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Analysis of the evolution of hake (*Merluccius hubbsi* and *Merluccius australis*) catch and effort by Spanish vessels operating in the Patagonian shelf area since the beginning of this industrial fishery

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ABSTRACT

The hake fishery (*Merluccius hubbsi* and *Merluccius australis*) is one of the most important ones for Spanish vessels operating in the Southwest Atlantic. Both species are widely distributed along the Patagonian shelf, although *M. australis* occupies mainly more southern waters. This paper presents a historical review of fishery data on the Spanish fishing fleet operating in the SW Atlantic collected and collated during the EC Study Project 99/016 "Data collection for stock assessment of two hakes (*Merluccius hubbsi* and *M. australis*) in International and Falkland waters of the SW Atlantic", in order to analyse the evolution of catch and effort in the hake fishery since 1983 to 2000. Data on landings and effort by Spanish vessels from 1983 onwards were utilised to study trends and shifts within the fishery. These data were provided by Asociación Nacional de Armadores de Buques Congeladores de Pesca de Merluza (ANAMER), the most important Spanish ship-owners fishing association operating in distant fishing grounds. Catch and effort data collected by observer's programmes carried out by Instituto Español de Oceanografía (IEO) and the Falkland Islands Government Fisheries Department (FIGFD), as well as by observers provided by the project were used to estimate CPUE by area and season.

The data included landings in kgs by commercial size category of hake (both species together) and effort made by vessels appertaining to ANAMER in number of fishing days and number of vessels by vessel size category. Conversion factors obtained by scientific observers onboard of these vessels were used to obtain the whole catch from landings. Total effort of the Spanish fleet was estimated from ANAMER logbooks, assuming a similar pattern for the whole fleet and taking into account the different ratio of ANAMER fleet compared to the total Spanish fleet. An increase of the catches and effort was observed from 1983 to a maximum in 1990 coinciding with the closure of Namibian fisheries. After that, catches and effort decreased corresponding to the development of the Greenland halibut fishery in the NW Atlantic, until its stabilisation from 1993. CPUE showed different patterns of fishing activity by area and season.

Keywords: hake, catch, effort, Spanish fishing fleet, commercial size category, vessel size category

INTRODUCTION

Bottom trawl fisheries in the Patagonian Shelf targeting for hakes, cephalopods and other finfish by-catch species are among the most important worldwide and have a great socio-economic value to the EU fishing fleet and to the EU seafood industry. Fishery resources in the Patagonian Shelf occur and are exploited inside Argentinean EEZ, around the Falkland/Malvinas islands and in adjacent international waters, representing in many cases a typical example of what is known as straddling stocks.

The fishing grounds in the SW Atlantic support some of the most important fisheries worldwide, with hakes and cephalopods being the main commercial species and accounting a mean of 500,000 and 700,000 tons per year respectively in recent times; important quantities of by-catch species are also caught and used for human consumption. These fisheries are very important to the EU fishing fleet, since more than 160 big EU freezing trawlers have been operating in this region from 1983 onwards (60 of them around the Falkland/Malvinas waters and in the High Seas, and a further 100 vessels owned by EU companies are operating in joint ventures inside the Argentinean EEZ) to provide the EU seafood industry with important amounts of finfish and cephalopods.

It is estimated that only vessels operating around the Falkland/Malvinas waters and in the High Seas sustain about 4,000 direct number of people in employment at sea and more than 20,000 indirect jobs on land in EU countries (remarkably Spain). It is estimated that catches in Falkland Islands and in International Waters (excluding those from vessels in joint ventures in Argentinean EEZ) have a first sale value of around 600 million Euros, (ANAMER *Pers. Comm*.) per year.

Sporadically commercial fishing by Spanish boats in the Patagonian Shelf started in early 1960s and continued irregularly until 1983, from which its presence was regular in the area although alternating their activity with the fishing grounds in the South East Atlantic. The crisis on the Namibian fisheries at the end of the 1980s was the reason for the increase of the operations in the SW Atlantic, reaching the maximum activity in 1990 with more than 80 boats flying Spanish flag. Since then, effort experienced a fluctuating reduction in number of vessels, mainly due to the development of new fisheries by this fleet in the North Atlantic and to a changing registration process to joint ventures based in the Falkland/Malvinas islands, leading to few more than 20 Spanish boats operating nowadays in these fishing grounds.

Recent problems related with overexploitation of hake have resulted in the seasonal closure of this fishery by Argentinean authorities. This closure has not only affected the EU fishing fleet operating in the area but also the EU seafood industry and consumers, since the reduction of the catches has induced an increase in prices.

Spanish Fisheries in the SW Atlantic

These fisheries are carried out by bottom trawlers and comprise target and by-catch species with different proportions of discards. Target species may be discarded due to several reasons such as non-commercial size, bad conditions, etc; by-catch species experienced a reduction in discards since early 90s due to their introduction as marketable species to consumers. In recent years discard percentages have decreased below 15%, except for Patagonotothen spp (100% discarded).

Three main fisheries could be defined in the Patagonian Shelf for the Spanish fleet. The first target fishery is that of hake, comprising *Merluccius hubbsi* (common hake) and *Merluccius australis* (austral hake). Although *M. australis* is more appreciated in the market, it is much more scarce and restricted to southern areas. The second fishery is that directed to Illex squid (*Illex argentinus*) and the third one is the Loligo fishery (*Loligo gahi*).

Apart from these target species, also increasing quantities of by-catch species are retained onboard with commercial purposes, being patagonian toothfish (*Dissostichus eleginoides*), kingclip (*Genypterus blacodes*), hoki (*Macruronus magellanicus*), red cod (*Salilota australis*) and southern blue whiting (*Micromesistius australis*) the most important in the catch.

The fishing pattern is thought to be directed by a number of fishing market criteria to target one or another species. There is also a seasonal effect of abundance and fishing aims to take advantage of the seasonal abundance of each group. Depth is a factor clearly affecting distribution and abundance of all fished species. Table 1 shows the most important species of the fishery. The four first are considered target species whilst the remaining are the main by-catch species.

Table 1. Main species in the fishery.

SCIENTIFIC NAME	SPANISH NAME	ENGLISH NAME
Merluccius hubbsi	Merluza común argentina.	Common hake
Merluccius australis	Merluza austral	Southern (austral) hake
Illex argentinus	Pota	Shortfin squid
Loligo gahi	Calamar	Common squid
Macruronus magellanicus	Merluza de cola	Hoki or whiptailed hake
Micromesistius australis	Polaca	Southern blue whiting
Genypterus blacodes	Rosada	Kingclip
Salilota australis	Bertorella, Brótola	Red cod
Dissostichus eleginoides	Merluza negra, Robalo	Patagonian toothfish
Patagonotothen spp	Marujito	Rock cod

All these species are highly influenced by the oceanographic conditions of the area. Shortfin squid perform yearly large migratory movements from the South of Brazil to Falklands, maybe related to its life cycle. Common squid is more confined to a relative small area within Falklands waters, named Loligo-box, but with great explosions of abundance in Autumn (March to May). Finfish use to take advantage of the current dynamics, moving southward in summer together with the Brazilian current and northward in winter making use of the Falkland/Malvinas current that is actually an offshoot of the Antarctic Circumpolar Current. The boundary between the cold Malvinas Current water and warmer inshore water parallels the coast until about the latitude of Buenos Aires, where the Malvinas encounters the Brazil Current (Deacon, 1937; Gordon., 1981; Legekis & Gordon. 1982). This interaction creates a very complicated fluid dynamics problem: the flow of the Falkland/Malvinas Current is turned into the South Atlantic Ocean, while the warm Brazil Current waters are pushed toward the coast.

Main fishing areas

Common hake (*Merluccius hubbsi*) is widely distributed in the SW Atlantic since the vicinity of Cabo Frío in Brazil (22º S) to Southern Argentina (55º S) at depths between 50 to 500 m. The overall distribution of both *Merluccius hubbsi* and *M. australis* on the southern part of the Patagonian Shelf is quite similar, although *M. australis* tends to occur deeper and further south than *M. hubbsi* (Cousseau and Perrotta, 2000). Both species undertake seasonal migrations from their inshore spawning grounds to offshore feeding grounds (Bezzi et al., 1995) but the patterns of their migrations have only been studied in detail for the northern populations of *M. hubbsi* (Aubone et al., 2000). Shelf and continental slope waters around the Falkland Islands are used as adult feeding grounds by both *M. hubbsi* and *M. australis* - juvenile fish have only been encountered there on a few occasions (Tingley et al., 1995).

Due to its wider distribution, two main fishing areas can be defined for common hake, one of them around the Falkland/Malvinas islands in which are known as Falkland Islands Interim and Outer

Conservation Zones (FICZ and FOCZ respectively) and the second one in the High Seas, outside the Argentinean EEZ. Austral hake is fished mainly in the deeper shelf area between the 200m and 500m contours in the south-west of the FICZ.

The activity of the Spanish vessels in the High Seas area is reduced to those portions of the continental shelf and slope sticking out of the Argentinean EEZ, i.e. a small patch around 42º S and a bigger area comprised between parallels 43º 30' and 48º S, namely "Zone 42 S and 46 S" respectively (Figure 1).

With the purpose of a better study of these fisheries more in agreement with the distribution of the different species, the fishing grounds around the isles have been divided in three sub areas since the start of the monitoring of Spanish fisheries in the SW Atlantic in 1988:

- **Malvinas North (MN)**
- **Malvinas West (MW)**
- **Malvinas South (MS)**

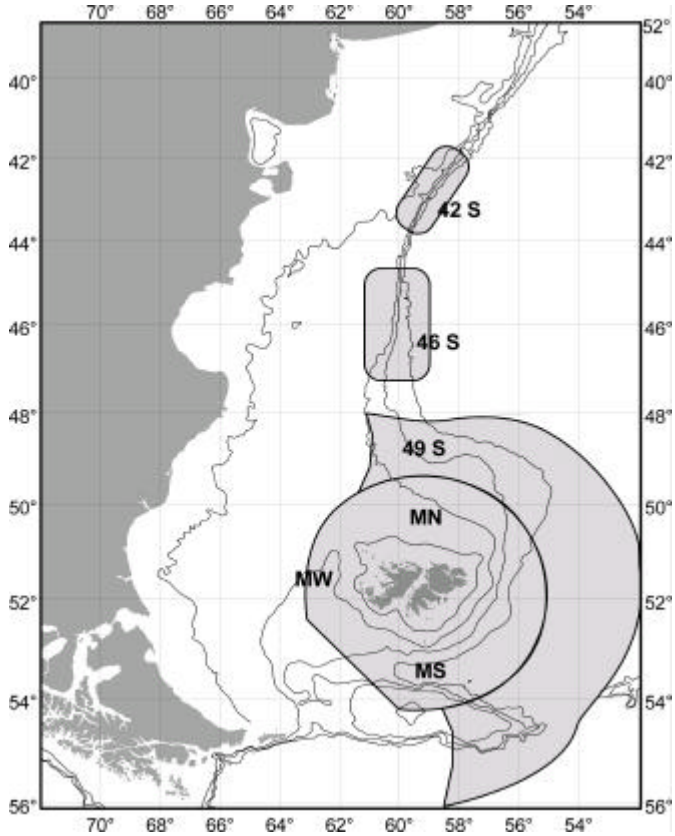


Figure 1. - Main fishing areas in the Patagonian Self for the Spanish fishing fleet

METHODS AND RESULTS

The EC Study Project 99/016 "Data collection for stock assessment of two hakes (*Merluccius hubbsi* and *M. australis*) in international and Falkland waters of the SW Atlantic" ran from January 2000 to December 2001. The main objective of the project was the collection and collation of already existing and newly acquired fishery and biological recorded by scientific observers needed for preliminary assessment of two hake species occurring in the study area. In addition to this basic remit, additional objectives included the creation of a common database, analysis of commercial activity, study of spawning seasons and areas, discard pattern and length-frequency composition of target and non-

target species, estimation of annual by-catch rates, analysis of trophic relationships, marine mammals by-catch and sightings, morphometric analysis for stock differentiation, and developing GIS applications for analysis of the data collected.

The project provided an opportunity to collect and integrate for the first time at European level the necessary fishery and biological data for the development of partial stock assessment for the future rational management of the fisheries in the area. Such management is needed for the sustainability of the commercial fisheries, the conservation of the onshore and offshore jobs and the supply of fish to the most important markets worldwide.

As stated above, the project used already existing information collected by observer programmes onboard commercial vessels, ran by FIGFD and IEO since 1987 and 1988 respectively. One important fact when dealing with this type of data (i.e. data collected onboard of commercial boats) is the lack of a complete spatial coverage. The own exploitation pattern, which looks for the highest fishing yields, did not allow us to sample all areas and months. As a result we obtain a patchy sample, possibly biased by the commercial activity. Observers recorded in a haul by haul basis data on fishing activity such as catch and discards of all caught species, effort, position, depth, etc.

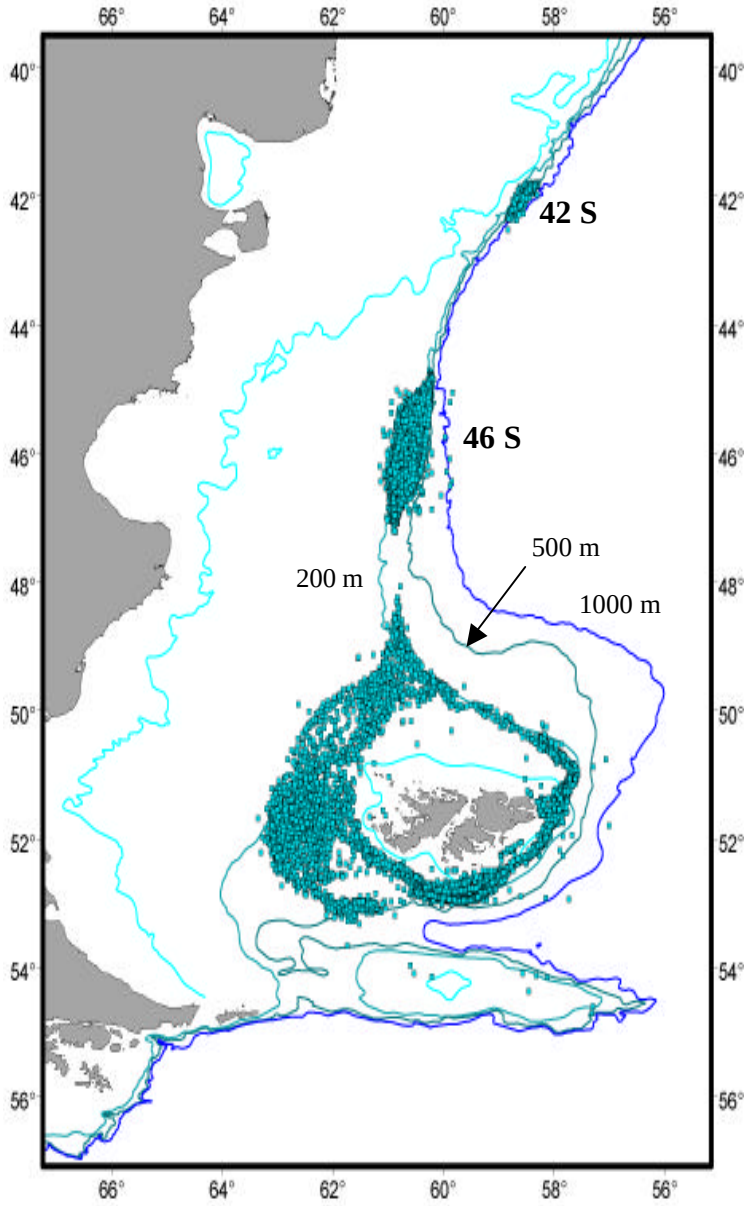


Figure 2. – Location of the observed fishing operations

The IEO observer programme was established in 1988 to collect fishery and biological data aboard commercial vessels of the Spanish fishing fleet operating in the South West Atlantic, with the aim of creating a historical data series to furnish future assessment and management in specific areas of the Patagonian Shelf. IEO contributed to this project with historical and new fishery, biological and environmental data collected by observers during the period 1989-2001, by a total of 73 observers. ANAMER has contributed to increase the sample coverage throughout the duration of the project (2000-2001) with a total of 6 observers and 600 observer days (funded by the project), representing an increase of 30% in the annual sampling coverage over the mean of observed hauls in the last 5 years. The overall location of the observed hauls used (more than 15,000) is shown in Figure 2. All the information registered by the observers was integrated into the database generated for this project. A summary of this information is presented in Tables 2 and 3.

Table 2. - Summary of the information collected by Spanish observers from 1989 to 2001

Year	Observers	Hauls observed	Length samples	Biological samples
89	15*	3127	1229	1296
90	8*	1494	828	786
91	7*	1332	797	841
92	7*	1453	710	557
93	4*	1278	683	515
94	4*	1126	606	383
95	4*	1148	401	291
96	4*	1330	633	410
97	4*	1129	584	380
98	4*	1126	606	362
99	6*	1238	692	420
00	3* + 2**	1553	813	510
01	3* + 4**	1837	1082	895
Total	**79**	**19171**	**9664**	**7646**
***IEO observers, ** Project observers (ANAMER)**				

Table 3. - Data available in the FIGFD database

Description	Approximate
Number of observed hauls on 'hake' licensed vessels (1989 to 2000).	1,200
Number of observed hauls consisting of >50% hake (*M. hubssi* and *M.*	300
Number of sexed length samples (*M. hubbsi*; 1989-2000).	14,500
Average number of sexed length samples per year (*M. hubbsi*; 1989-2000).	1,200
Number of length-weight samples (*M. hubbsi*;1990-2000).	5,500
Average number of length-weight samples per year (*M. hubbsi*; 1990-2000).	550
Number of age-length samples (*M. hubbsi*; 1990-2000).	3,800
Average number of age-length samples per year (*M. hubbsi*; 1990-2000).	350
Number of stomach samples collected (*M. hubbsi*; 2000).	250
Number of morphometric/meristic samples collected (*M. hubbsi*; 2000).	50

Besides the information on catch and effort collected by scientific observers, another commercial data used for this study included landings of hake (both species together) and effort by ANAMER vessels in kgs by commercial size category (Table 4), number of fishing days and number of vessels by size category (tonnage) correspondingly.

Table 4. - Commercial size category and price of hakes

Merluccius australis			*Merluccius hubbsi*		
Category	**Weight (grams)**	**Price (Spanish, pts)**	**Category**	**Weight (grams)**	**Price (Spanish, pts)**
			0	<250	140
			1X	251-400	160
			1	401-600	200
2	601-800	430	2	601-800	230
3	801-1500	550	3	801-1500	280
4	1501-2400	600	4	1501-2400	300
5	>2400	650	5	>2400	342

Conversion factors obtained by scientific observers onboard of these vessels were used to estimate the whole catch from landings. Total effort of the Spanish fleet was estimated from ANAMER logbooks, assuming a similar pattern for the whole fleet and taking into account the different ratio of ANAMER fleet compared to the total Spanish fleet along the period 1983-2000.

Data on catch and effort in combination with other information such as position, depth, time of the year, SST, etc, recorded by observers, was used to analyse and define fishing patterns by area and season.

Catches

Figure 3 shows the evolution of estimated hake catches by Spanish vessels in the Patagonian Shelf since the start of the fishery in 1983, with around 7.000 tons in that year (total weight). During following years, catches evolved in a similar way than number of vessels (Figure 3), reaching its maximum value in 1990 with 101.700 tons, what apparently indicates that this was the target species in the first years.

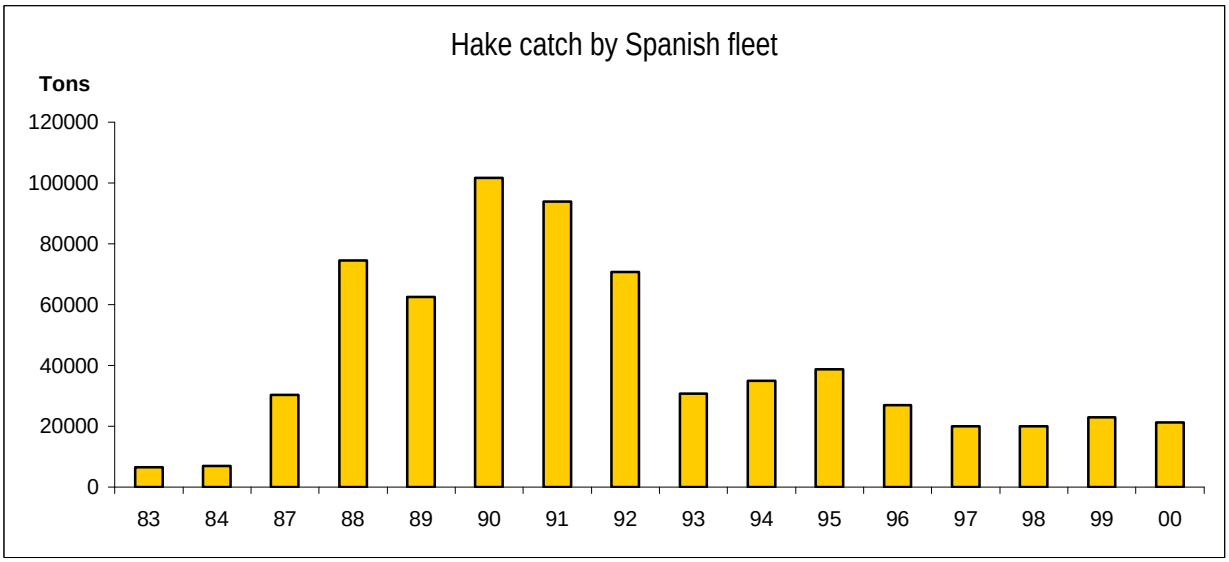


Figure 3. - Estimation of total Hake catch (Tons) by the whole Spanish fishing fleet (based in ANAMER data)

The maximum value in hake catches could be also caused by the dropping of the squid market in these dates, what forced the fleet to target for hake. In a similar way to effort evolution, a severe

decline of catches can be observed from 1990, falling to slightly up to 30,000 tons in 1993. From this moment and with the exception of the small recovery in 1994-95 biennium where 35.000 and 38.700 T of hake were caught respectively, hake catches by the Spanish fishing fleet are around 20.000 T/ year. Low catches of hake in 1983 and 1984 could be due to misreporting and the decrease in 1989 could be related to the disappearance of 8 class vessels (Figures 7 and 8).

Effort

As it can be seen in Figures 4 and 5, a constantly increased effort process, in the total number of vessels and total fishing days was produced from the start of the fishery in 1983 until 1990, when the decline of the effort begun. After this year, the process presents a slight effort reactivation from 1994 with the squid market recovery, reaching a maximum in 1995 caused by the fishing crisis with Canada (Greenland halibut war) that forced several vessels to head for SW Atlantic in April 95.

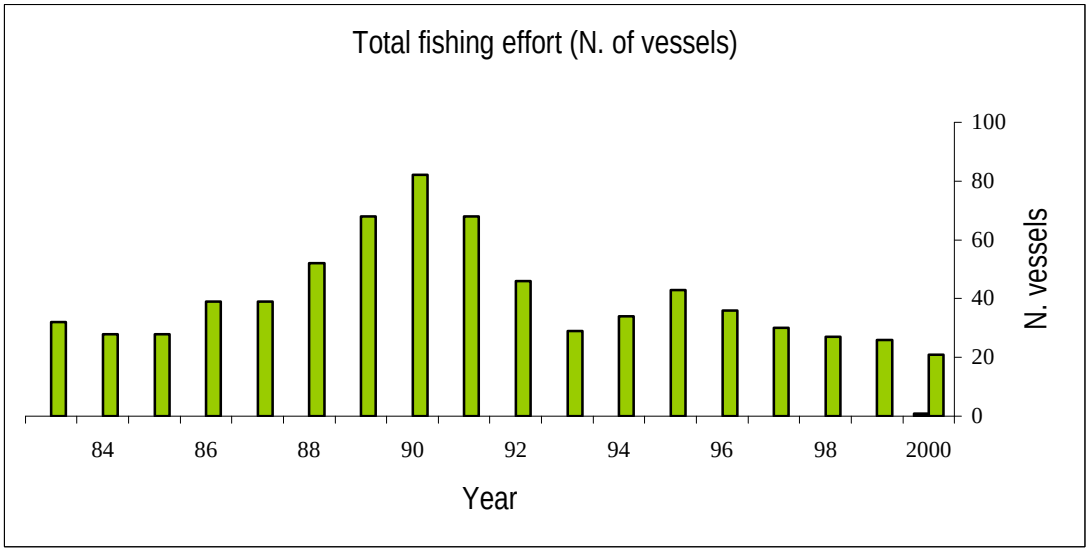


Figure 4. Fishing effort in number of vessels (all categories together)

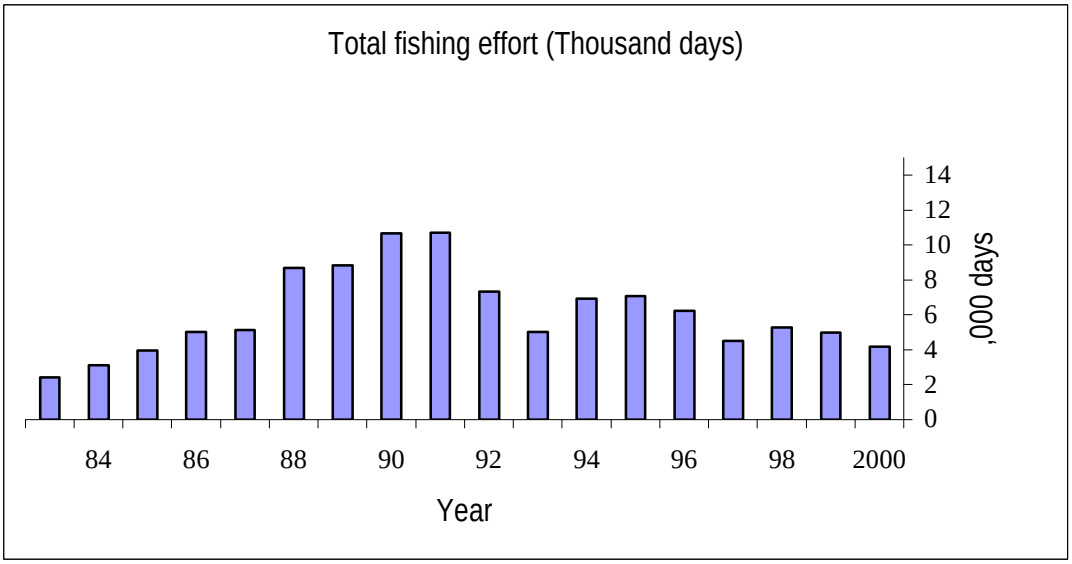


Figure 5. Fishing effort in thousand of days (all categories together)

The reduction process in effort by Spanish boats operating in the SW Atlantic fishing grounds observed from 1990 to 2000 can be due to three main causes that seem to be the reason for this decrease:

- the drop of the squid market
- the development of a new fishery for Spanish vessels targeting for Greenland halibut in the North West Atlantic
- the compliance with the Common Fisheries Policy by Spain, by reducing its fleet during 1989-1999 in accordance with the rules of the Financial Instrument for Fisheries Guidance (FIFG) of EU DG Fisheries, under Multi Annual Guidance Programmes (MAGPs) as shown in Figure 6.

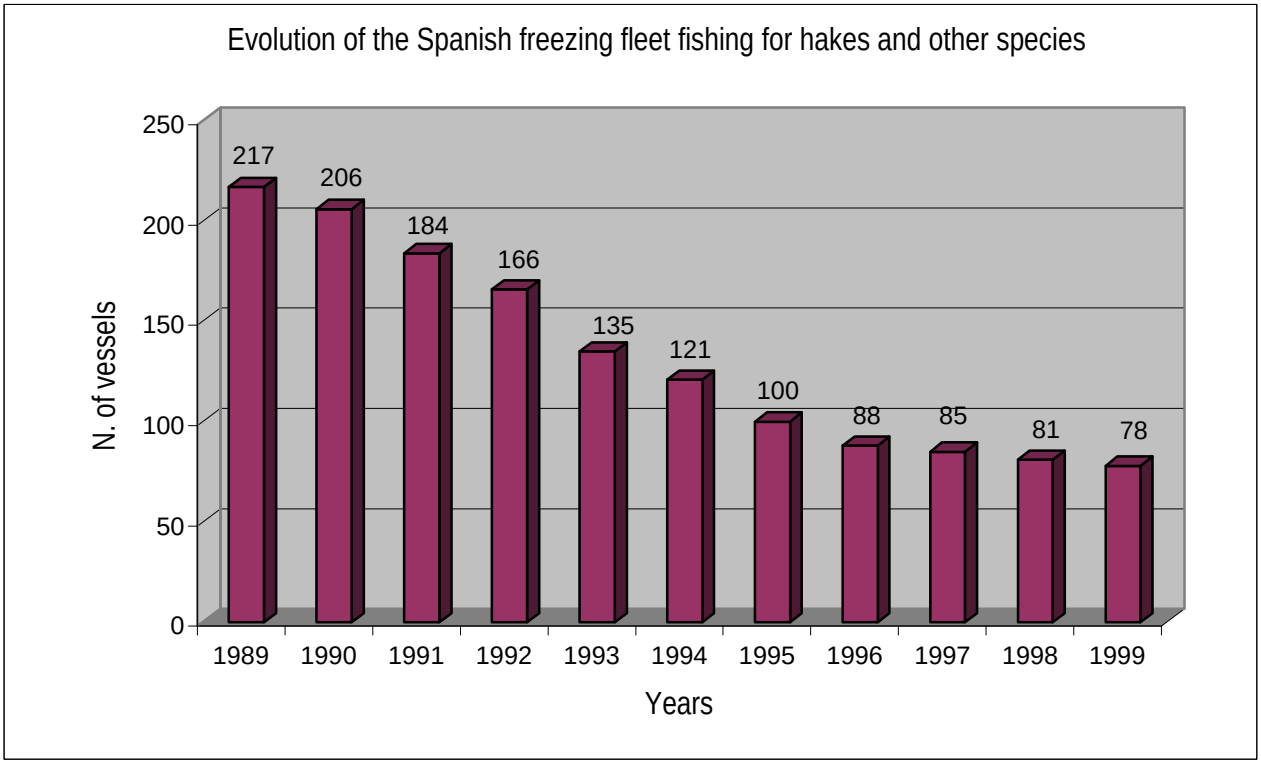


Figure 6. Evolution of the Spanish freezing fleets fishing for hakes and other species, in number of vessels during the period 1989-1999 (Source ANAMER)

The gradual decrease in the number of vessels from 1990 to nowadays is, among other factors, a reflect of the consolidation of the Falkland Islands Government Fishery Policy related to assignation of fishing licenses to vessels in a joint-venture regime. This process is clearly shown in Figure 7: category 8 disappeared in 1988 and all other categories experienced a decline because vessels moved to the mentioned joint-ventures.

On the other hand, the strong drop in category 7 since 1995 is also explained because most of them joined the Greenland halibut fishery in NW Atlantic. A similar process can be observed in the number of fishing days (Figure 8).

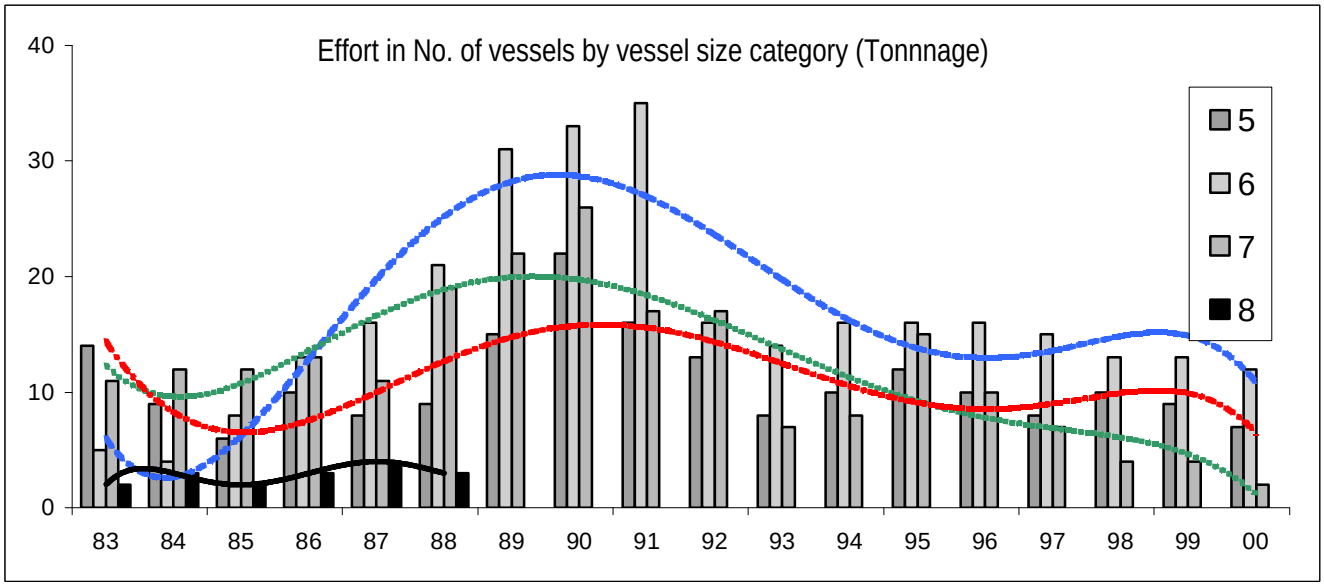


Figure 7. Trends in effort in number of vessels by vessel size category. Vessel categories: 5 < 500 TRB, 6 > 500 < 1000 TRB, 7 > 1000 < 2000 TRB, 8 > 2000 TRB

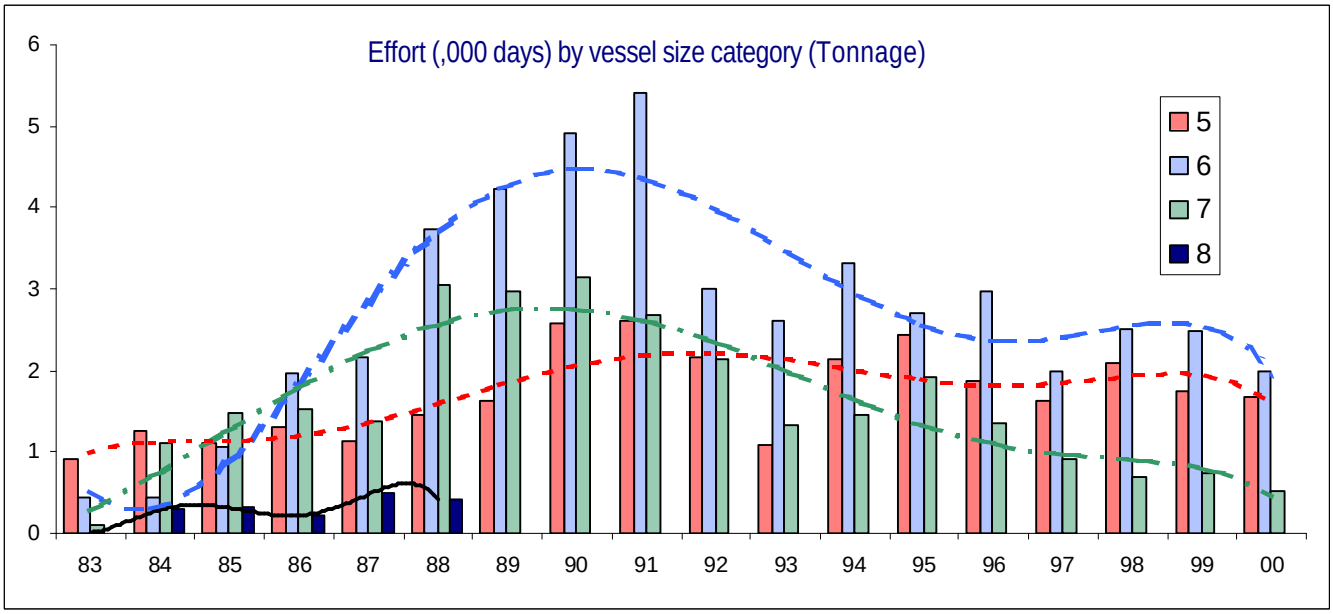


Figure 8. Trends in effort in number of fishing days by vessel size category. Vessel categories: 5 < 500 TRB, 6 > 500 < 1000 TRB, 7 > 1000 < 2000 TRB, 8 > 2000 TRB

CPUE

As described above, ANAMER provided historical data on catches and effort by its fleet in the Southwest Atlantic from 1983 to 2000 that allowed the estimation of the total catch of hake by the whole Spanish fleet in those fishing grounds, as well as the estimation of the total effort by the Spanish fleet in the mentioned area. All these data were used to have CPUE estimations of *Merluccius hubbsi* and *M. australis*, based in commercial activity. Observed CPUE of both species is shown in Figures 9 and 10.

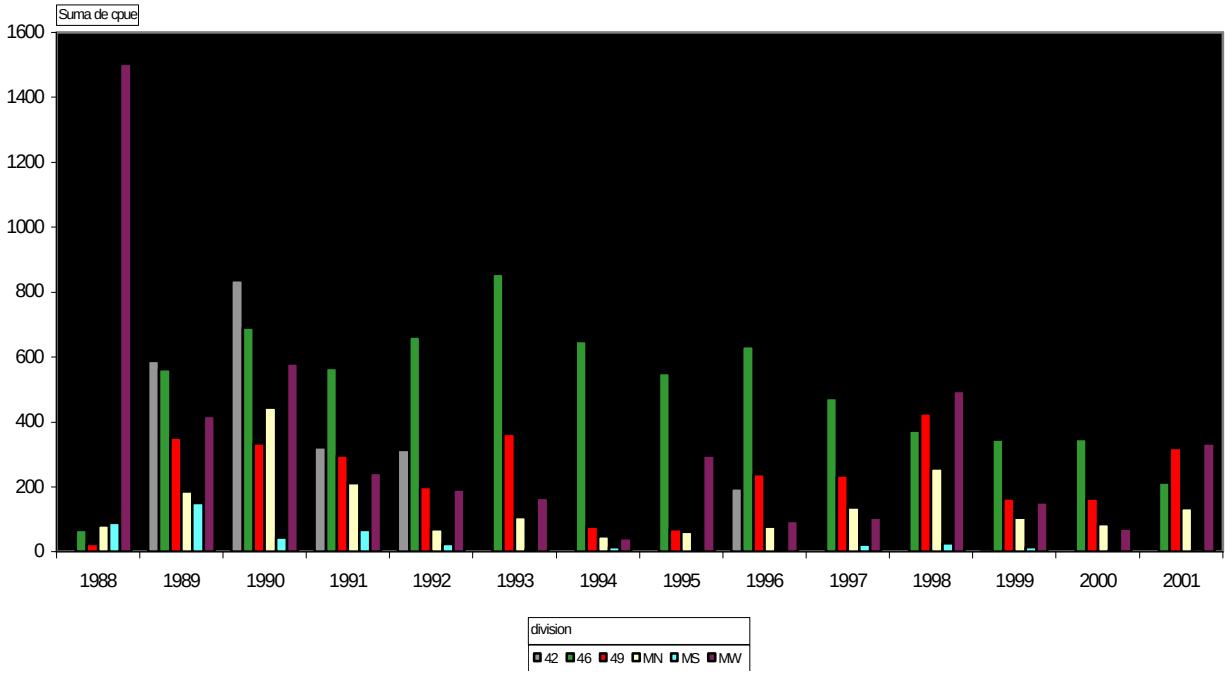


Figure 9. Observed CPUE (kgs/hour) of *Merluccius hubbsi*

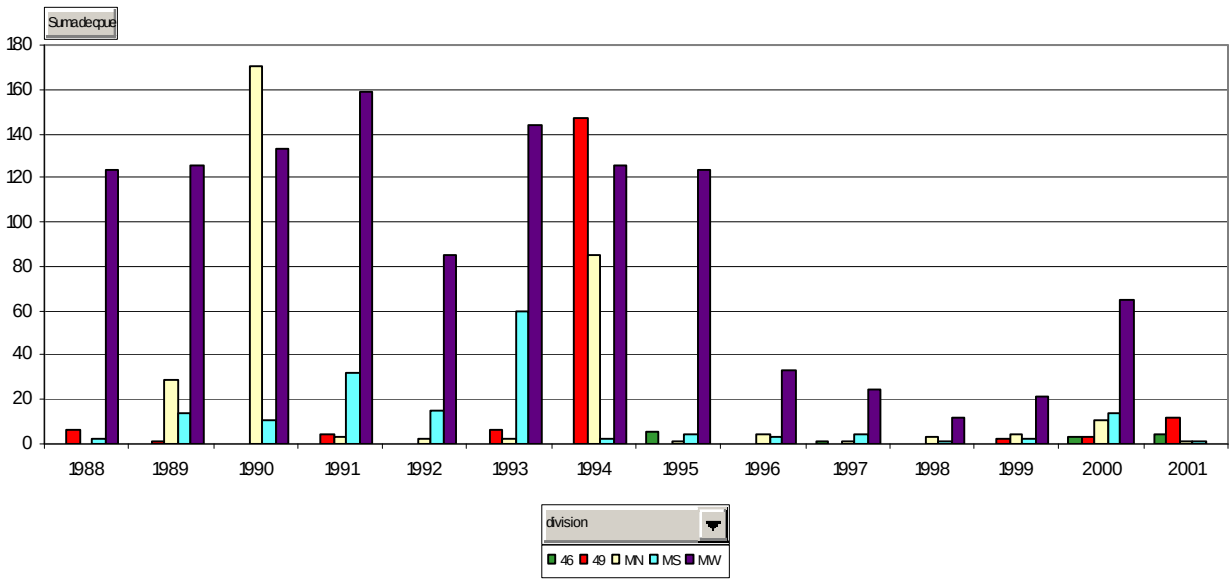


Figure 10. Observed CPUE (kgs/hour) of *Merluccius australis*

Historical and new data about catch and effort of target species registered by IEO, FIGFD and ANAMER observers on a haul by haul basis were collated and used in analyses to obtain CPUE by species, area, month and depth strata, to have an index of the abundance of these species in the study period. Maps on a long-term average were made to show shifts in CPUE (Figure 11).

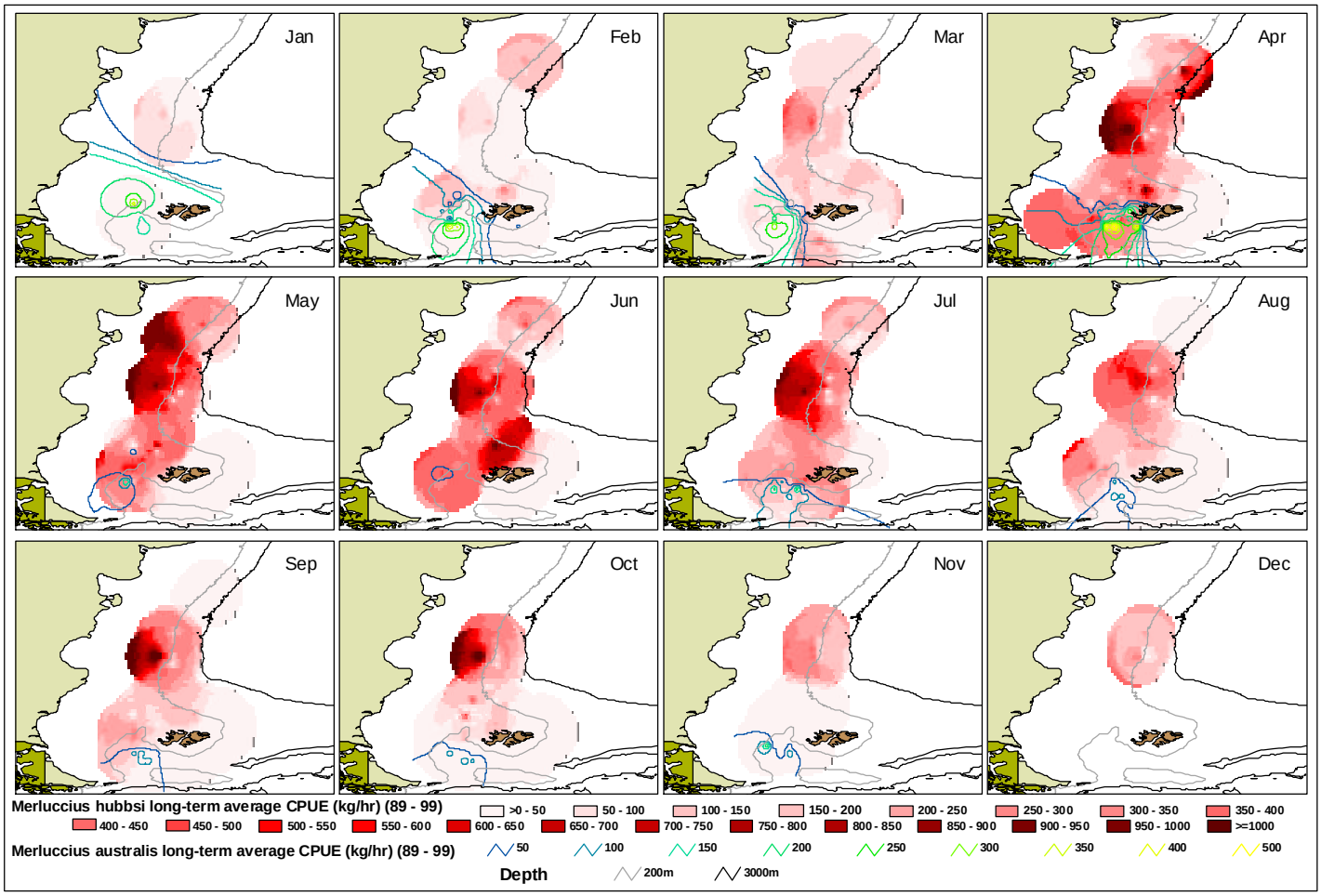


Figure 11. – Long-term average CPUE of target species

Comparisons between CPUE estimations from on-board observers and from commercial data were made. A database and a GIS (Geographical Information System) were developed for environmental and fishery data assembly, integration and management. The GIS was used to describe and model effects of sea temperature and currents on hake distribution, condition indices and growth rates, by using the following data:

- Fishery data

Fishery data used in the project were from 1989 – 1999. The data were recorded haul by haul, and include catches (kg, by species), starting and end time, starting and ending position, gear, and the environmental data mentioned above.

- Fishing locations and observed effort

The locations of hauls from 1989 to 2001 are displayed in Figure 2, and show that fishing activities are located in 3 areas. The North area is from 44?S northwards (Area 42 S). The Middle area is

between 44?S and 47? 30'S (Area 46 S). The South area is from 47? 30'S southwards and the Falklands Islands area (FICZ/FOCZ). Most hauls are located along the shelf edge, between 200 m and 1000 m depth. However, in the south area, the shelf area in the west of Falkland Islands is also important. Trends in fishing observed effort for the whole area are shown in figures 12 and 13 for IEO and FIGFD data separately.

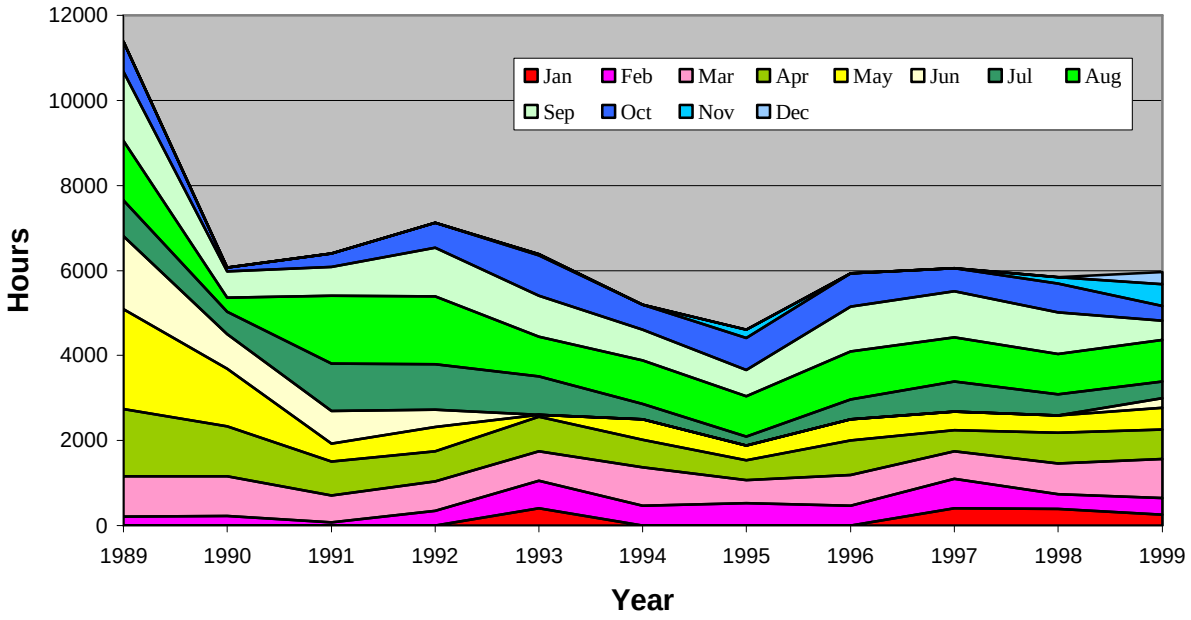


Figure 12. Total observed fishing effort in the whole area (IEO data)

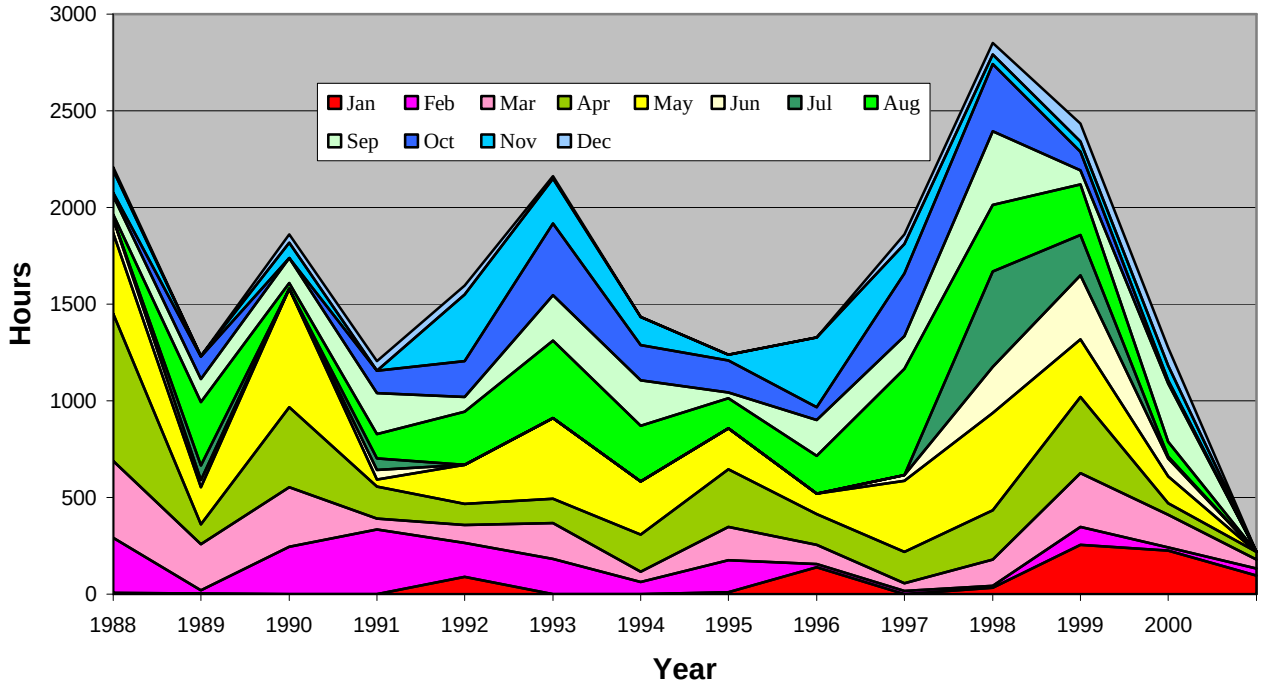


Figure 13. Total observed fishing effort in the whole area (FIGFD data)

- Fishery abundance

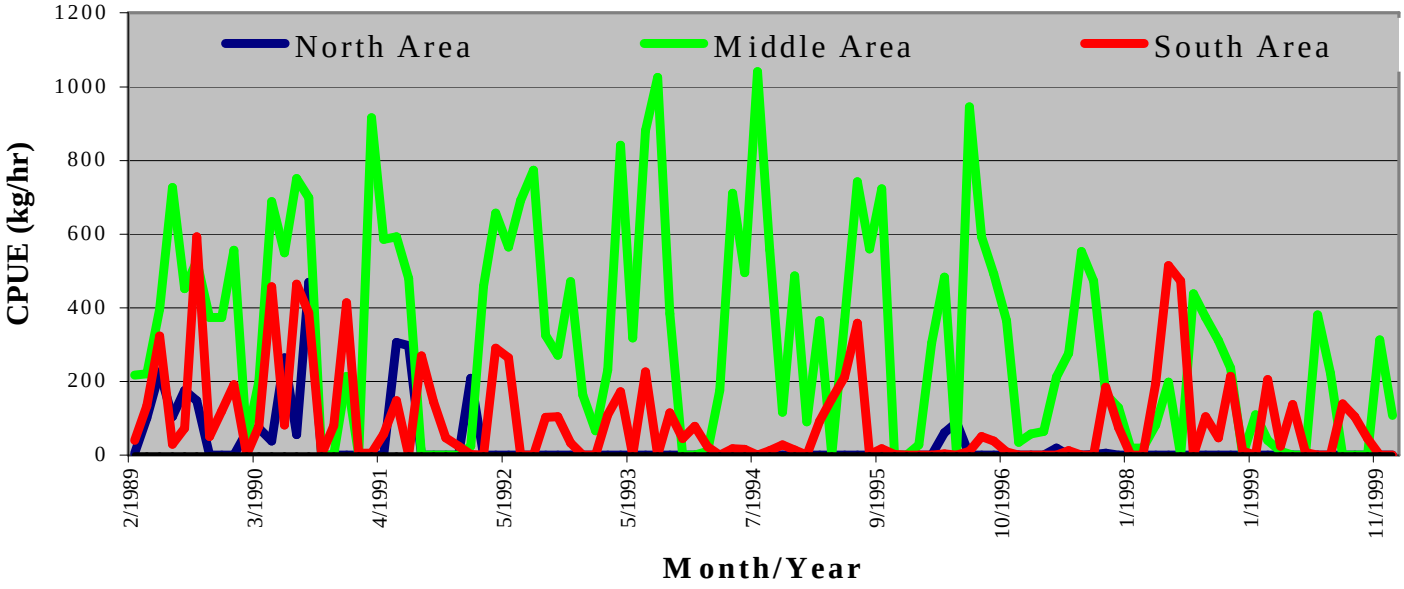
Long-term monthly average catches during observed hauls from 1989 onwards

Figure 10 shows the long-term monthly average catches of *M. hubbsi* and *M. australis*. These have markedly decreased since 1994. These were higher from 1991 to 1995, but since then the species has nearly disappeared.

- CPUE

Monthly CPUE (catches per unit effort, kg/hr) were calculated at a spatial resolution of 0.5? degree longitude and 0.5? latitude square. Although *M. hubbsi* occurs in all area, but the highest CPUE is in the middle area. In 1989 and 1990, both south and middle areas have high abundance. From 1990 to 1997, CPUE in the south area decreased and the abundance in middle area increased. Since 1997, CPUE in the middle area has dropped dramatically, and it seems that CPUE in the south area has begun to recover (Figure 14).

Figure 14. Monthly average CPUE (*Merluccius hubbsi*)



Regarding *M. australis* in the south area, CPUE increased from 1991, but dropped dramatically from 1996 (Figure 15).

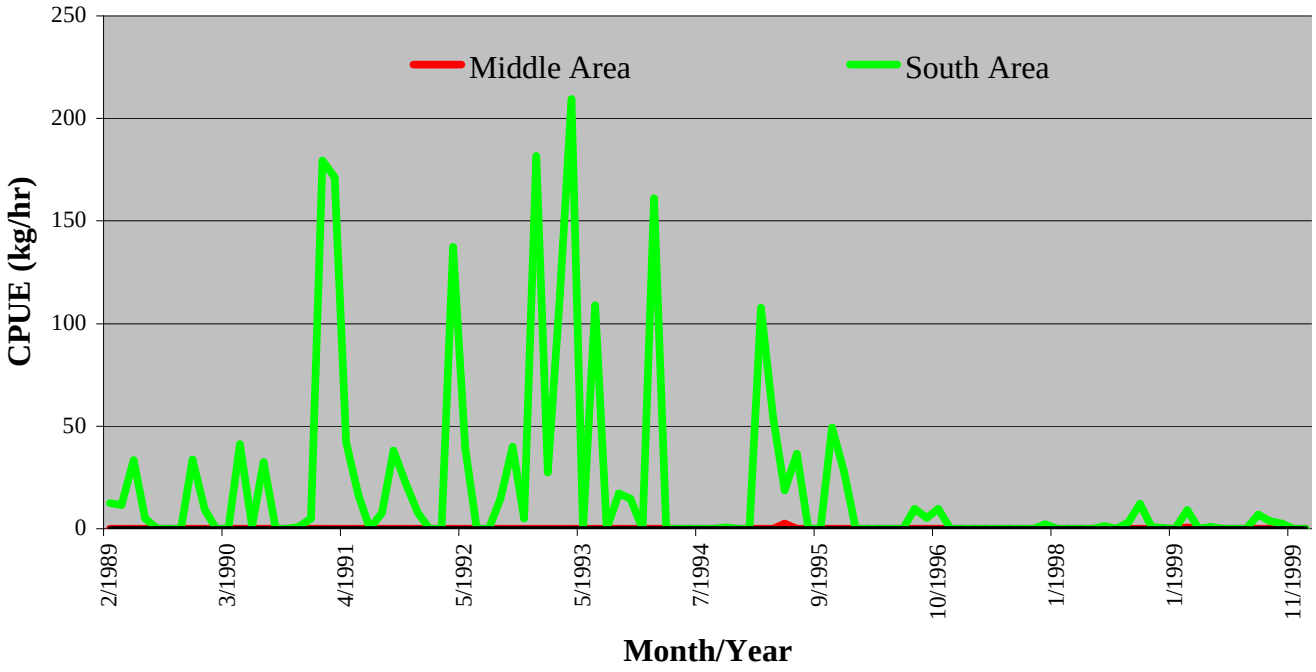


Figure 15. Monthly average CPUE (*Merluccius australis*)

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