal assemblages in consideration of bottom depth off the continental shelf and upper Angolan slope. Red line = oil activity, meaning trawl stations in proximity to oil installations, Blue line = no oil activity, meaning trawl stations not close to oil installations. Lines represent the estimated WPUE, while dots represent the actual trawl stations. 50% of the data lies within the dashed lines. WPUE = kg. Note that the studied area only stretches from S06°00'- S07°55', and that oil activity only defines areas close to petroleum installations, and no other activity associated with petroleum industry.

Effects of oil activity on number of species

Results from model selection indicates that the favored model includes a bottom depth*oil activity effect (Table 10). Parameter estimates indicates that the effect is significant ($p_{\text{bottom depth*oil activity}}<0.05$, Table 11). Predictions from the most supported model suggests that number of species is higher in areas without oil activity compared to areas with oil activity in shallow areas within the study area of oil activity effects (between S06°00'- S07°55') (Figure 51). Towards greater bottom depths the difference in number of species mitigate. In bottom depths greater than 550 m this trend has shifted, resulting in a higher number of species in areas with oil activity compared to areas without oil activity (Figure 51).

Table 10. AIC-ranking of ZIP-models fitted to explore if number of species is affected by oil activity off the continental shelf and upper slope of the Angolan coast. Note that the models are fitted with poisson regression. df = degrees of freedom.

Model	df	AIC	△AIC
Bottom depth * Oil activity	4	324.1324	0
Bottom depth + Oil activity	3	326.0169	1.8845
Bottom depth + Oil activity + Latitude	4	328.0070	3.8746
Bottom depth + Oil activity * Latitude	5	328.6035	4.4711
Bottom depth + Latitude	3	330.4717	6.339
Bottom depth * Oil activity * Latitude	8	330.8023	6.6699
Bottom depth * Latitude	4	332.3928	8.2604
Latitude + Oil activity	3	343.0792	18.9468
Oil activity	2	344.2546	20.1222
Latitude * Oil activity	4	344.7769	20.6445
1	1	351.3738	27.2414

Table 11. Parameter estimates and explanatory level of bottom depth effect and oil activity effect on number of species for the most supported model from model selection. (Intercept) = No oil activity, Bottom depth = No oil activity, Oil activity = oil. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	3.2156089	0.0625800	51.384	< 0.0001 ***
Bottom depth	0.0003198	0.0001701	1.880	0.06004 .
Oil activity	-0.2510388	0.0852930	-2.943	0.00325 **
Bottom depth: Oil activity	0.0004725	0.0002396	1.972	0.04860 *

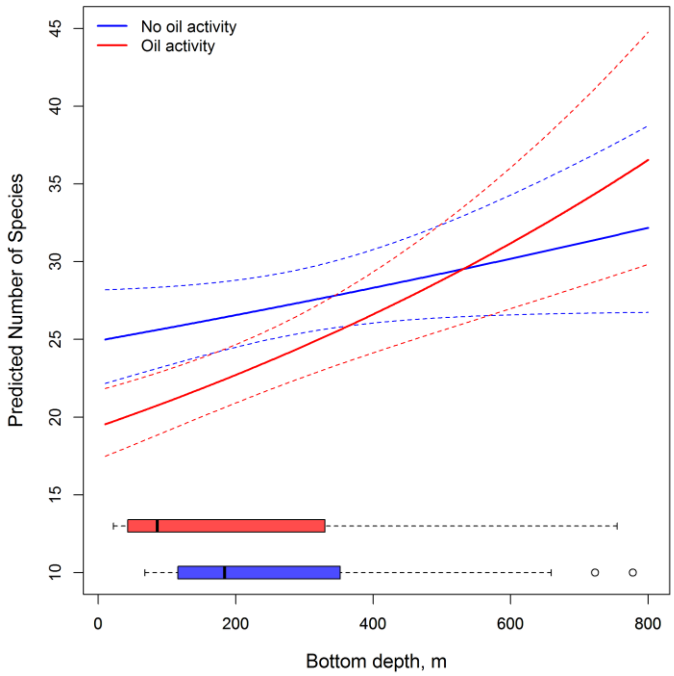


Figure 51. Predicted number of species corresponding to bottom depth in areas with and without oil activity. Predictions suggests a higher number of species in areas without oil installations in bottom depths below 550 m. In bottom depths greater than 550 m, predictions suggest a higher number of species in areas with oil activity. Blue line = no oil activity, red line= oil activity. Bottom depth is given in m. Horizontal box plots show the distribution of bottom depths among oil activity sites (red) and no-oil activity sites (blue). 50% of the depth observations are located within the boxes, 90% within the whiskers. Note that the studied area only stretches from S06°00'- S07°55', and that oil activity only defines areas close to petroleum installations, and no other activity associated with petroleum industry.

Single-species oil analyses

Commercial pelagic species:

Because of unpredicted troubles during analyses for the pelagic species, I chose to exclude them from the single-species oil analyses. These problems was essentially problems with fitted values, maybe because of over fitted data, as well as missing values.

Commercial demersal species:

Dentex angolensis

Model selection favored a model with an interaction effect between bottom depth and oil activity on NPUE of *D. angolensis* (Table 12, for complete table with all fitted models see appendix). Parameter estimates indicate a significant effect of bottom depth and oil activity ($p_{\text{bottom depth}^2\text{*oil}}$

activity<0.0001, table 34 in appendix). Predictions of the interaction effect between bottom depth and oil activity on NPUE of *D. angolensis* suggests there is higher NPUE in areas with oil activity, compared to areas without oil activity (Figure 52). When correcting for salinity and temperature, a model with an interaction effect between bottom depth, oil activity and salinity was favored (table 35 in appendix). This model has a lower AIC-value than the original favored model without salinity. The model received an error, so it is unknown if the effects of salinity are significant or not.

Table 12. AIC-ranking for the 5 most supported ZIP-models used to explore if oil activity affects NPUE of *D. angolensis* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	△AIC
Bottom depth² * Oil activity	Bottom depth	8	3681.557	0
Oil activity * Bottom depth	Bottom depth	6	3908.053	226.496
Oil activity * Bottom depth	Oil activity	6	3913.981	232.424
Latitude² * Oil activity	1	7	4011.132	329.575
Latitude² * Oil activity	Latitude	8	4011.249	329.692

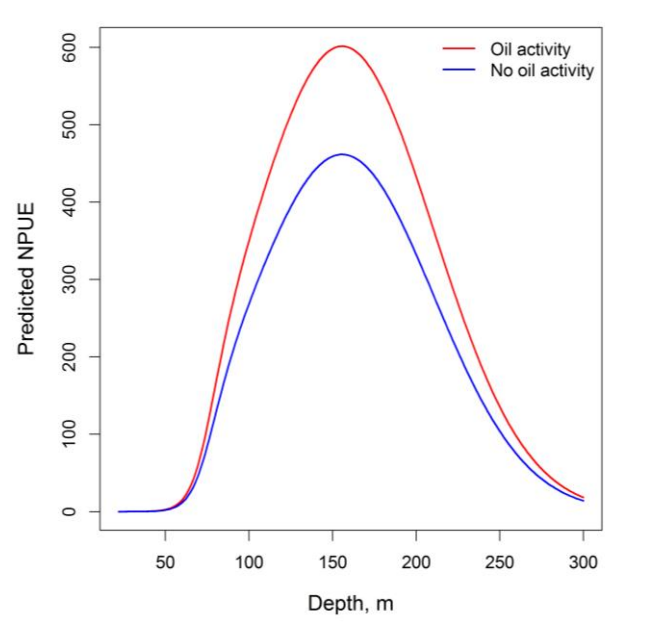


Figure 52. Predicted NPUE of *D. angolensis* corresponding to bottom depth in areas with and without oil activity. Predictions suggests a higher NPUE of *D. angolensis* in areas with oil activity compared to areas with no oil activity. Blue line = no oil activity, red line= oil activity. Bottom depth is given in meters. Note that oil activity only defines areas close to petroleum installations, and no other activity associated with petroleum industry.

Pagellus bellottii

Model selection favored a model with an interaction effect between bottom depth and oil activity on NPUE of *P. bellottii* (table 36 in appendix). Because the model received some kind of error message, parameter estimates for the model could not be provided, and it is unknown whether or not the effects of the favored model are significant or not. Predictions of the interaction effect between bottom depth and oil activity on NPUE of *P. bellottii* suggests there is higher NPUE in areas with oil activity, compared to areas without oil activity (Figure 53).

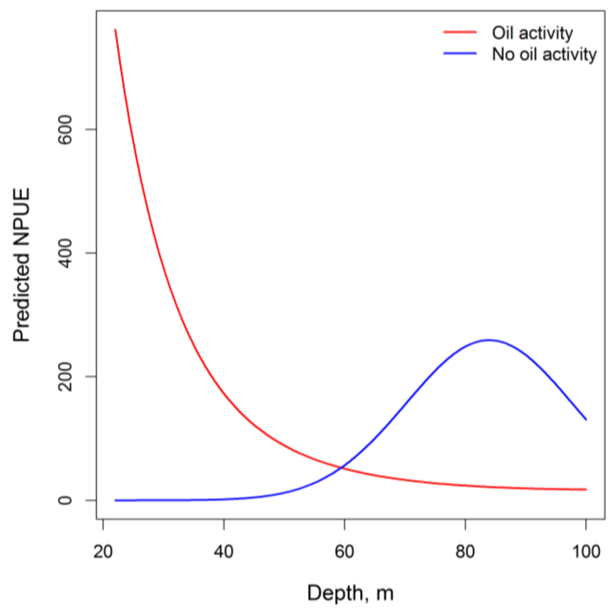


Figure 53. Predicted NPUE of *P. bellottii* corresponding to bottom depth in areas with and without oil activity. Predictions suggests a higher NPUE of *P. bellottii* in areas with oil activity on lower bottom depths than 60 m. Above 60 m NPUE of *P. bellottii* is highest in areas with no oil activity. Blue line = no oil activity, red line= oil activity. Bottom depth is given in meters. Note that oil activity only defines areas close to petroleum installations, and no other activity associated with petroleum industry.

Non-commercial demersal species:

Citharus linguatula

Model selection favored a model with an interaction effect between bottom depth and oil activity on NPUE of *C. linguatula* (table 37 in appendix). Parameter estimates indicate a significant effect of bottom depth and oil activity ($p_{\text{bottom depth}^2 * \text{oil activity}}=0.0099$, table 38 in appendix). Predictions of the interaction effect between bottom depth and oil activity on NPUE of *C. linguatula* suggests there is higher NPUE in areas with oil activity in shallow bottom depths (Figure 54). In bottom depths greater than 120 m, NPUE is higher in areas with no oil activity (Figure 54). When correcting for salinity and temperature, a model with an interaction effect between bottom depth, oil activity and salinity was favored (table 39 in appendix). This model has a lower AIC-value than the original favored model without salinity. The model received an error, so it is unknown if the effects of salinity are significant or not.

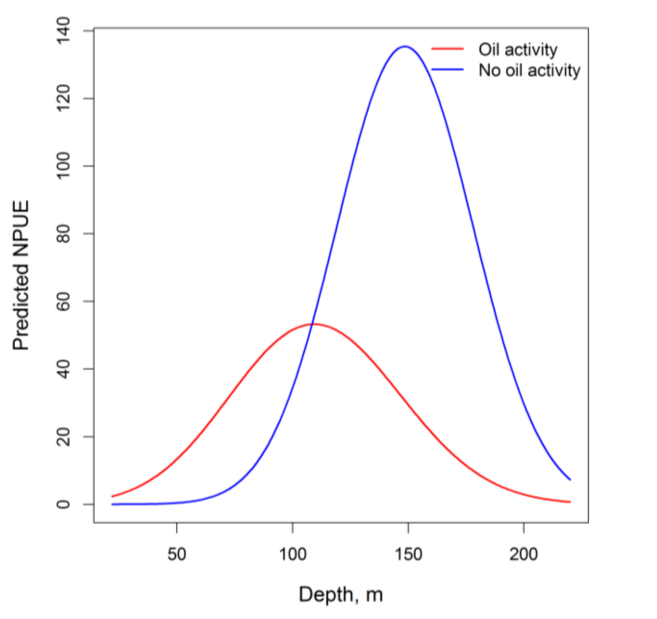


Figure 54. Predicted NPUE of *C. linguatula* corresponding to bottom depth in areas with and without oil activity. Predictions suggests a higher NPUE of *C. linguatula* in areas with oil activity in bottom depths lower than 120 m. Above 120 m bottom depth NPUE of *C. linguatula* is highest in areas with no oil activity. Blue line = no oil activity, red line= oil activity. Bottom depth is given in meters. Note that oil activity only defines areas close to petroleum installations, and no other activity associated with petroleum industry.

Discussion

Even though there is no significant difference in NPUE from 1989 to 2010, several aspects could have influenced the catch efficiency of RV Dr. Fridtjof Nansen. Tow duration was standardized to 30 min in 1991, and in 1994 the old RV Dr. Fridtjof Nansen was replaced by the new RV Dr. Fridtjof Nansen (Axelsen and Johnsen, 2014). Catch efficiency can differ between different vessels despite them using the same gear (Engås and Godø, 1989) among other because different vessels may have different noise pattern and different pull power. Other modifications to the gear between the surveys in 1989 and 2010 include the replacement of the Waco trawl doors with the Thyborøn type, change in diameters of the bobbins, introduction of tickler chains, introduction of constraining rope, and introduction of the trawl monitoring system SCANMAR (Axelsen and Johnsen, 2014). Even minor modifications in trawling gear could have an effect on trawl performance and thus might have an effect on trawl catches (Axelsen and Johnsen, 2014). In addition, the surveys in 1989 were less standardized in terms of seasons and depth coverage (Axelsen and Johnsen, 2014). In addition, the modifications of the gear could affect number of bottom-dwellers (Axelsen and Johnsen, 2014). For example the catch rate of bottom dwellers fell when tickler chains were not used with the Gisund Super demersal trawl in Angola (Axelsen and Johnsen, 2014). In addition, the introduction of the new RV Dr. Fridtjof Nansen in 1994 lead to considerably higher catches of bottom dwellers (Axelsen and Johnsen, 2014). As well as Axelsen and Johnsen (2014) conclude that the introduction of new trawl doors in 2000 is likely to have a significant effect on increased sampling efficiency on sea-bed oriented species. In 2010 the depth range stretched to greater depths than in 1989, and the Cabinda area north of Congo river was included in 1989 but not in 2010. Because of improved trawl performance it is fair to suggest that under otherwise equal conditions catch rates would be higher in 2010. However this effect is very difficult to quantify and likely to be relatively small. In addition, Axelsen and Johnsen (2014) states that despite the changes in gear, the time series from Angola is reasonably robust and might not have significant effects on catch rates in terms aggregation, except the increase in bottom-dwellers.

The significant increase in number of species from 1989 to 2010 corresponds with IMR's record for number of species from all surveys with RV Dr. Fridtjof Nansen (Table 1 in appendix). This record shows an overall increase in number of species from the surveys in 1989 and 2010 and until today. Even though it is found that number of species can increase as a result of heavy exploitation (Bianchi et al., 2000), the increase in number of species can be affected by higher knowledge and greater experience among the taxonomists on the RV Dr. Fridtjof Nansen (Table 1 in appendix). In addition, the recorded number of species is more stable and overall highest from 1999 (Table 1 in appendix), which is when the standardization of gear and survey design had truly been set into force in the Angola surveys (Axelsen and Johnsen, 2014). It is assumed that the significant increase in number of species from 1989 to 2010 might be affected to some degree by changes in methods, and use of more experienced taxonomists. Axelsen and Johnsen (2014) states that some caution should be exercised when time series from the early surveys with RV Dr. Fridtjof Nansen are explored for trends. Especially when the explored trends regard other species or groups of species than those of primary interest, which the survey methodology was designed for in surveys from Angola before 1999 (Axelsen and Johnsen, 2014). However, these effects seem to be more likely to affect NPUE, as discussed above, than number of species. The latitudinal effect on number of species shows an increase in number of species towards the northern parts of the study area for both years, therefore these are not likely to be affected by changes in gear or crew. The trend is strongest in 2010, which is to be expected regarding the factors discussed above. However, change in number of species is more likely a result of change in oceanographic features that in turn result in faunal shifts off the continental shelf and the upper Angolan slope (Bianchi, 1992). The northwards increase in number of species is likely to be a result of the normally high species diversity in the tropics (Bianchi et al., 2000), and corresponds with other studies from the same area which also shows an increase in number of species towards lower latitudes (Jarre et al., 2015, Yemane et al., 2015). The fact that the northwards increase is strongest in 2010 might be a result of species migrating from lower towards higher latitudes. This spatial migration from lower to higher latitudes is expected as a result of climate changes and global warming (Cochrane et al., 2009, IPCC, 2007, Karl and Melillo, 2009). Fish and invertebrates are poikilotherms (i.e. their body temperature varies with the surroundings), which makes them highly sensitive to temperature changes of their environment (Williams and Rota, 2010). Bottom depth effect on number of species shows an increase in number of species towards greater bottom depths for both years. Other studies from the Benguela region have also found that species richness have increased towards greater bottom depths (Yemane et al., 2015). Jarre et al. (2015) did not find any significant effect on number of demersal fish species corresponding to greater depths in Angola, they did however find this very trend in Namibia and South-Africa. In addition, biomass of zooplankton is found to increase towards greater bottom depths in the area, especially south of the Angola-Benguela front (Postel et al., 2007), and zooplankton is an important source of nutrition for other marine species (DeVries and Stein, 1992). Note that the study area was also expanded to greater bottom depths in the 2010 survey compared to 1989. This could also affect results, especially when comparing the two years, and contribute to the stronger trend in 2010. Further research is important to increase our understanding of these changes.

In the single-species analyses, the same model was favored for all species from single-analyses. This model included an interaction effect between latitude, bottom depth and year, but there was great difference in how each species responded to latitude and bottom depth. Predictions for *C. atlanticus* shows a shift from north in 1989 to south in 2010. The high presence of *C. atlanticus* in the north in 1989 corresponds with the findings of Gabriela Bianchi based on the same dataset from 1989 (Bianchi, 1992). The temperature changes with the seasonal upwelling off the northern and central parts of the Angolan coast, as well as the boundaries of the oceanographic frontal zone varies greatly with seasonal and inter-annual fluctuations (Bianchi, 1992). The differences between species is probably a result of changes in ecological preference to different oceanographic conditions such as salinity, oxygen levels, and/or changes in water temperature, which gives a natural latitudinal faunal shift in demersal assemblages in the study-area (Bianchi, 1992). Predictions indicate that several of the species (*C. atlanticus, S. officinalis, D. Macrophthalmus, C. linguatula, P. bellottii, U. canariensis and S. microlepis*) have experienced a shift from north in 1989 to south in 2010. This could be a respond to changes in water temperature, which causes some species to migrate further south as discussed above. Note that some problems (mentioned above) occurred with some models during analyses. Whatever reason for the problems during analyses, the predictions for many of the species in this study might function as a poor indication for the true condition, so further studies are needed to determine if predictions are accurate. Poorly fitted models could also result in homogenous results from model selection.

In areas with oil activity NPUE seem to increase southward and toward greater bottom depths. This could mean that oil activity has a stronger effect on abundance of demersal assemblages in greater depths, compared to more shallow depths. Studies have found that oil activity is likely to support important ecological functions (Andrew and Pepperell, 1992, Hall et al., 2000, Martin and Lowe, 2010, Scarcella et al., 2011, Stanley and Wilson, 2000), enhancing productivity for fish (Martin and Lowe, 2010). Scarcella et al. (2011) found that the influence on fish assemblages reached at least up to 171-204 m from the platform, and the effect was strongest for reef-dwelling benthic fish. Considering there have been newly discovered deep-water coral reef off the Angolan coast (S07°17'-07°19') (Le Guilloux et al., 2009), it is possible that reef-dwelling species are attracted to the artificial reefs provided by the deep-water oil activity and thus results in increased NPUE. However, to determine if this is truly a reason for increased NPUE, further monitoring and studies is necessary. There seem to be no clear trend in NPUE in areas without oil activity. Numbers of demersal assemblages seem to be evenly spread throughout the study area. However, there seem to be a stronger increase in NPUE northwards and towards greater bottom depths, as well as towards shallower bottom depths in the southern parts of the study area. This might be because of higher abundances and species richness in the northern areas. However, further studies are needed to confirm this. WPUE was overall highest in areas with no oil activity, which is similar to the predictions of NPUE. Further, WPUE decreases northwards for both areas with no oil activity and with oil activity, which is also consistent with predictions of NPUE. The distribution of demersal assemblages in terms of NPUE and WPUE in areas with no oil activity is probably a result of the natural variables resulting in different groupings of assemblages (Bianchi, 1992). Number of species is highest in areas without oil activity in shallow bottom depths (<550 m). In greater bottom depths (>550 m), number of species is highest in areas with oil activity. This could mean that oil activity, in terms of oil installations, does have an aggregating effect on some demersal species in greater depths than 550 m, while they have a negative, or no effect on number of species in ground waters. Studies from the Adriatic Sea have found that platforms there had an aggregating effect on species richness and diversity, also among benthic or necto-benthic species (Fabi et al., 2002, Fabi et al., 2004). However, these platforms were all on shallower depths than 550 m (Fabi et al., 2002, Fabi et al., 2004). In addition there is a range of variables that can affect the abundance and species richness, such as bottom type (Bianchi, 1992, Scarcella et al., 2011), seasons (Fabi et al., 2002, Fabi et al., 2004, Stanley and Wilson, 1997), ocean currents (Stanley and Wilson, 1997), depth (Bianchi, 1992, Stanley and Wilson, 1997), temperature (Bianchi, 1992, Yemane et al., 2015) salinity (Bianchi, 1992, Mhlongo et al., 2015), and oxygen (Yemane et al., 2015). Other factors that could cause an increase in number of species around oil installations might be artificial light (Olsen and Valdemarsen, 1977), or installations can provide alternate nutrition for marine organisms (Wolfson et al., 1979). In nutrient poor deep sea areas, oil activity might improving food availability, providing a niche for some species. However, further investigation is needed to understand the effect of oil installations on number of species in the area. It should also be of further interest to investigate if spatial changes' respond to environmental variables (e.g. salinity and temperature) has an impact on effect of spatial changes in relation to oil installations, as well as to investigate other effects the petroleum industry has on the assemblages in the area.

Predictions for *D. angolensis* indicate that the species has a higher abundance in terms of NPUE in areas with oil activity compared to areas with no oil activity. This could mean that oil installations does have a positive effect on the species. Predictions for *P. bellottii* in terms of NPUE indicate that the species has a higher abundance in areas with oil activity in depths shallower than 60 m. However, the trend shifts in depths greater than 60 m where *P. bellottii* has a higher abundance in areas with no oil activity. Predictions for *C. linguatula* in terms of NPUE indicate a higher abundance in areas with oil activity in waters shallower than 100 m, whereas the abundance is much higher in greater depths than 100 m in areas with no oil activity. No previous studies from the area that could strengthen or disprove this predictions was found. The three species mentioned above seem to have received little attention in terms of how they respond to oil activity so far. Single-species analyses for oil effects was characterized by the same warning messages and errors as mentioned above for the pelagic species. Therefore a majority of the species was excluded from the study. The correction for salinity and temperature in the single-species analyses was characterized by deficient data. This could mean that observed effects are mainly caused by other factors such as those mentioned above, rather than of oil installations. Because oil exploitation constitutes such an important part of Angolan economy (Jarre et al., 2015), the effects of oil activities in the area should receive more attention. This is especially interesting because of the deep extend of the offshore installations which extend as far as 2000 m (Jarre et al., 2015), which could have a positive ecological effect of assemblages. A variety of compounds from oil installations have been found to have local impacts on benthic fauna in the Benguela region (Jarre et al., 2015). Today the number of studies on ecological effects of oil installations, and oil activity in general seem to be very scarce in the Angola-Benguela region. Another aspect could be that oil installations are often surrounded by a protection zone from where all types of fisheries are banned (Fabi et al., 2004), including in Angola (Ramos, 2011). Because of the fishing prohibitions often associated with oil installations the increase in abundance and number of species can be a result of the protected area the oil installations provide (Fabi et al., 2004). Further studies are necessary to provide a better understanding of the effects of oil activity in Angola. Note that oil activity in this study only defines areas close to oil installations. I have not taken other elements from oil activities into account such as ballast water from oil tankers, the traffic of oil tankers, installation of facilities, oil spills etc.

In the Benguela-region, several commercial species have experienced overfishing (Cury and Shannon, 2004, Kirkman et al., 2015), and there have been shifts in stocks that have been associated with overfishing (Bianchi, 1992, Boyer et al., 2001, Cury and Shannon, 2004). In recent years, the Angolan government have raised questions about why there have been observed depletions in fish stocks in recent years (Ramos, 2011). To monitor spatial changes in assemblages with greater confidence, it is important to keep monitoring and studying different marine assemblages in the area. Especially considering changes in stocks can be hard to detect, despite overfishing or long-term indirect effects of fishing (Kirkman et al., 2015).

Fish is the main source of protein for millions of people, and is an important economical income for many countries (FAO, 2012) including Angola. With the growing human population, and increasing food and hunger problem (Cribb, 2010, FAO, 2012, Paul, 2010) the fishing pressure is likely to continue to increase. Spatial migration of stocks are likely to have most negative effects on tropical fisheries (Cochrane et al., 2009, Williams and Rota, 2010), with species migrating to higher latitudes. Angola was recently ranket as the number one national economy vulnerable to climate effects on fisheries (Allison et al., 2009)

We still know little about the effects climatic changes (IPCC, 2007), and other anthropogenic impacts will have on marine ecosystems, and thus what effects this will have for the human population in the future. Changes in habitat as a result of climate changes can affect coastal and marine ecosystems, as global warming can affect ocean temperatures, salinity, upwelling and current regimes (IPCC, 2014). Fortunately, there have been, and still is an increasing emphasis on effects of climate change on the Benguela ecosystem, such as the NansClim project (2009-2014) (Loeng and Stenevik, 2015). Through the Nansen program, there have been collected great amounts of data (both of oceanography and biodiversity), which have still not been utilized (Loeng and Stenevik, 2015).

It is of great importance that regional research is continued, especially considering that there are several sub-systems in the Benguela Ecosystem, which are likely to be affected of climate changes (Jarre et al., 2015). Because of this, further studies and monitoring of fish populations is important for a better understanding of natural and anthropogenic effects on global fish communities and their ecology, as well as to provide a better understanding of the species ecology, which is important for good conservation and management of the species and ecosystems.

Conclusion

Fluctuations in demersal assemblages are likely to occur as result of natural fluctuations and of anthropogenic impacts. Based on findings from an earlier study on trawl performance it is assumed that both NPUE and WPUE is likely to be influenced by upgrades in gear and more systematic methods that took place between 1989 and 2010. However, the effects are assumed to be of minor significance.

Increase in number of species is likely to be a response to climatic changes, with tropical species migrating towards higher latitudes as tropical waters increase in temperature. In addition, data is likely to be affected to some degree of more experienced taxonomists combined with improved gear on the research vessel RV Dr. Fritjof Nansen. The increase in number of species towards lower latitudes for both years corresponds with other studies from the same area which also shows an increase in number of species towards lower latitudes. The increase in number of species towards greater bottom depths for both years does also correspond with other studies in the area. The fact that observed trends are strongest in 2010, for both latitude and bottom depth might also indicate spatial migrations, which could be caused by global warming. However, further studies on the subject are important to increase our understanding of these changes.

Single-species analyses indicate a variety in species response to latitude and bottom depth. These differences is expected considering natural shifts in assemblages according to oceanographic features in the area. Southward shifts from 1989 to 2010 are seen in many of the species. Further monitoring and studies of the species used in single-species analyses is needed to provide more accurate predictions of the species response to latitude and bottom depth.

The distribution of demersal assemblages in terms of NPUE and WPUE corresponding to oil activity in terms of oil installations is probably a result of the natural variables resulting in different groupings of assemblages. Oil activity, in terms of oil installations, seem to have a positive effect on number of demersal species in deep waters (>550 m) off the continental shelf and upper slope of Angola. This could be an effect of the oil installations functioning as artificial reefs for deep-water reefs in the area, or as shelter from fisheries. However, no literature seem to exist from the area to strengthen or weaken this theory. In other parts of the world similar findings does exist. On depths shallower than 550 m number of species is highest in areas without oil activity. This could mean that oil installations has a negative, or no effect on number of species in ground waters. The distribution of demersal assemblages in terms of NPUE and WPUE in areas with no oil installations is probably a result of the natural variables resulting in different groupings of assemblages. Literature and studies on effects of the oil activity on marine assemblages in Angola is still scarce.

Predictions for *D. angolensis* indicate that the species has a higher abundance in terms of NPUE in areas with oil activity compared to areas with no oil activity. Predictions for *P. bellottii* in terms of NPUE indicate that the species has a higher abundance in areas with oil activity in depths shallower than 60 m. However, the trend shifts in depths greater than 60 m where *P. bellottii* has a higher abundance in areas with no oil activity. Predictions for *C. linguatula* in terms of NPUE indicate a higher abundance in areas with oil activity in waters shallower than 100 m, whereas the abundance is much higher in greater depths than 100 m in areas with no oil activity. No studies were found regarding any of the three species responde to oil activity in terms of oil installations. Single-species analyses with oil activity was characterized by deficient data, and many of them would not give any predictions or estimates at all. Only three species, mentioned above, had enough data to be included in single-species analyses. Whatever reason for the problems during analyses, predictions should be interpreted with caution.

Although there is an increasing number of studies and literature of observed trends in different fish stocks and assemblages from the Benguela marine ecosystem, there are still several aspects that still receives little attention. Fortunately there is an increasing emphasis on effects of climate change on the Benguela-system.

References:

Figures and tables:

Figure (p. 1):

Institute of Marine Research, *IMRs research vessel Dr. Fridtjof Nansen* [photograph]

Figure 1:

Bianchi (1992) [**map: 1989**], *Fig. 1,* In: *Study of the demersal assemblages of the continental shelf and upper Angolan slope*, Marine Ecology progress series. p. 2

Krakstad et al.,(2010) [**map: 2010**]**,** *Fig. 2.1-2.3,* In: *Survey of the fish resources of Angola, Final Report.* p. 5-7

Figure 2:

Sumalia et al., FAO, [Map],

Fig: 1, In: *Management of shared Hake stocks in the Benguela Marine Ecosystem.* Ch. 1, At: http://www.fao.org/docrep/006/y4652e/y4652e0c.htm (Accessed on 10.05.2015)

Figure 3:

IHS map for global exploration & production service, [Map] At: https://www.ihs.com/products/petrodaily-west-africa-offshore-oil-gas.html (Accessed on 03.03.2014,)

Figure 4: O. Alvheim. IMR [photograph] *B. auritus*

Figure 5: O. Alvheim. IMR [photograph] *C. atlanticus*

Figure 6: O. Alvheim. IMR [photograph] *C. chrysurus*

Figure 7: O. Alvheim. IMR [photograph] *C. officinalis*

Figure 8:

Arias M. A (2009) [photograph] *S. orbignyana*. At: http://www.ictioterm.es/nombre_cientifico.php?nc=218 (Accessed on 13.01.2015)

Figure 9: O. Alvheim. IMR [photograph] *T. trecae*

Figure 10: O. Alvheim. IMR [photograph] *B. barbata*

Figure 11: O. Alvheim. IMR [photograph] *D. angolensis*

Figure 12: O. Alvheim. IMR [photograph] *D. macrophthalmus*

Figure 13:

Noyelle, Frans (2006) [photograph] *G. decadactylus.* At: http://www.abc-sportvissen.be/paginas-droomvissen/Kapitein%20soort.htm (Accessed on 10.03.2015)

Figure 14: O. Alvheim. IMR [photograph] *M. polli*

Figure 15: O. Alvheim. IMR [photograph] *P. bellottii*

Figure 16: O. Alvheim. IMR [photograph] *U. canariensis*

Figure 18: O. Alvheim. IMR [photograph] *C. linguatula*

Figure 19: O. Alvheim. IMR [photograph] *N. africanus*

Figure 20: O. Alvheim. IMR [photograph] *R. miraletus*

Figure 21: O. Alvheim. IMR [photograph] *S. microlepis*

Figure 22:

Matsuura, Keiichi [photograph] *Y. blackfordi.* At: http://fishbase.sinica.edu.tw/summary/Yarrella-blackfordi (Accessed on 02.02.2015)

Figures in appendix:

Figure 1: IMR, *Gisund Super bottom trawl*, [Drawing] (Accessed on 11.02.2015)

Tables in appendix:

Table 1: IMR, Recorded number of species per annum.

Reference list:

AKAIKE, H. 1974. A new look at the statistical model identification. *Automatic Control, IEEE Transactions on,* 19**,** 716-723.

ALLISON, E. H., PERRY, A. L., BADJECK, M. C., NEIL ADGER, W., BROWN, K., CONWAY, D., HALLS, A. S., PILLING, G. M., REYNOLDS, J. D. & ANDREW, N. L. 2009. Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and fisheries,* 10**,** 173-196.

ANDREW, N. & PEPPERELL, J. 1992. The by-catch of shrimp trawl fisheries. *Oceanography and Marine Biology: An Annual Review,* 30.

AXELSEN, B. E. & JOHNSEN, E. 2014. An evaluation of the bottom trawl surveys in the Benguela Current Large Marine Ecosystem. *Fisheries Oceanography*.

BARRATT, I. & ALLCOCK, L. 2012. Sepia orbignyana. The IUCN Red List of Threatened Species.

BIANCHI, G. 1986. *Fichas FAO de identifacao de espécies para propósitos comerciais. Guia de campo para as espécies comerciais marinhas e de águas salobras de Angola,* Rome, Preparado com o apoio da NORAD e da FAO (FIRM) Programa Regular, FAO.

BIANCHI, G. 1992. Study of the demersal assemblages of the continental shelf and upper Angolan slope. *Marine ecology progress series. Oldendorf,* 81**,** 101-120.

BIANCHI, G., GISLASON, H., GRAHAM, K., HILL, L., JIN, X., KORANTENG, K., MANICKCHAND-HEILEMAN, S., PAYA, I., SAINSBURY, K. & SANCHEZ, F. 2000. Impact of fishing on size composition and diversity of demersal fish communities. *ICES Journal of Marine Science: Journal du Conseil,* 57**,** 558-571.

BOARD, W. E. 2000. WoRMS Worlds Register of Marine Species.

BOYER, D., BOYER, H., FOSSEN, I. & KREINER, A. 2001. Changes in abundance of the northern Benguela sardine stock during the decade 1990–2000, with comments on the relative importance of fishing and the environment. *South African Journal of Marine Science,* 23**,** 67-84.

CARPENTIERI, P., COLLOCA, F. & ARDIZZONE, G. 2005. Day–night variations in the demersal nekton assemblage on the Mediterranean shelf-break. *Estuarine, Coastal and Shelf Science,* 63**,** 577-588.

CARTON, J. A. 1991. Effect of seasonal surface freshwater flux on sea surface temperature in the tropical Atlantic Ocean. *Journal of Geophysical Research: Oceans (1978–2012),* 96**,** 12593-12598.

CASAL, C. 2006. Global Documentation of Fish Introductions: the Growing Crisis and Recommendations for Action. *Biological Invasions,* 8**,** 3-11.

COCHRANE, K., DE YOUNG, C., SOTO, D. & BAHRI, T. 2009. Climate change implications for fisheries and aquaculture. *FAO Fisheries and aquaculture technical paper,* 530**,** 212.

COHEN, D. M., INADA, T., IWAMOTO, T. & SCIALABBA, N. 1990. FAO species catalogue. Vol. 10. Gadiform fishes of the world (Order Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. FAO Fish. Synop. 125(10). Rome: FAO. 442 p.

COOKE, S. J. & COWX, I. G. 2004. The role of recreational fishing in global fish crises. *BioScience,* 54**,** 857-859.

COSTELLO, C., GAINES, S. D. & LYNHAM, J. 2008. Can catch shares prevent fisheries collapse? *Science,* 321**,** 1678-1681.

CRIBB, J. 2010. *The coming famine: the global food crisis and what we can do to avoid it*, University of California Pr.

CURY, P. & SHANNON, L. 2004. Regime shifts in upwelling ecosystems: observed changes and possible mechanisms in the northern and southern Benguela. *Progress in Oceanography,* 60**,** 223-243.

D., F. R. P. 2000. FishBase. 07.07.2013 ed.: ITIS Catalouge of life.

DAGET, J. & NJOCK, J. C. 1986. *Polynemidae. p. 352-354. In J. Daget, J.-P. Gosse and D.F.E. Thys van den Audenaerde (eds.) Check-list of the freshwater fishes of Africa (CLOFFA). ISNB, Brussels; MRAC, Tervuren; and ORSTOM, Paris. Vol. 2.*

DEVRIES, D. R. & STEIN, R. A. 1992. Complex interactions between fish and zooplankton: quantifying the role of an open-water planktivore. *Canadian Journal of Fisheries and Aquatic Sciences,* 49**,** 1216-1227.

ENGÅS, A. & GODØ, O. R. 1989. Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. *Journal du Conseil: ICES Journal of Marine Science,* 45**,** 269-276.

ESCHMEYER, W. & FRICKE, R. 2000. Catalog of Fishes. 2012 ed.: Electronic Database accessible at http://research.calacademy.org/research/ichthyology/catalog/fishcatmain.asp. Captured on.

FABI, G., GRATI, F., LUCCHETTI, A. & TROVARELLI, L. 2002. Evolution of the fish assemblage around a gas platform in the northern Adriatic Sea. *ICES Journal of Marine Science: Journal du Conseil,* 59**,** S309-S315.

FABI, G., GRATI, F., PULETTI, M. & SCARCELLA, G. 2004. Effects on fish community induced by installation of two gas platforms in the Adriatic Sea. *Marine ecology. Progress series,* 273**,** 187-197.

FAO 2012. The State of World Fisheries and Aquaculture. FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS.

FAO 2014a. FAO FishFinder - Web Site. FAO FishFinder. FI Institutional Websites. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated . [Cited 3 March 2014]. http://www.fao.org/fishery/.

FAO 2014b. *The State of World Fisheries and Aquaculture (SOFIA)* Rome, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

FISCHER, W. & SCOTT, W. 1981. FAO species identification sheets for fishery purposes-eastern central Atlantic (fishing areas 34, 47 (in part).

GORDON, H. S. 1954. The economic theory of a common-property resource: the fishery. *The Journal of Political Economy,* 62**,** 124-142.

HALL, M. A., ALVERSON, D. L. & METUZALS, K. I. 2000. By-catch: problems and solutions. *Marine Pollution Bulletin,* 41**,** 204-219.

HAYS, G. C., RICHARDSON, A. J. & ROBINSON, C. 2005. Climate change and marine plankton. *Trends in Ecology & Evolution,* 20**,** 337-344.

HIRST, A. C. & HASTENRATH, S. 1983. Atmosphere-ocean mechanisms of climate anomalies in the Angola-tropical Atlantic sector. *Journal of Physical Oceanography,* 13**,** 1146-1157.

HOEGH-GULDBERG, O. & BRUNO, J. F. 2010. The impact of climate change on the world's marine ecosystems. *Science,* 328**,** 1523-1528.

HUTCHINGS, L., VAN DER LINGEN, C., SHANNON, L., CRAWFORD, R., VERHEYE, H., BARTHOLOMAE, C., VAN DER PLAS, A., LOUW, D., KREINER, A. & OSTROWSKI, M. 2009. The Benguela Current: An ecosystem of four components. *Progress in Oceanography,* 83**,** 15-32.

HÄDER, D.-P., KUMAR, H., SMITH, R. & WORREST, R. 2007. Effects of solar UV radiation on aquatic ecosystems and interactions with climate change. *Photochemical & Photobiological Sciences,* 6**,** 267-285.

IPCC 2007. *Climate Change 2007: impacts, adaptation and vulnerability: contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change*, Cambridge University Press.

IPCC 2014. *Climate change 2014: impacts, adaptation, and vulnerability,* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

ISLAM, M. S. & TANAKA, M. 2004. Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. *Marine pollution bulletin,* 48**,** 624-649.

ITC 2003. The Fishing Industry in Angola. *BUSINESS FOR DEVELOPMENT: IMPLICATIONS FOR EXPORT STRATEGY-MAKERS.* International Trade Centre.

JACKSON, J. B., KIRBY, M. X., BERGER, W. H., BJORNDAL, K. A., BOTSFORD, L. W., BOURQUE, B. J., BRADBURY, R. H., COOKE, R., ERLANDSON, J. & ESTES, J. A. 2001. Historical overfishing and the recent collapse of coastal ecosystems. *science,* 293**,** 629-637.

JARRE, A., HUTCHINGS, L., KIRKMAN, S. P., KREINER, A., TCHIPALANGA, P., KAINGE, P., UANIVI, U., VAN DER PLAS, A. K., BLAMEY, L. K. & COETZEE, J. C. 2015. Synthesis: climate effects on biodiversity, abundance and distribution of marine organisms in the Benguela. *Fisheries Oceanography,* 24**,** 122-149.

KARL, T. R. & MELILLO, J. M. 2009. *Global climate change impacts in the United States*, Cambridge University Press.

KIRKMAN, S. P., YEMANE, D., ATKINSON, L. J., KATHENA, J., NSIANGANGO, S. E., SINGH, L., AXELSEN, B. E. & SAMAAI, T. 2015. Regime shifts in demersal assemblages of the Benguela Current Large Marine Ecosystem: a comparative assessment. *Fisheries Oceanography,* 24**,** 15-30.

KORANTENG, K. A. 2001. Structure and dynamics of demersal assemblages on the continental shelf and upper slope off Ghana, West Africa.

KRAHN, M. M., YLITALO, G. M., BUZITIS, J., BOLTON, J. L., WIGREN, C. A., CHAN, S.-L. & VARANASI, U. 1993. Analyses for petroleum-related contaminants in marine fish and sediments following the Gulf oil spill. *Marine Pollution Bulletin,* 27**,** 285-292.

KRAKSTAD, J.-O., ZAERA, D., NSIANGANGO, S. & SANGOLAY, B. 2010. Survey of the fish resources of Angola, Final Report.

LAMBERT, D. 1992. Zero-inflated Poisson regression, with an application to defects in manufacturing. *Technometrics,* 34**,** 1-14.

LANKESTER, K. 2002. The EU-Angola fisheries agreement and fisheries in Angola.

LASS, H., SCHMIDT, M., MOHRHOLZ, V. & NAUSCH, G. 2000. Hydrographic and current measurements in the area of the Angola-Benguela Front. *Journal of Physical oceanography,* 30**,** 2589-2609.

LE GUILLOUX, E., OLU, K., BOURILLET, J.-F., SAVOYE, B., IGLÉSIAS, S. & SIBUET, M. 2009. First observations of deep-sea coral reefs along the Angola margin. *Deep Sea Research Part II: Topical Studies in Oceanography,* 56**,** 2394-2403.

LEBRETON, J.-D., BURNHAM, K. P., CLOBERT, J. & ANDERSON, D. R. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. *Ecological monographs,* 62**,** 67-118.

LECOMTE, J. B., BENOÎT, H. P., ANCELET, S., ETIENNE, M. P., BEL, L. & PARENT, E. 2013. Compound Poisson-gamma vs. delta-gamma to handle zero-inflated continuous data under a variable sampling volume. *Methods in Ecology and Evolution,* 4**,** 1159-1166.

LLORIS, D., MATALLANAS, J. & OLIVER, P. 2005. *Hakes of the world (Family Merlucciidae). An annotated and illustrated catalogue of hake species known to date. FAO Spec. Cat. Fish. Purp. 2:57p. Rome: FAO.*

LOENG, H. & STENEVIK, E. K. 2015. NansClim–climate effects on biodiversity, abundance and distribution of marine organisms. *Fisheries Oceanography,* 24**,** iii-iv.

MARTIN, C. J. & LOWE, C. G. 2010. Assemblage structure of fish at offshore petroleum platforms on the San Pedro Shelf of southern California. *Marine and Coastal Fisheries,* 2**,** 180-194.

MHLONGO, N., YEMANE, D., HENDRICKS, M. & LINGEN, C. D. 2015. Have the spawning habitat preferences of anchovy (Engraulis encrasicolus) and sardine (Sardinops sagax) in the southern Benguela changed in recent years? *Fisheries Oceanography,* 24**,** 1-14.

MOHRHOLZ, V., BARTHOLOMAE, C., VAN DER PLAS, A. & LASS, H. 2008. The seasonal variability of the northern Benguela undercurrent and its relation to the oxygen budget on the shelf. *Continental Shelf Research,* 28**,** 424-441.

NIELSEN, J. G. C., D M & R, M. D. F. R. C. 1999. Ophidiiform fishes of the world (Order Ophidiiformes). An annotated and illustrated catalogue of pearlfishes, cusk-eels, brotulas and other ophidiiform fishes known to date. FAO Fish. Synop. .

NOBRE, P. & SRUKLA, J. 1996. Variations of sea surface temperature, wind stress, and rainfall over the tropical Atlantic and South America. *Journal of climate,* 9**,** 2464-2479.

OLSEN, S. & VALDEMARSEN, J. W. Fish distribution studies around offshore installations. 1977. ICES.

OSTROWSKI, M., DA SILVA, J. C. & BAZIK-SANGOLAY, B. 2009. The response of sound scatterers to El Niño-and La Niña-like oceanographic regimes in the southeastern Atlantic. *ICES Journal of Marine Science: Journal du Conseil,* 66**,** 1063-1072.

PAUL, J. A New Era of World Hunger? The Global Food Crisis Analyzed. 2010. Global Policy Forum (GPF).

POSTEL, L., DA SILVA, A. J., MOHRHOLZ, V. & LASS, H.-U. 2007. Zooplankton biomass variability off Angola and Namibia investigated by a lowered ADCP and net sampling. *Journal of Marine Systems,* 68**,** 143-166.

QUÉRO, J.-C., J.C., N. & DE LA HOZ, M. M. 2004. *Yarrella Blackfordi* [Online]. Food and Agriculture Organization of the United Nations. Available: http://www.fishbase.org/ [Accessed 13.02.2015.

RAMOS, M., L. 2011. Angola's oil industry operations.: Open Society Initiative for Southern Africa (OSISA).

REASON, C. & ROUAULT, M. 2006. Sea surface temperature variability in the tropical southeast Atlantic Ocean and West African rainfall. *Geophysical research letters,* 33.

RICHARDSON, P. L. & WALSH, D. 1986. Mapping climatological seasonal variations of surface currents in the tropical Atlantic using ship drifts. *Journal of Geophysical Research: Oceans (1978–2012),* 91**,** 10537-10550.

ROPER, C. F. E., SWEENEY, M. J. & NAUEN, C. E. 1984. FAO species catalogue VOL. 3. Cephalopods of the world. An Annotated and Illustrated Catalogue of Species of Interest to Fisheries. Rome: Food and Agriculture Organization of the United Nations.

ROSENZWEIG, C., KAROLY, D., VICARELLI, M., NEOFOTIS, P., WU, Q., CASASSA, G., MENZEL, A., ROOT, T. L., ESTRELLA, N. & SEGUIN, B. 2008. Attributing physical and biological impacts to anthropogenic climate change. *Nature,* 453**,** 353-357.

SCARCELLA, G., GRATI, F. & FABI, G. 2011. Temporal and spatial variation of the fish assemblage around a gas platform in the northern Adriatic Sea, Italy. *Turkish Journal of Fisheries and Aquatic Sciences,* 11.

SERIGSTAD, B. 2009. Marine environmental survey of bottom sediments in Cabinda and Soyo province, Angola. April 2009.

SHANNON, L., AGENBAG, J. & BUYS, M. 1987. Large-and mesoscale features of the Angola-Benguela front. *South African Journal of Marine Science,* 5**,** 11-34.

SHANNON, L., BOYD, A., BRUNDRIT, G. & TAUNTON-CLARK, J. 1986. On the existence of an El Niño-type phenomenon in the Benguela system. *Journal of marine Research,* 44**,** 495-520.

SHANNON, L. & NELSON, G. 1996. The Benguela: large scale features and processes and system variability. *The South Atlantic.* Springer.

SHANNON, L. & PILLAR, S. 1986. The Benguela ecosystem. Part III. Plankton. *Oceanogr. Mar. Biol. Ann. Rev,* 24**,** 65-170.

SOKAL, R. R. & ROHLF, F. J. 1995. *Biometry: the principles and practice of statistics in biological research. Third edition. ,* New York, W. H. Freeman and Company.

STANLEY, D. R. & WILSON, C. A. 1997. Seasonal and spatial variation in the abundance and size distribution of fishes associated with a petroleum platform in the northern Gulf of Mexico. *Canadian Journal of Fisheries and Aquatic Sciences,* 54**,** 1166-1176.

STANLEY, D. R. & WILSON, C. A. 2000. Variation in the density and species composition of fishes associated with three petroleum platforms using dual beam hydroacoustics. *Fisheries Research,* 47**,** 161-172.

SÆTERSDAL, G., BIANCHI, G., STROMME, T. & VENEMA, S. C. 1999. *The Dr. Fridtjof Nansen Programme 1975-1993*, FAO.

TEAM, R. C. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, 2013. Version 2.12.1.

UNEP 1984. *Regional Seas Reports and Studies No. 46. The marine and coastal environment of the west and central african region and its state of pollution.* , United Nations Environment Programme.

UNEP 2005. *Ecosystems and human well-being: biodiversity synthesis. Millennium Ecosystem Assessment,* World Resources Institute, Washington, DC. , The United Nations Environment Programme.

VUONG, Q. H. 1989. Likelihood ratio tests for model selection and non-nested hypotheses. *Econometrica: Journal of the Econometric Society***,** 307-333.

WILLIAMS, L. & ROTA, A. 2010. Impact of climate change on fisheries and aquaculture in the developing world and opportunities for adaptation. *Fisheries Thematic Paper: Tool for project design.[Online]. Available: http://www. ifad. org/lrkm/pub/fisheries. pdf*.

WOLFSON, A., VAN BLARICOM, G., DAVIS, N. & LEWBEL, G. 1979. The marine life of an offshore oil platform. *Marine Ecology Progress Series,* 1**,** 81-89.

WORM, B., BARBIER, E. B., BEAUMONT, N., DUFFY, J. E., FOLKE, C., HALPERN, B. S., JACKSON, J. B., LOTZE, H. K., MICHELI, F. & PALUMBI, S. R. 2006. Impacts of biodiversity loss on ocean ecosystem services. *science,* 314**,** 787-790.

YAMAGATA, T. & IIZUKA, S. 1995. Simulation of the tropical thermal domes in the Atlantic: A seasonal cycle. *Journal of physical oceanography,* 25**,** 2129-2140.

YEMANE, D., MAFWILA, S. K., KATHENA, J., NSIANGANGO, S. E. & KIRKMAN, S. P. 2015. Spatio-temporal trends in diversity of demersal fish species in the Benguela current large marine ecosystem region. *Fisheries Oceanography,* 24**,** 102-121.

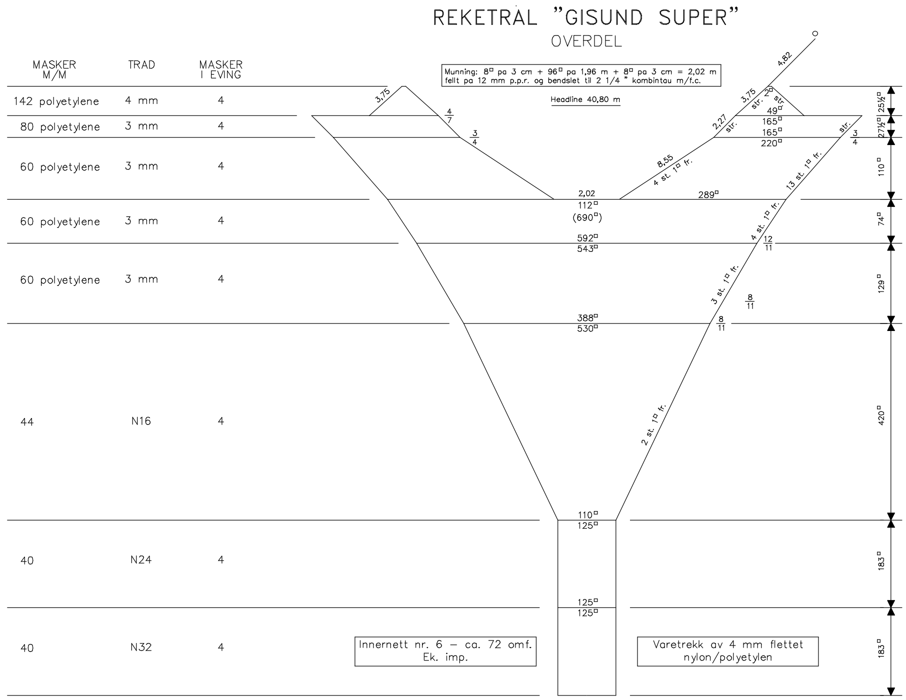
ZUUR A. F., IENO E. N., WALKER N., SAVELIEV A. A & M., S. G. 2009. *Mixed effects models and extensions in Ecology with R. ,* New York, Springer.

ZUUR, A. F., SAVELIEV, A. A. & IENO, E. N. 2012. *Zero inflated models and generalized linear mixed models with R*, Highland Statistics Limited Newburgh.

Appendix

Index

Gisund Super Trawl (Fig. 1–2):



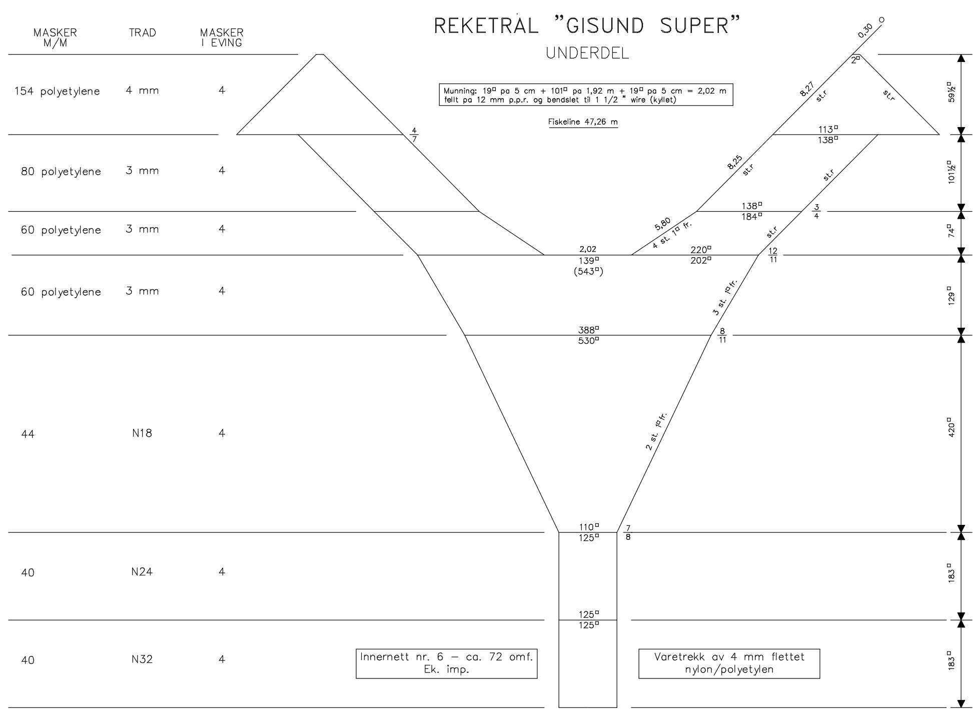


Figure 1. IMR's drawing of Gisund Super bottom (shrimp) trawl used in surveys with RV Dr. Fridtjof Nansen in 1989 and 2010. Drawing shows the upper and lower parts of the trawl respectively. Overdel = upper part, Underdel = Lower part. (Drawing: IMR)

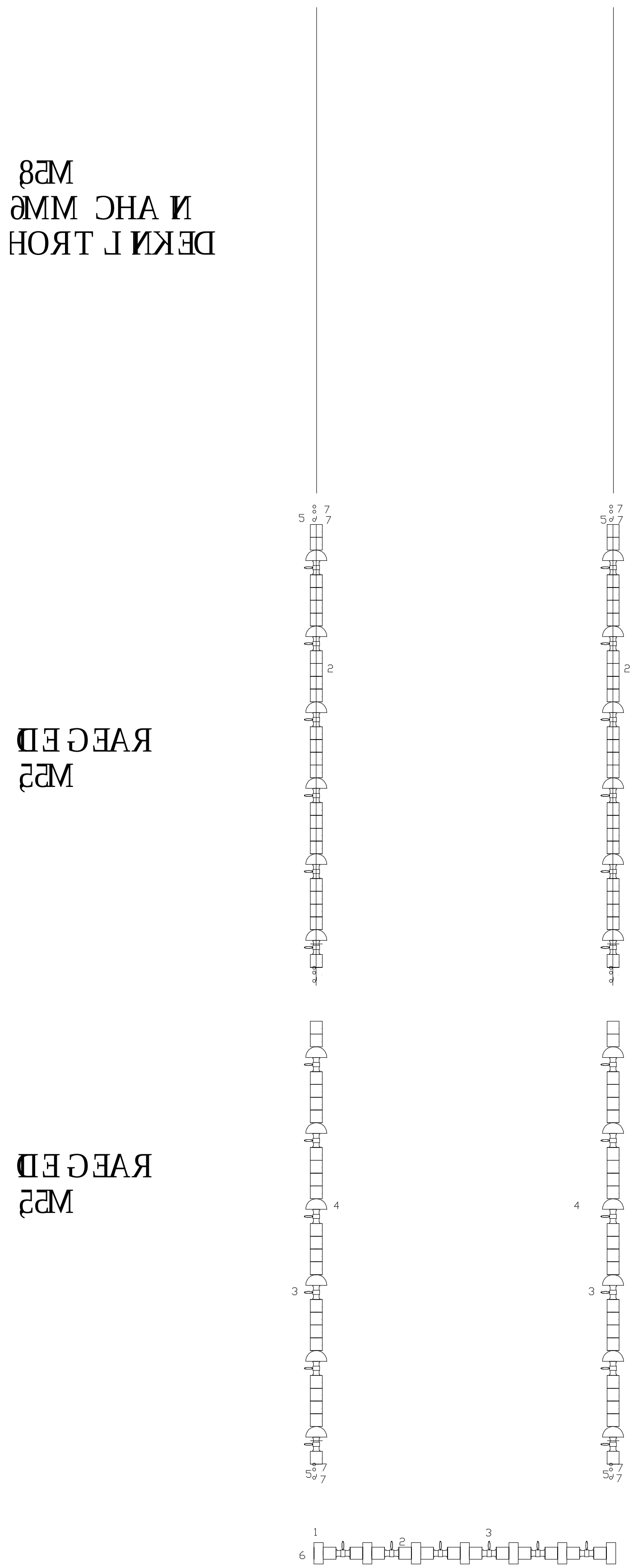


Figure 2. IMR's drawing of Gisund Super bottom (shrimp) trawl used in survey.with RV Dr. Fridtjof Nansen in 2010. Drawing shows chain and side gear. (Drawing: IMR)

Species list:

This list provides an overview over the species used in single-species analysis with common English names. The english species names follow the nomenclature from FAO.

Commercial pelagic species:

Brachydeuterus auritus	Bigeye grunt
Chlorophthalmus atlanticus	Atlantic greeneye
Chloroscombrus chrysurus	Atlantic bumper
Sepia officinalis [1]	Common cuttlefish
Sepia orbignyana [2]	Pink cuttlefish
Trachurus trecae	Cunene horse mackerel

Commercial demersal species:

Brotula barbata	Bearded brotula
Dentex angolensis	Angola dentex
Dentex macrophthalmus	Large-eye dentex
Galeoides decadactylus	Lesser African threadfin
Merluccius polli	Benguela hake
Pagellus bellottii	Red panadora
Umbrina canariensis	Canary drum

Common non-commercial demersal species:

Citharus linguatula	Spotted flounder
Nematocarcinus africanus	African spider shrimp
Raja miraletus	Brown ray, twineye skate
Synagrops microlepis	Thinlip splitfin
Yarrella blackfordi	

[1] The species sometimes migrate from deep to shallow waters (FAO 2015)
[2] The species has a wide bathymetric depth range (IUCN 2015)

Histograms from single species analyses (Fig. 3–17).

Histograms used for determining whether to use negative binomial distribution or not in single-species analyses. Histograms show log of NPUE for given species. Note that all histograms show the logarithm of NPUE>0.

Commercial pelagic species (Fig. 3–7):

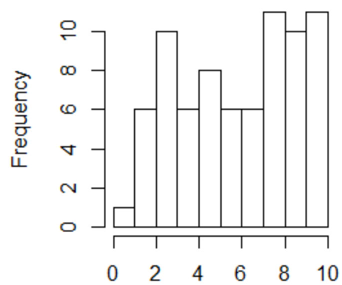


Figure 3. Histogram of NPUE>0 for *C. atlanticus.*

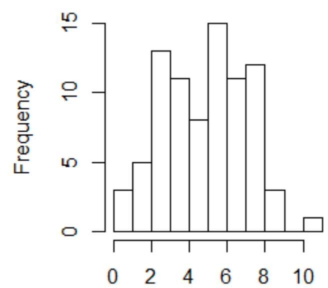


Figure 4. Histogram of NPUE>0 for *C. chrysurus*.

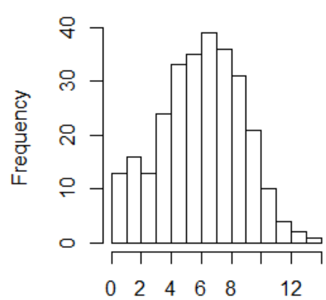


Figure 5. Histogram of NPUE>0 for *T. trecae.*

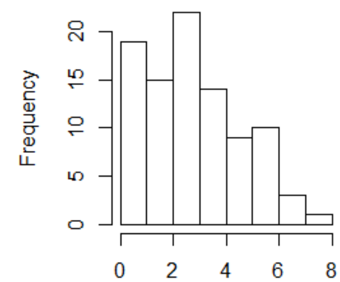


Figure 6. Histogram of NPUE>0 for *S. officinalis.*

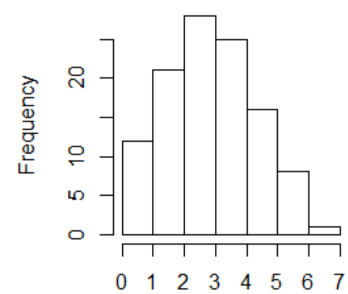


Figure 7. Histogram of NPUE>0 for *S. orbignyana.*

Commercial demersal species (Fig. 8–14):

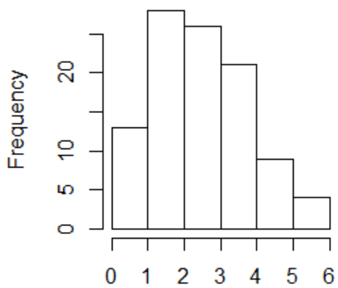


Figure 8. Histogram of NPUE>0 for *B. barbata.*

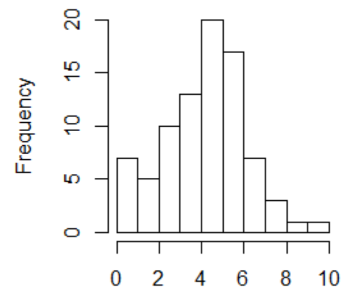


Figure 11. Histogram of NPUE>0 for *G. decadactylus.*

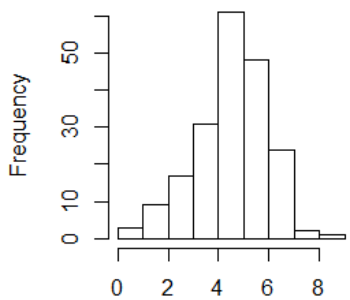


Figure 9. Histogram of NPUE>0 for *D. angolensis.*

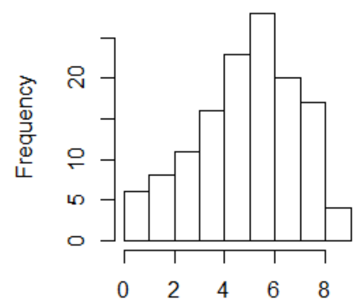


Figure 12. Histogram of NPUE>0 for *M. polli.*

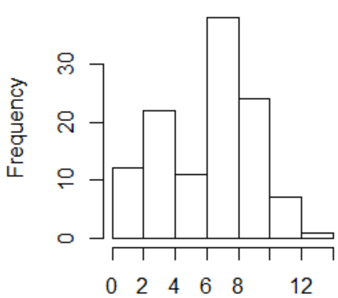


Figure 10. Histogram of NPUE>0 for *D. macrophthalmus.*

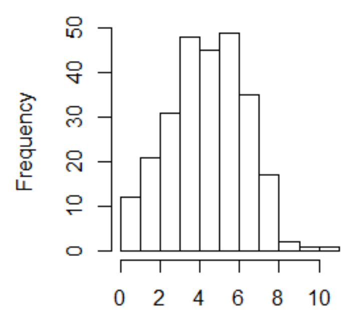


Figure 13. Histogram of NPUE>0 for *P. bellottii.*

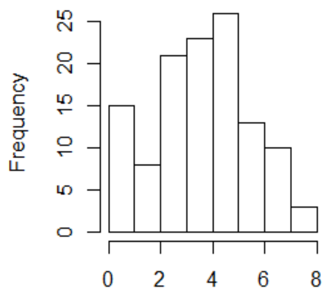


Figure 14. Histogram of NPUE>0 for *U. canariensis.*

Non-commercial common species (Fig. 15-17):

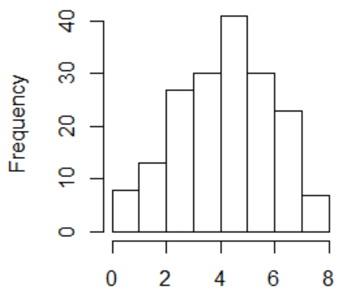


Figure 15. Histogram of NPUE>0 for *C. linguatula.*

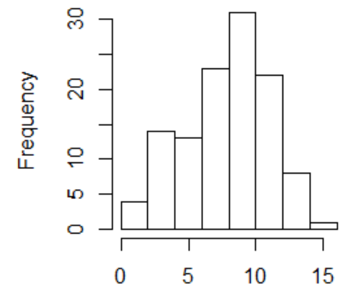


Figure 18. Histogram of NPUE>0 for *S. microlepis.*

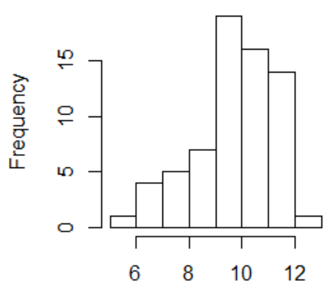


Figure 16. Histogram of NPUE>0 for *N. africanus.*

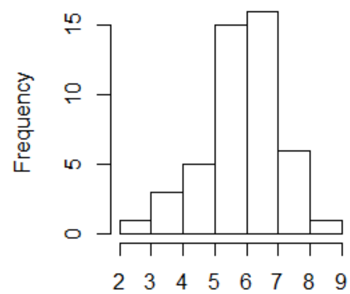


Figure 19. Histogram of NPUE>0 for *Y. blackfordi.*

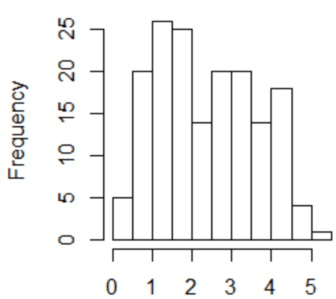


Figure 17. Histogram of NPUE>0 for *R. miraletus.*

Number of species per annum (Tab. 1):

Table 1. IMR's recorded number of species from surveys with demersal trawl in Angola during the period 1989-2013. First four digits in survey number refers to year. The surveys used in this study are highlighted in bold. (Table: IMR).

Survey number	Number of species
1989402	**271**
1989403	**287**
1989407	218
1991403	296
1991404	260
1992408	305
1994405	247
1995402	361
1996407	303
1997405	244
1997407	186
1998405	201
1999403	358
2000403	398
2001402	343
2002403	363
2003404	364
2004404	385
2005404	501
2006403	432
2007403	402
2008402	378
2009403	393
2010402	**397**
2011403	377
2012403	391
2013403	416

Figures and tables for single-species analyses (Fig. 20-29, Tab. 2-32):

This section contains complete tables providing all models used in single-species analyses, with corresponding AIC and ΔAIC values for each species. As well as tables with parameter estimates for the favored model for each species. Note: errors in some ZIP-models during analyses resulted in a differing number of models in the tables.

Commercial pelagic species (Fig.20-29, Tab. 2-11):

B. auritus

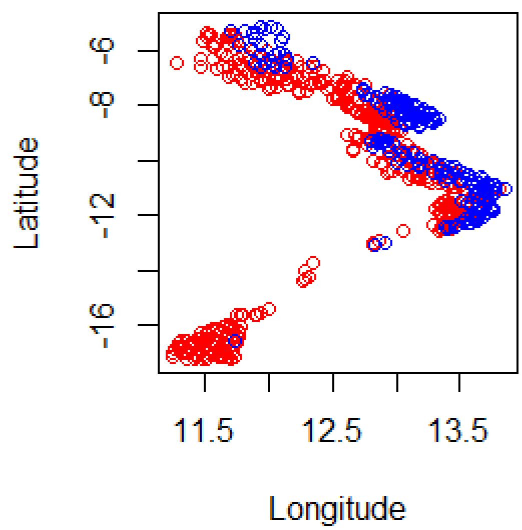


Figure 20. Scatter plot showing overall catch distribution of *B. auritus* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Table 2. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *B. auritus* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude^2 * Bottom depth * Year	Year	14	6912069	0
Latitude^2 * Bottom depth + Year	Year	9	7067343	155274
Latitude^2 * Bottom depth	1	7	7513432	601363
Latitude^2 * Bottom depth	Year	8	7535593	623524
Latitude^2 * Bottom depth	Latitude	8	7535804	623735
Year * Latitude	Latitude	6	7593138	681069
Latitude^2 + Bottom depth	Latitude	6	7776134	864065
Bottom depth * Year	Latitude + Bottom depth	7	7788377	876308
Bottom depth + Year	Latitude + Bottom depth	6	7835123	>876308
Latitude + Bottom depth	Latitude	5	8120671	>876308
Latitude	Latitude + Bottom depth	5	8126280	>876308
Latitude	Bottom depth	4	8126317	>876308

Count	Zero-inflated	df	AIC	∆AIC
Bottom depth	Latitude + Bottom depth	5	8302958	>876308
Bottom depth	Bottom depth	4	8302996	>876308

Table 3. Parameter estimates for favored model from model selection. Species = *B. auritus.* Model is displayed in sub-models. Note that model received a warning during analyses.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	9.678	-0.0034	2826.69	<0.0001
	Latitude	-39.52	-0.1044	-378.50	<0.0001
	$Latitude^2$	-1.4550	0.0903	-16.10	<0.0001
	Bottom depth	-0.0287	<0.0001	-306.08	<0.0001
	Year[2010]	0.3340	0.0224	14.90	<0.0001
	Latitude*Bottom depth	1.3450	0.0028	479.59	<0.0001
	$Latitude^2$*Bottom depth	-0.8355	0.0025	-335.75	<0.0001
	Latitude*Year[2010]	13.2600	0.8130	16.31	<0.0001
	$Latitude^2$*Year[2010]	46.0500	0.6077	75.76	<0.0001
	Bottom depth*Year[2010]	-0.0260	0.0005	-57.78	<0.0001
	Latitude*Bottom depth*Year[2010]	0.0918	0.0154	6.06	<0.0001
	$Latitude^2$*Bottom depth*Year[2010]	-0.5248	0.0122	-42.87	<0.0001
Zero-inflation	Intercept	0.4646	0.1066	4.358	<0.0001
	Year[2010]	0.1819	0.2021	0.900	0.368

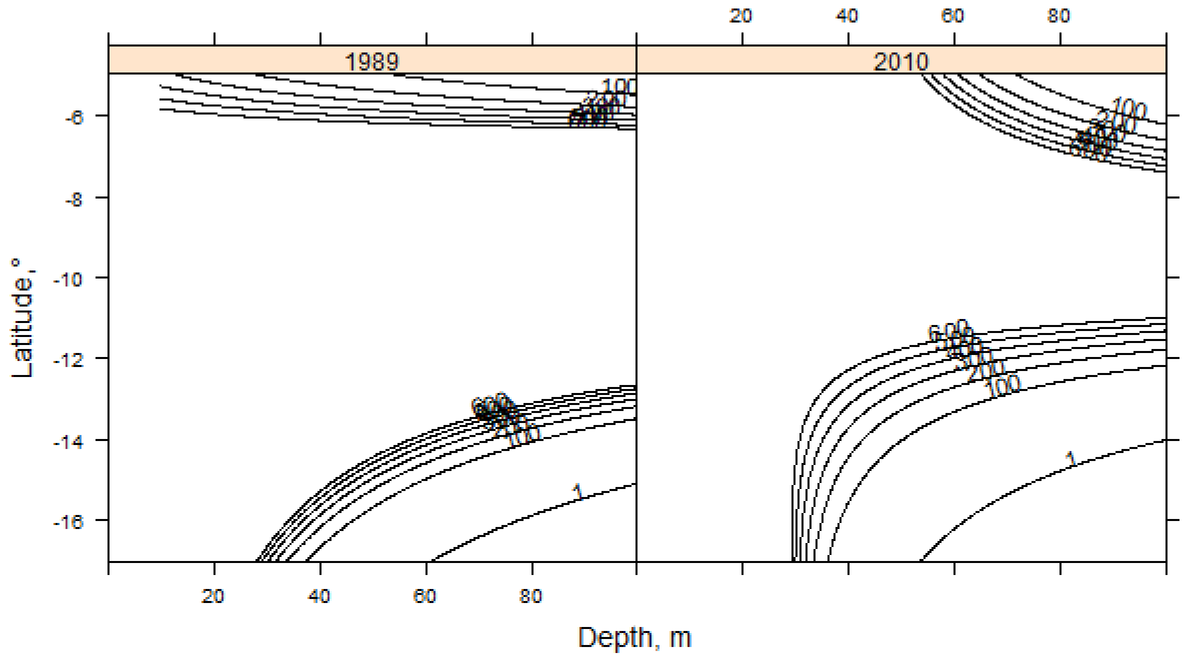


Figure 21. Predicted NPUE of *B. auritus* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model for *B. auritus,* see table above. NPUE is illustrated with contours and numbers. The model predictions were retrieved from parameter estimates, see table above.

C. atlanticus

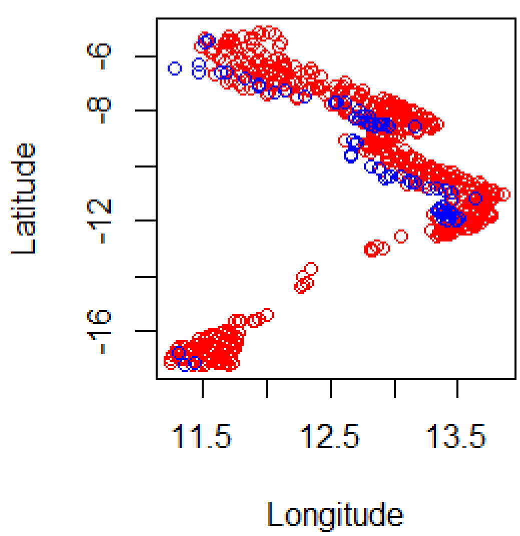


Figure 22. Scatter plot showing overall catch distribution of *C. atlanticus* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Table 4. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *C. atlanticus* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude^2 * Bottom depth * Year	Year	14	328221.0	0
Latitude^2 * Bottom depth + Year	Year	9	344511.4	16290
Latitude^2 * Bottom depth	Year	8	352505.6	24284.6
Latitude^2 * Bottom depth	1	7	352512.3	24291.3
Latitude^2 * Bottom depth	Latitude	8	352512.5	24291.5
Latitude^2 + Bottom depth	Latitude	6	355638.6	27417.6
Bottom depth * Year	Latitude + Bottom depth	7	363327.7	35106.7
Bottom depth + Year	Latitude + Bottom depth	6	366166.5	37945.5
Latitude + Bottom depth	Latitude	5	376674.9	>37945.5
Bottom depth	Latitude	4	380999.6	>37945.5
Year * Latitude	Latitude	6	385496.8	>37945.5
Bottom depth	Latitude + Bottom depth	5	386026.1	>37945.5
Latitude	Bottom depth	4	406900.5	>37945.5
Latitude	Latitude + Bottom depth	5	406901.7	>37945.5

Table 5. Parameter estimates for favored model from model selection. Species = *C. atlanticus.* Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	10,4000	0,0181	575,22	<0.0001
	Latitude	11,3500	0,5203	21,81	<0.0001
	Latitude^2	13,5000	0,4772	28,29	<0.0001
	Bottom depth	-0,0096	0,0001	-114,56	<0.0001
	Year[2010]	-1,4870	0,0438	-33,97	<0.0001
	Latitude*Bottom depth	0,0140	0,0025	5,68	<0.0001
	Latitude^2*Bottom depth	-0,1220	0,0023	-51,98	<0.0001
	Latitude*Year[2010]	-43,5900	1,6330	-26,70	<0.0001
	Latitude^2*Year[2010]	-4,5570	1,2800	-3,56	0,0004
	Bottom depth*Year[2010]	0,0058	0,0001	40,36	<0.0001
	Latitude*Bottom depth*Year[2010]	0,0462	0,0052	8,83	<0.0001
	Latitude^2*Bottom depth*Year[2010]	0,0837	0,0042	19,96	<0.0001
Zero-inflation	Intercept	2,2227	0,1665	13,353	<0.0001
	Year[2010]	-0,7411	0,2505	-2,958	0,0031

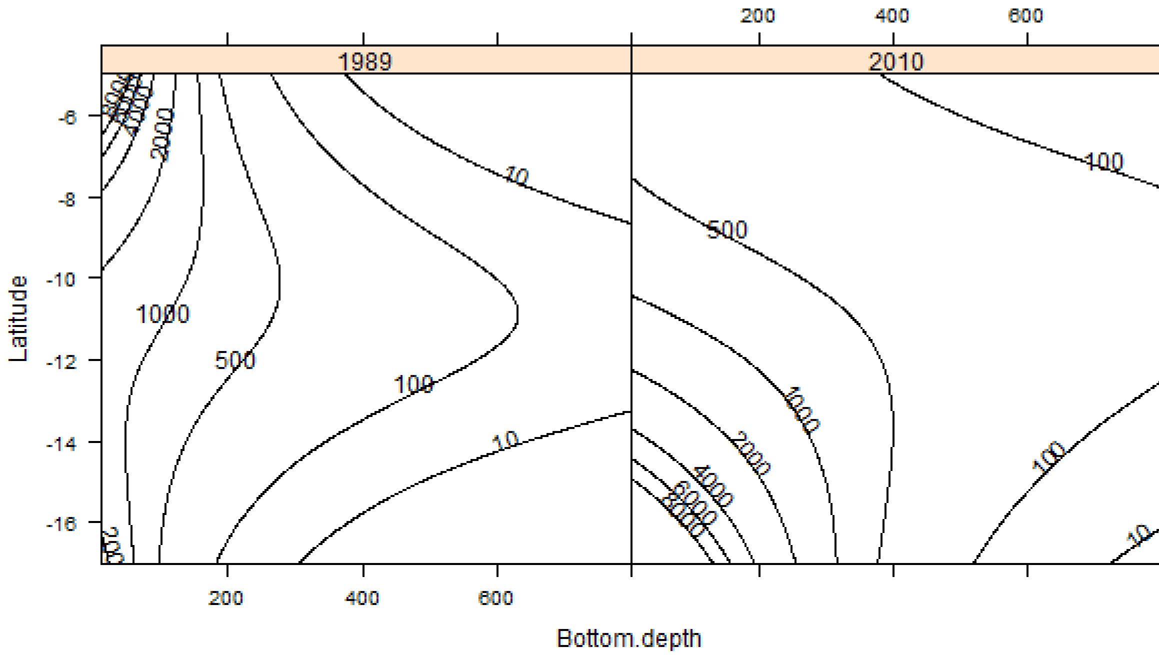


Figure 23. Predicted NPUE of *C. atlanticus* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model for *C. atlanticus,* see table above. NPUE is illustrated with contours and numbers. The model predictions were retrieved from parameter estimates, see table above.

C. chrysurus

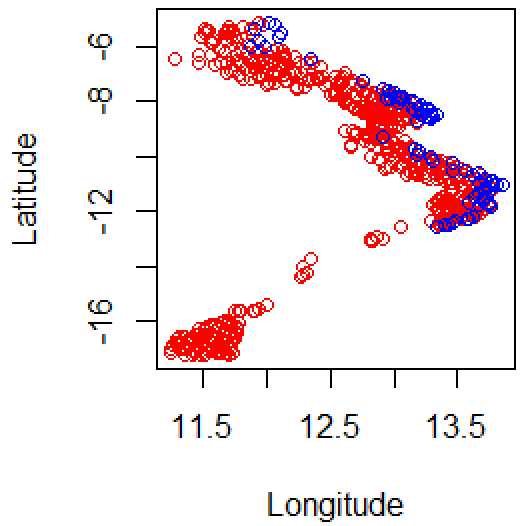


Figure 24. Scatter plot showing overall catch distribution of *C. chrysurus* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Table 6. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *C. chrysurus* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude^2 * Bottom depth * Year	Year	14	98701.81	0
Latitude^2 * Bottom depth + Year	Year	9	264446.23	165744.42
Bottom depth * Year	Latitude + Bottom depth	7	286087.26	187385.45
Bottom depth + Year	Latitude + Bottom depth	6	286096.73	187394.92
Latitude^2 * Bottom depth	1	7	299403.12	200701.31
Latitude^2 * Bottom depth	Latitude	8	299403.68	200701.87
Latitude^2 * Bottom depth	Year	8	299404.12	200702.31
Year * Latitude	Latitude	6	303335.07	204633.26
Latitude^2 + Bottom depth	Latitude	6	306199.95	>204633.26
Latitude + Bottom depth	Latitude	5	322922.71	>204633.26
Bottom depth	Latitude + Bottom depth	5	324881.29	>204633.26
Bottom depth	Bottom depth	4	324890.89	>204633.26
Bottom depth	Latitude	4	324985.09	>204633.26
Latitude	Latitude + Bottom depth	5	345269.22	>204633.26
Latitude	Bottom depth	4	345278.83	>204633.26

The most supported model received an **error.**

S. officinalis

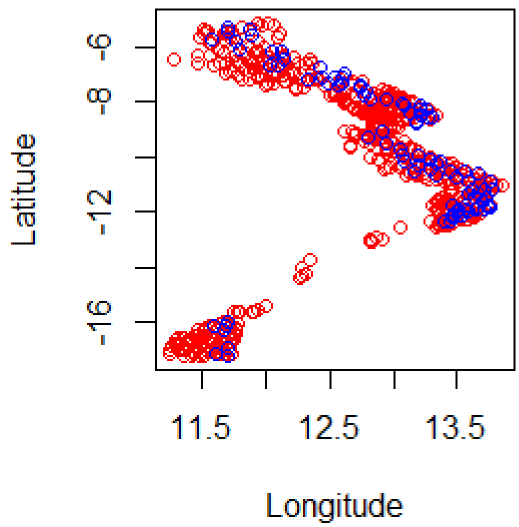


Figure 25. Scatter plot showing overall catch distribution of *S. offocinalis* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Table 7. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *S. officinalis* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude² * Bottom depth * Year	Year	14	11691.42	0
Latitude² * Bottom depth + Year	Year	9	11903.88	212.46
Latitude² * Bottom depth	Year	8	12321.97	630.55
Latitude² * Bottom depth	1	7	12333.24	641.82
Latitude² * Bottom depth	Latitude	8	12333.72	642.30
Latitude² + Bottom depth	Latitude	6	12596.36	904.94
Year * Latitude	Latitude	6	12876.44	1185.02
Latitude + Bottom depth	Latitude	5	12968.00	1276.58
Latitude	Latitude + Bottom depth	5	13480.37	>1276.58
Latitude	Bottom depth	4	13481.26	>1276.58
Bottom depth * Year	Latitude + Bottom depth	7	16731.49	>1276.58
Bottom depth + Year	Latitude + Bottom depth	6	16808.84	>1276.58
Bottom depth	Latitude + Bottom depth	5	18155.51	>1276.58
Bottom depth	Bottom depth	4	18156.40	>1276.58
Bottom depth	Latitude	4	18204.68	>1276.58

Table 8. Parameter estimates for favored model from model selection. Species = *S. officinalis.* Model is displayed in sub-models. Note that model received a warning during analyses.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	3.3120	0.0487	67.93	<0.0001
	Latitude	-39.7700	1.1700	-33.98	<0.0001
	Latitude^2	-7-7970	0.8441	-9.23	<0.0001
	Bottom depth	-0.0076	0.0005	15.27	<0.0001
	Year[2010]	-0.4403	1.6190	0.27	0.7856
	Latitude*Bottom depth	-0.1976	0.0134	14.70	<0.0001
	Latitude^2*Bottom depth	-0.0293	0.0092	-3.178	0.0014
	Latitude*Year[2010]	67.0700	52.8400	1.27	0.2043
	Latitude^2*Year[2010]	-13.3700	51.5500	-0.26	0.7953
	Bottom depth*Year[2010]	-0.1010	0.0456	-2.41	0.0158
	Latitude*Bottom depth*Year[2010]	1.3840	1.5250	0.90	0.3641
	Latitude^2*Bottom depth*Year[2010]	-1.5300	1.3910	-1.09	0.2735
Zero-inflation	Intercept	1.4421	0.1260	11.44	<0.0001
	Year[2010]	-0.3551	0.3405	-1.04	0.2970

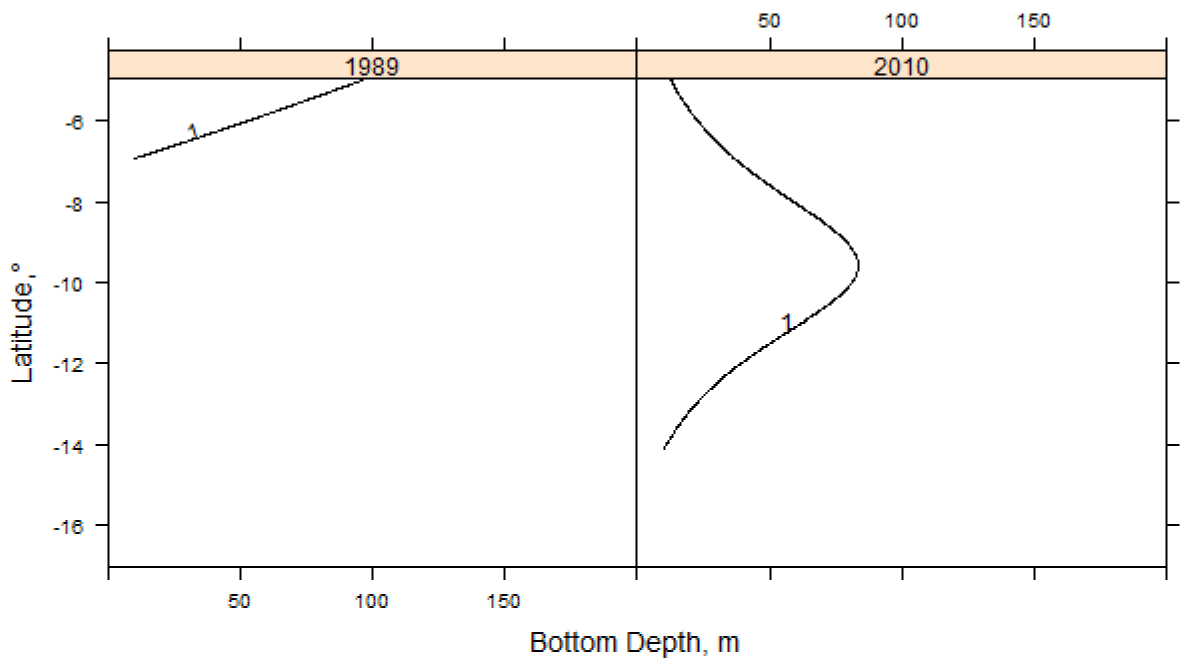


Figure 26. Predicted NPUE of *S. officinalis* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model for *S. officinalis,* see table above. NPUE is illustrated with contours and numbers. The model predictions were retrieved from parameter estimates, see table above.

S. orbignyana

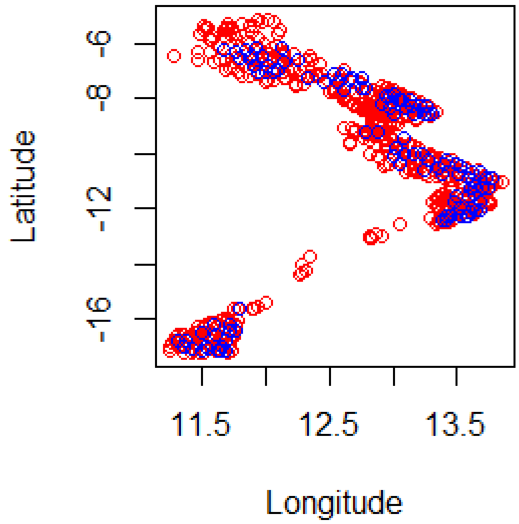


Figure 27. Scatter plot showing overall catch distribution of *S. orbignyana* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Table 9. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *S. orbignyana* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude² * Bottom depth * Year	Year	14	5006.324	0
Latitude² * Bottom depth + Year	Year	9	5147.545	141.221
Latitude² * Bottom depth	year	8	5409.730	403.406
Year * Latitude	Latitude	6	5419.383	413.059
Latitude	Bottom depth	4	5575.308	568.984
Latitude	Latitude + Bottom depth	5	5576.742	570.418
Latitude² * Bottom depth	1	7	5584.362	578.038
Latitude² * Bottom depth	Latitude	8	5585.341	579.017
Latitude² + Bottom depth	Latitude	6	5600.126	>579.017
Latitude + Bottom depth	Latitude	5	5611.622	>579.017
Bottom depth * Year	Latitude + Bottom depth	7	7295.257	>579.017
Bottom depth + Year	Latitude + Bottom depth	6	7465.373	>579.017
Bottom depth	Bottom depth	4	9220.023	>579.017
Bottom depth	Latitude + Bottom depth	5	9221.457	>579.017
Bottom depth	Latitude	4	9254.566	>579.017

Table 10. Parameter estimates for favored model from model selection. Species = *S. orbignyana.* Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	2.5842	0.3298	7.84	<0.0001
	Latitude	-41.3754	7.7248	-5.36	<0.0001
	Latitude^2	1.6413	5.1579	0.32	0.7503
	Bottom depth	0.0284	0.0049	5.75	<0.0001
	Year[2010]	0.9056	0.3339	2.71	0.0067
	Latitude*Bottom depth	0.5463	0.1151	4.75	<0.0001
	Latitude^2*Bottom depth	0.1227	0.0746	1.65	0.0998
	Latitude*Year[2010]	30.1245	7.8128	3.86	<0.0001
	Latitude^2*Year[2010]	3.9517	5.2891	0.75	0.4550
	Bottom depth*Year[2010]	-0.0310	0.0050	-6.23	<0.0001
	Latitude*Bottom depth*Year[2010]	-0.6125	0.1159	-5.28	<0.0001
	Latitude^2*Bottom depth*Year[2010]	-0.1673	0.0757	-2.21	0.0272
Zero-inflation	Intercept	3.1432	0.2478	12.69	<0.0001
	Year[2010]	-3.2487	0.2939	-11.05	<0.0001

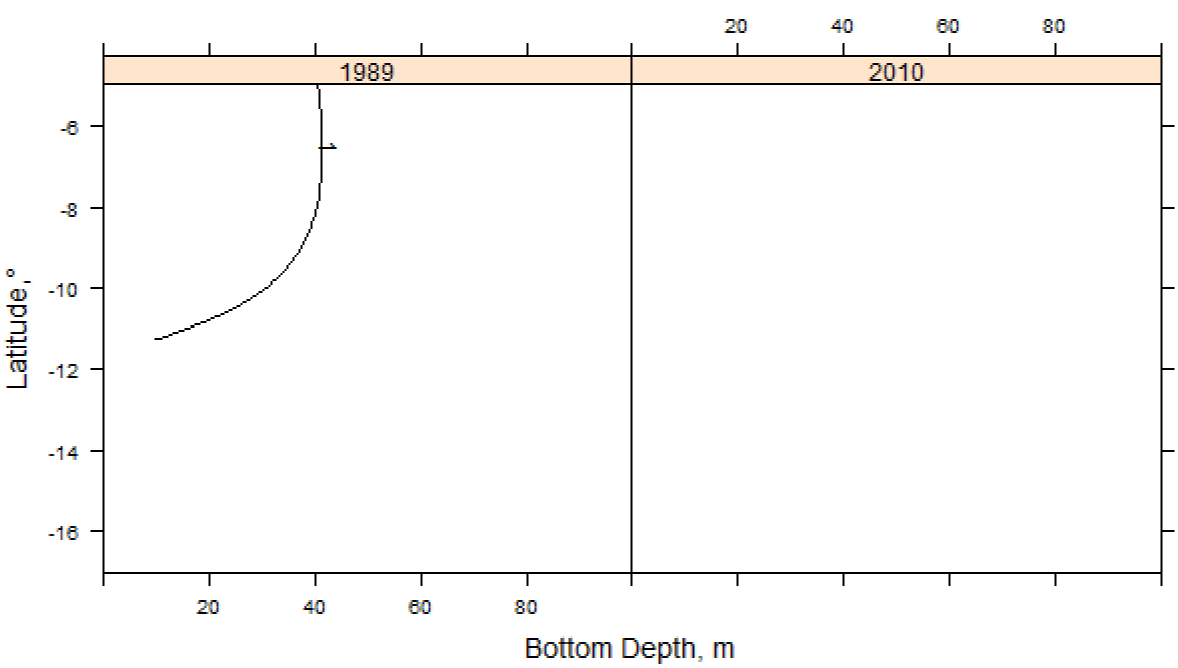


Figure 28. Predicted NPUE of *S. orbignyana* as function of latitude and bottom depth for 1989 and 2010. The predictions were estimated from the most supported ZIP-model for *S. orbignyana,* see table above. NPUE is illustrated with contours and numbers. The model predictions were retrieved from parameter estimates, see table above.

T. trecae

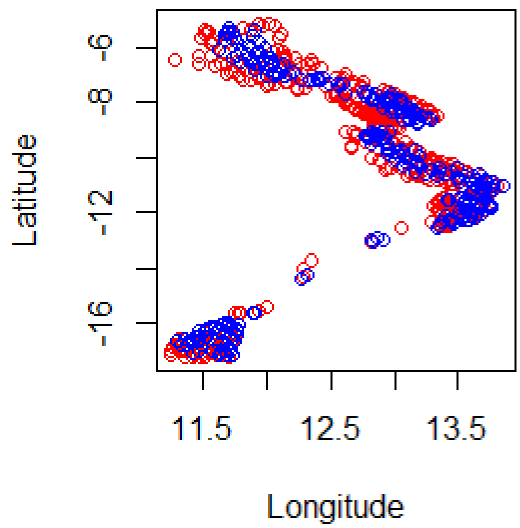


Figure 29. Scatter plot showing overall catch distribution of *T. trecae* of the continental shelf and upper slope of Angola during two surveys with bottom trawl in 1989 and one in 2010. Blue circles represent species present in trawl catch, red circles represent species absent in trawl catch.

Table 11. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *T. trecae* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
$Latitude^2$ * Bottom.depth * Year	Year	14	9002926	0
Year * Latitude	Latitude	6	10340737	1337811
$Latitude^2$ * Bottom.depth + Year	Year	9	11093449	2090523
$Latitude^2$ * Bottom depth	Year	8	11135509	2132583
$Latitude^2$ * Bottom depth	Latitude	8	11135516	2132590
$Latitude^2$ * Bottom depth	1	7	11135519	2132593
Latitude + Bottom depth	Latitude	5	11871204	2868278
Latitude	Latitude + Bottom depth	5	11882107	2879181
Latitude	Bottom depth	4	11882108	>2879181
Bottom depth	Latitude	4	12643751	>2879181

The most supported model received an **error.**

Commercial demersal species (Tab. 12-24):

B. barbata

Table 12. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *B. barbata* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
$Latitude^2$ * Bottom depth * Year	Year	14	3878.304	0
$Latitude^2$ * Bottom depth	Year	8	4452.802	574.498
$Latitude^2$ * Bottom depth + Year	Year	9	4454.465	576.161
$Latitude^2$ * Bottom depth	1	7	4493.834	615.53
$Latitude^2$ * Bottom depth	Latitude	8	4495.809	617.505
$Latitude^2$ + Bottom depth	Latitude	6	5373.888	1495.584
Latitude + Bottom depth	Latitude	5	5516.595	1638.291
Year * Latitude	Latitude	6	5630.586	1752.282
Latitude	Bottom depth	4	5741.352	>1752.282
Latitude	Latitude + Bottom depth	5	5742.694	>1752.282
Bottom depth * Year	Latitude + Bottom depth	7	5796.172	>1752.282
Bottom depth + Year	Latitude + Bottom depth	6	5902.720	>1752.282
Bottom depth	Bottom depth	4	5912.270	>1752.282
Bottom depth	Latitude + Bottom depth	5	5913.612	>1752.282
Bottom depth	Latitude	4	5918.657	>1752.282

Table 13. Parameter estimates for favored model from model selection. Species = *B. barbata.* Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	3.9240	0.1623	24.17	<0.0001
	Latitude	-104.8000	4.8410	-21.65	<0.0001
	$Latitude^2$	61.0400	3.2190	18.69	<0.0001
	Bottom depth	-0.0097	0.0015	-6.42	<0.0001
	Year[2010]	-0.1900	0.1900	-0.99	0.32
	Latitude*Bottom depth	0.9703	0.0500	19.53	<0.0001
	$Latitude^2$*Bottom depth	-0.6515	0.0318	-20.47	<0.0001
	Latitude*Year[2010]	40.9500	5.6000	7.37	<0.0001
	$Latitude^2$*Year[2010]	-37.1000	4.2920	-8.64	<0.0001
	Bottom depth*Year[2010]	0.0037	0.0017	2.08	0.04
	Latitude*Bottom depth*Year[2010]	-0.5430	0.0560	-9.73	<0.0001
	$Latitude^2$*Bottom depth*Year[2010]	0.3252	0.0408	7.964	<0.0001
Zero-inflation	Intercept	2.1703	0.1649	13.160	<0.0001
	Year[2010]	-1.4527	0.2281	-6.368	<0.0001

D. angolensis

Table 14. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *D. angolensis* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude² * Bottom depth * Year	Year	14	51166.04	0
Latitude² * Bottom depth + Year	Year	9	55640.16	4474.12
Bottom depth * Year	Latitude + Bottom depth	7	55882.89	4716.82
Latitude² * Bottom depth	Latitude	8	56207.88	5041.84
Latitude² * Bottom depth	1	7	56230.95	5064.91
Latitude² * Bottom depth	Year	8	56232.30	5066.26
Bottom depth + Year	Latitude + Bottom depth	6	57611.79	6445.75
Latitude² + Bottom depth	Latitude	6	57853.69	6687.65
Latitude + Bottom depth	Latitude	5	58427.57	>6687.65
Year * Latitude	Latitude	6	58768.37	>6687.65
Bottom depth	Latitude + Bottom depth	5	58771.79	>6687.65
Bottom depth	Latitude	4	58803.87	>6687.65
Bottom depth	Bottom depth	4	58806.32	>6687.65
Latitude	Latitude + Bottom depth	5	60613.39	>6687.65
Latitude	Bottom depth	4	60647.92	>6687.65

Table 15. Parameter estimates for favored model from model selection. Species = *D. angolensis.* Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	5.4320	0.0357	152.30	<0.0001
	Latitude	-67.2400	1.4690	-45.76	<0.0001
	Latitude²	38.1600	1.0010	38.10	<0.0001
	Bottom depth	-0.0041	0.0004	-11.14	<0.0001
	Year[2010]	1.1060	0.1230	8.99	<0.0001
	Latitude*Bottom depth	0.7094	0.0159	44.69	<0.0001
	Latitude²*Bottom depth	-0.4076	0.0103	-39.74	<0.0001
	Latitude*Year[2010]	33.9100	4.7080	7.20	<0.0001
	Latitude²*Year[2010]	-10.8200	2.8090	-3.85	<0.0001
	Bottom depth*Year[2010]	-0.0125	0.0011	-10.97	<0.0001
	Latitude*Bottom depth*Year[2010]	-0.0658	0.0435	-1.52	0.1307
	Latitude²*Bottom depth*Year[2010]	-0.0416	0.0253	-1.64	0.1007
Zero-inflation	Intercept	0.7402	0.1062	6.97	<0.0001
	Year[2010]	-0.2171	0.1896	-1.15	0.2520

D. macrophthalmus

Table 16. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *D. macrophthalmus* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
poly(Latitude, 2) * Bottom depth * year	year	14	2871534	0
poly(Latitude, 2) * Bottom depth + year	year	9	2915929	44395
poly(Latitude, 2) * Bottom depth	Latitude	8	2989831	118297
poly(Latitude, 2) * Bottom depth	year	8	2989846	118312
poly(Latitude, 2) * Bottom depth	1	7	2989858	118324
poly(Latitude, 2) + Bottom depth	Latitude	6	3006527	134993
Latitude + Bottom depth	Latitude	5	3692693	821159
year * Latitude	Latitude	6	3714023	842489
Latitude	Bottom depth	4	3982881	>842489
Bottom depth + year	Latitude + Bottom depth	6	4200161	>842489
Bottom depth	Latitude	4	4331388	>842489
Bottom depth	Bottom depth	4	4331538	>842489

Table 17. Parameter estimates for favored model from model selection. Species = *D. macrophthalmus.* Model is displayed in sub-models. Note that model received a warning during analyses.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	-11.2600	0.0696	-161.88	<0.0001
	Latitude	-383.8000	1.2650	-303.39	<0.0001
	Latitude^2	-159.2000	0.6188	-257.29	<0.0001
	Bottom depth	0.0192	0.0005	35.10	<0.0001
	Year[2010]	16.1900	0.2252	71.87	<0.0001
	Latitude*Bottom depth	0.3745	0.0105	35.70	<0.0001
	Latitude^2*Bottom depth	0.0497	0.0057	8.78	<0.0001
	Latitude*Year[2010]	388.6000	4.5920	84.62	<0.0001
	Latitude^2*Year[2010]	201.2000	2.5230	79.74	<0.0001
	Bottom depth*Year[2010]	-0.0222	0.0013	-16.60	<0.0001
	Latitude*Bottom depth*Year[2010]	-0.7203	0.0281	-25.64	<0.0001
	Latitude^2*Bottom depth*Year[2010]	-0.3348	0.0157	-21.28	<0.0001
Zero-inflation	Intercept	-0.0012	0.1493	-0.01	0.9930
	Year[2010]	1.8363	0.2703	6.79	<0.0001

G. decadactylus

Table 18. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *G. decatactylus* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
$Latitude^2$ * Bottom depth * Year	Year	14	87158.31	0
$Latitude^2$ * Bottom depth + Year	Year	9	93986.09	6827.78
$Latitude^2$ * Bottom depth	Latitude	8	94210.48	7052.17
$Latitude^2$ * Bottom depth	1	7	94220.58	7062.27
$Latitude^2$ * Bottom depth	Year	8	94221.82	7063.51
$Latitude^2$ + Bottom depth	Latitude	6	95909.61	8751.30
Latitude + Bottom depth	Latitude	5	99021.12	11862.81
Year * Latitude	Latitude	6	104453.18	17294.87
Latitude	Latitude + Bottom depth	5	106652.84	>17294.87
Latitude	Bottom depth	4	106668.15	>17294.87
Bottom depth * Year	Latitude + Bottom depth	7	110294.64	>17294.87
Bottom depth + Year	Latitude + Bottom depth	6	111330.20	>17294.87
Bottom depth	Latitude + Bottom depth	5	111849.35	>17294.87
Bottom depth	Bottom depth	4	111864.66	>17294.87
Bottom depth	Latitude	4	111975.88	>17294.87

The most supported model received an **error.**

M. polli

Table 19. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *M. polli* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
$Latitude^2$ * Bottom depth * year	Year	14	96533.87	0
$Latitude^2$ * Bottom depth + year	Year	9	100218.27	3684.4
Bottom depth * Year	Latitude + Bottom depth	7	101930.19	5396.32
Bottom depth + Year	Latitude + Bottom depth	6	106154.80	9620.93
$Latitude^2$ * Bottom depth	1	7	107927.96	11394.09
$Latitude^2$ * Bottom depth	Latitude	8	107928.85	11394.98
$Latitude^2$ * Bottom depth	Year	8	107929.14	11395.27
Year * Latitude	Latitude	6	108610.30	12076.43
$Latitude^2$ + Bottom depth	Latitude	6	111825.45	>12076.43
Latitude + Bottom depth	Latitude	5	113027.83	>12076.43
Bottom depth	Bottom depth	4	113718.63	>12076.43
Bottom depth	Latitude + Bottom depth	5	113720.63	>12076.43
Bottom depth	Latitude	4	113915.09	>12076.43
Latitude	Bottom depth	4	121349.26	>12076.43
Latitude	Latitude + Bottom depth	5	121351.26	>12076.43

Table 20. Parameter estimates for favored model from model selection. Species = *G. decadactylus.* Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	7.1020	0.0120	593.29	<0.0001
	Latitude	7.8810	0.3615	21.81	<0.0001
	Latitude^2	15.1200	0.3496	43.26	<0.0001
	Bottom depth	-0.0027	<0.0001	-48.44	<0.0001
	Year[2010]	-1.2360	0.0929	-13.30	<0.0001
	Latitude*Bottom depth	0.0183	0.0020	9.06	<0.0001
	Latitude^2*Bottom depth	-0.0771	0.0016	-49.74	<0.0001
	Latitude*Year[2010]	56.5400	3.0660	18.44	<0.0001
	Latitude^2*Year[2010]	-64.8100	2.8380	-22.84	<0.0001
	Bottom depth*Year[2010]	-0.0011	0.0002	-4.56	<0.0001
	Latitude*Bottom depth*Year[2010]	-0.0948	0.0008	-12.00	<0.0001
	Latitude^2*Bottom depth*Year[2010]	0.1165	0.0074	15.76	<0.0001
Zero-inflation	Intercept	1.3177	0.1227	10.92	<0.0001
	Year[2010]	-0.3323	0.2114	-1.57	0.1160

P. bellottii

Table 21. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *P. bellottii* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude^2 * Bottom depth * Year	Year	14	389263.1	0
Latitude^2 * Bottom depth + Year	Year	9	394546.2	5283.1
Latitude^2 * Bottom depth	Latitude	8	415925.5	26662.4
Latitude^2 * Bottom depth	1	7	415930.7	26667.6
Latitude^2 * Bottom depth	Year	8	415932.1	26669.0
Latitude^2 + Bottom depth	Latitude	6	416056.3	26793.2
Year * Latitude	Latitude	6	430217.9	40953.9
Bottom depth * Year	Latitude + Bottom depth	7	431111.5	41848.4
Bottom depth + Year	Latitude + Bottom depth	6	434130.5	>41848.4
Latitude	Latitude + Bottom depth	5	451558.3	>41848.4
Latitude	Bottom depth	4	451573.1	>41848.4
Latitude + Bottom depth	Latitude	5	451692.6	>41848.4
Bottom depth	Latitude + Bottom depth	5	452101.4	>41848.4
Bottom depth	Bottom depth	4	452116.2	>41848.4
Bottom depth	Latitude	4	452285.3	>41848.4

Table 22. Parameter estimates for favored model from model selection. Species = *P. bellottii.* Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	6.0020	0.0120	500.38	<0.0001
	Latitude	8.5420	0.3842	22.23	<0.0001
	Latitude^2	-20.4800	0.3324	-61.63	<0.0001
	Bottom depth	-0.0001	0.0002	-0.71	0.4776
	Year[2010]	-0.1756	0.0618	-2.84	0.0045
	Latitude*Bottom depth	-0.0626	0.0055	11.32	<0.0001
	Latitude^2*Bottom depth	-0.0254	0.0049	-5.19	<0.0001
	Latitude*Year[2010]	11.1100	2.4610	4.52	<0.0001
	Latitude^2*Year[2010]	3.7420	1.9800	1.90	0.0587
	Bottom depth*Year[2010]	-0.0081	0.0009	-9.50	<0.0001
	Latitude*Bottom depth*Year[2010]	-0.5549	0.0345	-16.10	<0.0001
	Latitude^2*Bottom depth*Year[2010]	0.1726	0.0283	6.10	<0.0001
Zero-inflation	Intercept	0.2064	0.0994	2.08	0.0378
	Year[2010]	-0.2464	0.1910	-1.29	0.1970

U. canariensis

Table 23. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *U. canariensis* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude^2 * Bottom depth * Year	Year	14	26032.00	0
Year * Latitude	Latitude	6	30044.43	4012.43
Latitude^2 * Bottom depth + Year	Year	9	30827.80	4795.80
Latitude^2 * Bottom depth	Latitude	8	30844.36	4812.36
Latitude^2 * Bottom depth	Year	8	30846.55	4814.55
Latitude^2 * Bottom depth	1	7	30846.91	4814.91
Latitude^2 + Bottom depth	Latitude	6	31021.93	4989.93
Latitude	Latitude + Bottom depth	5	31069.66	>4989.93
Latitude	Bottom depth	4	31071.15	>4989.93
Latitude + Bottom depth	Latitude	5	31087.25	>4989.93
Bottom depth * Year	Latitude + Bottom depth	7	34111.76	>4989.93
Bottom depth + Year	Latitude + Bottom depth	6	34907.23	>4989.93
Bottom depth	Latitude + Bottom depth	5	35343.79	>4989.93
Bottom depth	Bottom depth	4	35345.29	>4989.93
Bottom depth	Latitude	4	35371.99	>4989.93

Table 24. Parameter estimates for favored model from model selection. Species = *U. canariensis.* Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	4.9218	0.0660	74.52	<0.0001
	Latitude	-5.7493	1.3813	-4.16	<0.0001
	Latitude^2	6.7197	1.2767	5.26	<0.0001
	Bottom depth	-0.0060	0.0009	-7.06	<0.0001
	Year[2010]	0.1949	0.0806	2.42	0.0157
	Latitude*Bottom depth	-0.1925	0.0177	-10.85	<0.0001
	Latitude^2*Bottom depth	-0.1888	0.0149	-12.70	<0.0001
	Latitude*Year[2010]	30.7060	1.8286	16.80	<0.0001
	Latitude^2*Year[2010]	1.2467	1.7108	0.73	0.4662
	Bottom depth*Year[2010]	0.0063	0.0011	5.80	<0.0001
	Latitude*Bottom depth*Year[2010]	-0.3173	0.0031	-10.25	<0.0001
	Latitude^2*Bottom depth*Year[2010]	0.4314	0.0253	17.04	<0.0001
Zero-inflation	Intercept	1.4553	0.1286	11.32	<0.0001
	Year[2010]	-0.4429	0.2187	-2.03	0.0429

Common non-commercial demersal species (Tab. 25-32):

C. linguatula

Table 25. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *C. linguatula* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude^2 * Bottom depth * Year	Year	14	41447.40	0
Latitude^2 * Bottom depth + Year	Year	9	44681.58	3234.18
Latitude^2 * Bottom depth	Year	8	49504.02	8056.62
Latitude^2 * Bottom depth	Latitude	8	49541.52	8094.12
Latitude^2 * Bottom depth	1	7	49541.77	8094.37
Latitude^2 + Bottom depth	Latitude	6	52617.53	11170.13
Year * Latitude	Latitude	6	55758.38	14311.38
Latitude	Latitude + Bottom depth	5	63551.71	>14311.38
Latitude	Bottom depth	4	63555.00	>14311.38
Latitude + Bottom depth	Latitude	5	63607.68	>14311.38
Bottom depth * Year	Latitude + Bottom depth	7	74378.13	>14311.38
Bottom depth + Year	Latitude + Bottom depth	6	74385.69	>14311.38
Bottom depth	Latitude + Bottom depth	5	75073.89	>14311.38
Bottom depth	Bottom depth	4	75077.18	>14311.38
Bottom depth	Latitude	4	75136.12	>14311.38

Table 26. Parameter estimates for favored model from model selection. Species = *C. linguatula.* Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	4.0230	0.0528	76.25	<0.0001
	Latitude	-30.3700	1.2150	-25.00	<0.0001
	Latitude^2	-28.5400	1.2940	-22.06	<0.0001
	Bottom depth	0.0061	0.0005	11.41	<0.0001
	Year[2010]	2.8930	0.0812	35.62	<0.0001
	Latitude*Bottom depth	0.1130	0.0126	8.97	<0.0001
	Latitude^2*Bottom depth	0.1328	0.0142	9.34	<0.0001
	Latitude*Year[2010]	-124.4000	2.3860	-52.13	<0.0001
	Latitude^2*Year[2010]	65.9600	2.1840	30.20	<0.0001
	Bottom depth*Year[2010]	-0.0333	0.0009	-35.47	<0.0001
	Latitude*Bottom depth*Year[2010]	1.5970	0.0304	52.50	<0.0001
	Latitude^2*Bottom depth*Year[2010]	-0.9798	0.0267	-36.711	<0.0001
Zero-inflation	Intercept	1.2649	0.1195	10.59	<0.0001
	Year[2010]	-1.3538	0.1946	-6.96	<0.0001

N. africanus

Table 27. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *N. africanus* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude^2 * Bottom depth * Year	Year	14	1543370	0
Latitude^2 * Bottom depth + Year	Year	9	1831286	287916
Bottom depth + Year	Latitude + Bottom depth	6	1984636	441266
Year * Latitude	Latitude	6	1990012	446642
Latitude^2 * Bottom depth	Latitude	8	2007813	464443
Latitude^2 * Bottom depth	Year	8	2007813	464443
Latitude^2 * Bottom depth	1	7	2007825	464455
Latitude + Bottom depth	Latitude	5	2134504	591134
Latitude	Latitude + Bottom depth	5	2137254	>591134
Bottom depth	Latitude + Bottom depth	5	2158163	>591134
Bottom depth	Latitude	4	2158374	>591134

The most supported model received an **error.**

R. miraletus

Table 28. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *R. miraletus* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
$Latitude^2$ * Bottom depth * Year	Year	14	4017.013	0
$Latitude^2$ * Bottom depth + Year	Year	9	4061.204	44.191
Year * Latitude	Latitude	6	4434.389	417.376
$Latitude^2$ * Bottom depth	Year	8	4763.009	745.996
$Latitude^2$ * Bottom depth	Latitude	8	4851.067	834.055
$Latitude^2$ * Bottom depth	1	7	4854.581	837.568
$Latitude^2$ + Bottom depth	Latitude	6	4872.921	855.098
Latitude + Bottom depth	Latitude	5	4930.473	913.46
Latitude	Latitude + Bottom depth	5	5071.863	>913.46
Latitude	Bottom depth	4	5075.134	>913.46
Bottom depth * Year	Latitude + Bottom depth	7	5146.398	>913.46
Bottom depth + Year	Latitude + Bottom depth	6	5206.839	>913.46
Bottom depth	Latitude + Bottom depth	5	5645.701	>913.46
Bottom depth	Bottom depth	4	5648.969	>913.46
Bottom depth	Latitude	4	5701.293	>913.46

Table 29. Parameter estimates for favored model from model selection. Species = *R. miraletus*. Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	2.3870	0.075	31.88	<0.0001
	Latitude	-11.3000	1.4910	-7.58	<0.0001
	$Latitude^2$	-0.6241	1.4390	-0.43	<0.0001
	Bottom depth	-0.0006	0.0009	-0.76	0.6646
	Year[2010]	1.5470	0.0843	18.35	<0.0001
	Latitude*Bottom depth	-0.0320	0.0177	-1.81	0.0704
	$Latitude^2$*Bottom depth	0.0177	0.0162	1.09	0.2748
	Latitude*Year[2010]	3.1600	1.8020	1.75	0.0796
	$Latitude^2$*Year[2010]	2.7910	1.7680	1.58	0.1144
	Bottom depth*Year[2010]	-0.0074	0.0010	-7.45	<0.0001
	Latitude*Bottom depth*Year[2010]	-0.0515	0.0216	-2.39	0.016
	$Latitude^2$*Bottom depth*Year[2010]	-0.0526	0.0202	-2.60	0.009
Zero-inflation	Intercept	1.5826	0.1314	12.05	<0.0001
	Year[2010]	-2.0660	0.2177	-9.49	<0.0001

S. microlepis

Table 30. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *S. microlepis* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Latitude^2 * Bottom depth * Year	Year	14	10105748	0
Latitude^2 * Bottom depth + Year	Year	9	11031579	925831
Latitude^2 * Bottom depth	Latitude	8	11610357	1504609
Latitude^2 * Bottom depth	1	7	11610359	1504611
Latitude^2 * Bottom depth	Year	8	11610361	1504613
Latitude^2 + Bottom depth	Latitude	6	12366825	2261077
Latitude + Bottom depth	Latitude	5	12914405	2808657
Bottom depth	Latitude + Bottom depth	5	12937266	2831518
Bottom depth	Bottom depth	4	12937270	>2831518
Bottom depth	Latitude	4	12937282	>2831518
Latitude	Latitude + Bottom depth	5	15360805	>2831518
Latitude	Bottom depth	4	15360809	>2831518

Table 31. Parameter estimates for favored model from model selection. Species = *S. microlepis.* Model is displayed in sub-models.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	11.3300	0.0019	5855.4510	<0.0001
	Latitude	-52.0500	0.0503	-1035.6960	<0.0001
	Latitude^2	-29.4000	0.0310	-735.2460	<0.0001
	Bottom depth	-0.0078	<0.0001	-662.1170	<0.0001
	Year[2010]	-0.4001	0.0049	-81.5210	<0.0001
	Latitude*Bottom depth	0.3287	0.0004	829.6880	<0.0001
	Latitude^2*Bottom depth	0.0414	0.0003	138.3460	<0.0001
	Latitude*Year[2010]	29.3300	0.1422	206.2850	<0.0001
	Latitude^2*Year[2010]	28.7700	0.1302	220.9840	<0.0001
	Bottom depth*Year[2010]	0.0004	<0.0001	15.6060	<0.0001
	Latitude*Bottom depth*Year[2010]	-0.2617	0.0009	-281.1150	<0.0001
	Latitude^2*Bottom depth*Year[2010]	-0.0020	0.0008	-2.5450	0.0109
Zero-inflation	Intercept	1.3893	0.1234	11.26	<0.0001
	Year[2010]	0.1277	0.2260	0.57	0.5720

Y. blackfordi

Table 32. Complete table with ZIP-models used to explore which variables (latitude and bottom depth) best explains NPUE of *Y. blackfordi* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
$Latitude^2$ * Bottom depth * Year	Year	14	13618.24	0
$Latitude^2$ * Bottom depth + Year	Year	9	13754.90	136.66
$Latitude^2$ * Bottom depth	Year	8	15612.35	1994.11
$Latitude^2$ * Bottom depth	1	7	15674.10	2055.86
$Latitude^2$ * Bottom depth	Latitude	8	15674.40	2056.16
$Latitude^2$ + Bottom depth	Latitude	6	20989.99	7371.75
Bottom depth * Year	Latitude + Bottom depth	7	21442.23	7823.99
Bottom depth + Year	Latitude + Bottom depth	6	21940.87	8322.63
Bottom depth	Bottom depth	4	22958.65	>8322.63
Bottom depth	Latitude + Bottom depth	5	22958.82	>8322.63
Year * Latitude	Latitude	6	22971.91	>8322.63
Latitude + Bottom depth	Latitude	5	23090.90	>8322.63
Bottom depth	Latitude	4	23168.80	>8322.63
Latitude	Bottom depth	4	25745.96	>8322.63
Latitude	Latitude + Bottom depth	5	25746.14	>8322.63

The most supported model received an **error.**

Histograms oil analyses (Fig. 30-31):

Histograms used for determining whether to use negative binomial distribution or not in oil analyses. Histograms show log of NPUE and WPUE from 2010. Note that histograms show the logarithm of NPUE>0 and WPUE>0 respectively.

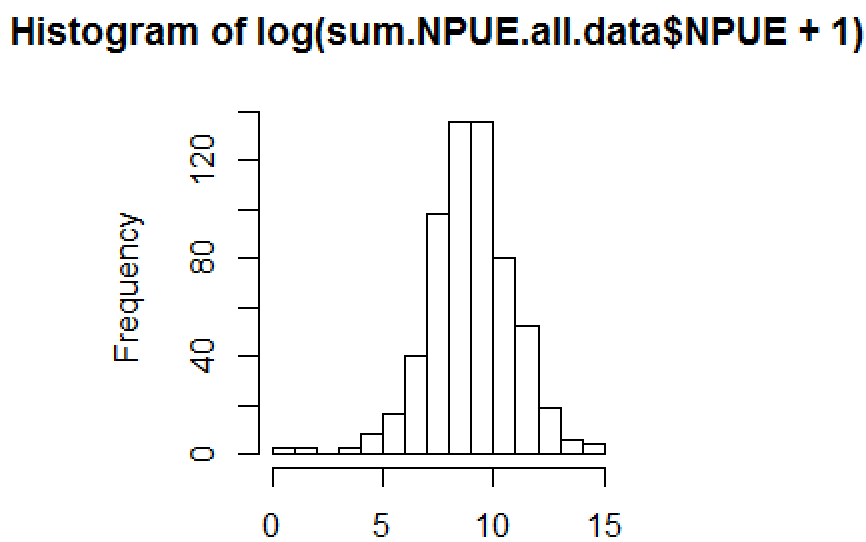


Figure 30. Histogram of NPUE from 2010. Note that histogram shows NPUE>0.

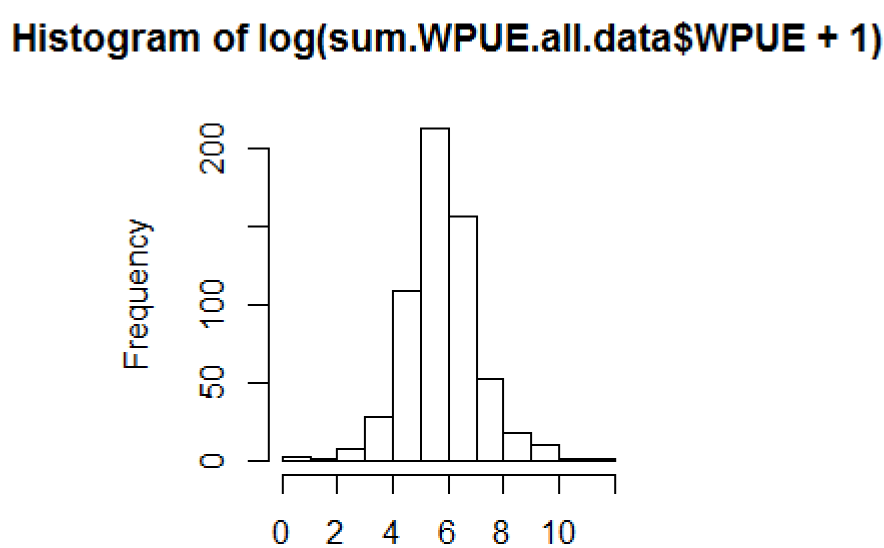


Figure 31. Histogram of WPUE from 2010. Note that histogram shows WPUE>0.

Histograms single-species oil analyses (Fig. 32-34):

Histograms used for determining whether to use negative binomial distribution or not in single-species analyses. Histograms show NPUE from 2010 for given species. Note that all histograms show the logarithm of NPUE>0.

Commercial demersal species (Fig. 32-33):

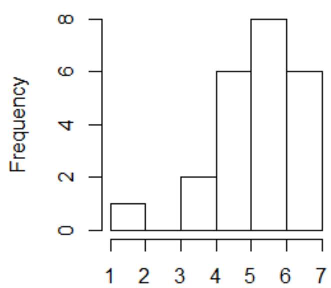


Figure 32. Histogram of NPUE>0 for *D. angolensis.*

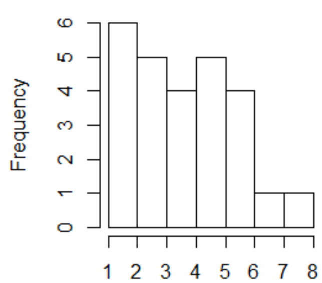


Figure 33. Histogram of NPUE>0 for *P. bellottii.*

Common non-commercial demersal species (Fig. 34):

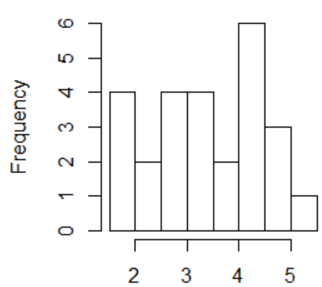


Figure 34. Histogram of NPUE>0 for *C. linguatula*

Tables and figures from single-species oil analyses (Tab. 33-39):

Commercial demersal species (Tab. 33-36):

D. angolensis

Table 33. Complete table with ZIP-models used to explore which variables (latitude, bottom depth and oil activity) best explains NPUE of *D. angolensis* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Bottom depth²* Oil activity	Bottom depth	8	3681.557	0
Oil activity * Bottom depth	Bottom depth	6	3908.053	226.496
Oil activity * Bottom depth	Oil activity	6	3913.981	232.424
Latitude² * Oil activity	1	7	4011.132	329.575
Latitude² * Oil activity	Latitude	8	4011.249	329.692
Bottom depth² + Oil activity	Bottom depth	6	4313.666	632.109
Bottom depth²	Bottom depth	5	4395.542	713.985
Oil activity * Latitude	Oil activity	6	4427.312	745.755
Oil activity * Latitude	Latitude	6	4429.430	>745.755
Latitude² + Oil activity	Latitude + Bottom depth	7	4498.368	>745.755
Latitude² + Oil activity	Latitude	6	4504.636	>745.755
Oil activity + Latitude	Oil activity	5	4584.905	>745.755
Oil activity + Latitude	Latitude	5	4587.023	>745.755
Oil activity + Bottom depth	Bottom depth	5	5230.824	>745.755
Oil activity + Bottom depth	Oil activity	5	5236.753	>745.755
Oil activity	Oil activity + Bottom depth	5	5419.289	>745.755
Oil activity	Bottom depth	4	5426.823	>745.755
Oil activity	Oil activity	4	5432.751	>745.755
Oil activity	Oil activity	4	5432.751	>745.755
Oil activity	Latitude	4	5434.869	>745.755

Table 34. Parameter estimates for favored model from model selection. Species = *D. angolensis.* The model is shown in sub-models. (Intercept) = No oil activity, Bottom depth² = No oil activity, Oil activity = oil.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	1.3240	0.3120	4.24	<0.0001
	Bottom depth	-54.5840	3.7510	-14.55	<0.0001
	Bottom depth²	-21.7750	1.7670	-12.32	<0.0001
	Oil activity	-79.2750	9.8360	-8.06	<0.0001
	Bottom depth*Oil activity	-966.7130	119.6790	-8.08	<0.0001
	Bottom depth²*Oil activity	-364.0170	42.2100	-8.62	<0.0001
Zero-inflation	Intercept	-2.2880	1.1230	-2.04	0.0420
	Bottom depth	0.0060	0.0060	0.95	0.0440

Temperature and salinity:

Table 35. ZIP-models used to correct for salinity and temperature in oil analyses of *D. angolensis*. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Bottom depth^2 * Oil activity * Sal	Bottom depth	14	2998.566	0
Bottom depth^2 * Oil activity * Temp	Bottom depth	14	3234.228	235.662
Bottom depth^2 * Oil.activity + Sal	Bottom depth	9	3291.526	292.960
Bottom depth^2 * Oil activity + Temp	Bottom depth	9	3367.821	369.255

The most supported model received an **error**.

P. bellottii

Table 36. Complete table with ZIP-models used to explore which variables (latitude, bottom depth and oil activity) best explains NPUE of *P. bellottii* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Bottom depth^2 * Oil activity	Bottom depth	8	4456.713	0
Bottom depth^2 + Oil activity	Bottom depth	6	5021.225	564.512
Oil activity * Bottom depth	Bottom depth	6	5115.009	658.296
Oil activity * Bottom depth	Oil activity	6	5120.539	663.826
Oil activity + Bottom depth	Bottom depth	5	5214.837	758.124
Oil activity + Bottom depth	Oil activity	5	5216.635	759.922
Bottom depth^2	Bottom depth	5	5881.178	1424.465
Latitude^2 * Oil activity	Latitude	8	7353.414	2896.701
Latitude^2 * Oil activity	1	7	7354.217	>2896.701
Oil activity * Latitude	Oil activity	6	7509.309	>2896.701
Oil activity * Latitude	Latitude	6	7511.743	>2896.701
Latitude^2 + Oil activity	Latitude + Bottom depth	7	7663.730	>2896.701
Latitude^2 + Oil activity	Latitude	6	7706.525	>2896.701
Oil activity + Latitude	Oil activity	5	7723.816	>2896.701
Oil activity + Latitude	Latitude	5	7726.250	>2896.701
Oil activity	Bottom depth	4	8566.364	>2896.701
Oil activity	Oil activity + Bottom depth	5	8568.019	>2896.701
Oil activity	Oil activity	4	8608.509	>2896.701
Oil activity	Oil activity	4	8608.509	>2896.701
Oil activity	Latitude	4	8610.943	>2896.701

The most supported model received an **error.**

Common non-commercial demersal species (Tab. 37-39):

C. linguatula

Table 37. Complete table with ZIP-models used to explore which variables (latitude, bottom depth and oil activity) best explains NPUE of *C. linguatula* off the continental shelf and upper slope of the Angolan coast. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Bottom depth^2* Oil activity	Bottom depth	8	493.6955	0
Bottom depth^2	Bottom depth	5	606.0296	112.3341
Bottom depth^2 + Oil activity	Bottom depth	6	606.0379	112.3424
Oil activity * Bottom depth	Bottom depth	6	686.7929	193.0974
Oil activity + Bottom depth	Bottom depth	5	691.1310	197.4355
Oil activity * Bottom depth	Oil activity	6	718.4997	224.8042
Latitude^2 + Oil activity	Latitude + Bottom depth	7	721.2869	227.5914
Latitude^2 * Oil activity	Latitude	8	721.7641	228.0686
Oil activity + Bottom depth	Oil activity	5	722.8372	>228.0686
Latitude^2 * Oil activity	1	7	726.8133	>228.0686
Oil activity + Latitude	Latitude	5	744.2269	>228.0686
Latitude^2 + Oil activity	Latitude	6	746.1994	>228.0686
Oil activity * Latitude	Latitude	6	746.2066	>228.0686
Oil activity + Latitude	Oil activity	5	751.2761	>228.0686
Oil activity * Latitude	Oil activity	6	753.2558	>228.0686
Oil activity	Oil activity + Bottom depth	5	984.4995	>228.0686
Oil activity	Bottom depth	4	987.5574	>228.0686
Oil activity	Latitude	4	1012.2143	>228.0686
Oil activity	Oil activity	4	1019.2635	>228.0686
Oil activity	Oil activity	4	1019.2635	>228.0686

Table 38. Parameter estimates for favored model from model selection. Species = *C. linguatula.* The model is shown in sub-models. (Intercept) = No oil activity, Bottom depth^2 = No oil activity, Oil activity = oil.

Sub model	Predictor term	Estimate	SE	z	p
Poisson	Intercept	-27.7560	2.1020	-13.21	<0.0001
	Bottom depth	-383.5310	25.2920	-15.16	<0.0001
	Bottom depth^2	-164.9740	10.5400	-15.65	<0.0001
	Oil activity	9.1630	6.2600	1.46	0.1433
	Bottom depth*Oil activity	109.0750	76.0310	1.44	0.1514
	Bottom depth^2*Oil activity	66.0070	25.5830	2.58	0.0099
Zero-inflation	Intercept	0.8086	1.2477	0.65	0.5169
	Bottom depth	-0.0351	0.0196	-1.79	0.0738

Temperature and salinity:

Table 39. ZIP-models used to correct for salinity and temperature in oil analyses of *C. linguatula*. All models are provided with corresponding AIC and ΔAIC-values. df = degrees of freedom.

Count	Zero-inflated	df	AIC	ΔAIC
Bottom depth^2 * Oil activity * Sal	Bottom depth	14	438.0028	0
Bottom depth^2 * Oil activity * Temp	Bottom depth	14	447.3758	9.0000
Bottom depth^2 * Oil activity + Temp	Bottom depth	9	481.8735	43.8707
Bottom depth^2 * Oil activity + Sal	Bottom depth	9	485.9274	485.9274

The most supported model received an **error.**

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