

A Gap Analysis of the Distributions of Cephalopod Species Worldwide with a Focus on Commercially Important Species

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Abstract

Cephalopods are valuable species as they provide ecological functions and are also important commercially and scientifically. This study attempts to adequately describe the distribution of Class Cephalopoda as well as focusing on a few commercial species ranges. Data from an extensive literature search and several databases such as OBIS and AquaMaps were analyzed to show areas where information is lacking due to no research conducted in the area versus where literature research is excluded from OBIS. For the species distributions modeled in AquaMaps, an accuracy assessment was performed to show if all of the locations where the species have been found would be included within the suspected range. Recommendations for more research or greater conservation actions will also be given for each of the commercial species examined. Fisheries data on the commercial species will be compared to the distributional extents to show where better management practices might be needed.

Introduction

The cephalopod class is a fascinating and diverse set of species that are important biologically, commercially and scientifically. They exist in all marine habitats worldwide and provide a large part of the total global biomass of all marine species (Clarke, 1996). Scientific knowledge of cephalopod distributions and abundances is important to understand their contribution not only to ecological relationships but also to overall energy flow and transfer of materials (Piatkowski et al. 2001).

Overall, cephalopod species have been mostly ignored in the past and thought of as being a disturbance and useless bycatch. In the past thirty years or so, cephalopods have been more widely exploited in fisheries. These species are used to bait more traditional commercial fish and also for human consumption. In numerous studies of marine species such as large fish, mammals and birds, cephalopods have been found in the gut contents of these organisms. Thus cephalopods certainly are an important component in many areas of the food chain.

Cephalopods are key species in many habitats. They are predators as well as prey for many species in all environments around the world (Pierce et al. 2008). Although many squid and octopus species are short lived, they contribute greatly to the energy flow and material production in the environment. Many squid species live at quite large depths and so transfer energy, resources and nutrients between deep water and more shallow water systems. They also transfer energy when they make feeding and spawning migrations over large areas.

In the Antarctic zone, squid dominate the diet of many species including toothed whales, elephant seals, albatrosses and sperm whales. Due to the larger number of squid in this area, estimated at around 300,000 tons, the squid essentially occupy the niche normally filled by epipelagic fish (Rodhouse and White, 1995). This shows that cephalopods are just as important as fish ecologically, if not more so. Cephalopods reside in even more habitats worldwide than fish and so their importance in ecological systems may even exceed that of fish species.

Many cephalopods are of high commercial value, causing an increase in fisheries for this class over the past few decades. Cephalopod catch amounts have grown exponentially and as of 1993 were rated as the third most important fishery in the world after tuna and shrimp fisheries, when considering the actual dollar value (FAO, 1993). Within the cephalopod class, the types of species most commonly exploited in commercial fisheries are squids. Squids tend to school in groups and many times make migrations between feeding and spawning grounds. This allows them to be easier to fish for since they can be caught in large aggregations. Most octopus and cuttlefish are solitary species and so commercially they are not harvested, although they are an important fishery for developing nations and tropical nations that may target them specifically on reefs (Caddy and Rodhouse, 1998). A few species of octopus are commercially fished, but this is a very small number of individual species. Nautilus are also fished for their shells which are used as ornaments.

Because of the difficulties of sampling techniques, stock assessments are inaccurate and hard to determine. Cephalopod distributions and densities are mostly determined by examining the stomach contents of their predators and through using fisheries data. These are not very comprehensive techniques and because of the life

history of these types of species, better management strategies need to be implemented. Cephalopods, excluding the nautilus, are difficult to assess mainly because their anatomy contains so few hard parts. Even aging species is difficult as not much of their bodies are left after they die. This also makes identification of species difficult, which can lead to errors in data collection.

Cephalopods are important scientifically due to their unique nervous system and sensory organs. These organisms have been used as research models in physiology, aging, molecular biology, neuroscience and immunology. In many cases the research is of a medical basis and so has implications for curing or treating diseases (Koueta and Boucaud-Camou 1999; Oestmann et al. 1997).

Although studies of cephalopods have increased greatly in the past few decades, analysis on the overall information that has been acquired is lacking. Many studies have analyzed selective areas of the world and specific species, but few of these are overarching. A study by Rosa et al. (2008) describes the latitudinal gradients of species richness as relating to cephalopods in the Atlantic, but does not specifically cover areas where data are absent. Xavier et al. (1999) examined GIS data on cephalopods, but only those in the Antarctic region. Additionally, data have been collected from predator stomach contents and commercial trawling describing the distribution of cephalopods in many other locations such as eastern Australia and the southern Aegean Sea (Lansdell and Young, 2007; Lefkaditou et al. 2003). These are only a few examples of studies performed on cephalopods.

Each of these studies is important, and through bringing together data collected from different researchers, a comprehensive view of the Cephalopoda can be established. This study will attempt to perform an important analysis to provide information for conservationists and environmental managers covering preexisting cephalopod data. The objective of this project is to determine and define spatial areas where information is lacking on cephalopod species. This may be accomplished by looking at individual species, families or any other groups, which appear to have significant gaps in the literature or in mapping data. A few of the most important commercial species will also be examined in greater detail to help see where management might be needed and how these highly impacted populations and species are being effected by fisheries pressures.

An accuracy assessment on distributional models of some of the commercial species will also be conducted.

Methods

Using Ocean Biogeographical Information Systems (OBIS), database queries on Class Cephalopoda were performed. Different separations of the species and species types were implemented to break down the cephalopods into workable groups that could be examined on a closer level. Separate commercially important species determined from the literature were also evaluated to further identify their distributions.

Cephalopods can be separated into several large groups. These groups comprise of, nautilus (Nautilidae), octopods (Octopoda and Vampyromorpha), the cuttlefish (Sepioidea) and the squids (Myopsida, Oegopsida, Idiosepiidae and Bathyteuthoidea). The cuttlefish currently are classified within the Superorder Decapodiformes. This grouping includes the squids and the cuttlefish. Although there is some disagreement as to the exact separation, for this study, the Sepioidea order will be considered cuttlefish. Another species that does not currently fit into any of these groups is *Spirula spirula*. This species is classified by itself within its own group, Spirulidae.

There is still much discrepancy of the exact phylogeny within the Class Cephalopoda among researchers. For the purposes of this study, the classification developed by Richard E. Young, Michael Vecchione and Katherine M. Mangold for The Tree of Life Project (TOL) will be used (Young et al. 2008). The majority of their classification is based off that of Naef (1921-1923). The full classification is available in Appendix A.

In addition to evaluating groups of species by type, individual species are also examined in further detail. The species evaluated in this study are species commercially important to fisheries. The following species were chosen based on their catch rates from 1980 to 2001 (Table 1) (FAO, 2005).

Table 1: Species Considered Due to Commercial Importance

1. *Illex argentinus*
2. *Todarodes pacificus*
3. *Dosidicus gigas*
4. *Nototodarus sloanii*
5. *Ommastrephes bartramii*
6. *Illex illecebrosus*
7. *Todarodes sagittatus*
8. *Illex coindetii*
9. *Martialia hyadesi*
10. *Loligo gahi*
11. *Loligo pealeii*
12. *Loligo vulgaris reynaudii*
13. *Octopus vulgaris*
14. *Sepia officinalis*

Maps of the species distributions were created using Quantum GIS and ArcGIS software. An exhaustive literature search was also performed to verify that data has been entered into the OBIS database and was being included in the analysis. For data that is available in the literature but is not found in the database, appropriate notes will be made and OBIS researchers will be notified.

Another source of data, called AquaMaps was also used to look at the commercial species distributions. AquaMaps is a joint project from FishBase and SeaLifeBase, which uses environmental parameters to predict species ranges. Some of the environmental parameters that are used are temperature, depth, salinity and primary productivity.

Nine of the commercial species examined in the study have modeled distributions in AquaMaps (Table 2). This distributional data will be imported into ArcGIS and compared with the point data from OBIS showing exact areas where species were found. An accuracy assessment will be performed to determine how many of the species sample points are within the AquaMaps distributional area and how many are not. This will

allow the overall accuracy of the AquaMaps distribution to be determined when compared to data in OBIS.

Table 2: Species with modeled distributional ranges in AquaMaps used for the accuracy assessment.

1. *Dosidicus gigas*
2. *Illex argentinus*
3. *Illex coindetii*
4. *Illex illecebrosus*
5. *Loligo pealeii*
6. *Loligo vulgaris reynaudii*
7. *Ommastrephes bartramii*
8. *Octopus vulgaris*
9. *Todarodes sagittatus*

The expected results of this project are overall comprehensive distributional determination for the Cephalopoda. Distributional information will also be available for specific groups of cephalopods as well as a few of the most important commercial species. An accuracy assessment showing how well the model for AquaMaps works will also be conducted. Feedback to OBIS and AquaMaps on their data will also be given.

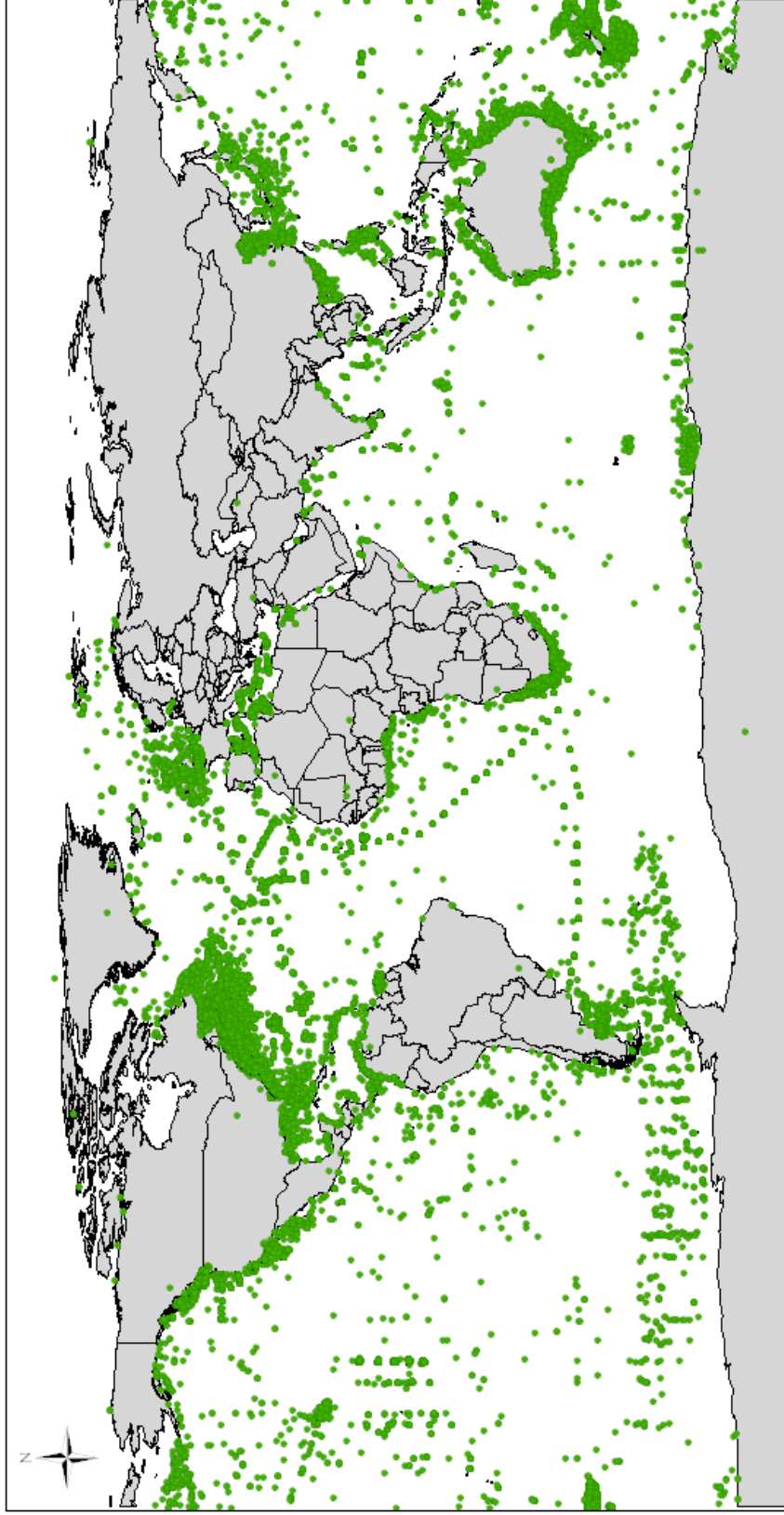
Results

Distributional Data

Overall maps of the entire class Cephalopoda confirmed that cephalopods have a worldwide distribution (Figure 1).

Figure 1: Total Cephalopod Distribution Worldwide

Total Cephalopod Distribution Worldwide



Legend

Cephalopods

World Land Mass

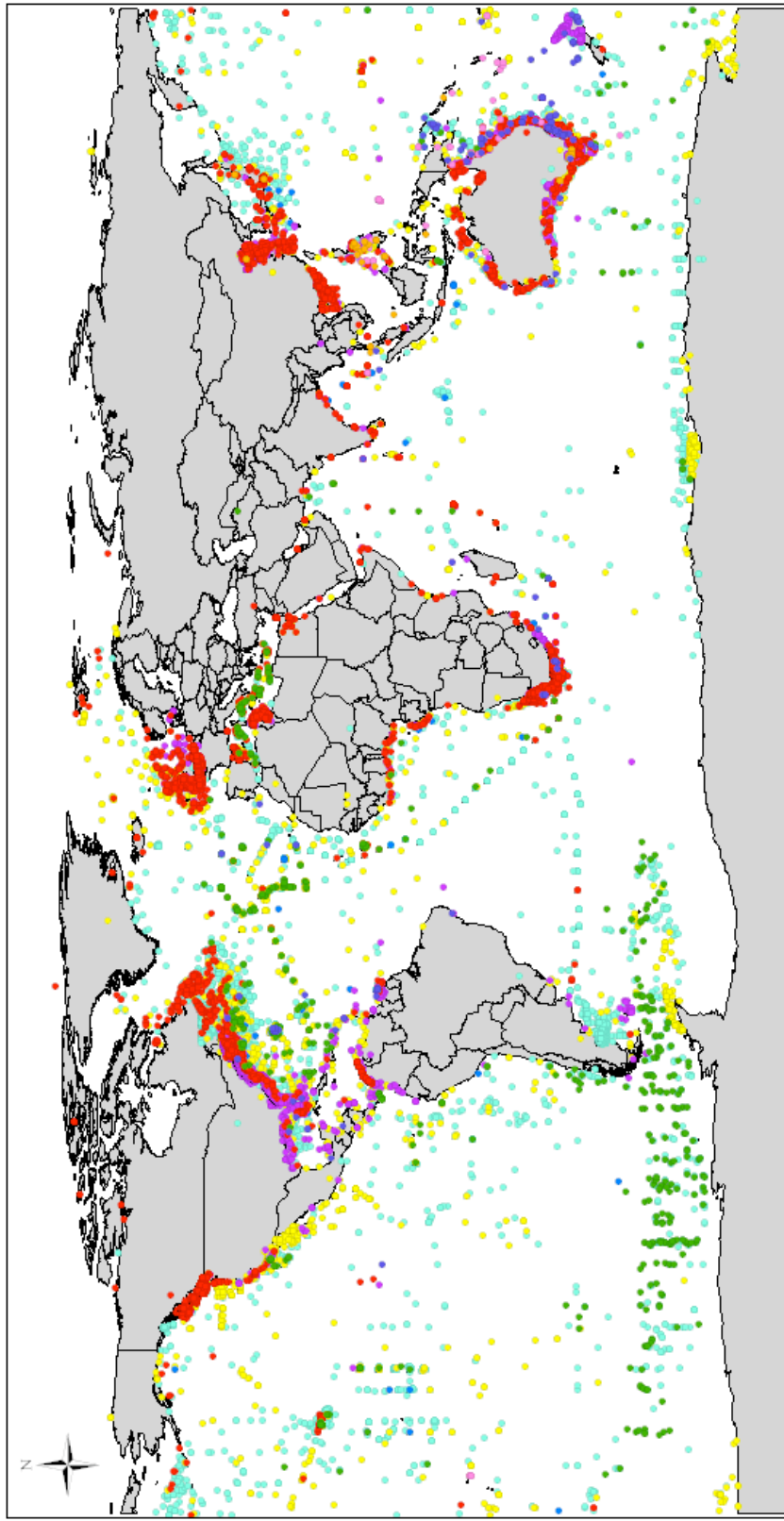
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Cephalopoda can be broken down into groups with similar attributes to further look at the diversity of areas worldwide. After separating Nautilidae, we are left with the Decapodiformes and Octopodiformes. These two groups are still very large in that we will break them down a little further for the purposes of this study. In total, we have separated Cephalopoda into nine groups. The groups chosen were the Nautilidae, Octopoda, Vampyromorpha, Sepioidea, Myopsida, Oegopsida, Idiosepiidae, Bathyteuthoidea and Spirulida. Once the species are broken down into the nine different groups, some patterns can be seen (Figure 2).

Figure 2: Large Groupings of Cephalopods Worldwide

Cephalopod Distribution Worldwide by Large Groups



Legend

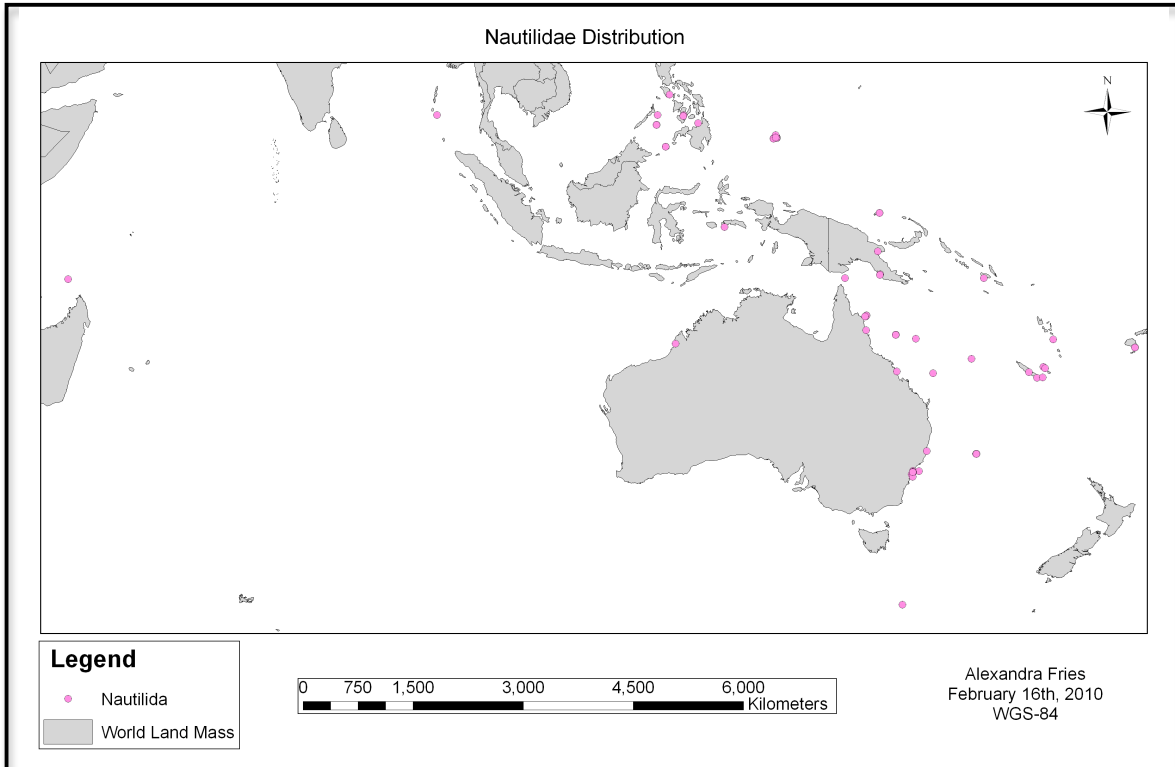
| | | | |
|--------------|-----------------|------------------|-----------------|
| Spirulida | Bathyteuthoidea | Vampyroteuthidae | World Land Mass |
| Idiosepiidae | Sepioidae | Octopoda | |
| Nautilida | Myrropsida | Oegopsida | |



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The Nautilidae in particular are limited to the East Indian Ocean and the South Western Pacific (Figure 3).

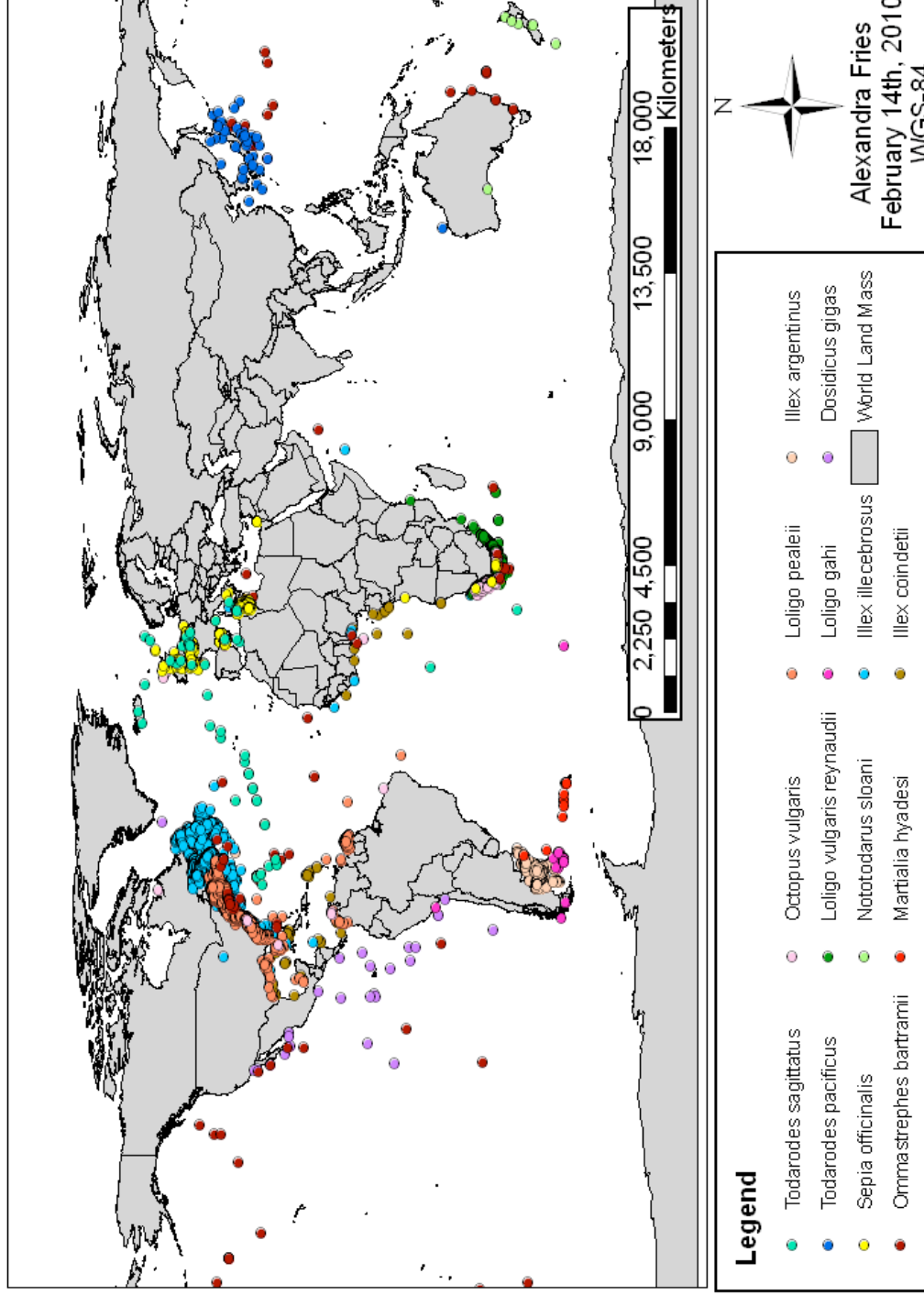
Figure 3: Total Distribution of Nautilidae



The commercial species chosen for this study had distributions that ranged widely (Figure 4).

Figure 4: Distributions of Commercial Species

Commercially Important Cephalopod Species



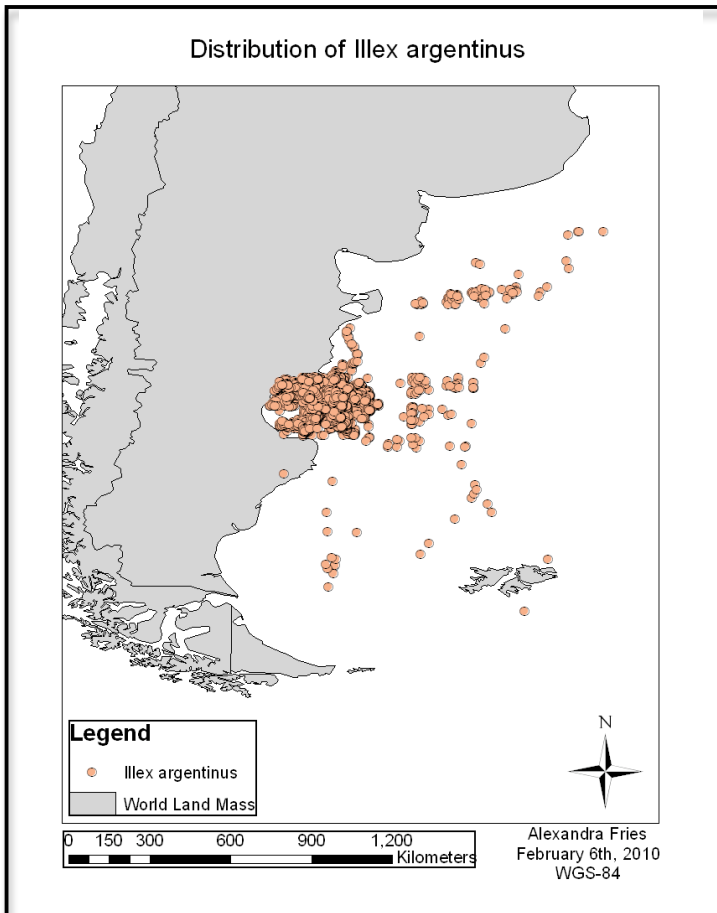
The commercial species examined in this study showed varying distributions. Each species will be briefly discussed with reference to the literature.

Species Distributions

Illex argentinus

Illex argentinus, or the Argentine shortfin squid lives in the southwestern Atlantic Ocean off the coast of South America (Figure 5).

Figure 5: Selected Distribution of *Illex argentinus*



The Argentine shortfin squid is a very important fishery for Argentina (Chen et al. 2007). In 1980, the catch weight for this species in thousand metric tons was only 16, but

by 1988 had increased to 564.3 thousand metric tons. From 1989 to 2001 the catch varied from 410.1 to 1145.0, but on average was 688.62 thousand metric tons (FAO Species Catalogue for Fishery Purposes, 2005). This data shows that the *Illex argentinus* fishery is a very important resource.

The Argentine shortfin squid is a short lived species that reproduces once in it's lifetime. This squid lives for approximately one year, however, different spawning stocks exist in the Argentinean area. Because of the different timing of the populations' spawning events, juveniles and larvae can be found year round (Brunetti et al. 1998; Rodhouse et al. 1995).

One discrepancy or perhaps an error in the OBIS database of this species distribution is a data point located in the northwestern Atlantic Ocean. This is far from the known range of this species (Figure 6).

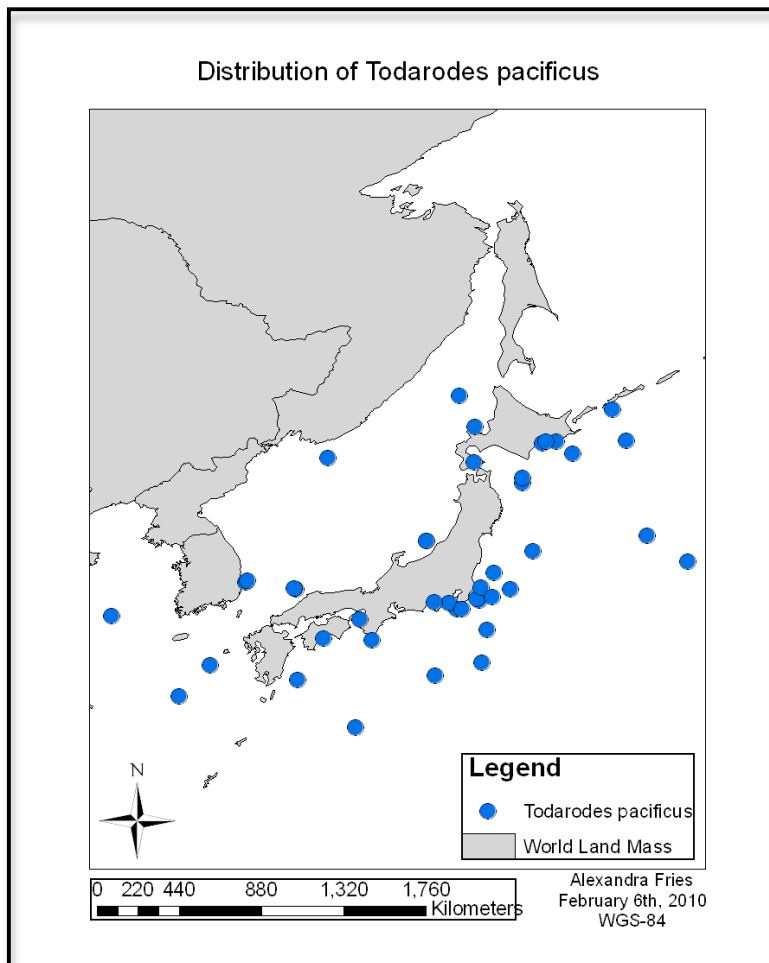
Figure 6: Total Distribution of *Illex argentinus*



Todarodes pacificus

The Japanese flying squid, *Todarodes pacificus* resides off of Japan in the western and northern pacific (Figure 7).

Figure 7: Distribution of *Todarodes pacificus*



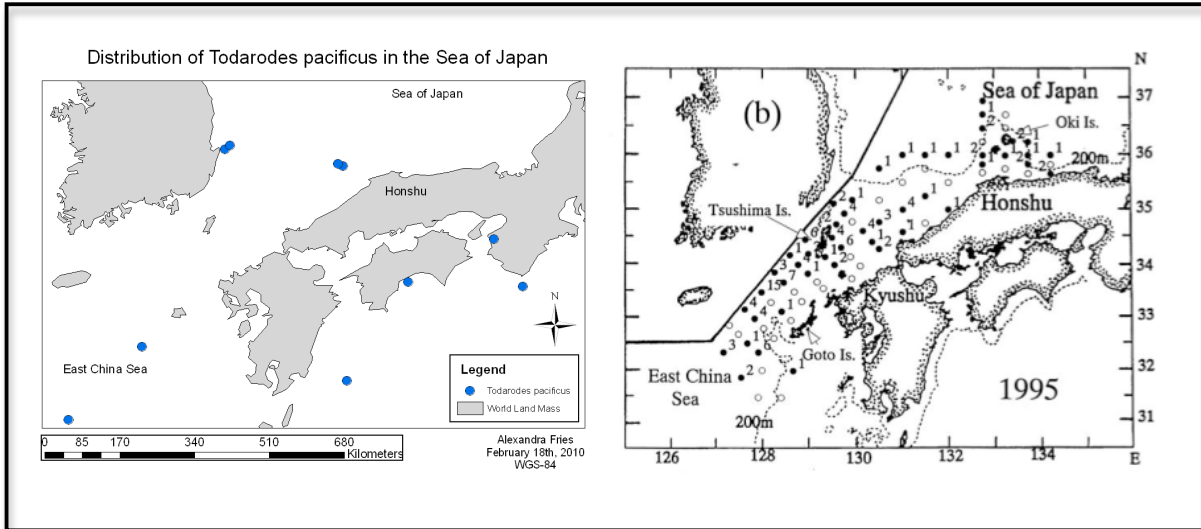
This species has been an important fishery for Japan since as early as 1900. Catch totals began to rise rapidly around the 1950's. From 1980 to 2001 the catch amounts for this species have varied from 141.4 to 715.9 thousand metric tons. The average *Todarodes pacificus* catch over this time period was 399.93 thousand metric tons (FAO Species Catalogue for Fishery Purposes, 2005).

Todarodes pacificus is short lived; existing for approximately one year. This species is comprised of three main spawning populations (Fukuda & Okazaki 1998; Goto 2002). Within its lifespan, this species makes two migrations. These migrations occur seasonally between the Pacific Ocean and the Sea of Japan. Temperature differences account for much of the variation in stock sizes and distributions (Sakurai et al. 2000).

A few papers examined in this study seem to have been excluded, and probably would not change the overall extent of the species range, but may show areas where species concentrations are higher. One of these studies is by Goto, (2002) which includes

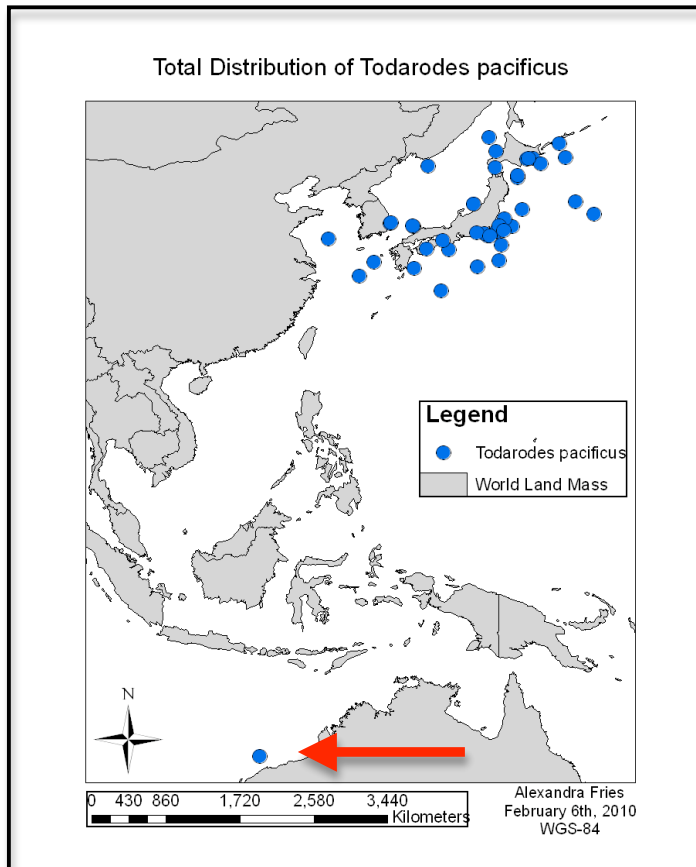
data from 1972-1999. This study compiled a large quantity of data showing paralarval presence (Figure 8) at sampling stations (Goto 2002).

Figure 8: Comparison of distribution in the Sea of Japan from OBIS and from Goto 2002. Closed circles show sampling points where paralarvae were found.



Inclusion of this data into the OBIS database would be beneficial in more closely pinpointing areas of high species density. There is also one data point showing a suspected sample of *Todarodes pacificus* off the northwestern coast of Australia (Figure 9).

Figure 9: Total Distribution of *Todarodes pacificus*



This area is not considered part of the natural distribution of *Todarodes pacificus*, and is most likely an error in reporting or identification.

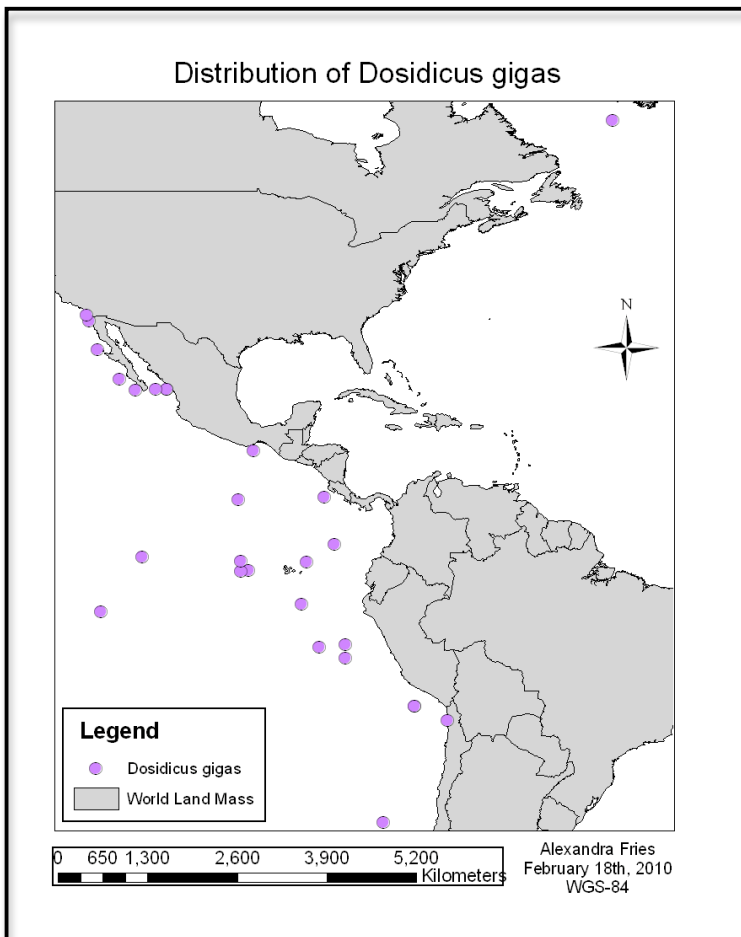
Dosidicus gigas

Dosidicus gigas, also known as the Jumbo or Humboldt squid, has a short lifespan of 1.5 - 2 years and extremely fast growth rates (Markaida et al. 2005). This species has a distribution that ranges from Southern Chile to Northern California along the Eastern Pacific coast (Ehrhardt, 1991). The range has expanded further north and south, although the exact causes for this are uncertain (Field et al. 2007; Gilly et al. 2006; Zeidberg & Robinson, 2007).

The Jumbo Squid has also shown strange episodic migrations, sometimes during El Nino, where it was observed as far north as southeast Alaska (Field et al. 2007; Wing, 2006). These species can travel up to 30 miles a day for several consecutive days. Large numbers of individuals have been seen migrating to the southern reaches of their

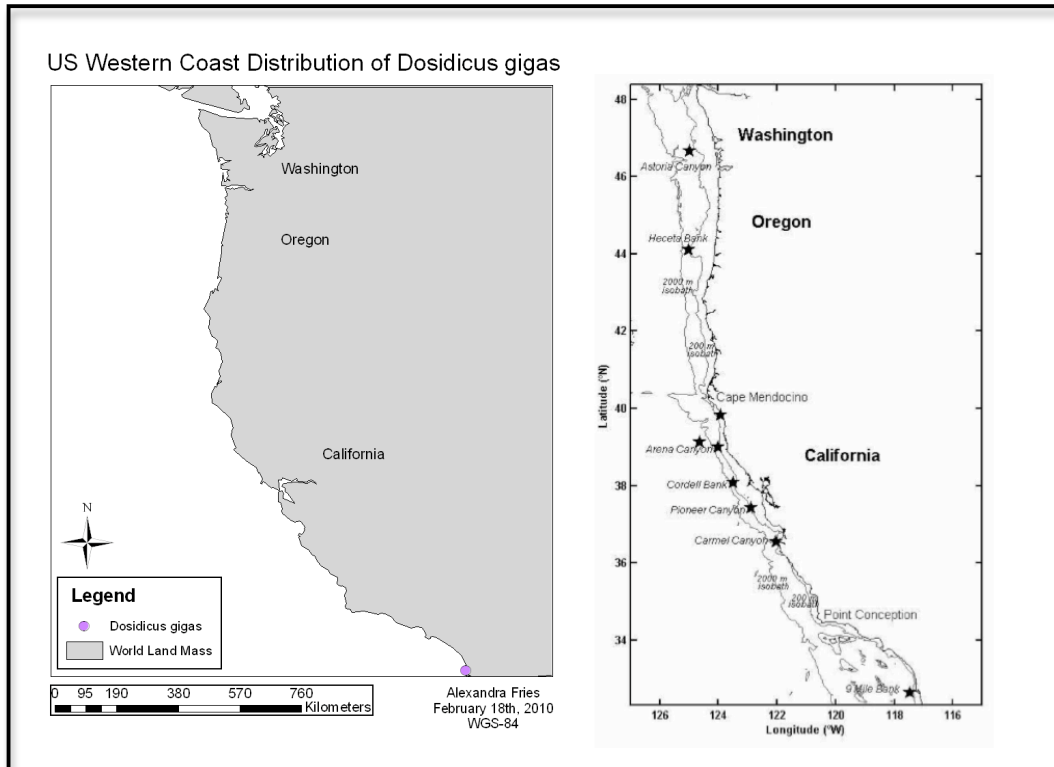
distribution as well (Field et al. 2007; Gilly et al. 2006). Unfortunately, the distribution extracted from the OBIS database appears to be lacking a lot of data points when compared to the literature (Figure 10).

Figure 10: Overall distribution map



From the study by Field et al. (2007), several locations where *Dosidicus gigas* was collected for a food habits examination can be seen outside the range expressed by the data in OBIS (Figure 11). It would be very helpful for this data to be in OBIS so that the *Dosidicus gigas* fishery can be better managed. *Dosidicus gigas* is especially important to the Eastern Pacific food webs, as it is a top predator with many trophic interactions (Ehrhardt, 1991; Zeidberg & Robison, 2007).

Figure 11: United States Western Coast Distribution of *Dosidicus gigas* from Field et al. 2007 compared to the same area from OBIS



Dosidicus gigas is a species that grows very large in a short amount of time, making it an ideal commercial species. From 1980 to 1990 catch values of *Dosidicus gigas* ranged between 0.1 and 19.1 thousand metric tons. The average during this 10 year period was only 6.81 thousand metric tons. It was not until 1991 that the Jumbo Squid fishery began to take off. Through 1991 to 2001 the total catch increased exponentially compared to the previous 10 years. The *Dosidicus gigas* catch average increased from 6.81 to 134.93 thousand metric tons; an increase of more than 1800% (FAO Species Catalogue for Fishery Purposes, 2005). Through 2004 - 2007 the fishery exceeded catches of 600 thousand metric tons. Commercial fisheries for the Jumbo Squid are based in Mexico, Peru and Chile (Gilly et al. 2006).

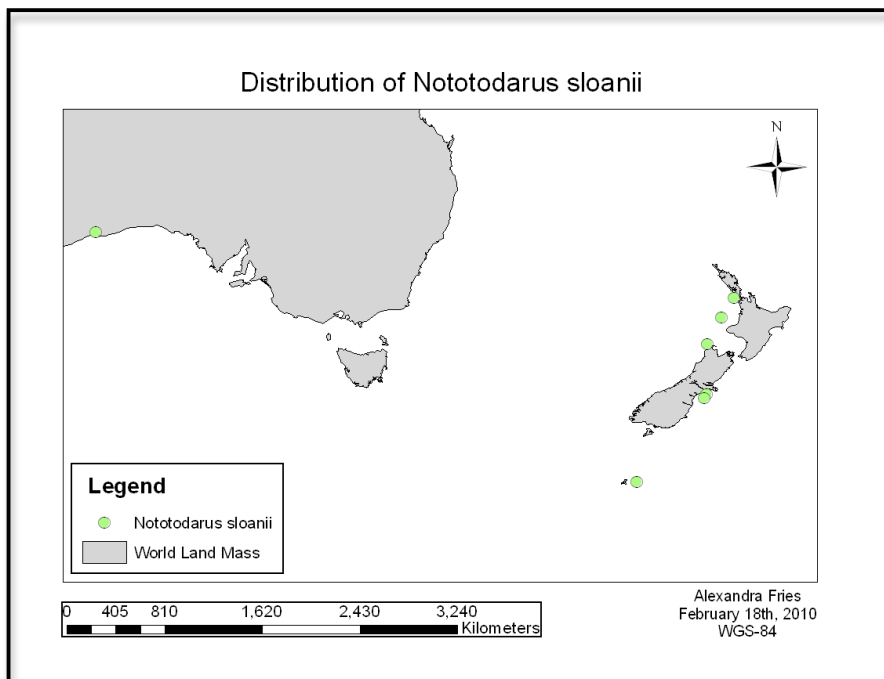
Overall, there is a lot of data from the literature from the last 5 years or so that is not currently included in the OBIS database. From the data that we do have, there is one

data point located off of the northwestern Atlantic coast, south of Greenland. This area is not considered part of the natural distribution of *Dosidicus gigas*, and is most likely an error in reporting or identification.

Nototodarus sloanii

The New Zealand Arrow squid, *Nototodarus sloanii*, is an important species in the South Pacific Ocean, residing off the coasts of New Zealand (Figure 12). This species prefers warmer shallower waters when compared to come other squid species and so is found very close to coastal regions (Jackson et al. 2000).

Figure 12: Total Distribution Map of *Nototodarus sloanii*



The fishery for the New Zealand Arrow squid is difficult to determine because many times catch trends are not separated by species. *Nototodarus sloanii* is also a very short lived species, with one spawning event occurring after approximately 200 days when it matures. Soon after maturity and reproduction, the species dies, living only a little over a year (Dunn, 2009; Uozumi, 1998).

Nototodarus sloanii is an important fishery for New Zealand due to the fact that other important deep water fisheries in this area are decreasing (Chilvers, 2008). From

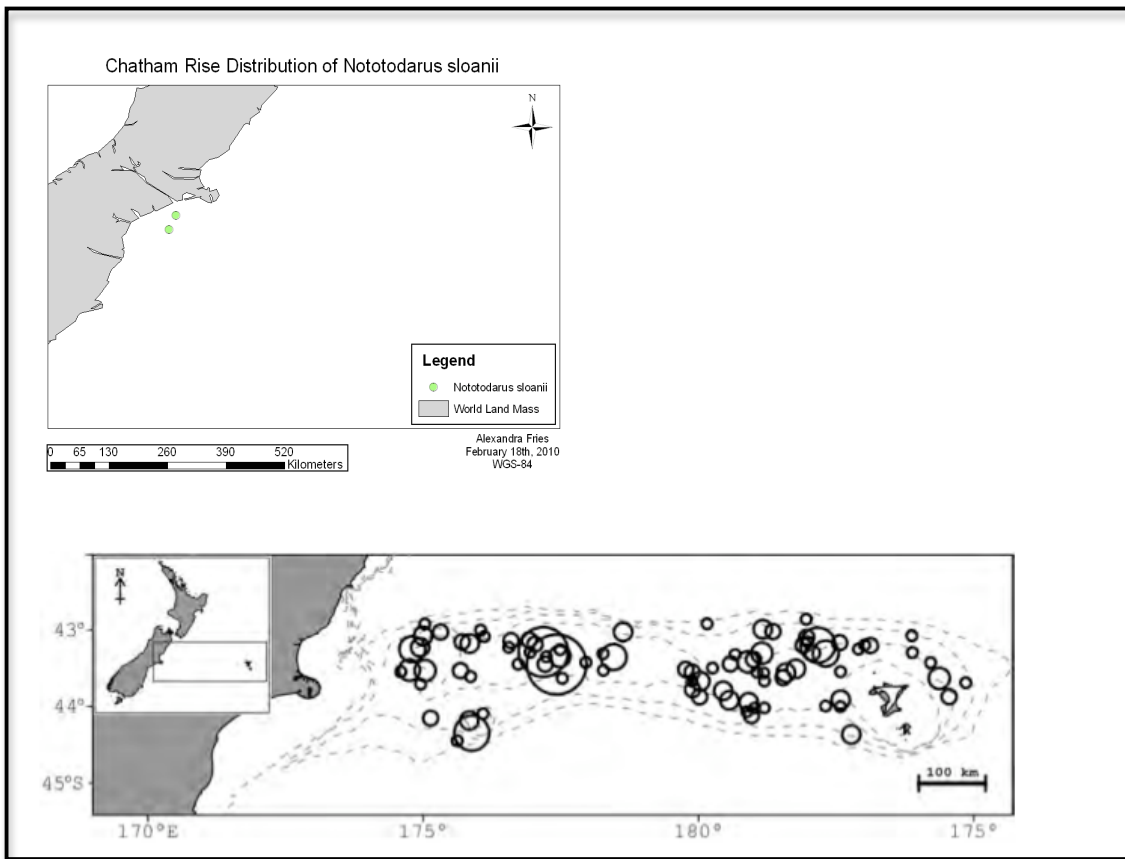
1981 - 2001 the *N. sloanii* fishery remained relatively stable with values ranging from 25.6 to 94.1 thousand metric tons. The average catch during this 20 year period was 51.75 thousand metric tons (FAO Species Catalogue for Fishery Purposes, 2005). From 2001-2006, the fishery remained generally the same (Table 3), with the average for this period rising to just 67.058 thousand metric tons (Chilvers, 2008).

Table 3: *Nototodarus sloanii* catch amounts in tons. TACC is the total allowable commercial catch. SQU expresses different fishing areas for the squid and how much catch was taken per area (New Zealand Ministry of Fisheries- Chilvers, 2008).

| Fishing year | Total NZ Squid catch (SQU1J, SQU1T and SQU6T) | SQU6T catch | % total NZ SQU harvest taken from SQU6T | % TACC harvest taken from SQU6T |
|--------------|---|-------------|---|---------------------------------|
| 2001-02 | 48173 | 11502 | 24 | 9 |
| 2002-03 | 43719 | 6887 | 16 | 5 |
| 2003-04 | 84962 | 34635 | 41 | 27 |
| 2004-05 | 86075 | 27314 | 32 | 21 |
| 2005-06 | 72361 | 17425 | 24 | 14 |
| Average | 67058 | 19553 | 27 | 15 |

Nototodarus sloanii only encompasses a small distributional area. To further demonstrate where the highest concentrations of this species are found within the New Zealand area, inclusion of much more fisheries and research data would be beneficial. A map from Dunn (2009), show area where sampling of *N. sloanii* occurred (Figure 13). More data like this incorporated into OBIS would prove useful in protecting a possibly threatened species.

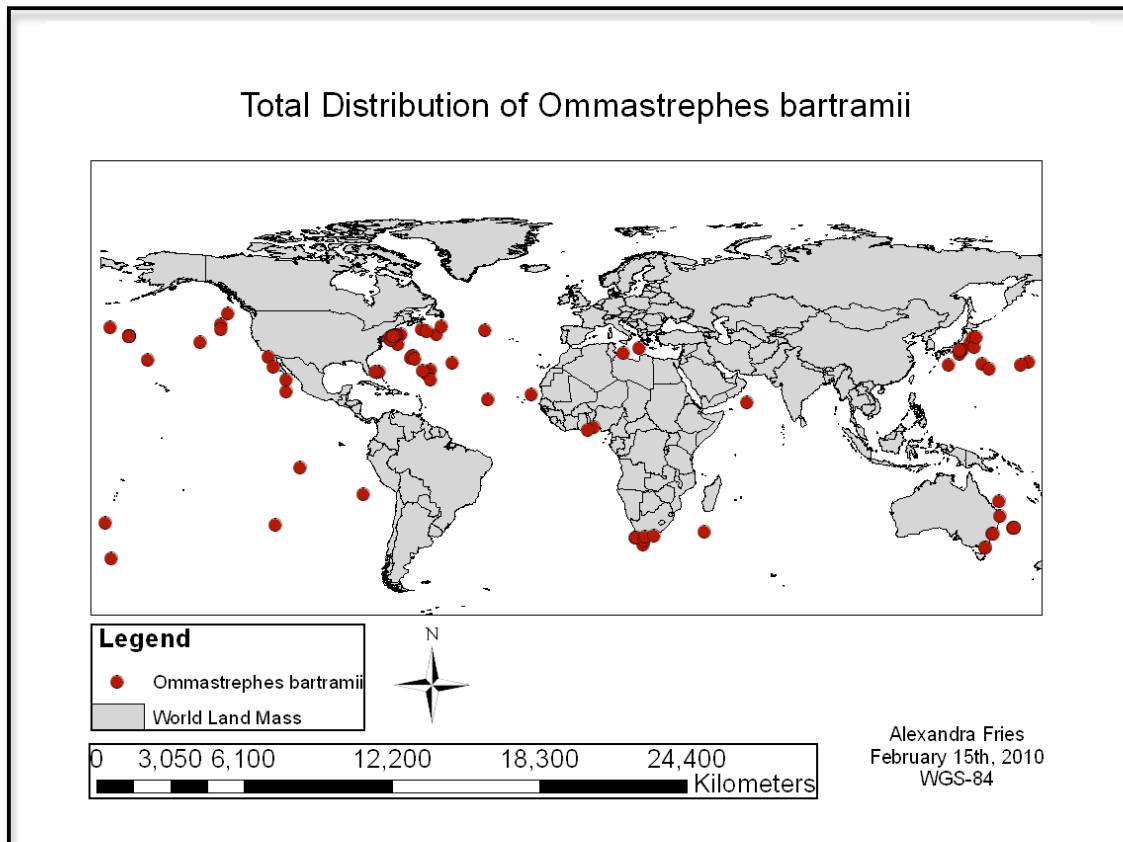
Figure 13: *Nototodarus sloanii* sampling locations on the Chatham Rise in South Eastern New Zealand. Circle area is proportional to the size of the sample taken (Dunn 2009).



Ommastrephes bartramii

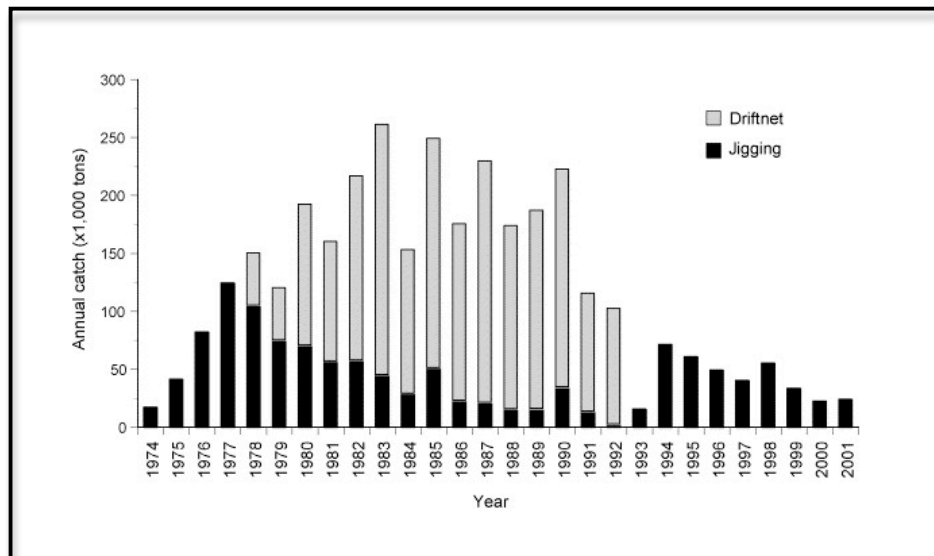
The red flying squid, *Ommastrephes bartramii*, has a distribution which ranges worldwide (Figure 14) in temperate and subtropical waters (Brunetti & Ivanovic 2004; Roper et al. 1984; Watanabe et al. 2004). Because of its large range, there are many reproductively separate populations of this species (Bower and Ichii 2005; Katugin, 2002). There is one population that resides in the North Pacific which is comprised of two cohorts due to seasonal differences in spawning (Chen & Chiu 1999; Dunning, 1998). This population also makes seasonal migrations between spawning and feeding grounds (Bower & Ichii 2005; Chen et al. 2007). Another population occurs in the North Atlantic, and a third in the South Pacific. The South Pacific population is theorized to be two separate populations due to its discontinuity at the tip of South America and Australia (Bower & Ichii 2005; Dunning, 1998).

Figure 14: Worldwide Distribution of *Ommastrephes bartramii*.



Ommastrephes bartramii has a single year lifespan and maturity occurs between 7 and 10 months of age. Fishing of this species occurred in the North Pacific as early as 1974 by Japan. In the 1980's, Korea, Japan and Taiwan further developed the fishery by using drift nets. Drift nets were extremely efficient in catching the red flying squid and catches ranged from 248 to 378 thousand metric tons from 1985-1990 (Murata & Nakamura, 1998). In 1992, this method was outlawed, and catches dropped to averaging around 150 thousand metric tons (Araya, 1983; Brunetti & Ivanovic, 2004). Catches decreased even further afterwards (Figure 15).

Figure 15: *Ommastrephes bartramii* catch rates in the North Pacific from 1974-2001.



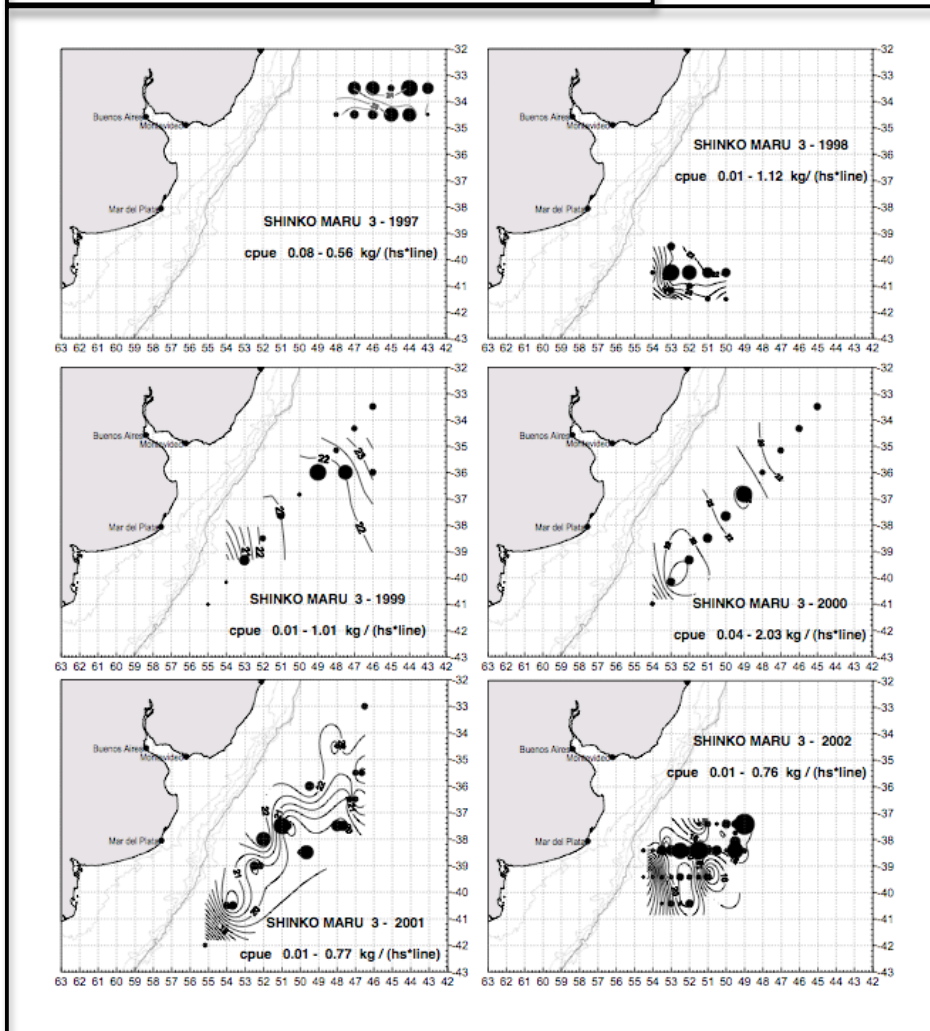
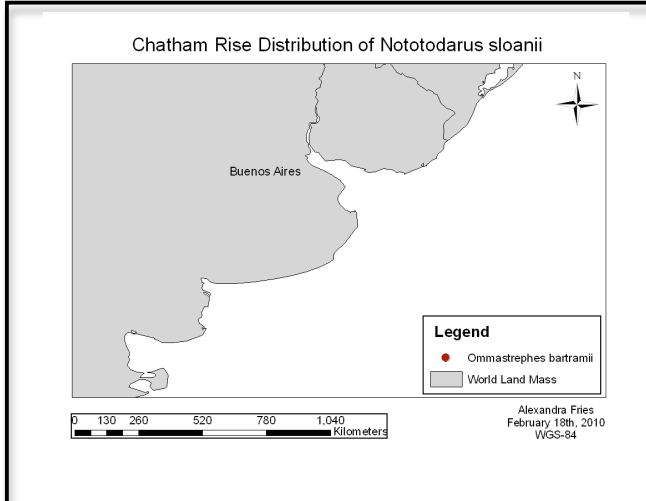
In the Southwest Atlantic off of Brazil, a study was performed by Brunetti and Ivanovic to determine the potential for a fishery in this region (2004). Although this study found somewhat large numbers of individuals for the number of stations they employed, the total metric tons of catch was low, do to small body sizes. The average metric tons that were caught from 1997 - 2002 were only 1.96. The numbers of individuals were relatively notable however (Table 4).

Table 4: Date, number of stations performed, time and depth of fishing, total catch in weight and number of individuals as well as average catch per unit effort in weight and in number of individuals for the six jigging cruises carried out (Brunetti & Ivanovic, 2004).

| Year | Date | Number of stations | Time of fishing (night) | Time of fishing (day) | Depth of fishing (m) | Total catch (kg) | Total catch (N°) | Mean CPUE (kg/h*lin) | Mean CPUE (N°/h*lin) |
|--------------|-------------------------|-----------------------|-------------------------|-----------------------|---------------------------------|------------------|------------------|----------------------|----------------------|
| 1997 | 1 - 9 March | 10 | 19:00 04:30 | | 80 - 170 | 2,114 | 8,464 | 0.339 | 1.363 |
| 1998 | 2 - 11 March | 10 (night) 3 (day) | 18:00 06:00 | 06:30 12:30 | 160 - 200 nig. 290 - 300 day | 1,999 | 3,898 | 0.391 | 0.773 |
| 1999 | 27 February 10 March | 12 | 20:00 05:00 | | 150 - 180 | 1,593 | 3,212 | 0.329 | 0.661 |
| 2000 | 26 February 7 March | 10 | 20:00 05:00 | | 160 | 2,825 | 4,640 | 0.683 | 1.130 |
| 2001 | 6 - 16 April | 20 | 19:00 06:00 | | 160 | 1,818 | 2,297 | 0.239 | 0.303 |
| 2002 | 16 May 1 June | 32 | 19:00 07:00 | | 160 - 180 | 1,426 | 1,804 | 0.144 | 0.183 |
| Total | | | | | | 11,775 | 24,315 | 0.292 | 0.559 |

There is much more data that is currently available that is not accessible through OBIS. The catch data in the South Atlantic off of Argentina would be especially useful (Figure 16).

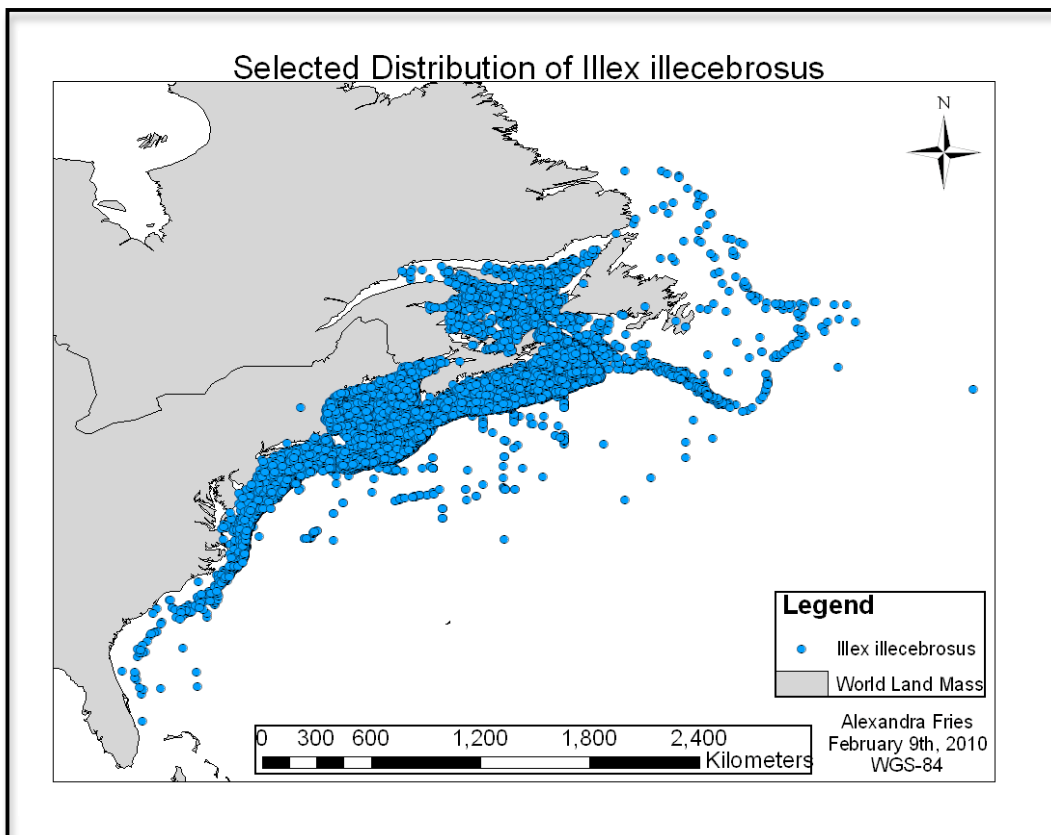
Figure 16: Comparison of OBIS distributional data off of Argentina versus Brunetti & Ivanovic cruise data (2004). Figure from Brunetti & Ivanovic shows the catch per unit effort of *Ommastrephes bartramii*. Size of the circle corresponds to catch amount.



Illex illecebrosus

The northern shortfin squid, *Illex illecebrosus*, resides in the North Atlantic Ocean from Florida to Great Britain (Figure 17). This species is highly migratory and inhabits mainly continental shelf and continental slope areas (Hendrickson, 2004; Roper et al. 1998).

Figure 17: Selected Distributional Map for *Illex illecebrosus*.

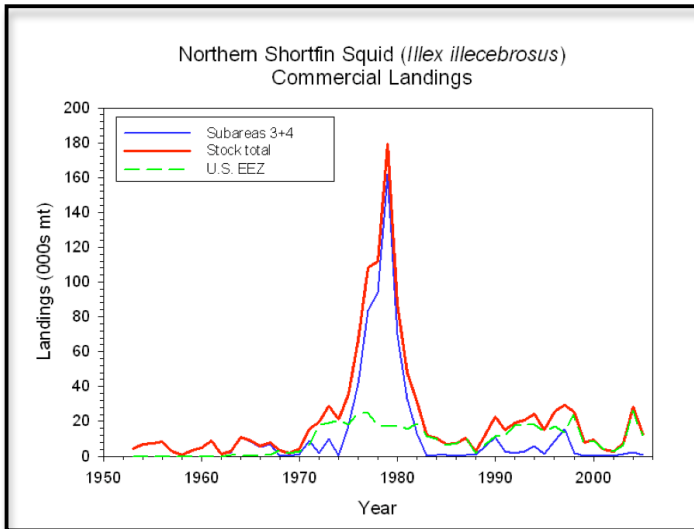


Illex illecebrosus has a short lifespan of about 18 months (Mesnil, 1977), which ends directly after a single spawning event (O'Dor et al. 1980). A short lifespan can cause management to be difficult especially because of the high importance of this species as a commercial fishery (Powell et al. 2003).

Fishing of this species began as early as 1911 (Hendrickson & Showell, 2006). By the 1970's the fishery had expanded from 1.6 thousand metric tons in 1969 to 173.3 thousand metric tons in 1979 (Figure 18). However, by 1981 the catch amounts had

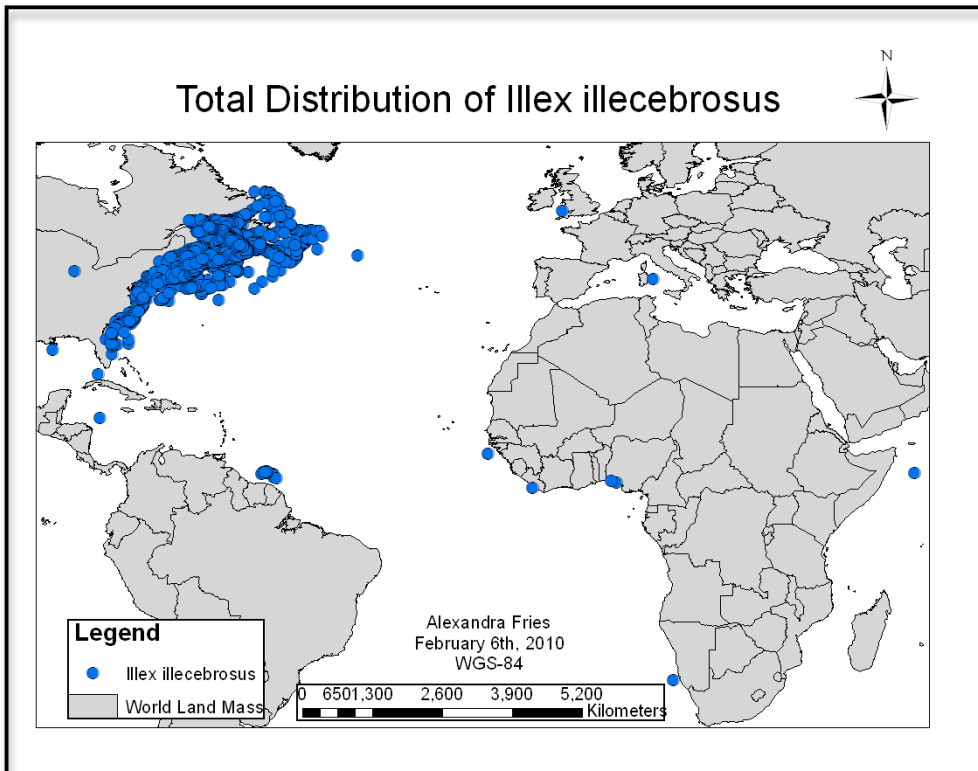
dropped to only 50.2 thousand metric tons (FAO Species Catalogue for Fishery Purposes, 2005; Hendrickson, 1998). From 1982-2001 the average catch amounts were only 18.5 thousand metric tons, a stark contrast to the catch only a few decades earlier (FAO Species Catalogue for Fishery Purposes, 2005).

Figure 18: Fishery Data from 1950-2000 from Hendrickson 1998.



Overall, the data in OBIS is comprehensive for the North Atlantic region from Florida to Nova Scotia. The supposed range extending across Greenland to Britain is lacking, with only one data point off the British Isles. A few points from the database are outside the natural range of the northern shortfin squid. These points can be seen in the total distribution map on the east and west coasts of Africa, as well as in the Mediterranean (Figure 19). A clustering of points is also located off the northeast coast of South America. It is uncertain whether these points are accurate expressions of the distributional range of *Illex illecebrosus*.

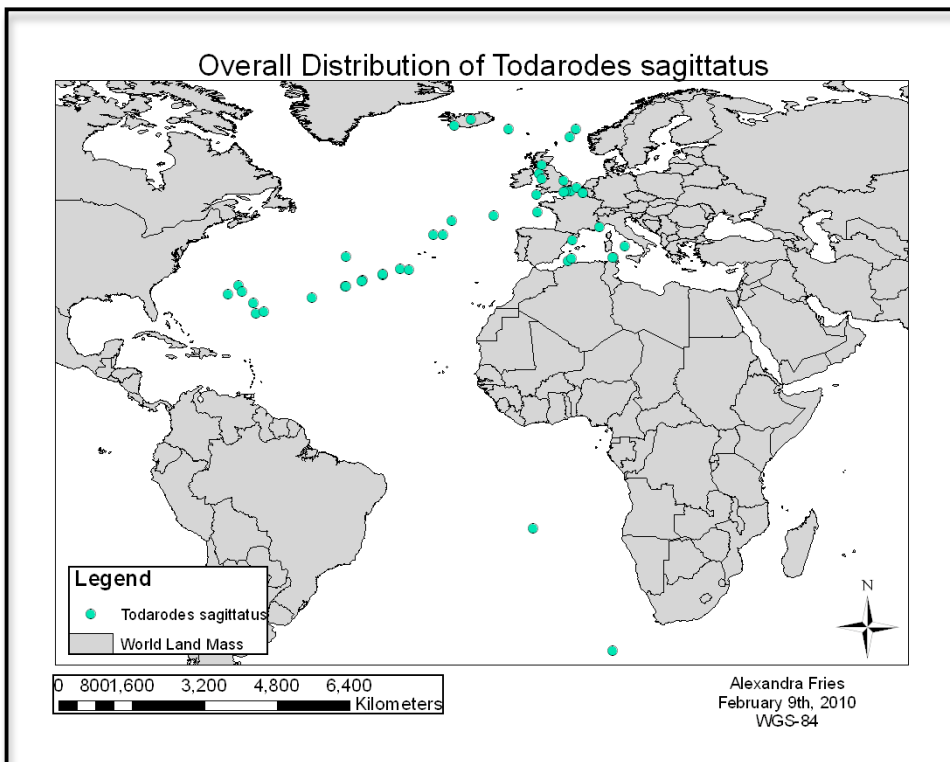
Figure 19: Overall Distributional Extent Map



Todarodes sagittatus

This species, also known as the European flying squid, generally maintains an oceanic lifestyle in much of the Northern Atlantic (Figure 20). The distribution ranges from Bermuda in the west, toward Iceland, and extends to the Mediterranean and along the Northwest coast of Africa (Nesis, 1987; Nigmatullin et al. 2002).

Figure 20: Total Distribution of *Todarodes sagittatus*



Todarodes sagittatus matures at about 8 to 9 months of age and the life cycle ends after one year of age (Nigmatullin et al. 2002; Nigmatullin & Laptikhovsky, 1999). Because of this species short lifespan and variable spawning time, it has not made a very consistent fishery (Quetglas et al. 1998b).

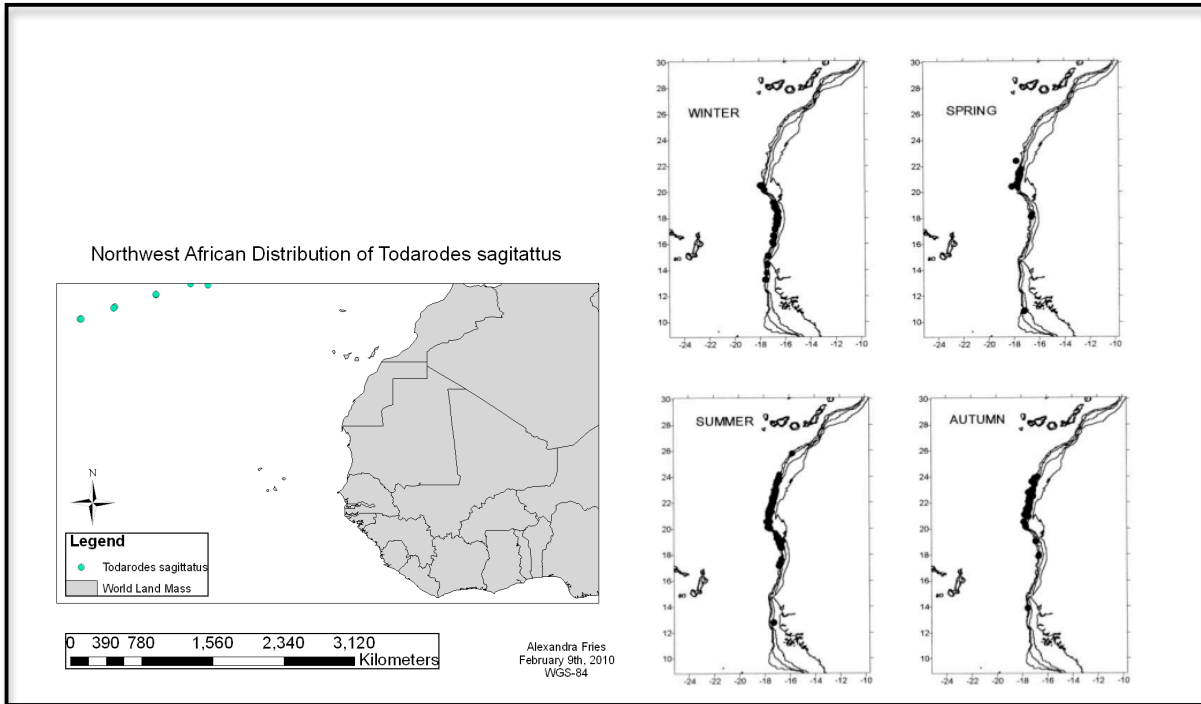
There has not been strong fishing effort directed at the European flying squid. *Todarodes sagittatus* has been collected through by-catch in Southern European trawl fisheries and jigging fisheries. Many of these fisheries occurred off of Norway, as well as Italy and Greece (Borges & Wallace, 1993; Mangold & Boletzky, 1987). This species appears to show two or three separate populations, from Atlantic Ocean off western Africa, the Mediterranean Sea and off the Norwegian Coast.

From 1980 to 2001, the catch amounts of *Todarodes sagittatus* have ranged from 4.3 to 22.5 thousand metric tons. However, the average catch was very low at only 9.9 thousand metric tons (FAO Species Catalogue for Fishery Purposes, 2005).

The data expressed in OBIS showing the distributional characteristics of the European flying squid are moderately comprehensive when considering the lack of studies on the subject. The only important area where more data is available is directly off the northwest African coast. Although not the best of quality from the paper by

Nigmatullin et al. (2002), there is data available which would better show this species distribution (Figure 21).

Figure 21: Comparison of *Todarodes sagittatus* distribution off Northwest Africa.

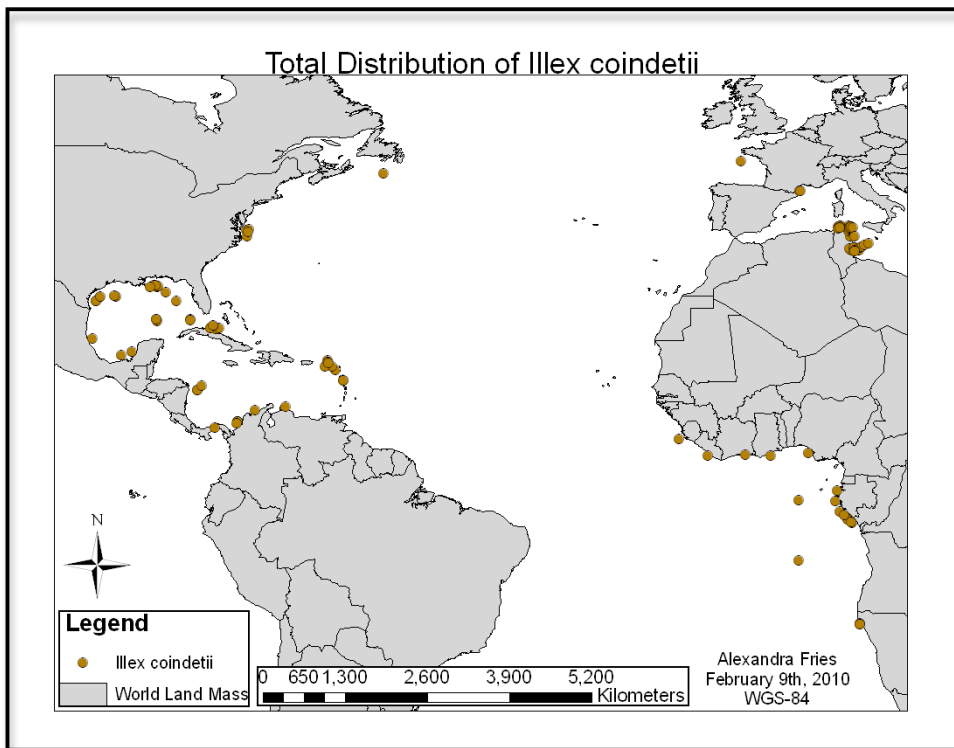


Overall, because of the inconsistencies in exploratory trawling data, it is unlikely that the European flying squid will ever be focused on directly as a fisheries resource.

Illex coindetii

The broadtail shortfin squid, *Illex coindetii* is distributed in the tropical and subtropical Atlantic as well as the Mediterranean Sea (Arkhipkin et al. 2000; Mangold & Boletzky 1987; Roper et al. 1984). This species has a wide range in the Atlantic (Figure 22) but is mostly made up of smaller populations with less migratory behavior than other similar species (Arkhipkin et al. 2000; Arvanitidis et al. 2002).

Figure 22: Total Distribution of *Illex coindetii*

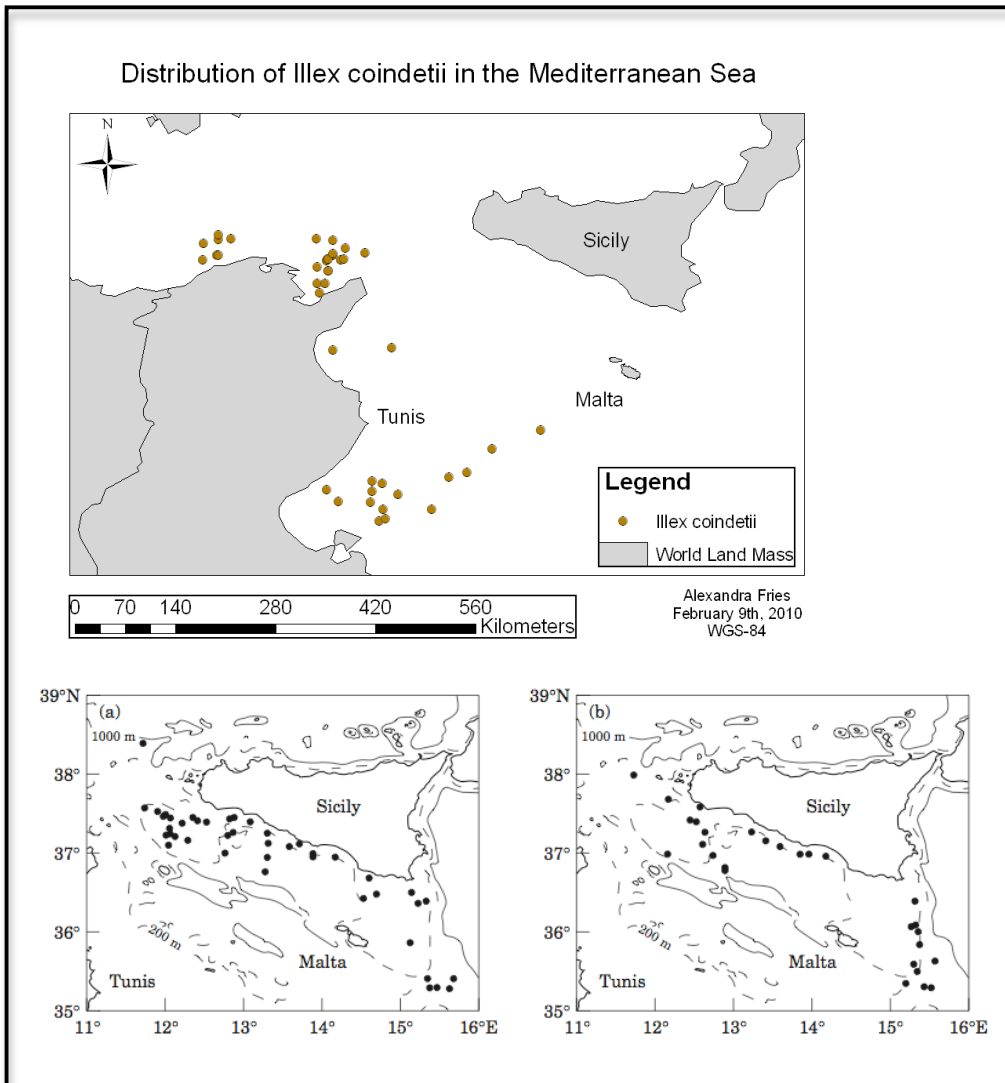


There is some disagreement about when maturity occurs for the broadtail shortfin squid and how long the life span lasts. Some studies show life spans of 6 to 7 months (Arkhipkin et al. 2000), while others find the life cycle to last a year or perhaps even a year and a half (Arvanitidis et al. 2002; Sanchez, 1995). Regardless of these differences, *Illex coindetii* has a large vulnerability to fishing pressures because of its short life time.

The fishery for *Illex coindetii* is focused mainly in the Mediterranean Sea (Arvanitidis et al. 2002). Compared to other cephalopod fisheries, the catch weights seem low, but for the small spatial area that this species is fished in, the values are significant. From 1982 to 2001 the catch values ranged between 100 metric tons and 1200 metric tons (FAO Species Catalogue for Fishery Purposes, 2005).

Because of the large fishery in the Mediterranean Sea, the distribution for this area is relatively well expressed in OBIS (Figure 23).

Figure 23: Mediterranean Distributional Extent from OBIS and from Arkhipkin et al. (2000)



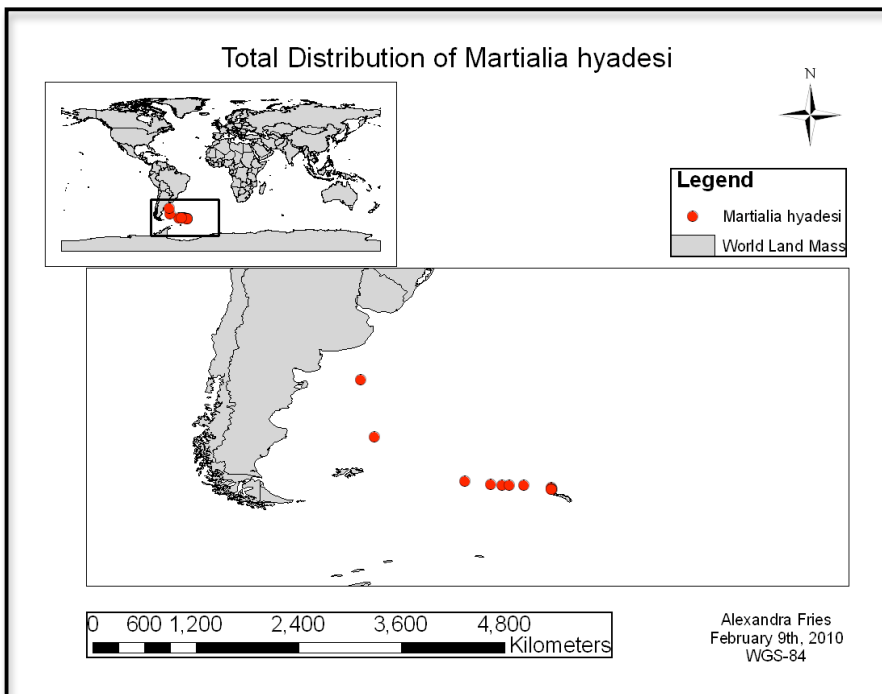
As far as the other populations in the western Atlantic and off the western coast of Africa in the eastern Atlantic, there is very little data available. There are very few papers discussing these other populations, which made it difficult to compare the OBIS mapped data to current and past research.

Martialia hyadesi

The seven star flying squid, *Martialia hyadesi*, is a polar species occurring around the Antarctic Polar Frontal Zone (APFZ)(Gonzalez et al. 1997; Rodhouse 1991). The life span of *Martialia hyadesi* is theorized as being between one and two years in length (Anderson & Rodhouse 2001; Rodhouse et al. 1994). It has been caught primarily between the Falkland Islands and South Georgia (Anderson & Rodhouse 2001). The

overall distribution seems very small and is not completely understood at this point (Figure 24). Strandings and identification of the species have been observed as far away as the Macquarie and Kerguelen islands (O'Sullivan et al. 1983; Piatkowski et al. 1991).

Figure 24: Overall Distribution of *Martialia hyadesi*



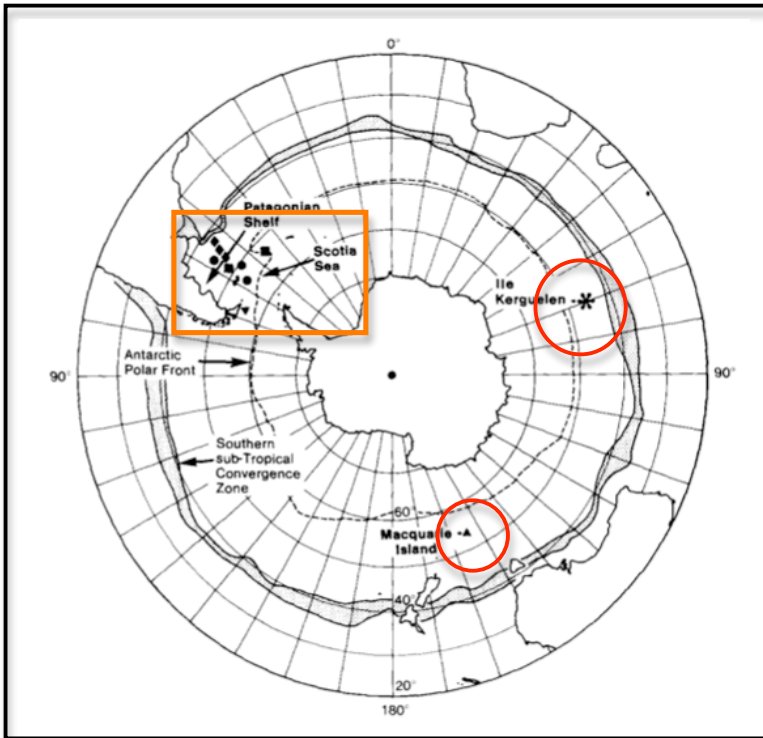
Martialia hyadesi catch is very small when compared to the *Illex argentinus* fishery which occurs in the same general region. The seven star flying squid has actually been a product of bycatch in the *I. argentinus* fishery more than being caught as a part of it's own fishery (Gonzalez et al. 1997; Rodhouse & White 1995).

From between 1986 and 2001, the catch amounts for *Martialia hyadesi* ranged from 0.0 to 24.0 thousand metric tons. The highest catch years were 1986, 1990, 1995 and 1997, with catch amounts of 8.4, 11.6, 24.0 and 8.4 thousand metric tons, respectively (FAO Species Catalogue for Fishery Purposes, 2005). Although this species is not currently being exploited as a fishery, there have been some studies to determine the viability of a fishery of *Martialia hyadesi*. These studies have generally been attempting to determine how high the catch rates could be for this species (Gonzalez et al. 1994; Piatkowski et al. 1991).

There is a little additional data currently available that is not accessible through

OBIS. This data suggests that the distribution of the seven star flying squid is circumpolar and not only limited to the Patagonian Shelf and the Scotia Sea (Piatkowski et al. 1991). We can compare the differences in the distribution available through OBIS and that by Piatkowski et al. (1991) although the map formats are quite different (Figure 25).

Figure 25: Total Distributional Extent from Piatkowski et al. (1991). The orange rectangle shows the area where OBIS data give the distributional extent to be. The red circles show areas outside of this range where *Martialia hyadesi* has been sampled.



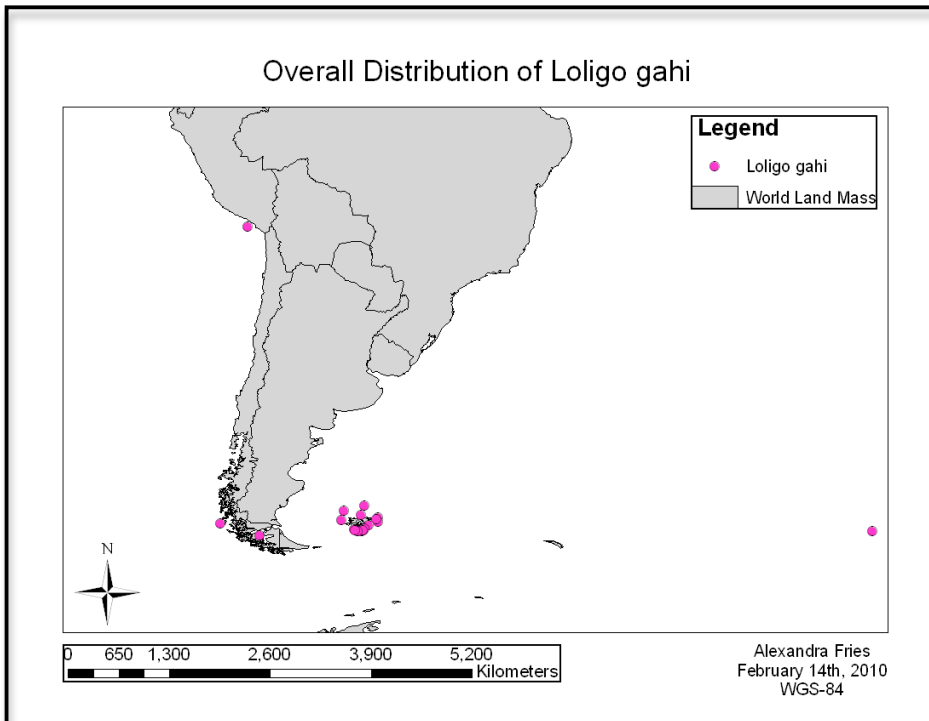
More data needs to be included in OBIS to better understand the distributional extent of *Martialia hyadesi* and to ensure sustainability if a fishery is developed for this species.

Loligo gahi

The Patagonian longfin squid, *Loligo gahi*, is a species that resides primarily off

the south east coast of South America surrounding the Falkland Islands (Arkhipkin et al. 2001; Roa-Ureta & Arkhipkin 2007). This species has also been found on the western coast of South America, as far north as Peru (Figure 26).

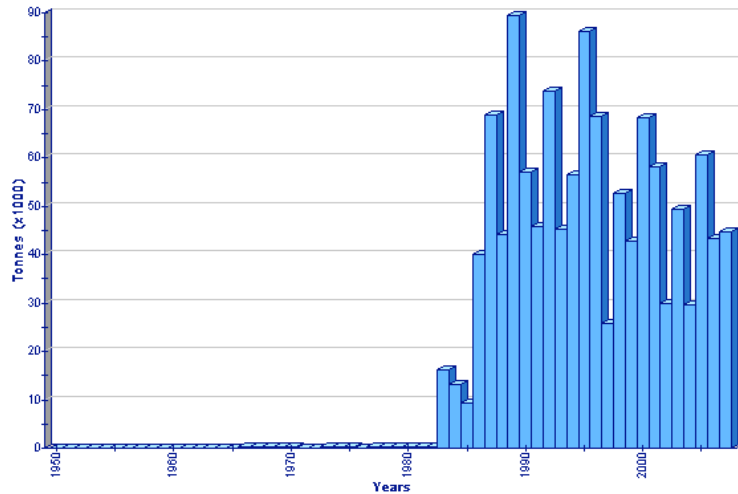
Figure 26: Total Distribution of *Loligo gahi*



There are two different spawning cohorts within the *Loligo gahi* population surrounding the Falkland Islands. One group spawns in autumn while the other spawns in the spring. These two reproductive groups have different body sizes and growth rates due to the difference in temperature at the time of their spawning (Arkhipkin et al. 2001; Patterson, 1988).

Despite the fact that little is known about *Loligo gahi*, it makes up a significant fishery in the Patagonian shelf region (Figure 27). From 1983 to 2001 catch rates varied from 9.2 to 89.2 thousand metric tons. The average over this time period was rather high at 49.9 thousand metric tons (FAO Species Catalogue for Fishery Purposes, 2005).

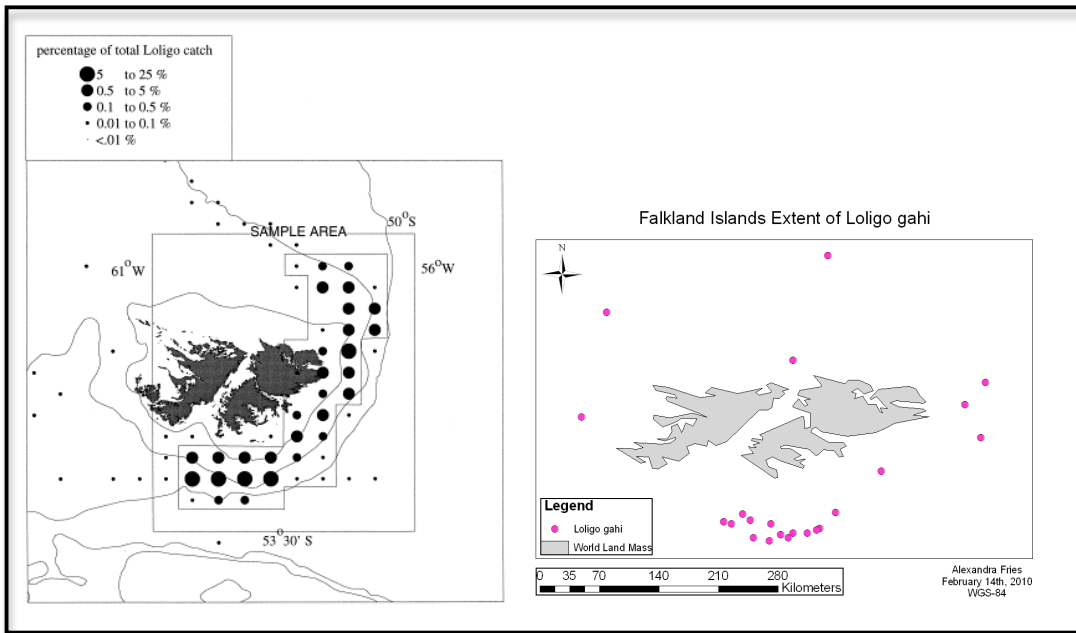
Figure 27: Fishery data from *Loligo gahi*, from Roper et al. 1984.



In order to fish for *Loligo gahi*, a license must be obtained. Only 15 to 18 of these licenses are issued each fishing season (Agnew et al. 1998; Falkland Islands Government, 2000). Overall, the *Loligo gahi* fishery is probably one of the best managed squid resource (Hatfield & des Clers 1998; Roa-Ureta & Arkhipkin 2006).

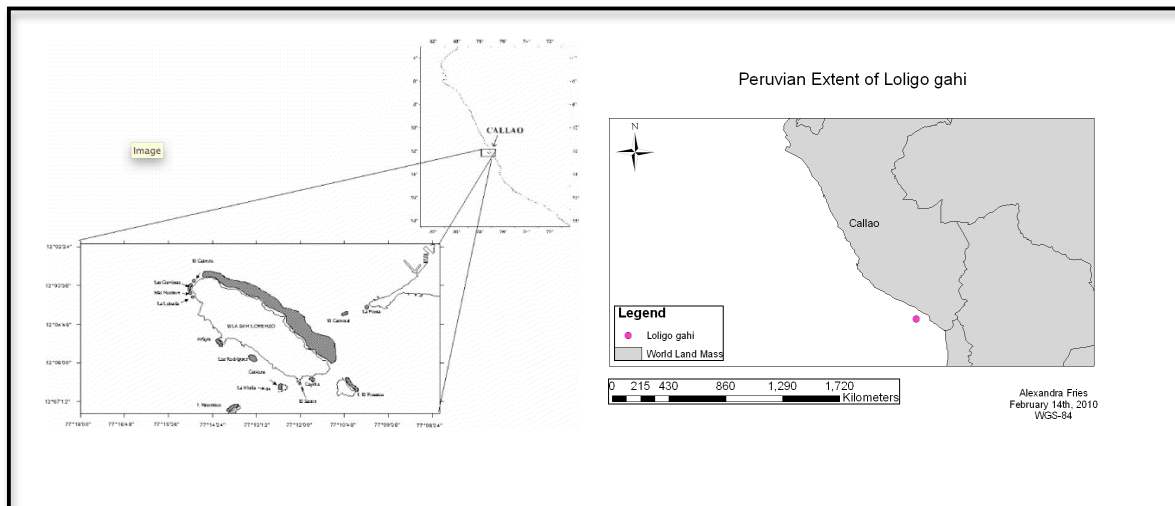
The distributional area expressed in OBIS is not as conclusive as would be suggested by the current management practices of the *Loligo gahi* fishery. More data is available that is not in OBIS, specifically for the area directly surrounding the Falkland Islands (Figure 28).

Figure 28: Falkland Island extent as shown by OBIS compared to Agnew et al. 1998.



Loligo gahi also makes up an important artisanal fishery off Callao in Peru (Villegas, 2001). In OBIS, there is only one recorded point off Peru, slightly south of the Callao region. When compared to a distributional extent provided by Villegas (2001), we can see that there is perhaps an important extent of Loligo gahi that needs to be included (Figure 29).

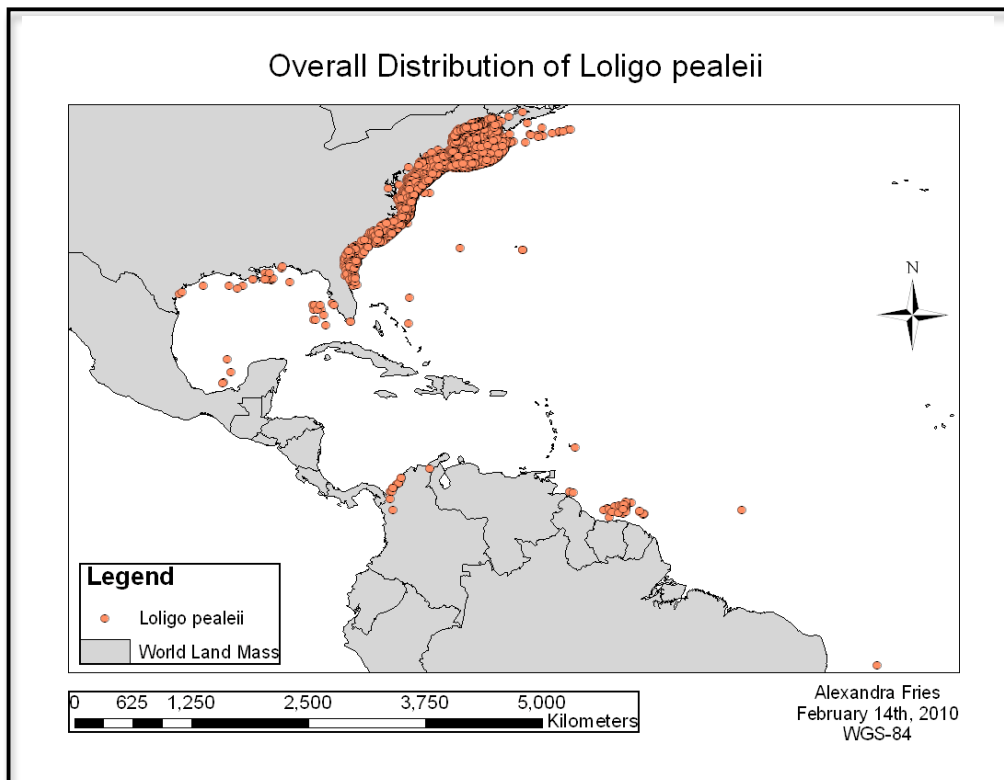
Figure 29: Peru region shown by OBIS compared to Villegas 2001



Loligo pealeii

Loligo pealeii, also known as the longfin inshore squid, resides in the western Atlantic Ocean (Figure 30) from Nova Scotia, through the Gulf of Mexico and down to the northern Brazilian coast (Buresch et al. 2006; Hunsicker & Essington 2006). Some migrations have been seen to occur (Staudinger 2006), in particular a seasonal migration north of Cape Hatteras between spawning and feeding grounds. According to a study by Buresch et al., there are at least four separate spawning populations from Cape cod to Delaware along the continental shelf (2006).

Figure 30: Overall Distribution of *Loligo pealeii*

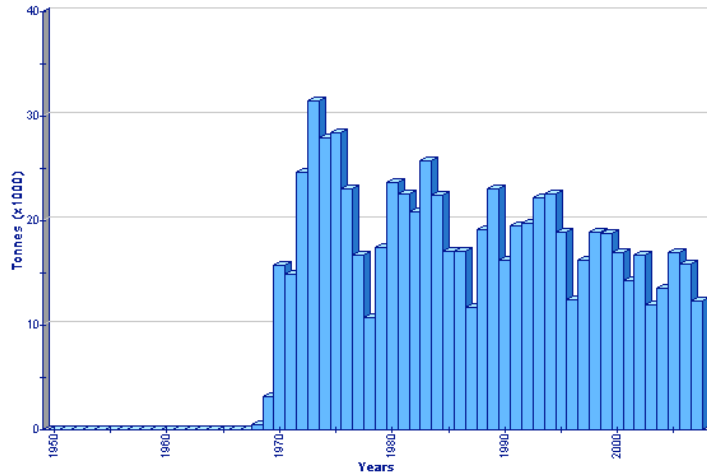


Currently the *Loligo pealeii* fishery is managed as a single stock unit. Because there are different spawning populations, a management strategy such as this greatly overlooks the effects fishing has on multiple groups, which migrate to different areas for feeding and spawning (Buresch et al. 2006).

The fishery began mainly in the late 1960's (Roper et al. 1984), spiking in 1973 to around 32 thousand metric tons (Figure 31). From 1980 to 2001, the *Loligo pealeii*

fishery has remained at a steady level, only slightly decreasing. Within this time period the catch amount ranged from between 11.7 and 25.7 thousand metric tons. The average catch was 19.1 thousand metric tons per year (FAO Species Catalogue for Fishery Purposes, 2005).

Figure 31: Fishery Data for *Loligo pealeii* from Roper et al. 1984.

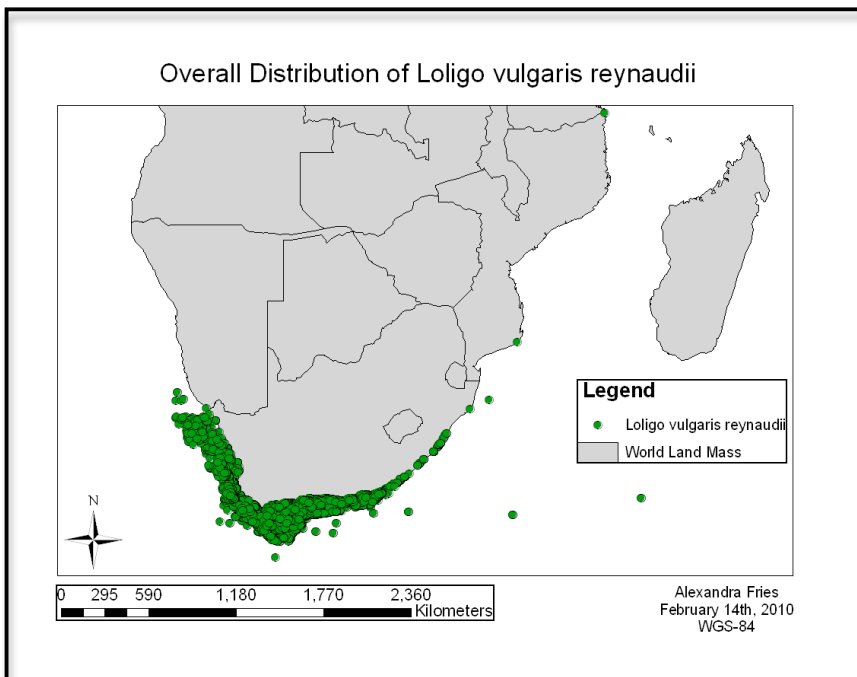


Overall, the data in OBIS showing the distribution of *Loligo pealeii* is comprehensive and clearly displays the range of this species.

Loligo vulgaris reynaudii

Loligo vulgaris reynaudii, sometimes called the Chokka squid, resides directly along the South African coast (Roberts 2005) (Figure32).

Figure 32: Total Distribution of *Loligo vulgaris reynaudii*



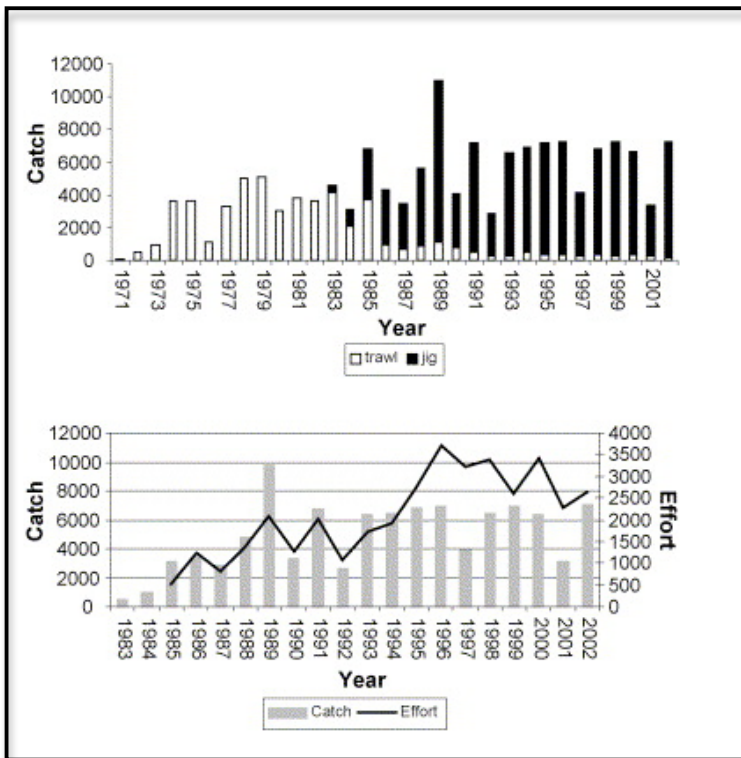
There is much controversy over whether or not this is a single species or if it is a subspecies of *Loligo vulgaris*. For the purposes of this study, we will consider *Loligo vulgaris reynaudii* as its own species. One of the reasons for deciding this, is that the OBIS database currently accepts the Chokka squid as a single species and not a subspecies.

The fishery for *Loligo vulgaris reynaudii* began since the early 1900's. At this time, a trawling method was used, and the Chokka squid was a large bycatch component while the main targets of the fishery were sole and hake (Cochrane et al. 1997; Glazer & Butterworth 2006). Beginning around the early 1980's a jig fishery developed to directly catch *Loligo vulgaris reynaudii* (Olyott et al. 2006). This new, more directed fishery took in approximately 7,000 metric tons a year (Figure 33). Even though this fishery is smaller than other squid fisheries previously discussed, it is an important resource for South Africa (Augustyn, 1990).

The management of *Loligo vulgaris reynaudii* includes limiting the amount of fishing effort that can be done on the resource. This is done by having closed fishing seasons and by capping the amount of people allowed to fish for the squid. However, the area where the Chokka squid lives is so small and centralized that more than 90% of the fishing is located in the spawning grounds of this species. This is an issue that should be

addressed when looking at the best management practices for the *Loligo vulgaris reynaudii* fishery (Sauer 1995).

Figure 33: Catch amounts for *Loligo vulgaris reynaudii* using trawl fishing and jig fishing methods from Glazer and Butterworth (2006).

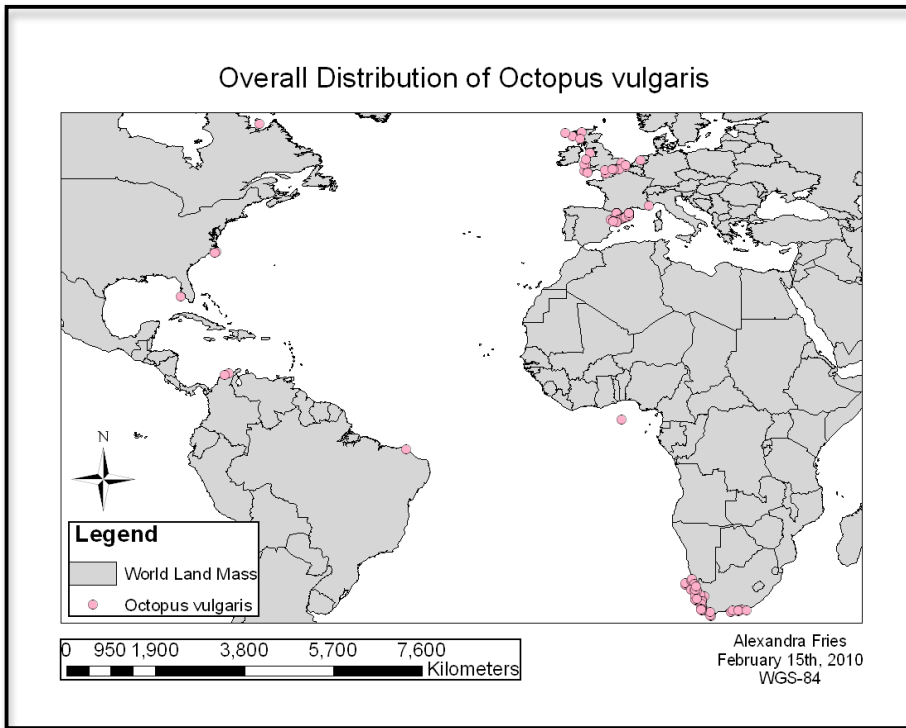


Overall, the data in OBIS showing the distribution of *Loligo vulgaris reynaudii* is comprehensive and clearly expresses the range of this species. Since this species is so focused locally off of South Africa, it is easy to see the range and distribution of the species within this small area.

Octopus vulgaris

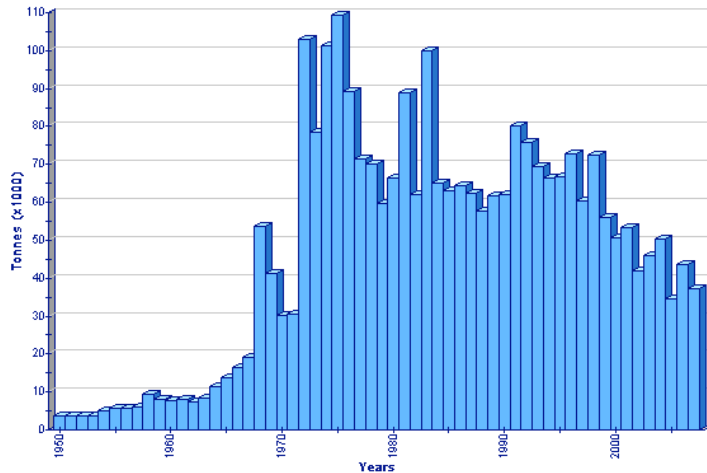
Octopus vulgaris, or the common octopus, has a worldwide distribution (Warnke et al. 2004), focused in the tropics and subtropical to temperate zones (Figure 34). This includes the Mediterranean Sea as well (Katsanevakis & Verriopoulos 2006; Mangold, 1983; Quetglas et al. 1998a).

Figure 34: Distribution of *Octopus vulgaris*



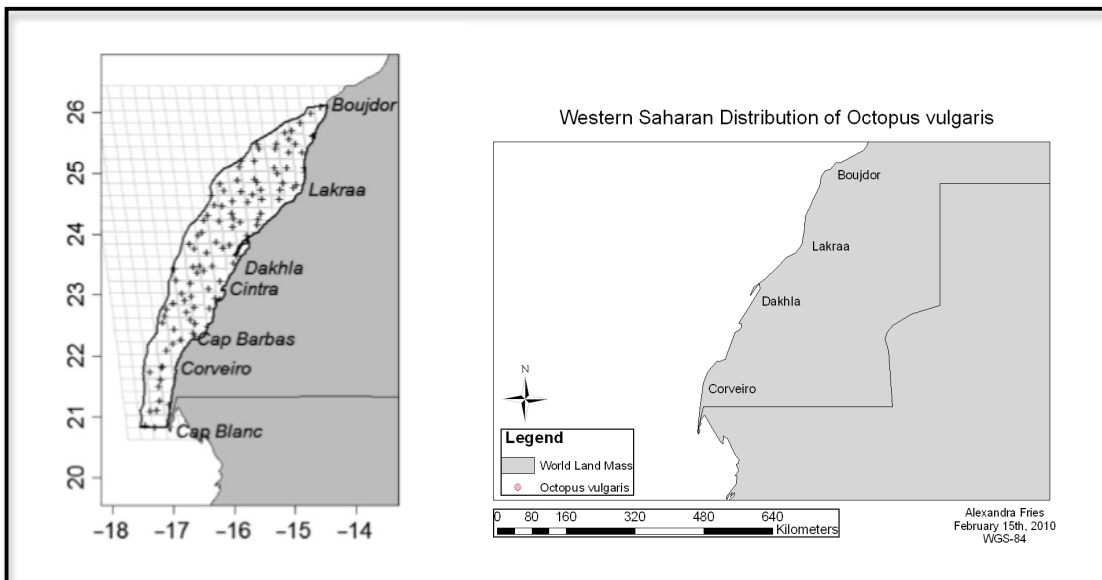
The fishery for *Octopus vulgaris* began as early as the 1950's. The catch amounts around the 1950's and 1960's were only around 10 thousand metric tons. By 1972, the fishery had greatly expanded with catch rates over 100 thousand metric tons (Figure 35). These amounts gradually decreased, but remain significant even at 50 to 70 thousand metric tons taken per year (Roper et al. 1984).

Figure 35: Fishery data for *Octopus vulgaris* from Roper et al. 1984



Since this species has such a wide distribution, it is understandable that not all currently known data would be included in the OBIS database. One area where data is missing is off the coast of Western Sahara (Figure 36).

Figure 36: Comparison of the *Octopus vulgaris* distribution off the Western Saharan coast between OBIS and Faraj and Bez (2007). Sampling points where *Octopus vulgaris* was caught are seen as points.

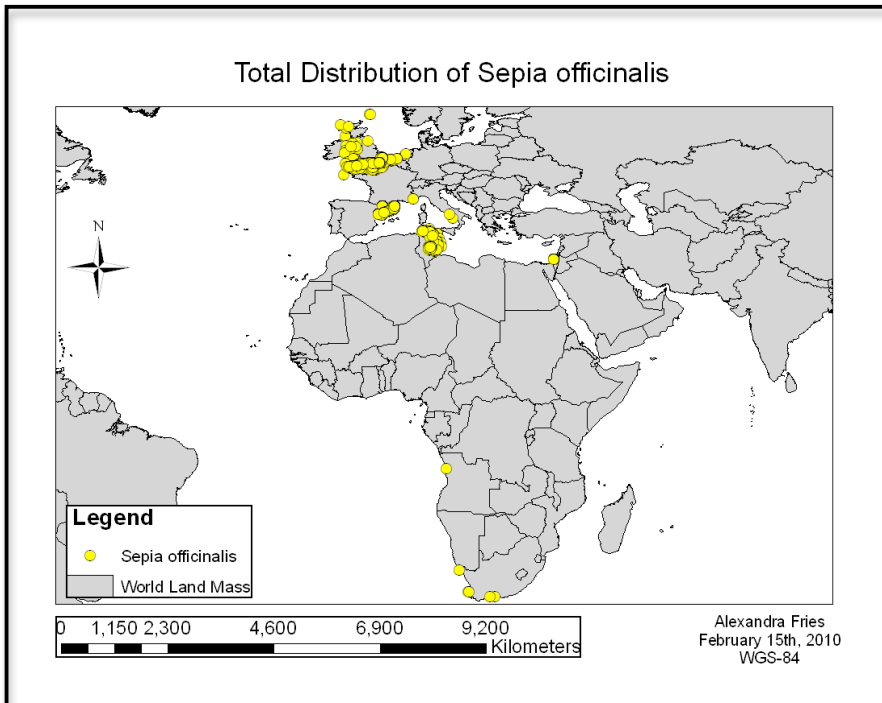


Sepia officinalis

Sepia officinalis, the common cuttlefish, is distributed from the Baltic Sea to the

eastern Atlantic Ocean off South Africa (Figure 37). It is also distributed through the Mediterranean Sea (Guerra, 2006; Perez-Losada et al. 2007).

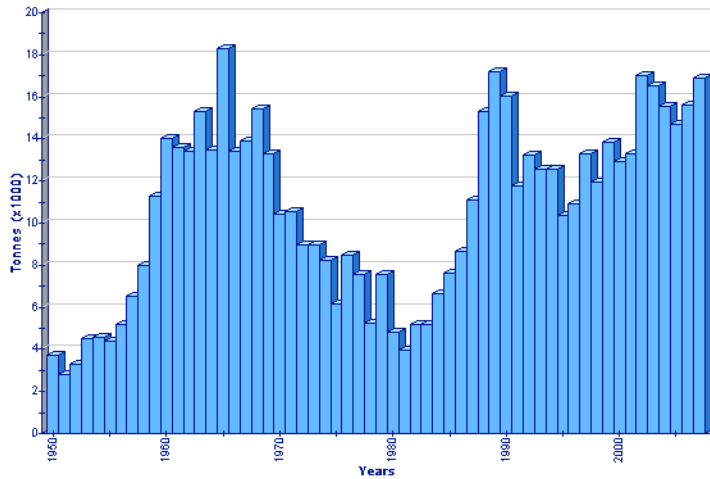
Figure 37: Distribution of *Sepia officinalis*



This species has a short lifespan that lasts from one to two years, with death occurring soon after spawning (Perez-Losada et al. 2007). It has been theorized that *Sepia officinalis* is made up of several different spawning populations that do not share genetic material because of physical barriers such as the separating of the Atlantic and Mediterranean Sea by the Strait of Gibraltar (Perez-Losada et al. 2002), or in the areas surrounding the English Channel and the Celtic Sea (Wang et al. 2003).

Migrations for this species have been seen to occur for all stocks around the world. The fishery for this species is very large, although due to problems in reporting specific species, the amounts may be unnecessarily low when compared to other cephalopod species (Figure 38).

Figure 38: Fishery Information for *Sepia officinalis* from Roper et al. 1984.



The fishery for *Sepia officinalis* was established as early as the 1950's, with catch rates at around 4 thousand metric tons. In 1965, the catch spiked at 18 thousand metric tons and then slowly reduced until it spiked again in the 1990's and by the late 2000's was again at approximately 17 thousand metric tons per year (FAO Species Catalogue for Fishery Purposes, 2005; Roper et al. 1984). Unfortunately, recording of cuttlefish species types within fisheries is very low, so most of the time the catch amounts are only expressed as being within the Sepiidae or Sepiolidae. In 2001, the total catch amounts for Sepiidae and Sepiolidae were 519.3 thousand metric tons (FAO Species Catalogue for Fishery Purposes, 2005). This is a huge amount of cephalopods that are being exploited and not adequately recorded as a take within the fishery.

Overall, the data in OBIS adequately describes the distribution of *Sepia officinalis*. There is some controversy over whether this species resides along the southwest coast of Africa to South Africa, but there is not very much research in this area to be certain if this is a valid extent of the distribution.

Accuracy Assessment

A model of the distributional extent of nine of the commercial species was used to compare the accuracy of the model with actual locations of the species from OBIS. The model was used from AquaMaps, which uses environmental parameters to determine the

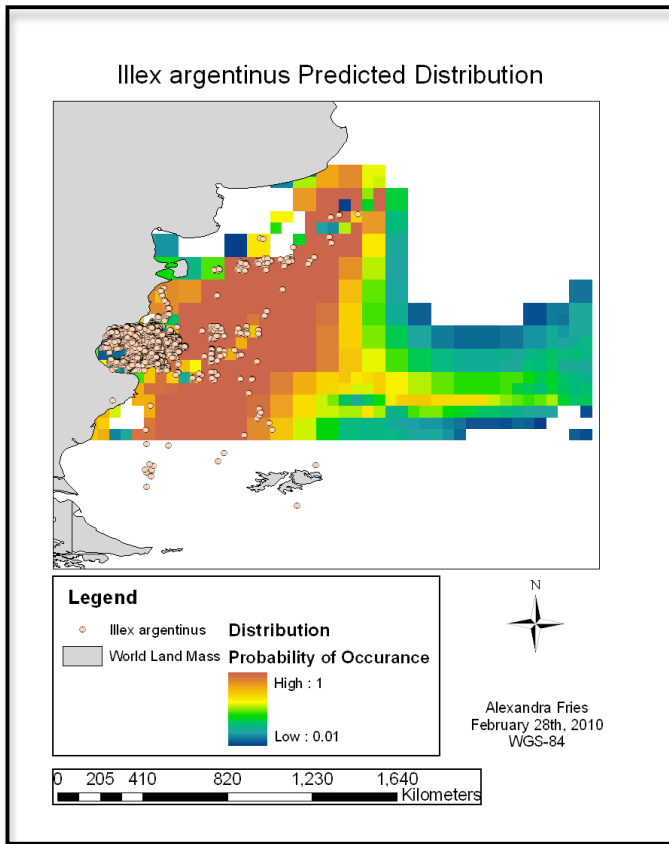
probability of each species range. The imported data from AquaMaps were used in conjunction with OBIS data to see how accurate the probabilities for species ranges are (Table 5).

Table 5: The number of records from OBIS for selected commercial species that are in or out of the distributional range modeled by AquaMaps. The percent included is also the percent accuracy for the AquaMaps model for each species.

| Species | In | Out | Total | Percent Included |
|----------------------------------|--------|--------|--------|------------------|
| <i>Dosidicus gigas</i> | 25 | 2 | 27 | 93% |
| <i>Illex argentinus</i> | 7918 | 876 | 8794 | 90% |
| <i>Illex coindetii</i> | 104 | 9 | 113 | 92% |
| <i>Illex illecebrosus</i> | 24212 | 474 | 24686 | 98% |
| <i>Loligo pealeii</i> | 15601 | 180 | 15781 | 99% |
| <i>Loligo vulgaris reynaudii</i> | 200696 | 118511 | 319207 | 63% |
| <i>Octopus vulgaris</i> | 460 | 287 | 747 | 62% |
| <i>Ommastrephes bartramii</i> | 32 | 57 | 89 | 36% |
| <i>Todarodes sagittatus</i> | 18 | 28 | 46 | 39% |

An example of the map produced by using both AquaMaps distribution and OBIS point data shows a general overlay of the data for *Illex argentinus* (Figure 39).

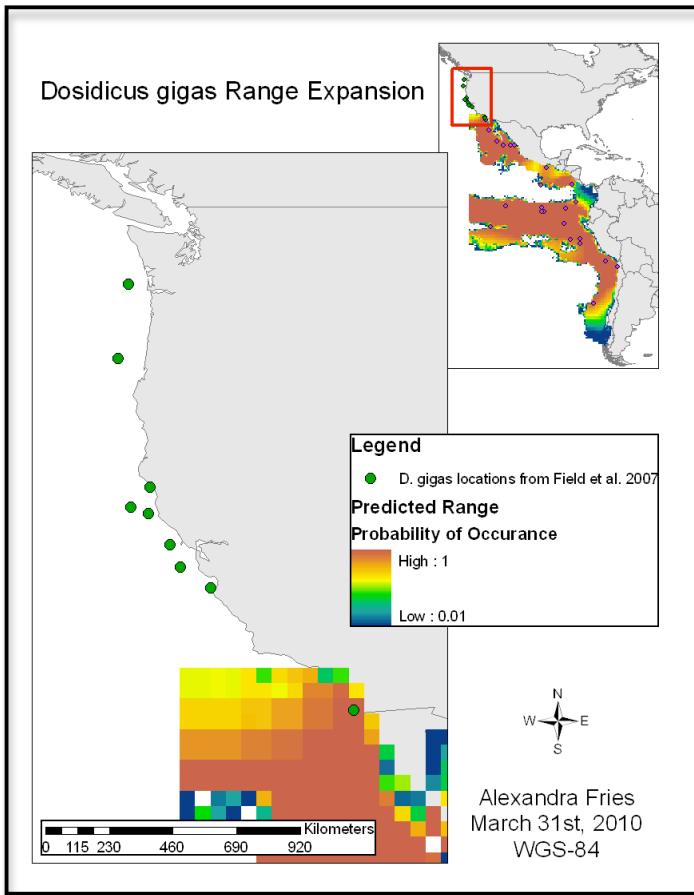
Figure 39: *Illex argentinus* distribution and species occurrence overlay.



The most accurate distributions that included the highest percentages of species locations were for *Loligo pealeii*, *Illex illecebrosus*, *Dosidicus gigas*, *Illex coindetii* and *Illex argentinus*. All of these species have accuracy percentages at or above 90%. The distributions for *Loligo vulgaris reynaudii* and *Octopus vulgaris* were moderately accurate with accuracy percentages in the low 60's. Two species distributions seem to be poorly representative of the actual locations where species are found, these being the ranges for *Ommastrephes bartramii* and *Todarodes sagittatus* with accuracy rates at only 36% and 39% respectively.

In order to create more accurate models, additional sampling points should be included in the original model formula. The following map shows an example of sampling points by Field et al. (2007), seen in green, which are not included within the AquaMaps model for *Dosidicus gigas* (Figure 40).

Figure 40: *Dosidicus gigas* Range Expansion Map with data from Field et al. 2007 and AquaMaps distributional range.



These points have been read into ArcGIS and added on to a map of the suspected distribution for *Dosidicus gigas* created from AquaMaps. All but one point falls outside the distribution that AquaMaps modeled. This shows that the model may need adjustments to accurately express the species distributions. In addition, including these and addition points originally will make a more robust model, which is important for managing species and predicting species ranges.

Discussion

Overall, cephalopod distributions occur worldwide and the commercial species occur in a variety of locations as well, with some spanning a small area while others span the entire oceans. Out of the commercial species examined in this study, several of them appear to have adequate data available to be able to approximate the distribution and manage the fishery at an acceptable level. Each species will be briefly summarized and

recommendations will be made. Some of the important parameters to consider for fisheries management are natural mortality, vulnerability, fishing mortality, catchability and recruitment.

Distributional Data

Although distributions of marine species can never be fully understood, using qualitative data from the literature and OBIS maps, it was determined that the following species examined in this study have adequate data to describe their distributions. These species are *Illex argentinus*, *Loligo pealeii*, and *Loligo vulgaris reynaudii*. *Illex illecebrosus* has a pretty comprehensive distribution, but only in the western Atlantic Ocean.

Species that could have better distributional extents determined are *Todarodes pacificus*, *Dosidicus gigas*, *Nototodarus sloanii*, *Ommastrephes bartramii*, *Todarodes sagittatus*, *Illex coindetii*, *Martialia hyadesi*, *Loligo gahi*, *Octopus vulgaris*, and *Sepia officinalis*. The species in particular that have very little sampling accomplished are *Dosidicus gigas*, *Todarodes sagittatus*, *Martialia hyadesi*, and *Sepia officinalis*.

Fishery Importance

Most of the species examined in this study have some commercial importance. The species that have had the highest catch rates most recently are *Illex argentinus*, *Todarodes pacificus*, and *Dosidicus gigas*. Since these species are so commercially exploited it is important to establish better distributional maps and ranges so that the fisheries can be managed sustainably.

Accuracy assessment

Overall, the information gained from the accuracy assessment shows that the models used by AquaMaps can be used to positively identify locations where species are found. The models used for mapping specific species distributions are relatively accurate as long as the original species locations have been inputted into the formula. For those species that have less research completed on their distributions, the AquaMaps spatial range approximation was not as accurate. An accuracy assessment including an ROC curve to further increase the precision of the data would be a useful addition to this study.

Future Research

This study highlights the need for additional research to be focused on cephalopod fisheries, which are expanding and becoming more widespread. More sampling of important commercial cephalopod species as well as those species with the potential for fisheries exploitation is especially important. Distributional data of these species can give a more accurate view of the organisms' ranges as well as the population size in many cases.

Also, as more data is included in OBIS, better distributional maps and models can be established for fisheries information and species management. Proper sustainability of the fisheries resources should be established for cephalopods to ensure viable and successful populations for these species. These species are an important resource that should not be overwhelmed and threatened by excessive fishing.

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Appendix A

Classification

Class: Cephalopoda Cuvier, 1797

Subclass: Nautiloidea Agassiz, 1847

Fam: Nautilidae Blainville, 182

Subclass: Coleoidea Bather, 1888

Division: Neocoleoidea Haas, 1997

Superorder: Octopodiformes Berthold and Engeser, 1987

Order: Vampyromorpha Robson, 1929

Fam: Vampyroteuthidae Thiele, in Chun, 1915

Order: Octopoda Leach, 1818

Suborder: Cirrata Grimpe, 1916

Fam: Cirroteuthidae Keferstein, 1866

Fam: Stauroteuthidae Grimpe, 1916

- Fam: Opisthoteuthidae Verrill, 1896
- Suborder: Incirrata Grimpe, 1916
 - Fam: Amphitretidae Hoyle, 1886
 - Fam: Bolitaenidae Chun, 1911
 - Fam: Octopodidae Orbigny, 1839 In: Ferussac and Orbigny, 1834-1848
 - Fam: Vitreledonellidae Robson, 1932
- Superfamily: Argonautoidea Naef, 1912
 - Fam: Alloposidae Verrill, 1881
 - Fam: Argonautidae Cantraine, 1841
 - Fam: Ocythoidae Gray, 1849
 - Fam: Tremoctopodidae Tryon, 1879
- Superorder: Decapodiformes Leach, 1817
 - Order: Oegopsida Orbigny, 1845
 - Fam: Architeuthidae Pfeffer, 1900
 - Fam: Brachioteuthidae Pfeffer, 1908
 - Chiroteuthid families
 - Fam: Batoteuthidae Young and Roper, 1968
 - Fam: Chiroteuthidae Gray, 1849
 - Fam: Joubiniteuthidae Naef, 1922
 - Fam: Magnapinnidae Vecchione and Young, 1998
 - Fam: Mastigoteuthidae Verrill, 1881
 - Fam: Promachoteuthidae Naef, 1912
 - Fam: Cranchiidae Prosch, 1847
 - Fam: Cycloteuthidae Naef, 1923
- Enoploteuthidae families
 - Fam: Ancistrocheiridae Pfeffer, 1912
 - Fam: Enoploteuthidae Pfeffer, 1900
 - Fam: Lycoteuthidae Pfeffer, 1908
 - Fam: Pyroteuthidae Pfeffer, 1912
- Fam: Gonatidae Hoyle 1886
- Histioteuthid families
 - Fam: Histioteuthidae Verrill, 1881
 - Fam: Psychroteuthidae Thiele, 1920
- Lepidoteuthid families
 - Fam: Lepidoteuthidae Naef, 1912
 - Fam: Octopoteuthidae Berry, 1912
 - Fam: Pholidoteuthidae Voss, 1956
- Fam: Neoteuthidae Naef, 1921
- Fam: Ommastrephidae Steenstrup, 1857

Subfamily: Illicinae Possett, 1891

Genus: *Illex* Steenstrup 1880

Subfamily: Ommastrphinae Possett, 1891

Genus:

Subfamily: Todarodinae Adam, 1960

Genus:

Fam: Onychoteuthidae Gray, 1847

Fam: Thysanoteuthidae Keferstein, 1866

Order: Myopsida Naef, 1916

Fam: Australiteuthidae Lu, 2005

Fam: Loliginidae Lesueur, 1821

Genus: *Loligo*

Loligo africana Adam, 1950

Loligo bleekeri Keferstein, 1866

Loligo forbesii Steenstrup, 1856

Loligo gahi, D'Orbigny, 1835 in 1834-1847

Loligo media Linnaeus, 1758

Loligo ocula Cohen, 1976

Loligo opalescens Berry, 1911

Loligo pealeii Lesueur, 1821

Loligo pickfordi Adam, 1954

Loligo plei Blainville, 1823

Loligo roperi Cohen, 1976

Loligo sanpaulensis Brakoniecki, 1984

Loligo subulata Lamarck, 1798

Loligo surinamensis Voss, 1974

Loligo vietnamensis Nguyen, 1994

Loligo vulgaris Lamarck, 1798

Genus: *Loliolus*

Loliolus affinis Steenstrup, 1856

Loliolus beka Sasaki, 1929

Loliolus hardwickei Gray, 1849

Loliolus japonica Hoyle, 1885

Loliolus sumatrensis D'Orbigny, 1835 in Ferussac and
D'Orbigny, 1834-1848

Loliolus uyii Wakiya and Ishikawa, 1921

Genus: *Lolliguncula*

Lolliguncula argus Brakoniecki and Roper, 1985

Lolliguncula brevis Blainville, 1823

Lolliguncula diomedea Hoyle, 1904

Lolliguncula mercatoris Adam, 1941

Lolliguncula panamensis Berry, 1911

Order: Sepioidea Naef, 1916

Suborder: Sepiida Keferstein, 1866

Fam: Sepiidae Keferstein, 1866

Suborder: Sepiolida Naef, 1916

Fam: Sepiadariidae Fischer, 1882

Fam: Sepiolidae Leach, 1817

Order: Spirulida Haeckel, 1896

Fam: Spirulidae Owen, 1836

Order uncertain

Superfamily: Bathyteuthoidea nov.

Fam: Bathyteuthidae Pfeffer, 1900

Fam: Chtenopterygidae Grimpe, 1922

Fam: Idiosepiidae Fischer, 1882