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DATA COLLECTION FOR STOCK ASSESSMENT OF TWO HAKES (*Merluccius hubbsi* AND *M. australis*) IN INTERNATIONAL AND FALKLAND WATERS OF THE SW ATLANTIC

Study Project 99/016

FINAL REPORT, 14/05/02

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ABSTRACT

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 data 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, 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.

Historical fishery and biological data series available from IEO and FIGFD (since 1988 and 1987 respectively) were provided to the project. New fishery and biological data were collected by scientific observers provided by IEO, ANAMER and FIGFD, and placed on board Spanish fishing vessels operating in the study area during the project period. Data on fishing activity included effort, catches and discards of target and non-target species on a haul-by-haul basis. Biological information (size, sex, maturity stage, etc) of target and non-target species was recorded on a daily basis. Data on landings and effort were provided by ANAMER to its subcontractor (MG OTERO) for processing and estimation of total catch and effort of the whole Spanish fishing fleet in the area; MG OTERO was also responsible for organisation of observers in collaboration with ANAMER staff in Vigo and Port Stanley. Ancillary data on location, time of fishing, depth, SST, SBT, sea roughness, wind, etc, was recorded on a haul-by-haul basis. This type of information was essential for development of GIS at AU to relate the species distribution to physical and environmental factors. Other information collected was about by-catches and sightings of small cetaceans and seabirds, and biological samples such as otoliths, stomachs and whole specimens of hakes for subsequent studies on growth (IEO, FIGFD), diet and morphometrics (AU).

All the historical and new data collected during the project were collated and integrated into a common database designed by all participants and built at IEO. The information was used for preliminary assessment of two hake populations co-ordinated by RRAG during a workshop held in London in July 2001. All these data will be analysed and written up for future publications. Discard rates of target species were generally low in all areas and seasons with the highest discard rate for Notothen sp. (around 100% of the catch). *Illex* squid was found to be the major by-catch for hake fishery in the 46 S area.

IEO observers reported data on incidental catches of marine mammals and sea birds since 1993 and the analysis of this information was made by AU. The observed mortality in the fishing gears comprised small numbers of black-browed albatross, gentoo penguin and the hourglass dolphin. The species most frequently sighted was the Peale's dolphin, although this species did not appear in by-catches, followed by the hourglass dolphin.

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.

NON-SPECIALIST SUMMARY

BACKGROUND

The fishing grounds of the Patagonian Shelf support some of the most important fisheries in the world, with hake (*Merluccius hubbsi* and *Merluccius australis*) and cephalopods (*Illex argentinus* and *Loligo gahi*) being the main commercial species for fleets from coastal states, EU and Far East countries. The annual mean catch of the different fleets is around 600,000 tons of hake. These fleets also catch important quantities of squid and accompanying species such as Patagonian toothfish (*Dissostichus eleginoides*), Kingclip (*Genypterus blacodes*), Hoki (*Macruronus magellanicus*), Red cod (*Salilota australis*) and Southern blue whiting (*Micromesistius australis*).

These fishing grounds are currently one of the most important to the Spanish bottom trawler freezing fleet, mainly based in Vigo (NW Spain). This fleet is composed of about 40 vessels, besides another 20 and 100 respectively that operate in joint ventures with Falkland and Argentinean flags.

Short description of the fisheries.

Target fisheries:

Three main fisheries could be defined in the Patagonian Shelf for the Spanish fleet. The first target fishery and also the most important is that of hake, comprising *Merluccius hubbsi* and *Merluccius australis*. 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*).

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.

By-catch fisheries:

The most important by-catch species are Patagonian toothfish (*Dissostichus eleginoides*), Kingclip (*Genypterus blacodes*), Hoki (*Macruronus magellanicus*), Red cod (*Salilota australis*) and Southern blue whiting (*Micromesistius australis*). All these fisheries comprise both retained catch and discard for all species. Target species may be also discarded due to several reasons. In recent years discard percentages have decreased below 15%, except for *Patagonotothen* spp (100% discarded). This should be analysed in further works in order to understand possible changes in fishing patterns as well as to evaluate possible emerging target species and their fishery potential.

PROJECT OBJECTIVES

The main objective of the current proposal was the collection of fishery and biological information needed for hake assessment in international and Falkland waters, through a program of scientific observers on board Spanish commercial trawlers fishing in the Patagonian shelf. The presence of biological observers on board is the only way to obtain reliable information on catch, effort and biological characteristics of the catch in a fishery developed by big trawlers with fish processing and freezing capabilities. The project also aimed to obtain accurate information on the level of by-catch and discarding of non-target species, marine mammals and other non-commercial species, together with biological information of all the species present in the fishery, both in international waters and the FICZ and the FOCZ.

The work of this project fell under six main tasks:

1. On-board collection of catch, discards and effort data of the two hake target species
2. On-board data collection for selected non-target species especially for Patagonian toothfish (*Dissostichus eleginoides*)).
3. On-board biological sampling for the two hake and non-target species (size, sex, maturity stage, etc).
4. Collection of commercial catch and effort data
5. Database assembly and maintenance
6. Preliminary stock assessment

MATERIALS AND METHODS

The only way to obtain reliable information on catch, effort and biological characteristics of the catch in a fishery prosecuted by big trawlers with fish processing and freezing capabilities in such a distant area is by scientific observers placed on board the commercial vessels. The observers attended training courses on species identification, data collection and sampling methods at IEO, after which they were deployed on board vessels of ANAMER. MG OTERO organised their boarding in Montevideo, Port Stanley and Punta Arenas as well as their trans-shipment to other ships and their return to Vigo, in strong co-ordination with ANAMER. While on-board ships, the observers kept periodically in contact with IEO reporting their activities, which were surveyed and controlled in collaboration with MG OTERO.

Observers recorded catch of all the species caught for each haul of the trip using laptop computers. Catch and discards were recorded separately for each of the two hake species. Additionally, effort, geographical position of the vessel, depth, gear characteristics, environmental data and all the other relevant information on the haul was collected and recorded using laptops and specific software developed for this purpose. A total of 600 observer-days paid by the project were spent trying to cover all fishing seasons and the main fishery areas in both International and FICZ/FOCZ waters. IEO also provided a total of 400 observer-days per year of their own observers. FIGFD have collected fisheries and observer data on hake over the period of the project, for comparison with Spanish observer data. This has included sampling by-catch hake from non-hake fisheries, such as the squid fisheries around the Falkland Islands. Commercial and observer data on target and accompanying species was analysed jointly to estimate and compare CPUE by area, fishing season and depth strata for each species. Historical data collected by IEO and FIGFD was also included in the analysis.

Biological samples to determine monthly length distributions by sex of target and non-target species were recorded daily. Size and weight of target and non-target species were recorded by stratified sampling to calculate length-weight relationships and their variation in time and space.

Monthly length-frequencies of hake were used for cohort analysis, using standard software. Assessment based on cohort analysis was carried out for the stocks in international waters. The suitability of a range of other possible approaches to stock assessment was reviewed. Environmental influences on CPUE were also investigated and spatial patterns of CPUE analyzed. The data used for this analysis extend from the start of the fishery in the mid-1980s to the present.

RESULTS

During the setting up phase, completion of the development of the new software and design of the database structure was made. The database was ready by the end of the first project year, allowing the integration of the data available at IEO, FIGFD and ANAMER referring to fishing activity (catch, effort, discards, landings, etc) and biology (length, sex, maturity stage, etc) of target and non-target species, for common analyses. These data, together with environmental and physical information were integrated into a GIS, to analyse geographically referenced biological and fishery information in relation to oceanographic factors. During the second project year, a workshop on assessment was held in London at RRAG facilities to analyze data and test several hypotheses on hake stocks distribution.

The raw data derived from the project comprised:

1. Time series for species composition in catches.
2. Time series of CPUE by species, season and geographical area.
3. Time series of size composition, sex ratio, mean body weights, length/weight relationships and recruitment indices for the target and non-target species of the fishery in each one of the fishing areas of the Patagonian shelf.
4. Estimates of proportion and composition of discards.
5. Time series of maturity stages, gonadal development and feeding indices for the target species.
6. Quantitative and qualitative description of the diet of the main fish predators.
7. Time series of catch and effort of the whole Spanish fleet.

These data were used to derive results on:

1. The description of the Spanish fisheries in the Patagonian shelf.
2. The temporal and spatial patterns of the fisheries and life-cycles of the fished stocks over the studied period, and retrospective analysis employing the already existing database.
3. Trophic relationships involving the target species.
4. Revised estimates of fishing mortality, incorporating amounts discarded.
5. Preliminary estimates of the size of the fished stocks of hake in international waters, and comparison of these estimates with those produced inside the FICZ and in Argentinean waters.
6. Preliminary species- and area-specific estimates of by-catch rates.
7. Existence of different stocks of hakes within the study area

Results are presented by objective and, within each objective, by task. Some tasks address more than one objective and tasks therefore sometimes appear out of sequence.

The main species of the fishery are listed in the following table:

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

PHASE 1. SETTING UP.

1.1 Appointment of new staff.

Spain

José María Bellido was employed in August 2000 to participate in the co-ordination and monitoring of the observer program and the statistical modelling. In addition Xosé Antón Cardoso was employed in July 2000 to carry out the setting up of the database, the observers software and the GIS analysis.

Scotland

Jianjun Wang was employed as a Research Fellow in June 2000 to carry out the statistical and GIS analysis of the data collected over the duration of the project. In addition, M. Begoña Santos (Research Fellow) and a Temporary Assistant (Mr. Samuel Desormonts), were employed to process and analyse the stomach contents collected during the project and carried out the morphometric measurements on the hake samples. In 2001 a new Temporary Assistant (Mr. Antony Bishop) was employed to do the same type of work.

1.2. Purchase of computing hardware and software.

One Pentium III (Scenic 600Mhz) and one Pentium II computer were purchased respectively in Spain and Scotland to hold the databases.

1.3. Project Meetings.

Two co-ordination meetings were held at the Instituto Español de Oceanografía, Centro Oceanográfico de Vigo, Spain, another co-ordination meeting took place in Aberdeen, Scotland, and a final co-ordination meeting was held in London, UK. The first meeting took place from the 10th to the 12th of April 2000 in Vigo. The second meeting took place on the 6th of July 2000 in Aberdeen alongside other meetings to minimise costs. The third meeting took place in Vigo from the 12th-14th December 2000 at IEO and ANAMER buildings. The fourth co-ordination meeting, including a workshop on hake assessment, was held in London from the 16th to the 18th of July 2001 at RRAG facilities.

1.4. Selection and training of observers

Five observers from IEO (3) and ANAMER (2) were selected and trained during the year 2000 and another six observers from IEO (3) and ANAMER (3) were selected and trained during the year 2001. A selection and searching of boats was made among vessels associated with ANAMER; after training courses, the observers were deployed to Montevideo and Port Stanley for their embarkation with the collaboration of ANAMER-associated companies in Stanley (Sulivan Shipping Services and Atlantis) and subcontracted company based in Vigo (M.G. Otero) which had responsibility for organising for embarkation and transhipping of the observers.

PHASE 2. SAMPLING AND DATA ANALYSIS.

Objective 1. Collection of fishery and biological information needed for hake assessment in international and Falkland waters, through a program of scientific observers on board Spanish commercial trawlers fishing in the Patagonian shelf.

Task 1. On-board collection of catch, discards and effort data of the target hake species.

Description on data collection by IEO and ANAMER

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 contributes 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.

All the information registered by the observers was integrated into the database generated for this project. A summary of this information is presented in Table 1 and the overall location of the observed hauls is shown in Figure 1 (location by year of the observed hauls can be seen in Annex I). Data collected by Spanish observers in the 2nd half of 2001 and integrated in the database - although not used in assessment for obvious reasons (assessment was made in July 2001 with data from 1988 till the first fishing season of 2001) - reach until the first week of December 2001. Figure 1 of Annex I shows the pictures of target and non-target species.

Table 1. - 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)**				

Fishery data (catch, effort, discards)

Each observer recorded on a haul by haul basis the following information:

1. The species composition of the total catch. Catch composition by species is estimated multiplying the mean weight of a single box of each single species by the number of boxes of that species frozen in each fishing operation and by a conversion factor to estimate the whole fish weight from processed weight.
2. The time spent fishing (effort), being the time lag from the start to the end of each fishing set. Start and end time was recorded in Greenwich Meridian Time (GMT) units.
3. The species composition of the discards. The weight of discards by species is estimated by the observer with the help of the sailor in charge of selection of discards.

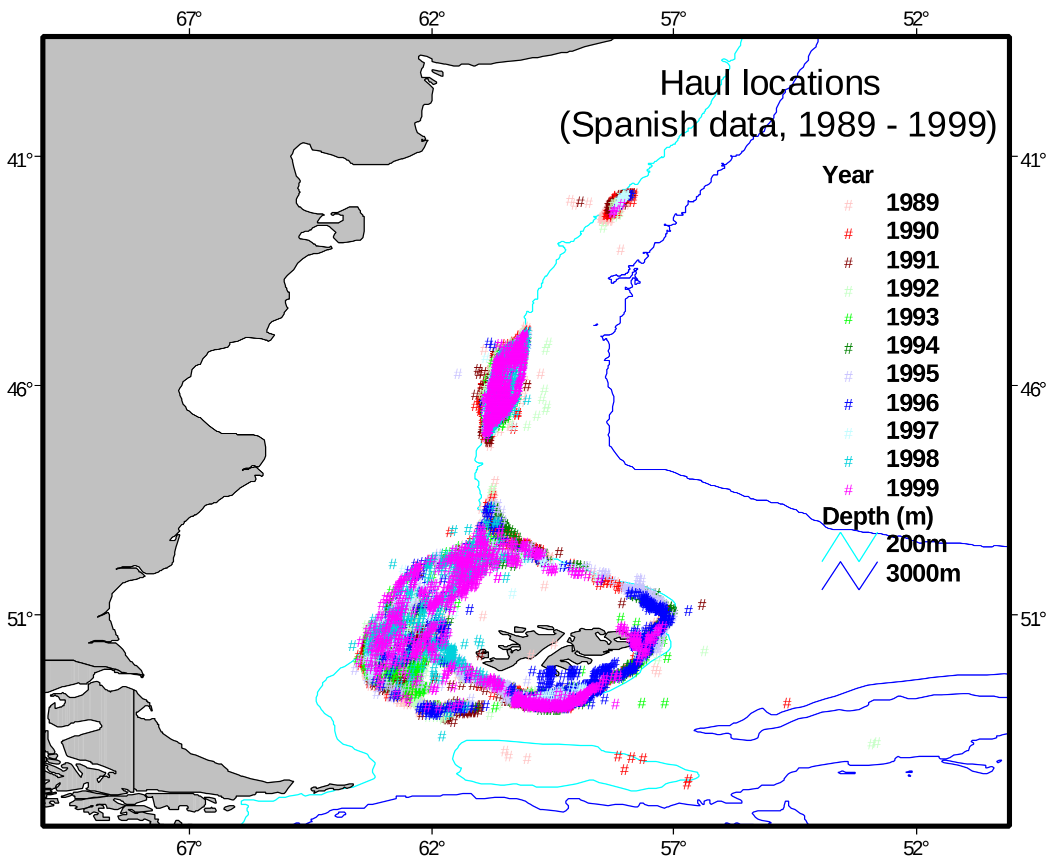


Figure 1. - Geographical position of hauls recorded by Spanish observers

Biological data (length distributions, sex ratio, maturity, etc)

Daily length samples of *M. hubbsi*, *M. australis*, were made separately by sex. The sampling was random to obtain the length distribution for both species by sex. The biological sampling was stratified to obtain a wide coverage of all length classes. Length, sex, maturity stage, weight, and stomach fullness were recorded as routine by the observers. Length samples of non-target species were made periodically, recording length and sometimes weight of each specimen. In the case of cephalopods the sampling was made by sex.

Hake otoliths for readings to obtain age-length keys as well as stomachs of both species were collected to quantify diet of the target species. Hake specimens were also taken in the high seas and inside the FICZ to carry out morphometric and meristic measurements in order to establish possible differences between both areas. Stomach contents of by-catch fish species were sampled to provide an indication of diet composition, in particular the extent of predation on young hake

Supplementary data (main characteristics of every haul, environmental and physical data)

This comprised fishing location, depth, tow time, SST, SBT, sea state, lunar cycle, sky pattern, sea state, wind speed, etc. The observers also have collected information about the characteristics of the vessel such as length, tonnage, crew number, hold capacity, etc.

Description on Data collection by FIGFD

The Falkland Islands Government Fisheries Department (FIGFD) observer programme was established, along with the Falklands Interim Conservation Zone (FICZ), in 1987. Observers collect biological, catch-composition and supplementary (environmental, protected species and vessel details) data aboard commercial vessels operating on licenses issued by FIGFD. These licenses include the ‘hake’ licence which allows targeting of *Merluccius* species. However, vessels holding these licences often target other species and deployment of observers in the hake fishery is largely opportunistic. Most observer effort is directed at the more commercially important fisheries for the squids *Loligo gahi* and *Illex argentinus*, and ‘general finfish’ including southern blue whiting, *Micromesistius australis australis*. Consequently most of the hake data collected by FIGFD observers (approximately 75% of sexed lengths) are derived from the by-catch of vessels which are not targeting hake, especially those with ‘general finfish’ licences.

The ‘hake’ and ‘general finfish’ fleet consists mainly of Spanish and Falkland registered trawlers with a typical GRT of 1,500 to 2,000 t. Approximately 1,200 hauls on ‘hake’ licensed vessels were observed between 1989 and 2000.

During each observer trip, lasting an average of 27 days, observers recorded:

1. The species composition, by estimated weight, of the catch and discards including protected species.
2. The length, sex and maturity for randomly-selected specimens of one or two of the most abundant species in the catch by weight. 100 specimens per species are measured when they are finfish and 200 specimens are measured per species when they are squid.
3. Environmental and operational data such as the time and position at which the net is shot, soak time, average depth of fishing, sea surface temperature taken using a hand thermometer and, where practicable, bottom temperature recorded by electronic loggers attached to the net.
4. Additional environmental information such as wind speed and sea state, at the observer’s discretion.
5. Cetacean and seabird interactions where known.

Observers also collect the following data by species:

6. Length-weight by sex.
7. Age-length by sex and maturity.

As a rule, the data listed under points 6 and 7 are obtained through non-random sampling by observers. Otoliths are read at the Sea Fisheries Institute, Gdynia, Poland. Biological data (length, sex, maturity and length-weight data) for non-target finfish species are collected opportunistically by observers on all fleets, when time allows. FIGFD has undertaken regular research surveys since 1999. Fishing takes place along transects and biological data are collected for species encountered, using largely the same sampling strategy as the observer programme, though more species are sampled and additional data are collected. Data described under points 1 to 3 and 6 to 7 above, and derived from both the observer programme and research surveys are available on the FIGFD database. In addition, FIGFD observers have also collected about 250 *M. hubbsi* stomachs and some samples of whole hakes from commercial vessels within the FICZ, for analysis by AU.

FIGFD collects data reported by vessels by radio and in logbooks. These data include the total daily fishing effort and catch of the major target species, and the midday and midnight positions of the vessels at a resolution of 15' longitude and 30' latitude. Currently no distinction is made between the two hake species (*M. hubbsi* and *M. australis*) in reports from vessels. However, RRAG has developed a method for separating catches into the two species on the basis of observer data and geographic distinctions (see section 6).

Data available in the FIGFD database are summarised in Table 2. The geographical position of each haul is shown in Figure 2.

Table 2. - 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. australis*)	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

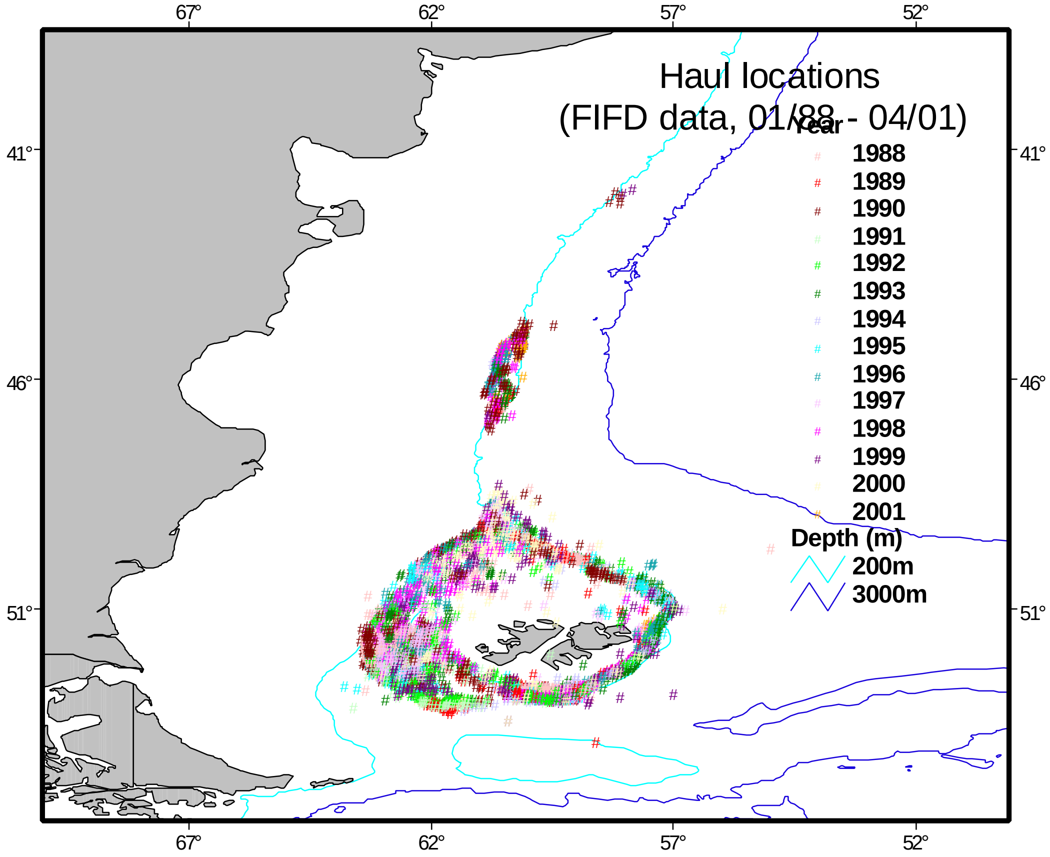


Figure 2. - Geographical position of hauls recorded by FIGFD observers

1.1. Calculation of CPUE of the target species by area and season.

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 made at IEO to obtain CPUE by species, area, month and depth strata (Table 1ANNEX), to have an index of the abundance of these species in the study period. Maps on a long-term average were made by AU in collaboration with IEO (Figure 3) to show shifts in CPUE. Figures 4 and 5 show the observed CPUE of both target species between 1988 and 2001.

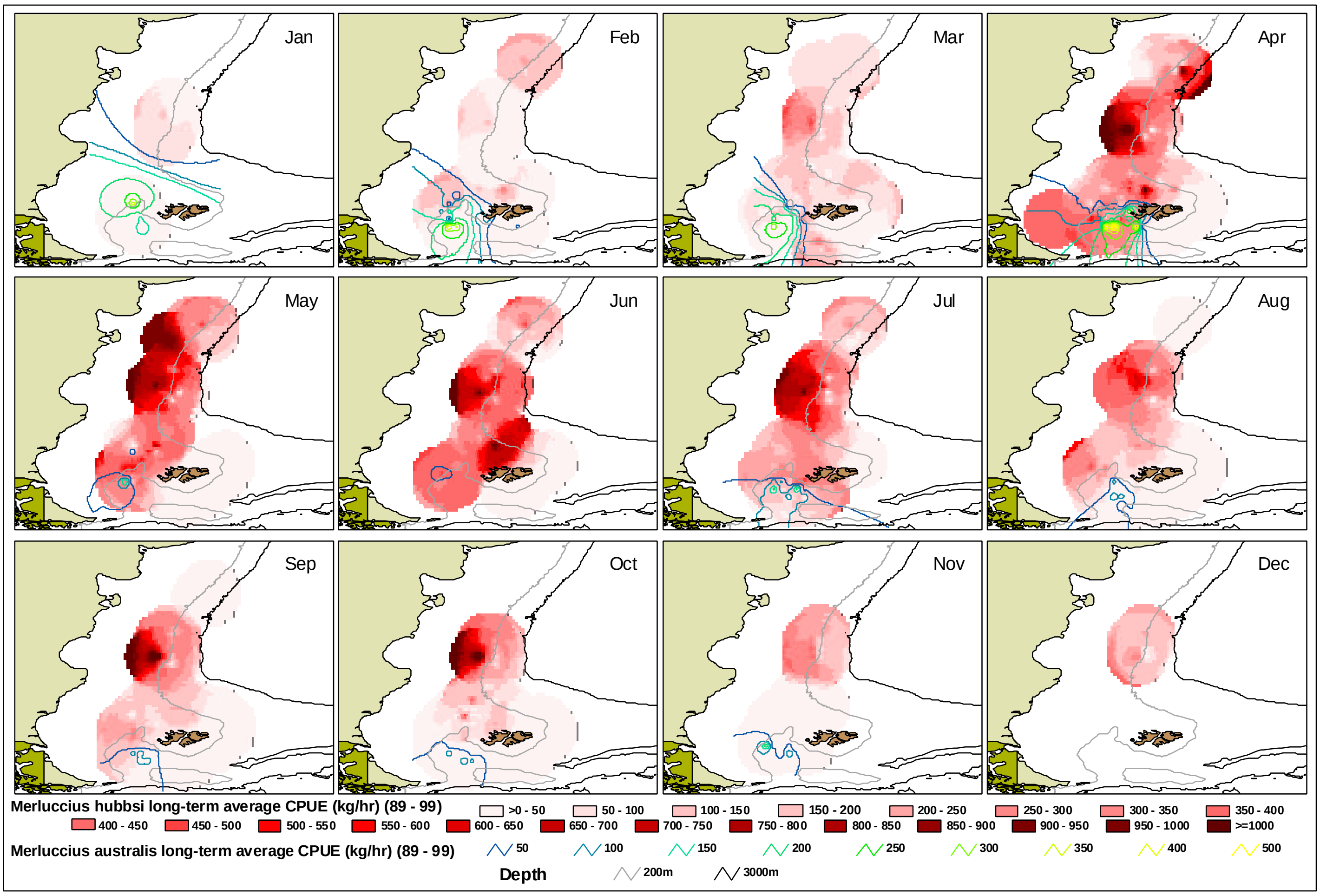


Figure 3. – Long-term average CPUE of target species

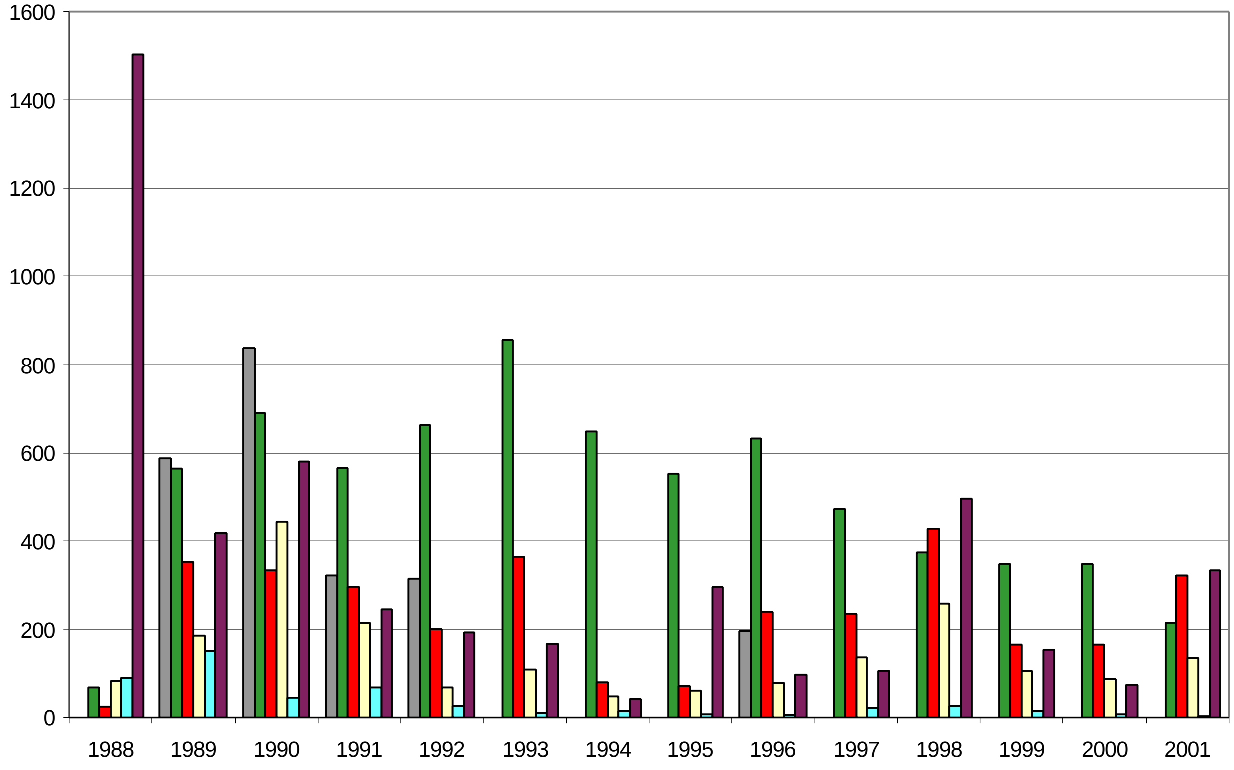


Figure 4. Observed CPUE (kgs/hour) of *M. hubbsi*

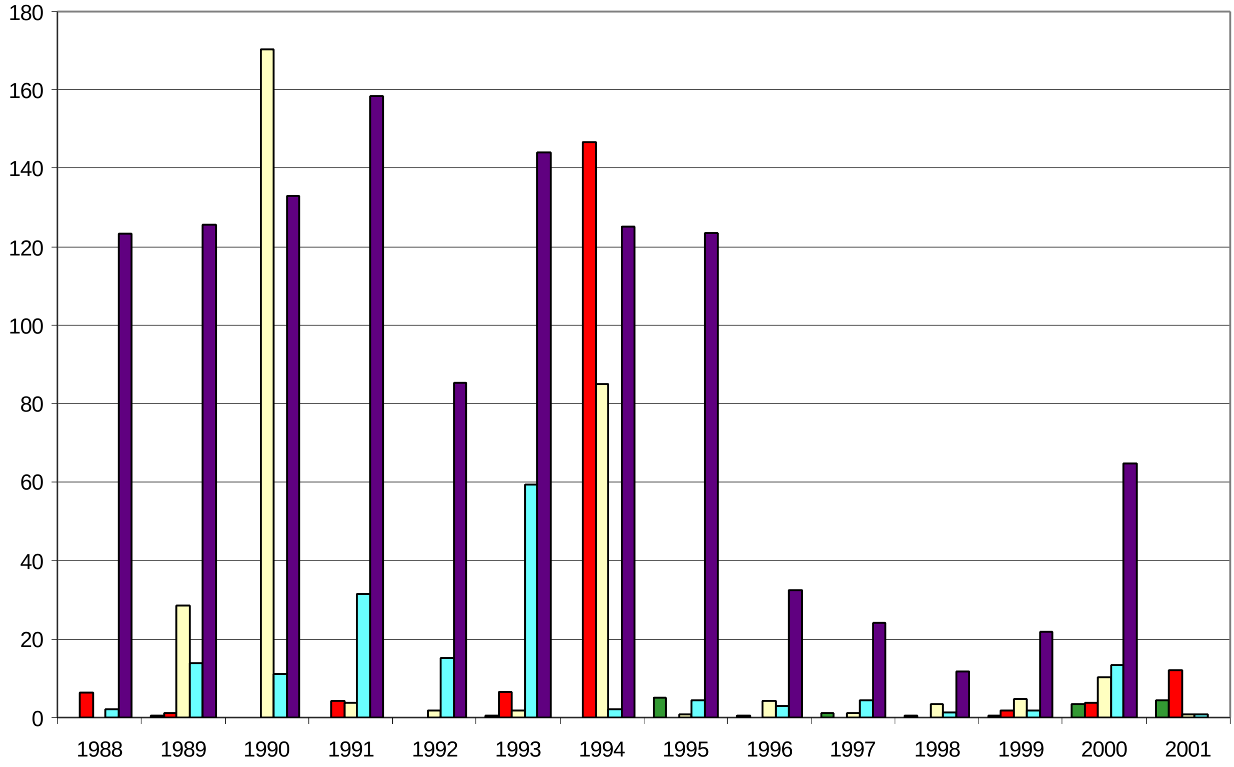


Figure 5. Observed CPUE (kgs/hour) of *M. australis*

1.2. Study of the discard pattern of target species.

Analysis of the discard pattern of target species by the Spanish fleet from historical data on a haul by haul basis from 1989 to 2001 was initiated during 2000 and finished in 2001. These analyses were made jointly by AU and IEO to describe the proportion of target species in the total catch and the amount of discards. A description of the discard pattern by the Spanish fleet in the Patagonian Shelf fisheries was made and some results can be seen in Table 3.

The discards ratio was calculated for each haul, defined as the ratio of total discards to the total catches. In Figure 6 can be seen the locations of hauls with different *Merluccius hubbsi* discard ratios, by "hake target" hauls and "non-hake target" hauls, respectively. Annex VI (GIS) also shows monthly total discards by "hake target" and "non-hake target" hauls. It can be seen that the lowest proportion of discards was seen in 1990 and 1991. In the north area (from 44?S northwards), hake discarding was recorded in 1989 and 1990. Both hake target and non-hake target fishing have discards records. In the middle area (between 44?S and 47? 30'S), high discards were seen in July 1996. Over 250 t of *Merluccius hubbsi* were discarded. Hake target fishing made the major contribution to discards in this area. In the south area (from 47? 30'S southwards), nearly 120 t *Merluccius hubbsi* were discarded in April 1989. High discarding also occurred in 1995 and 1996. Discards are mainly from non-hake target fishing hauls in this area.

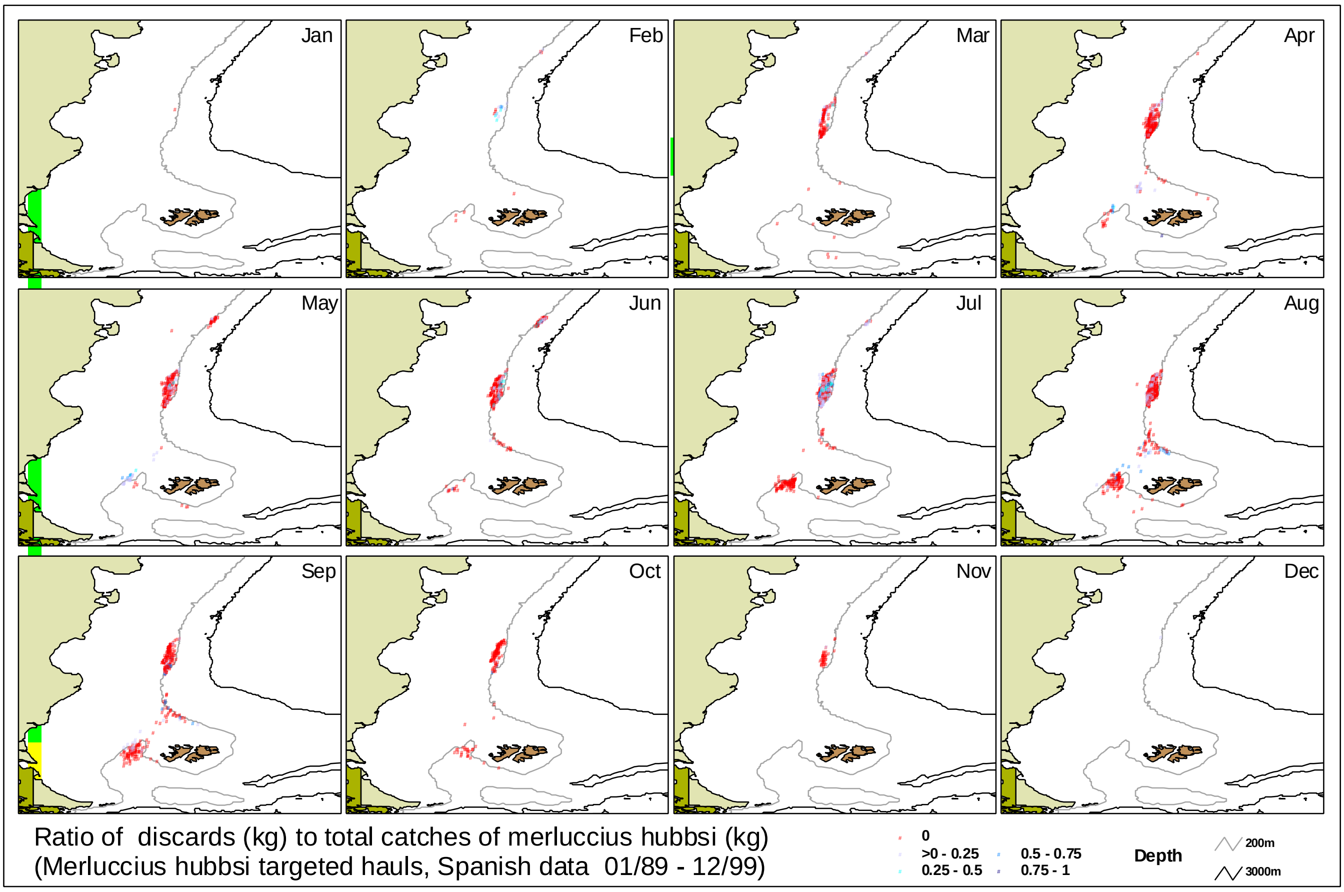


Figure 6. Ratio of discards (*Merluccius hubbsi*)

Table 3. – Observed catch (kgs), discards, effort, percentage of discards and CPUE by fishing area.

Year	(All)								
Month	(All)	**Division**							
Species	Data	Unknown	42	46	49	MN	MS	MW	Total
Merluccius hubbsi	total catch	8,978	745,165	13,684,464	371,999	506,868	383,594	6,083,910	21,784,978
	total discard	52	61,031	649,185	23,265	17,374	70,583	310,726	1,132,215
	total effort	68	2,906	29,566	1,730	4,556	11,822	22,599	73,246
	Percentage	0.58	8.19	4.74	6.25	3.43	18.40	5.11	5.20
	CPUE	132.97	256.47	462.84	215.05	111.25	32.45	269.21	297.42
Merluccius australis	total catch		3	5,170	11,422	25,847	27,046	1,354,813	1,424,303
	total discard		0	219	0	108	3,786	63,086	67,199
	total effort		10	205	133	723	2,653	14,392	18,116
	Percentage		0.00	4.24	0.00	0.42	14.00	4.66	4.72
	CPUE		0.33	25.17	85.68	35.77	10.19	94.14	78.62
Illex argentinus	total catch	23,717	4,964,931	8,996,737	338,602	3,044,048	345,533	2,470,419	20,183,987
	total discard	0	13,291	120,801	14,678	21,156	39,247	62,674	271,847
	total effort	42	4,302	20,584	623	2,376	3,790	6,787	38,503
	Percentage	0.00	0.27	1.34	4.33	0.70	11.36	2.54	1.35
	CPUE	563.57	1,154.14	437.07	543.63	1,281.07	91.18	364.00	524.21
Loligo gahi	total catch	332	36,002	766,540	208,644	5,912,235	44,118,443	742,402	51,784,597
	total discard	3	277	59,020	1,207	39,267	536,862	45,107	681,742
	total effort	26	291	10,246	1,157	5,144	22,999	9,667	49,530
	Percentage	0.84	0.77	7.70	0.58	0.66	1.22	6.08	1.32
	CPUE	12.57	123.86	74.81	180.34	1,149.45	1,918.25	76.80	1,045.51
Macruronus magellanicus	total catch	618	74,550	557,434	296,606	622,614	81,815	7,000,196	8,633,832
	total discard	222	21,286	225,389	111,916	135,528	38,417	1,607,914	2,140,672
	total effort	26	847	8,527	1,119	2,425	1,915	20,213	35,073
	Percentage	35.99	28.55	40.43	37.73	21.77	46.96	22.97	24.79
	CPUE	23.97	87.99	65.37	265.01	256.76	42.71	346.32	246.17
Micromesistius australis	total catch	1	10,081	90,645	166	2,148,299	2,054,380	10,056,432	14,360,003
	total discard	1	9,441	31,633	166	38,428	465,445	1,205,123	1,750,236
	total effort	1	492	543	35	719	3,465	11,043	16,299
	Percentage	100.00	93.65	34.90	100.00	1.79	22.66	11.98	12.19
	CPUE	0.77	20.48	166.81	4.74	2,989.70	592.90	910.62	881.05
Genypterus blacodes	total catch	1,553	37,525	1,128,876	53,016	85,211	49,279	883,124	2,238,584
	total discard	0	2,282	13,593	1,607	2,748	5,331	31,746	57,307
	total effort	43	1,520	25,330	1,383	2,884	5,648	19,609	56,418
	Percentage	0.00	6.08	1.20	3.03	3.23	10.82	3.59	2.56
	CPUE	35.77	24.69	44.57	38.33	29.54	8.73	45.04	39.68
Salilota australis	total catch	2,870	11,288	153,109	71,794	148,439	402,830	3,381,358	4,171,688
	total discard	27	1,391	6,580	4,086	8,735	29,120	219,153	269,092
	total effort	48	1,239	10,137	1,417	3,164	11,344	22,001	49,350
	Percentage	0.95	12.32	4.30	5.69	5.88	7.23	6.48	6.45
	CPUE	59.28	9.11	15.10	50.68	46.92	35.51	153.69	84.53
Dissostichus eleginoides	total catch	407	2,289	24,377	6,127	19,844	51,244	426,435	530,723
	total discard	0	1,034	1,504	362	3,616	9,682	10,698	26,896
	total effort	27	366	3,264	492	1,530	5,139	14,631	25,448
	Percentage	0.00	45.18	6.17	5.91	18.22	18.89	2.51	5.07
	CPUE	15.30	6.25	7.47	12.46	12.97	9.97	29.15	20.86
Patagonotothen spp.	total catch		227,027	3,445,276	128,383	346,619	411,302	992,509	5,551,116
	total discard		225,867	3,396,943	83,043	346,619	422,510	993,489	5,468,471
	total effort		2,734	21,656	920	2,024	4,471	8,382	40,187
	Percentage		99.49	98.60	64.68	100.00	102.73	100.10	98.51
	CPUE		83.02	159.09	139.57	171.26	91.98	118.41	138.13

1.3. Estimation of the relationships between processed and whole fish weight.

Conversion factors for estimation of the relationships between processed and whole fish weight of target species were obtained by the observers during the same period. A mean of these conversion factors was used by onboard observers to estimate total catches by species and by haul (see Table 4). These conversion factors were also applied to estimate total catches of the whole Spanish fleet from processed landings provided by ANAMER, considering the yearly percentage of its fleet in relation to the entire Spanish fleet (Task 4). To estimate these conversion factors observers weighed individuals fish and squid before and after processing.

Table 4. – Conversion factors obtained by Spanish observers

COMMON NAME	SCIENTIFIC NAME	TYPE OF PROCESSING	C.F.
Illex	*Illex argentinus*	Skinless body (tube) Skin-on body (tube)	3 2
Argentinean hake	*Merluccius hubbsi*	Gutted/headed Skinned fillet	1.5 2.5
Austral hake	*Merluccius australis*	Gutted/headed	1.5
Kingclip	*Genypterus blacodes*	Gutted/headed	1.5
Red cod	*Salilota australis*	Gutted/headed	1.5
Southern blue whiting	*Micromesistius australis*	Skinned fillet Fillet	2.5 2
Skates	*Raja sp.*	Skinned wings	3
Hoki	*Macruronus magellanicus*	Skinned fillet Fillet	2.5 2

1.4. Use of data to obtain results and to feed task 6.

All the features of the sampling scheme was designed taking into account the needs and requirements of task 6 (assessment).

Task 2. On-board by-catch data collection.

2.1 Calculation of CPUE of non-target species by area and season, particularly for Patagonian toothfish

Historical and new data about catch and effort of the most important accompanying species such as Patagonian toothfish (*Dissostichus eleginoides*), Kingclip (*Genypterus blacodes*), Red cod (*Salilota australis*), Hoki (*Macruronus magellanicus*), Southern blue whiting (*Micromesistius* australis), Patagonian squid (*Loligo gahi*), and Illex squid (*Illex argentinus*) collected by IEO, FIGFD and ANAMER observers on a haul by haul basis from 1989 to 2001 were collated and integrated in the common database for analyses to estimate CPUE by species, area, month and depth strata to have an index of the abundance of these species (Tables 5 and 6). As can be seen in both tables, CPUE of toothfish was very low.

<u>Marine mammals. (See Annex I for tables on sightings</u>)

IEO also contributed to the project with historical data on by-catches and sightings of marine mammals collected since 1993 by observers trained to do this task by researchers of the Marine Mammals Project of the IEO with the following objectives:

- ? to record the interactions between fishing activities and marine protected fauna
- ? to advise national and international bodies with responsibilities in research and management of these species

Between 1993 and 2001, observers spent a total of 2540 days at sea on board Spanish fishing vessels. Their main task was to sample the fish and cephalopod catch and by-catch but they also recorded incidental sightings and by-catches of marine megafauna (seabirds and marine mammals). Sightings or catches of protected marine megafauna were recorded during 25 fishing trips. The information was processed, collated and checked before being integrated in the IEO project database for analysis.

Several species of sea birds and marine mammals were reported incidentally caught in the fishing nets. However, the 15 records over 9 years include three cetacean specimens in an advanced stay of decay when caught, and one bird (a seagull), which was released alive.

The 11 animals observed to be killed in the fishing gear included sea birds, pinnipeds and dolphins: three specimens of the black-browed albatross (*Diomedea melanophris*), one gentoo penguin (*Pygoscelis papua*), three hourglass dolphins (*Lagenorhynchus cruciger*),one crabeater seal (*Lobodon carcinophagus*), one South American sea lion (*Otaria byronia*), one South American fur seal (*Arctocephalus australis*) and one “grey seal”. The overall by-catch mortality for seabirds and marine mammals was approximately 4 animals per 1000 observer days at sea, with the highest mortality (>1 animal per 100 days at sea) being seen in 1993 (Table 7). Thus the by-catch rate is apparently low.

Sightings of 108 cetacean groups (942 animals) were made, with the highest sighting rate (1.14 animals per day) in 1995 and no sightings in 1993 or 1999 (Table 8). The species most frequently sighted was the Peale’s dolphin (*Lagenorhynchus australis*) followed by the hourglass dolphin. Other species of cetaceans observed were the common dolphin (*Delphinus* sp.), the pilot whale (*Globicephala* sp.), the sperm whale (*Physeter macrocephalus*) and the southern right whale (*Eubaleana australis*).

Table 5. – Observed catch (kgs), effort and CPUE by bathymetric stratum for all years.

year	(All)										
species		**stratum**									
	Datos	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500	> 500	Total general
Merluccius hubbsi	CPUE	121	448	215	250	113	122	81	30	43	78	299
	total catch	12,266	12,346,762	5,082,844	2,747,954	361,018	187,460	55,556	32,754	23,285	33,315	20,883,214
	total effort	101	27,531	23,683	11,001	3,182	1,540	683	1,106	537	425	69,789
Merluccius australis	CPUE	7	55	45	84	110	86	76	127	118	91	79
	total catch	50	33,661	253,891	490,986	239,935	82,624	28,531	157,577	97,839	15,326	1,400,421
	total effort	7	615	5,604	5,854	2,181	957	377	1,237	832	168	17,832
Illex argentinus	CPUE	318	365	468	653	413	862	1,356	805	994	1,423	490
	total catch	84,754	6,788,190	5,147,458	2,852,772	397,777	545,130	749,453	205,217	49,123	1,769,581	18,589,455
	total effort	267	18,601	10,996	4,367	964	633	553	255	49	1,243	37,927
Loligo gahi	CPUE	2,699	716	1,418	1,014	820	408	45	27	23	35	1,058
	total catch	1,225,446	10,127,407	27,604,507	9,555,869	2,332,156	280,804	10,547	20,456	6,414	2,233	51,165,838
	total effort	454	14,135	19,468	9,422	2,843	688	235	769	275	64	48,351
Macruronus magellanicus	CPUE	187	103	384	245	198	192	123	70	107	66	246
	total catch	12,225	840,481	5,060,991	1,685,102	504,721	254,521	62,553	85,522	78,239	26,426	8,610,780
	total effort	66	8,155	13,183	6,875	2,547	1,326	510	1,217	728	402	35,007
Micromesistius australis	CPUE	725	623	361	608	1,720	3,050	2,034	251	356	116	883
	total catch	10,052	361,107	1,560,582	2,985,608	4,248,108	3,716,660	829,360	302,228	296,178	34,271	14,344,154
	total effort	14	580	4,317	4,912	2,469	1,218	408	1,203	832	296	16,250
Genypterus blacodes	CPUE	57	44	42	32	23	13	13	18	11	11	40
	total catch	3,674	960,175	798,438	326,772	58,195	6,284	1,441	1,923	237	742	2,157,880
	total effort	64	21,827	18,962	10,174	2,496	466	115	104	22	65	54,295
Salilota australis	CPUE	7	30	125	82	50	17	15	24	154	15	85
	total catch	402	306,850	2,619,852	983,592	162,716	18,832	4,904	9,445	16,582	1,552	4,124,727
	total effort	57	10,109	21,007	11,947	3,279	1,111	322	396	108	106	48,441
Dissostichus eleginoides	CPUE	23	5	15	14	24	31	35	65	132	84	21
	total catch	832	15,377	166,741	89,537	49,451	23,390	9,564	64,607	86,666	21,079	527,244
	total effort	36	2,945	11,150	6,253	2,086	749	276	991	658	251	25,395
Patagonotothen spp.	CPUE	35	149	162	93	112	97	101	66	42	58	138
	total catch	4,680	3,049,857	1,617,505	489,335	191,849	68,921	46,180	25,340	11,390	45,459	5,550,516
	total effort	135	20,484	9,970	5,273	1,708	711	459	385	270	778	40,171

Table 6. - Monthly observed catch (kgs), effort and CPUE by month.

year	(All)												
strata	(All)												
		month											
species	Datos	1	2	3	4	5	6	7	8	9	10	11	12	Total general
Merluccius hubbsi	CPUE	43.12	88.05	196.73	406.35	392.33	425.04	571.46	299.16	188.20	116.21	106.95	92.70	301.42
	total catch	75,646	332,476	1,467,455	4,316,387	3,474,103	1,768,994	4,504,247	3,302,913	1,616,730	695,214	183,787	36,984	21,774,936
	total effort	1,754	3,776	7,459	10,622	8,855	4,162	7,882	11,041	8,590	5,982	1,718	399	72,242
Merluccius australis	CPUE	115.71	144.74	139.63	99.41	71.77	36.28	46.85	57.44	56.57	45.70	40.39	17.33	78.62
	total catch	81,237	209,516	285,377	255,704	93,154	12,091	28,569	148,937	148,138	97,511	58,673	5,396	1,424,303
	total effort	702	1,448	2,044	2,572	1,298	333	610	2,593	2,619	2,134	1,453	311	18,116
Illex argentinus	CPUE	1,123.66	664.77	688.42	592.10	467.98	527.83	22.72	25.50	58.97	8.82	29.56	244.34	510.90
	total catch	1,593,919	2,691,837	5,611,647	5,478,334	2,853,171	1,690,040	64,511	58,780	79,258	2,994	8,978	49,515	20,182,984
	total effort	1,419	4,049	8,151	9,252	6,097	3,202	2,839	2,305	1,344	339	304	203	39,505
Loligo gahi	CPUE	68.03	2,937.82	2,182.88	1,612.91	1,307.83	466.65	362.13	921.17	644.60	269.12	2.31	2.11	1,032.36
	total catch	11,871	5,305,605	9,129,825	9,349,791	9,082,176	671,818	1,169,756	8,814,956	6,029,788	1,564,687	2,725	79	51,133,077
	total effort	175	1,806	4,182	5,797	6,944	1,440	3,230	9,569	9,354	5,814	1,181	37	49,530
Macrurorus magellanicus	CPUE	55.95	215.74	218.18	273.92	193.69	170.55	108.97	164.28	246.88	450.60	364.74	199.22	244.71
	total catch	86,745	520,515	985,630	1,243,506	462,526	216,210	212,857	795,619	1,018,918	2,153,507	770,939	115,656	8,582,628
	total effort	1,550	2,413	4,517	4,540	2,388	1,268	1,953	4,843	4,127	4,779	2,114	581	35,073
Micromesistius australis	CPUE	1,813.44	1,660.79	301.39	228.25	90.54	11.79	27.19	304.81	624.83	741.81	1,638.38	5,953.92	881.05
	total catch	1,557,742	2,317,990	534,149	455,747	71,722	4,032	6,338	524,268	1,783,844	1,614,943	2,788,631	2,700,598	14,360,003
	total effort	859	1,396	1,772	1,997	792	342	233	1,720	2,855	2,177	1,702	454	16,299
Genypterus blacodes	CPUE	16.08	21.14	42.67	52.10	44.32	53.79	38.86	33.54	33.86	33.34	40.99	110.10	39.66
	total catch	28,153	77,808	303,600	464,254	257,008	149,603	227,133	261,660	190,869	167,455	70,292	39,746	2,237,581
	total effort	1,751	3,680	7,114	8,911	5,799	2,781	5,846	7,801	5,637	5,022	1,715	361	56,418
Salilota australis	CPUE	128.23	59.97	79.74	77.63	62.07	54.82	39.22	94.09	115.40	133.61	67.77	3.22	84.49
	total catch	128,162	174,896	478,136	624,333	402,338	118,412	127,000	613,275	685,821	712,272	104,454	582	4,169,682
	total effort	999	2,917	5,997	8,043	6,482	2,160	3,238	6,518	5,943	5,331	1,541	181	49,350
Dissostichus eleginoides	CPUE	16.76	24.12	15.43	20.21	9.70	14.20	13.08	30.11	28.65	15.58	17.79	10.46	20.82
	total catch	14,994	27,712	32,035	57,245	19,902	7,475	23,480	142,984	122,409	51,602	27,104	2,779	529,722
	total effort	895	1,149	2,076	2,833	2,051	527	1,795	4,749	4,273	3,312	1,524	266	25,448
Patagonotothen spp.	CPUE	234.57	161.20	190.03	135.06	94.40	67.30	114.15	122.38	136.17	150.90	134.56	131.06	135.63
	total catch	243,161	439,317	831,273	691,762	325,462	153,440	558,343	667,326	716,456	666,304	119,179	38,530	5,450,553
	total effort	1,037	2,725	4,375	5,122	3,448	2,280	4,891	5,453	5,261	4,416	886	294	40,187

Table 7. “Megafauna” by-catch mortality recorded by fishery observers

Season	No of Observers	Days at sea	*Lagenorynchus cruciger*	*Otaria byronia*	*Lobodon carcinophagus*	*Arctocephalus australis*	*“Grey seal”*	*Pygoscelis papua*	*Diomedea melanophris*	ALL	BY-CATCH RATE (No/day)
			By-catch mortalities recorded								
1993	2	225	2	1	0	0	0	0	0	3	0.0133
1994	5	396	1	0	1	0	0	0	0	2	0.0051
1995	2	225	0	0	0	0	0	0	0	0	0.0000
1996	2	211	0	0	0	0	0	1	1	2	0.0095
1997	2	222	0	0	0	0	0	0	0	0	0.0000
1998	4	435	0	0	0	0	1	0	1	2	0.0046
1999	1	103	0	0	0	0	0	0	0	0	0.0000
2000	5	485	0	0	0	1	0	0	0	1	0.0021
2001	2	238	0	0	0	0	0	0	1	1	0.0042
SUM	25	2540	3	1	1	1	1	1	3	11	0.0043

Table 8. Sightings of cetaceans by fishery observers

(a) Number of groups

Season	Observers	*Days*	*Delfinus sp.*	*Eubaleana australis*	*Globecephala sp.*	*Physeter macrocephalus*	*Lagenorhynchus australis*	*Lagenorynchus cruciger*	Unidentified	ALL	Sightings rate (No/day)
1993	2	225								0	0.00
1994	5	396		1		1		15	3	20	0.05
1995	2	225			5		14		6	25	0.11
1996	2	211	1	1			6			8	0.04
1997	2	222		1			17		2	20	0.09
1998	4	435				1	8		3	12	0.03
1999	1	103								0	0.00
2000	5	485				2	3		7	12	0.02
2001	2	238					8		3	11	0.05
SUM	25	2540	1	3	5	4	56	15	24	108	

(b) Number of individuals

Season	Observers	*Days*	***Delfinus* sp.**	***Eubaleana australis***	***Globecephala* sp.**	***Physeter macrocephalus***	***Lagenorhynchus australis***	***Lagenorynchus cruciger***	**Unidentified**	**ALL**	**Sightings rate (No/day)**
1993	2	225								0	0.00
1994	5	396		2		5		120	19	146	0.37
1995	2	225			164		65		28	257	1.14
1996	2	211	8	1			36			45	0.21
1997	2	222		1			94		2	97	0.44
1998	4	435				1	55		42	98	0.23
1999	1	103								0	0.00
2000	5	485				2	31		31	64	0.13
2001	2	238					85		150	235	0.99
SUM	25	2540	8	4	164	8	366	120	272	942	

2.2. Study of the discard pattern of non-target species.

Analysis of the discard pattern of the aforementioned by-catch species of the Spanish fleet from historical data registered by IEO observers on a haul by haul basis from 1989 to 2001 was initiated during the second half of year 2000 and finished in the third quarter of 2001 after a workshop at Aberdeen University.

Percentages of discard in relation to total catch are shown in Table 9. The most discarded species are *Patagonotothen* spp, with around the 100% discarded, second is *Macruronus magellanicus*, with around 25% discarded, then *Micromesistius australis* (12%) and *Salilota australis* (6%). These percentages once vary depending on the division, year and fishing season. The four target species have percentages of discards below 5%. In recent years percentages have decreased below 15%, except for *Patagonotothen* spp (100% discarded). This should be analysed in further work to understand possible changes in fishing patterns as well as to evaluate possible emerging target species and their fishery potential.

2.3. Study of the species composition of the catch in order to elaborate a faunal guide of the area.

A faunal guide was elaborated by the IEO Vigo team (see PDF file included in the report). This benefits from information collected during the historical observers program of the IEO, which comprises samples and photographs since 1989.

The guide contains information on around 65 different species of fishes, 5 species of cephalopods and 9 species of crustaceans. It is intended to be a useful tool for observers on board and skippers, to identify all species and to record new species which may appear. The information provided for every species includes distribution, diagnosis, biology, size, environment, climate, commercial importance and dangerous. It also includes maps for every species.

The guide was finished at the end of 2001 and is expected to be printed in the first quarter of 2002. Observers will test it during the year 2002. The final format could be on paper (book) and a CD-ROM, as for delivery of the project.

Table 9. Percentages of discards in relation to total catch

year	(All)								
month	(All)	**division**							
species	Data	Unknown	42	46	49	MN	MS	MW	Total
Merluccius hubbsi	total catch	8,978	745,165	13,684,464	371,999	506,868	383,594	6,083,910	21,784,978
	total discard	52	61,031	649,185	23,265	17,374	70,583	310,726	1,132,215
	total effort	68	2,906	29,566	1,730	4,556	11,822	22,599	73,246
	Percentage	0.58	8.19	4.74	6.25	3.43	18.40	5.11	5.20
	CPUE	132.97	256.47	462.84	215.05	111.25	32.45	269.21	297.42
Merluccius australis	total catch		3	5,170	11,422	25,847	27,046	1,354,813	1,424,303
	total discard		0	219	0	108	3,786	63,086	67,199
	total effort		10	205	133	723	2,653	14,392	18,116
	Percentage		0.00	4.24	0.00	0.42	14.00	4.66	4.72
	CPUE		0.33	25.17	85.68	35.77	10.19	94.14	78.62
Illex argentinus	total catch	23,717	4,964,931	8,996,737	338,602	3,044,048	345,533	2,470,419	20,183,987
	total discard	0	13,291	120,801	14,678	21,156	39,247	62,674	271,847
	total effort	42	4,302	20,584	623	2,376	3,790	6,787	38,503
	Percentage	0.00	0.27	1.34	4.33	0.70	11.36	2.54	1.35
	CPUE	563.57	1,154.14	437.07	543.63	1,281.07	91.18	364.00	524.21
Loligo gahi	total catch	332	36,002	766,540	208,644	5,912,235	44,118,443	742,402	51,784,597
	total discard	3	277	59,020	1,207	39,267	536,862	45,107	681,742
	total effort	26	291	10,246	1,157	5,144	22,999	9,667	49,530
	Percentage	0.84	0.77	7.70	0.58	0.66	1.22	6.08	1.32
	CPUE	12.57	123.86	74.81	180.34	1,149.45	1,918.25	76.80	1,045.51
Macruronus magellanicus	total catch	618	74,550	557,434	296,606	622,614	81,815	7,000,196	8,633,832
	total discard	222	21,286	225,389	111,916	135,528	38,417	1,607,914	2,140,672
	total effort	26	847	8,527	1,119	2,425	1,915	20,213	35,073
	Percentage	35.99	28.55	40.43	37.73	21.77	46.96	22.97	24.79
	CPUE	23.97	87.99	65.37	265.01	256.76	42.71	346.32	246.17
Micromesistius australis	total catch	1	10,081	90,645	166	2,148,299	2,054,380	10,056,432	14,360,003
	total discard	1	9,441	31,633	166	38,428	465,445	1,205,123	1,750,236
	total effort	1	492	543	35	719	3,465	11,043	16,299
	Percentage	100.00	93.65	34.90	100.00	1.79	22.66	11.98	12.19
	CPUE	0.77	20.48	166.81	4.74	2,989.70	592.90	910.62	881.05
Genypterus blacodes	total catch	1,553	37,525	1,128,876	53,016	85,211	49,279	883,124	2,238,584
	total discard	0	2,282	13,593	1,607	2,748	5,331	31,746	57,307
	total effort	43	1,520	25,330	1,383	2,884	5,648	19,609	56,418
	Percentage	0.00	6.08	1.20	3.03	3.23	10.82	3.59	2.56
	CPUE	35.77	24.69	44.57	38.33	29.54	8.73	45.04	39.68
Salilota australis	total catch	2,870	11,288	153,109	71,794	148,439	402,830	3,381,358	4,171,688
	total discard	27	1,391	6,580	4,086	8,735	29,120	219,153	269,092
	total effort	48	1,239	10,137	1,417	3,164	11,344	22,001	49,350
	Percentage	0.95	12.32	4.30	5.69	5.88	7.23	6.48	6.45
	CPUE	59.28	9.11	15.10	50.68	46.92	35.51	153.69	84.53
Dissostichus eleginoides	total catch	407	2,289	24,377	6,127	19,844	51,244	426,435	530,723
	total discard	0	1,034	1,504	362	3,616	9,682	10,698	26,896
	total effort	27	366	3,264	492	1,530	5,139	14,631	25,448
	Percentage	0.00	45.18	6.17	5.91	18.22	18.89	2.51	5.07
	CPUE	15.30	6.25	7.47	12.46	12.97	9.97	29.15	20.86
Patagonotothen spp.	total catch		227,027	3,445,276	128,383	346,619	411,302	992,509	5,551,116
	total discard		225,867	3,396,943	83,043	346,619	422,510	993,489	5,468,471
	total effort		2,734	21,656	920	2,024	4,471	8,382	40,187
	Percentage		99.49	98.60	64.68	100.00	102.73	100.10	98.51
	CPUE		83.02	159.09	139.57	171.26	91.98	118.41	138.13

2.4. Estimation of annual by-catch rates for the sampled fleet for selected species

Analysis of the annual by-catch rates of the aforementioned by-catch species of the Spanish fleet from historical data registered by IEO observers on a haul by haul basis from 1989 to 2001 was initiated in the second half of 2000 and finished at the end of the project (see Tables 5 and 6). Historical and new data on marine mammal by-catches was synthesised and used to estimate by-catch rates.

2.5 Data analysis and provision of input data for task 6.

The IEO Vigo team has developed software that permits processing and manipulation of biological and fishery data in order to obtain standardised outputs. Study of historical and new data registered by IEO observers on a haul by haul basis from 1989 to 2001 was initiated in the second half of year 2000. Further analysis was made during the second year of the project.

Task 3. On-board biological sampling. (IEO)

3.1. Determine the monthly length frequencies of the two target hake species, to describe the seasonal pattern of size composition in the population and to identify periods of recruitment

Daily length and biological samples of *M. hubbsi*, *M. australis* were made by observers since 1989. Length samples were made separately by sex. The sampling was random to obtain the length distribution for both species by sex. Monthly length size distributions by sex, division and depth strata of two hake species were obtained for the whole period. Annual length distributions of *M. hubbsi* and *M. australis* for the period 1989-2000 are presented in Annex I. The biological sampling was stratified in order to obtain, a wide coverage of all length classes. Length, sex, maturity stage, weight, and stomach fullness were recorded as routine by the observers.

The number of length and biological samples of hakes (around 100 specimens were measured in each sample when possible) recorded from 1989 to 2001 and checked to be integrated in the general database is given in Tables 10 and 11.

Table 10. - Length samples of target species by IEO observers (1989-2001)

	Year												
SPECIES	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
M. hubbsi	468	282	413	187	159	93	39	55	144	158	157	173	191
M. australis	21	4	45	3	53		12	2		1	8	22	17
Total	**489**	**286**	**458**	**190**	**212**	**93**	**51**	**57**	**144**	**159**	**165**	**195**	**208**

Table 11. - Biological samples of target species by IEO observers (1989-2001)

	Year												
SPECIES	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
M. hubbsi	548	279	457	200	211	119	67	63	148	160	168	182	248
M. australis	21	5	38	17	83	4	51	12	1	3	10	28	35
Total	**569**	**284**	**495**	**217**	**294**	**123**	**118**	**75**	**149**	**163**	**178**	**210**	**283**

3.2. Determine the size composition of the non-target species (Patagonian toothfish, Kingclip, Hoki, Red cod, Southern blue whiting, etc.)

Length and biological samples of patagonian toothfish, kingclip, hoki, red cod, southern blue whiting, loligo and illex were made periodically and in the case of cephalopods they were made separately by sex. Length samples were made randomly to obtain the length distribution for each species by sex. Overall length distributions of non-target species for whole the period 1989-2000 are presented in Annex I. The biological sampling was stratified in order to obtain a wide coverage of all length classes. Length, sex, maturity stage, weight, and stomach fullness were recorded as routine by the observers.

The number of length and biological samples recorded from 1989 to 2001 and checked to be integrated in the general database is given in Tables 12 and 13.

Table 12. - Length samples of by-catch species by IEO observers (1989-2001)

	YEAR												
SPECIES	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
M. magellanicus		2		39	32	32	20	40	60	62	84	88	174
G. blacodes		5		13	76	36	6	41	65	67	56	50	95
S. australis		3		48	78	29	30	43	25	44	50	48	80
M. australis		10		18	35	19	34	54	12	24	10	43	99
D. eleginoides				4		2		8	2	15	4	18	30
S. brasiliensis								1		6		13	2
Notothenia													125
Raja sp.										1	2	3	
Loligo	545	278	276	306	187	316	234	318	99	130	204	130	108
Illex	195	244	63	96	63	79	26	56	158	88	90	134	145
Total	**740**	**542**	**339**	**524**	**471**	**513**	**350**	**561**	**421**	**437**	**500**	**527**	**733**

Table 13. - Biological samples of by-catch species by IEO observers (1989-2001)

	Year												
SPECIES	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
M. magellanicus		2	7			18		8	3	8	16	24	105
G. blacodes		5		3		3		3	4	11	8	19	83
S. australis		4	4	2		5	1		1	5	12	8	85
Micr. australis		4	9			4		1	1			2	79
D. eleginoides												16	24
S. brasiliensis												1	
Notothenia								3					13
Loligo	522	283	301	245	166	180	136	268	80	79	126	98	82
Illex	205	204	25	90	55	50	36	52	142	96	80	122	135
Total	**727**	**502**	**346**	**340**	**221**	**260**	**173**	**335**	**231**	**199**	**242**		

In order to have information on a bigger number of species, for 2001 the instructions given to the observers were revised. Instead of requiring length-frequency and biological data from selected non-target species, the requirement was changed to collecting data from one non selected by-catch species from the catch, chosen at random, from one haul every day. Fifty specimens should be measured. If less than 50 specimens are present, data should be collected from a second species (also chosen at random) and so on until 50 specimens in total have been measured from that haul.

3.3. Calculate the length-weight relationships of the main exploited species, and study the variations of these relationships with time and space

Length-weight samples were made by the observers during the same period to obtain the length-weight relationships of the main exploited species. To estimate these relationships, observers weighed and measured individuals fish and squid before they were processed. The study of the variations of these relationships with time and space was made to obtain a mean length-weight relationship for each species and for the studied period.

3.4. Study the spawning seasons and areas of hake using maturity data. Creation of an age-length key for hake on the Patagonian shelf by reading otoliths

Work related to this subtask was initiated in 2001 to study the spawning seasons and areas of target species by using maturity data. Mapping of maturity stages produced by AU using observer data are shown in Figure 7, by plotting spatial and temporal patterns of occurrence of large fish (from length-frequency distributions) and occurrence of mature fish (from biological data)

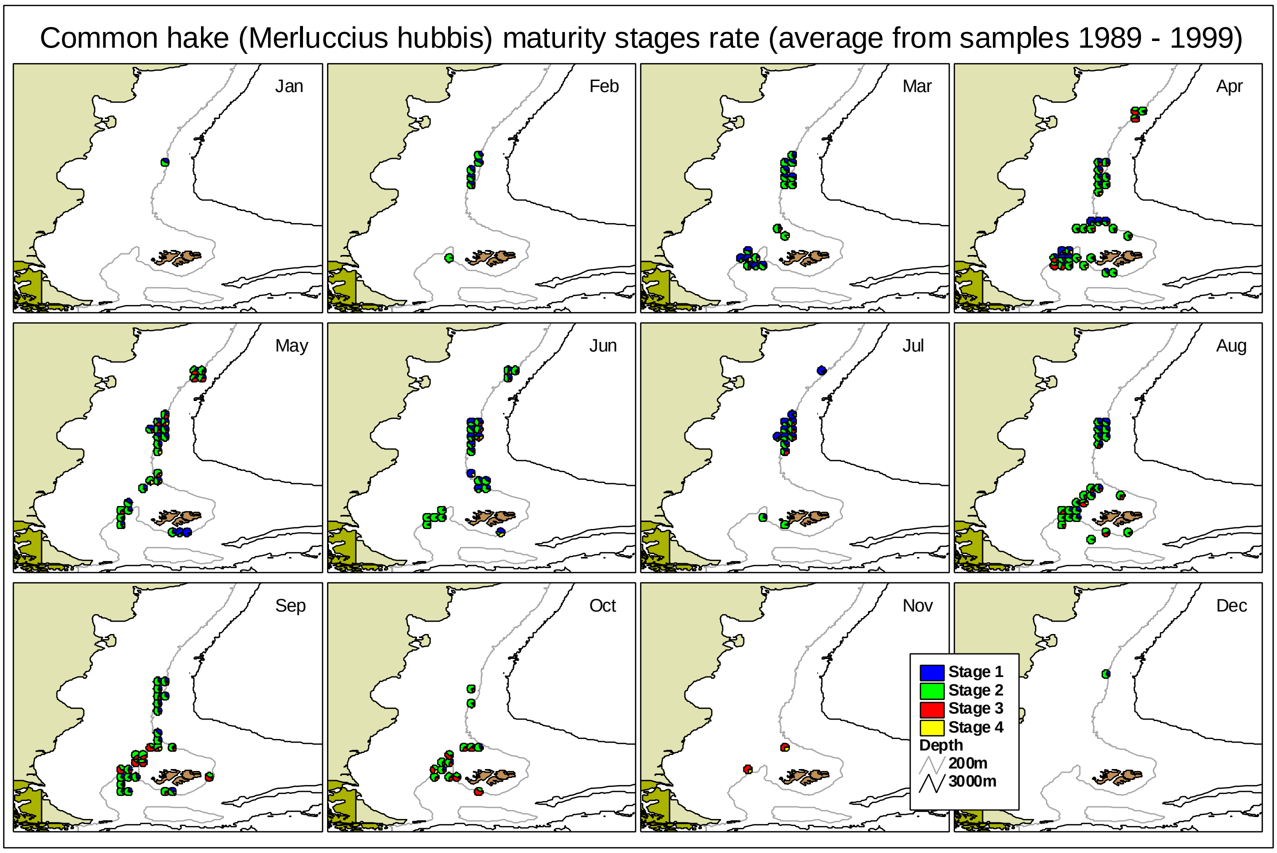


Figure 7. *Merluccius hubbsi* maturity stages (Spanish data)

<u>Distribution, maturity and migratory patterns of hakes (*Merluccius hubbsi* and *M. australis*) in Falkland waters.</u> *<u>(See Annex II for a more detailed description)</u>*

The overall distribution of both *Merluccius hubbsi* and *M. australis* in 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* (Podesta, 1990, 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).

Historically all vessels licensed to fish in the Falkland Conservation Zones have reported the total catch of both hakes together, making it difficult to separate catches by species. To investigate the monthly patterns in the distribution of the hake species we therefore used only the data collected by scientific observers. Catches were plotted for each month over the years 1988 – 2000. Data collected by FIFD and IEO observers were analysed separately to avoid possible bias in sampling protocols etc. The proportion of individuals at each maturity stage was also assessed on a monthly basis, separately for males and females, using aggregated data from 1988 to 2000.

Aggregated (over all years) plots of haul by haul CPUE of both sets of data show similar monthly patterns. Thus the IEO data is broadly in line with the suggested migration patterns based on the

FIFD observer data. CPUE on the shelf area east of the Argentine EEZ at 45 – 46°S shows a similar monthly pattern to that seen in the FICZ, in particular lower CPUE in December/January, suggesting that migration patterns to and from these areas are quite similar.

The majority of records of *M. australis* are from the deeper shelf area between the 200m and 500m contours in the south-west of the FICZ. However, *M. australis* is also encountered in small numbers over the shallower shelf in the north-west of the FICZ and right round the 200m contour, including some recorded occurrences in international waters as far north as 45°S.

M. hubbsi is abundant between the 150 and 300 m depth contours everywhere on the shelf and shelf edge around the Falkland Islands, and on the High Seas. Significant number of animals occur in the area southeast of the Islands (*Loligo* box) and there are also some records of *M. hubbsi* occurrence in shallow waters (<150 m).

Conclusions on distribution, maturity and migratory patterns of hakes

1. Both hake species utilise Falkland's waters as their feeding grounds and are most abundant in the ecotone zone to the west of the Islands.
2. Their feeding seasons, however, are different: *M. australis* appear in the FICZ in August, feed in summer-autumn, with highest catch rates in February-May prior to their departure to spawn, whereas *M. hubbsi* appear in the FICZ in February and feed in autumn-spring.
3. *M. hubbsi* utilise the Falkland shelf more extensively than *M. australis*, being abundant over the entire shelf area including south-east of the Islands, whereas *M. australis* tend to occur in the western part of the FICZ.
4. Their spawning seasons are also different – the austral winter for *M. australis* and the austral summer for *M. hubbsi.*

Growth of hake from Falkland Islands waters. *(See Annex III for a more detailed description)*

The two hake species caught in Falkland Islands' waters have very different size distributions. *M. australis* are commonly 60 – 80 cm total length whilst *M. hubbsi* are usually 30 – 60 cm.

Using ages from otoliths collected in November the difference in size at age in male and female *M. australis* is not quite significant at the 5% level (F = 1.8219, p = 0.05264). In contrast, the difference in size at age in male and female *M. hubbsi*, using otoliths sampled in April, is highly significant (F = 17.163, p < 2.2e-16).

Standard von Bertalanffy growth curves were fitted to the size at age data to summarise the pattern of growth in the two hake species. All otolith readings in the period 1988 – 2000 were used. Assuming a birth date of 1 July, the sampling date of the otoliths was used to adjust the fitted age to take account of growth since the last growth marker was laid down.

Fitted growth curves for *M. australis* were obtained and adjusted with the fitted coefficients for the von Bertalanffy growth curves. For both sexes size at age appears to be larger for fish from Falkland's waters than in Chilean waters. Size at age for males from Falklands waters is comparable with that in New Zealand waters but females in Falkland's waters are smaller.

Adjusted size at age data and the fitted growth curves for *M. hubbsi* were also found. Fitting the von Bertalanffy growth model using non-linear least squares does not yield especially good fits for either sex. The fitting process fails to converge for the male size at age data, whilst the fit to the female size at age data is acceptable but does not reach an asymptote within the size range sampled.

Two studies of the growth of *M. hubbsi* from the Argentine fishery have reported rather different growth curves. In females and smaller males, size at age for fish sampled in Falkland's waters is more or less bracketed by the two Argentine growth curves, though it is closer to the growth pattern reported by Rojo and Silvosa (1969). However all males larger than ~60cm total length fall outwith the size at age curves from Argentine waters. Furthermore there is evidence of a discontinuity in the size at age data for fish sampled in Falklands waters. Male *M. hubbsi* greater than 60cm total length are very rare indeed. Otolith sampling by FIFD observers is non-random, so it is not unreasonable for extremely large (or small) fish to be over-represented in the size at age data in comparison to their real occurrence in the population. However, another possibility is that the large male *M. hubbsi* in the otolith data are actually mis-identified *M. australis*.

For both species there is considerable variability in size at age that limits the value of fitted growth curves. Raw age-length keys for the two species, based on all otoliths collected by FIFD observers from 1988 – 2000 were obtained.

Otolith readings and age-length keys for hake species made by FIGFD in previous years and during the current project were provided and used in the assessment workshop held in London in July 2001.

3.5. Acquisition of data on trophic relationships of the target hake species from stomach contents of hake, Patagonian toothfish, kingclip, hoki, red cod, Southern blue whiting and marine mammals

Spanish fishery observers working in International Waters and around the Falkland Islands have collected stomachs from several fish species (target and by-catch). The sample material was frozen on board and transported to Vigo; then was sent to the University of Aberdeen for analysis.

For 2001, observers were provided with more detailed instructions about labelling of fish stomach contents samples. The targets set for sample collection included further hake samples from both Falklands and international waters, and also the main predator species. Observers also received instructions to retain stomach contents samples of any marine mammal by-catches. (none were obtained).

Stomach contents analysis. *(See Annex IV for a more detailed description)*

Introduction

The trophic relationship between predatory fish and the trophic position of predatory fish in the South West Atlantic ecosystem are poorly understood, but are of great importance to fisheries management (Velasco and Olaso, 1998), where it is useful in understanding the patterns of resource use, intra specific competition and the influence of predatory fish on the abundance and recruitment of other marine organisms (Du Buit, 1996).

The migratory behaviour and trans-boundary distribution of many commercial finfish and squid species in the South West Atlantic make them vulnerable to both natural and man made variations in prey availability, where a decrease in prey availability either from natural fluctuations or over fishing, in one area can also result in a decrease in the predator population, thus resulting in a cumulative decrease in fish numbers throughout its region of distribution. Due to the trans-boundary distribution of several species this cumulative decrease can also be a result of poor management strategies in neighbouring countries.

An understanding of the diet of these migratory species will enable these fluctuations to be incorporated into fisheries management strategies resulting in better management of these migratory fish stocks.

With the exception of *Merluccius hubbsi* little is known about the biology of these species in the South West Atlantic although studies on Hoki and Kingclip in New Zealand waters and South African waters have been carried out (Clarke, 1985,). Studies on common hake are limited to Argentine/Uruguayan waters (Ruiz and Fondacaro, 1997, Prenski and Bezzi, 1991, Ubal et al, 1987, Gaggiotti and Renzi, 1990, Arena et al, 1986, Otero et al, 1986). Data on the biology of commercial species found in Falklands waters is scarce (Norman, 1937, Wysokinski, 1974, Scott, 1982, Mouat et al, 2001, Arkhipkin et al, 2001, Janusz, 1986, Brickle et al, 2001,2001) although several studies are in progress.

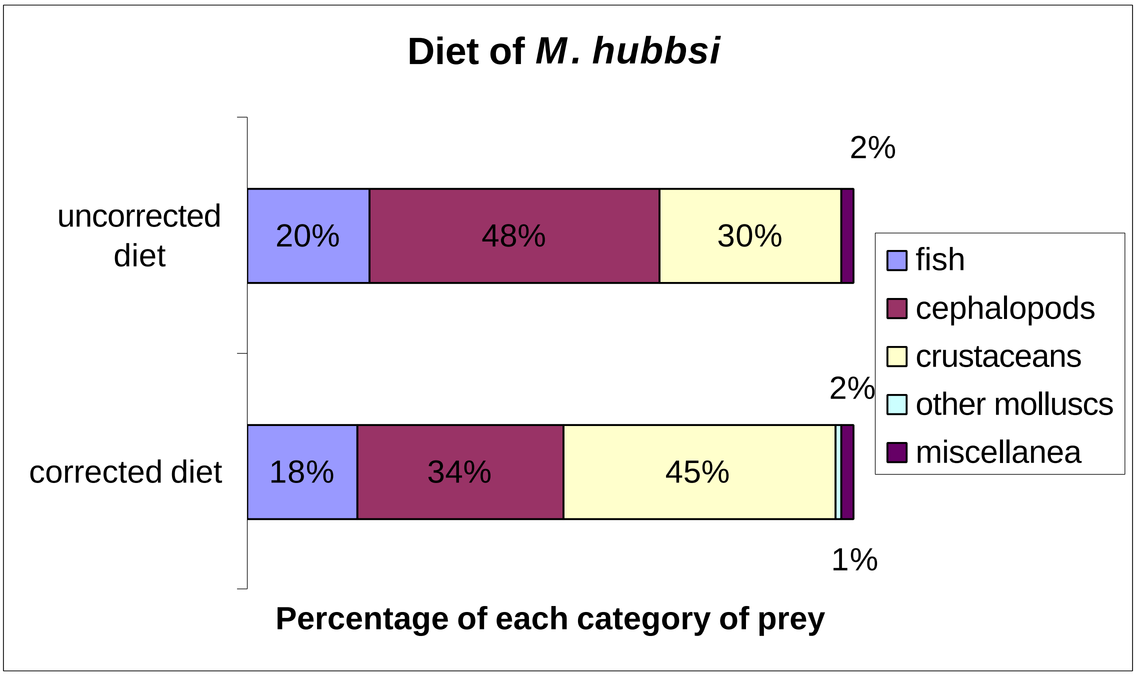
Material and methods

Stomachs from seven different commercial species were collected by fisheries observers whilst on commercial fishing vessels and research vessels operating in the Southwest Atlantic during 2000 and 2001. Of the 1590 stomachs analysed, 1020 came from *Merluccius hubbsi*, 264 from *Genypterus blacodes*, 94 from *Dissostichus eleginoides*, 91 from *Macruronus magellanicus*, 80 from *Salilota australis* and 41 from *Micromesistius australis australis* (Table 14). The stomachs were collected along with the animals' biometric data (length, weight, sex and maturity) for the majority of samples. On board the samples were deep frozen and returned to Vigo (Spain) where they were then transported to Aberdeen (Scotland) for further analysis.

During stomach analysis the full stomach weight (FSW) was noted along with both empty stomach weight (ESW) and contents weight (CW). The fullness of the stomach and digestive state of each of the prey items was also noted, with the contents identified to the lowest level of classification possible. With fish and cephalopods the otoliths and beaks were collected from prey items that could not be identified by eye, so positive identification could take place at a later date. All invertebrates were either placed in 70% ethanol or frozen for later identification, with only class being noted at this stage. In the case of squid, length, weight, sex and maturity was noted whenever possible. However if the squid was too well digested then lower beaks were kept for measuring lower rostral length (LRL). Total length can then be calculated with the use of allometric equations.

Table 14. Data on stomach contents analysis

	HAK	**KIN**	**TOO**	**WHI**	**BLU**	**BAC**
Number of Stomachs Analysed	1020	264	94	91	41	80
Number of stomachs containing net feeding	53	2	2	0	0	0
% net feeding	5.2	0.76	2.13	0	0	0
Number of empty stomachs	42	47	9	19	6	5
% Empty stomachs	4.12	17.8	9.57	20.88	14.63	6.25
Number of stomachs containing discard feeding	78	17	19	0	0	5
% Discard feeding	7.65	6.44	20.21	0	0	6.25
Number of stomachs removed from analysis	125	56	21	19	6	6
% of Stomachs removed from analysis	12.25	21.21	22.34	20.88	14.63	7.5
Mean number of prey categories in the stomachs	1.06	1.44	1.23	1.22	1.03	1.72



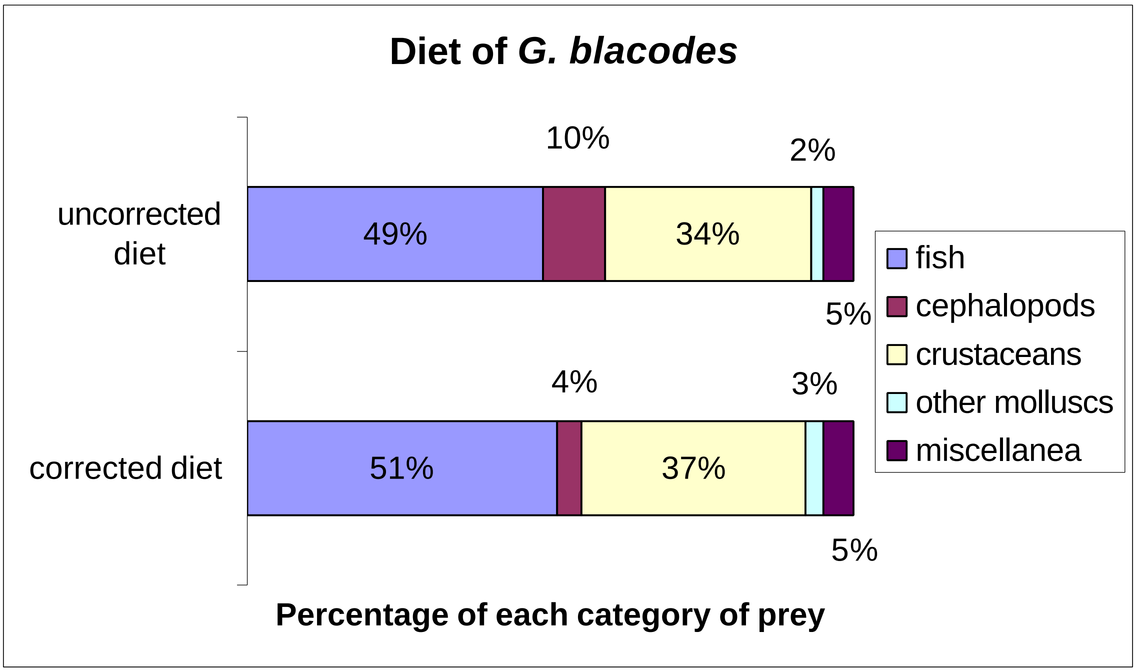


Figure 8. Percentage frequency of each prey category in the diet of *Merluccius hubbsi* (upper) and *Genypterus blacodes* (bottom).

Results and Conclusions

Prey identification indicated the presence of the squid *Loligo gahi* and *Illex argentinus*, the crustaceans *Munida gregaria*, *Cirriolus* sp. and the fish *Patagonotothen* spp.

Overall diet composition was not greatly affected by exclusion of data from stomachs thought to represent net or discard feeding. For *M. hubbsi*, the relative importance of crustaceans (which are unlikely to be taken during net feeding or discard feeding) increases in the adjusted diet.

The diet of *M. hubbsi* consists of three main categories of prey: fishes, crustaceans and cephalopods. The fish taken include anchovies, hakes, notothenids, myctophids and southern blue whiting. The crustacean species eaten are macrozooplanktonic species, euphausids and amphipods. The cephalopods eaten were squids, including the two commercially important species, *Illex argentinus* and *Loligo gahi*. The diet of *G. blacodes* comprises nekton (more than 50%) and fish, e.g. *Patagonotothen* sp. (Figure 8).

Of all species studied only Southern blue whiting showed no ontogenetic change in diet with predator length. This is probably due to the high abundance of its prey in the southwest Atlantic (Euphausiids and Hyperliid amphipods) pelagic region. The ontogenetic changes shown in all other species studied are thought to help regulate the competition between juveniles and adults for food (Ubal, 1986). The changes in diet between areas show that predatory fish are feeding on locally abundant prey items, with heavy reliance on a few species, such as Notothenid fish, *L. gahi* and *I. argentinus*. The cyclical migratory behaviour of many of the prey items either along the Patagonian shelf (such as *E. anchoita*, *S. fuegensis*, *I. argentinus*) or by depth (*L. gahi*, *M. ingens*) has resulted in the non-migratory and abundant notothenid fish being the dominant prey item for all species studied bar Southern Blue Whiting. Migratory species only occur in the diet when they become locally abundant and available to the predator. This results in predatory fish having narrow niche breadth ranges but with a few prey species having a high index of relative importance.

The impact of predation on the high seas and around the Falkland Islands is limited due to the fact that most predation mortality occurs in fish of a young age. Due to the distribution patterns of different year classes of common hake and other predatory fish within the southwest Atlantic. Immature fish tend to be found in shallow waters along the Patagonian shelf away from the targeted areas of commercial fishing vessels used in this study, thus resulting in little or no natural mortality in hake in these areas. Predatory interactions between these species (other than *M. australis* and *M. magellanicus*) are also small in the study area, however seasonal studies on the diet of predatory fish in and around the Falkland Islands may result in showing increased predation on commercial fish such as Southern blue whiting which use this area to spawn (as seen in the predation of southern blue whiting by *G. blacodes* in New Zealand waters).

A high level of dietary overlap seems to exist between different commercial fish species in the southwest Atlantic, this being a result of the dependency on few prey species. This report only shows a slight insight into the trophic relationships in the southwest Atlantic. Seasonal data may well reveal that although these fish are feeding on the same prey items they may well become available to them at different stages of there migration so that there is no direct competition for prey.

Morphological variability in the South Atlantic stocks of common Hake, M. hubbsi.

Introduction:

The use of morphometric and meristic characters as a tool used for defining population units has been used successfully on several occasions, with meristics and morphometrics being used to identify or differentiate between genera, species, sub species, groups within species and individuals (e.g. Boetius, 1980, Fridriksson, 1958, Pierce et al, 1994, Tudela, 1999, Bolles and Begg, 2000). Meristic characters are enumerable morphological features such as fin rays, gill rakers and vertebrae, where as morphometric characters are those obtained by measurements of body parts.

Morphometric and meristic differences arise when populations are relatively discrete with relatively little genetic flow allowing the two populations to differ phenotypically, these differences can also arise from differing environmental conditions in each geographic area (Mamuris et al, 1998).

In the southwest Atlantic spawning of *M. hubbsi* is thought to take place in two areas. The Bonaerense spawning ground in the waters around Uruguay (Autumn spawning) and of the coast of Argentina (PLACE) (summer spawning) (Otero et al, 1986). *M. hubbsi* is a migratory species with migrations along the coast and into deeper waters linked to the Brazil/ Falklands confluence and areas of localised upwelling, where food is abundant.

Previous studies pertaining to the use of morphometric variability in *M. hubbsi* in Argentine/Uruguayan waters as a tool for stock distinction have resulted in the identification of 3 possible stocks existing in the south Atlantic (Perrotta and Sanchez, 1992), with stock one found above 42º S in the Rio Plata region, stock two found between 44-48º S in the Golfo san Matias region and stock three found below 48º S around the Falkland islands and southern Patagonia (spawning area unknown). Other studies have indicated the presence of only 2 stocks (Sardella, 1984) where the northern stock was found above 42º S and the southern stock was found below 42º S.

This study discusses the results of a morphometric and meristic study of common and Patagonian hake from the high seas of the southwest Atlantic and from around the Falkland islands, with the aim of determining the presence or absence of more than one stock of *M. hubbsi*.

Materials and Methods

Sampling and sampling measurements:

Samples of whole hakes where collected from fishing vessels operating in the high seas of the Southwest Atlantic and from around the Falkland islands during 2000 and 2001. Samples were frozen and stored until analysed. Analysis took place in either IEO Vigo (Spain) or at Aberdeen University (Scotland).

External measurements including total length were taken from hake from all areas along with counts of fin rays. Internal measurements of bone from the head region were also taken for each of the fish. Scales were also removed from each fish from the same area (above the lateral line near to the operculum). Tables 15 and 16 show the list of morphometric measurements and meristic counts taken respectively.

Statistical analysis:

Using the statistical package MINITAB the data was screened for errors using regression analysis to detect any outliers, with any errors encountered corrected through reference to original data sheets. The original morphometric measurements of body variables were standardised using Total length, thus normalising the individuals in a sample to a single arbitrary size common to all samples. Standardisation of the fish morphometrics was carried out using a general linear modal to find the slope for each particular measurement (Table 17). The following equation was then used to find the standardised measurement for each of the variables.

$$Y^1=Y-bX$$

Where Y is the original observation, b is the slope and X is the total length.

Principle component analysis (PCA) of the morphometric measurements was then carried out using the first two components on both the raw data and standardised data for the external measurements, internal measurements and scale measurements separately and all measurements combined.

Table 15 Morphometric measurements taken from *M. hubbsi* and *M. australis* in the Southwest Atlantic.

Number	Code	Measurement (cm)
EXTERNAL MEASUREMENTS		
1	**AM**	Total Length
2	**AK**	Precaudal Length
3	**AE**	Head Length
4	**NO**	
5	**CD**	Eye Diameter
6	**OP**	Interobital Distance
7	**PQ**	Distance from Preorbital
8	**AF**	Predorsal Length
9	**NS**	Prepectoral Length
10	**NQ**	Pectoral fin Length
11	**QR**	Distance to 1st Dorsal fin
12	**FG**	Distance to 2nd Dorsal fin
13	**HI**	Length to Anal fin
14	**ST**	Length of Mouth
15	**AB**	
16	**XX**	Body Height
17	**YY**	Height of Caudal
18	**ZZ**	
SCALE MEASUREMENTS		
19	**SL**	Scale Length
20	**SW**	Scale Width
INTERNAL MEASUREMENTS		
21	**DLL**	Dentary Lower Length
22	**DH**	Dentary Height
23	**DUL**	Dentary Upper Length
24	**ML**	Maxilla Length
25	**MH**	Maxilla Height
26	**PML**	Pre-maxilla Length
27	**PMNH**	Pre-maxilla nose Height
28	**VW**	Vomer Width
29	**CW**	Cranium Width
30	**CH**	Cranium Height
31	**PTLL**	Post-temporal length
32	**PTSL**	Post-temporal length
33	**PTD**	Distance between post-temporal lengths
34	**OSL**	Opercular Length
35	**OCL**	Opercular Length
36	**OD**	Distance between Opercular Lengths

Table 16 Meristic counts taken from *M. hubbsi* and *M. australis* in the Southwest Atlantic

Number	**Code**	**Count**
EXTERNAL COUNTS		
1	**FRA**	Number of 1st Dorsal fin rays
2	**FRB**	Number of 2nd Dorsal fin rays
3	**FRC**	Number of Anal fin rays
INTERNAL COUNTS		
4	**DTOO**	Dentary Tooth count
5	**PTOO**	Pre-maxilla Tooth count
6	**VTOO**	Vomer Tooth count

Table 17 Slope coefficient for each morphometric measurement.

Number	Measurement	Slope Constant
EXTERNAL MEASUREMENTS		
1	Total Length	-
2	Precaudal Length	-11.530
3	Head Length	7.495
4		-1.053
5	Eye Diameter	4.7173
6	Interobital Distance	11.082
7	Distance from Preorbital	-0.341
8	Predorsal Length	1.027
9	Prepectoral Length	-24.328
10	Pectoral fin Length	-0.649
11	Distance to 1st Dorsal fin	8.891
12	Distance to 2nd Dorsal fin	-7.814
13	Length to Anal fin	16.08
14	Length of Mouth	26.03
15		3.145
16	Body Height	-15.669
17	Height of Caudal	3.372
18		-9.216
SCALE MEASUREMENTS		
19	Scale Length	1.4169
20	Scale Width	0.6497
INTERNAL MEASUREMENTS		
21	Dentary Lower Length	1.2585
22	Dentary Height	0.0233
23	Dentary Upper Length	0.7048
24	Maxilla Length	0.6329
25	Maxilla Height	0.08738
26	Pre-maxilla Length	0.8855
27	Pre-maxilla nose Height	0.14995
28	Vomer Width	0.2302
29	Cranium Width	0.9059
30	Cranium Height	0.1201
31	Post-temporal length	0.4766
32	Post-temporal length	0.1505
33	Distance between post-temporal lengths	0.5184
34	Opercular Length	0.3711
35	Opercular Length	0.4866
36	Distance between Opercular Lengths	0.4815

Results

The results of PCA for both the raw and standardised data show varying degrees of overlap, however there is enough separation to indicate a difference between those common hake collected from around the Falkland Islands and those collected from 42ºS and 46ºS. Patagonian hake also shows slight overlap with Common Hake although greater separation is observed.

The greatest degree of separation is observed in the PCA of the raw data from external measurements where

3.6. Data analysis and provision of data to task 6.

Fishery, biological and environmental data (SST, bathymetry, sea surface level residual, SBT, SSS, SBS) from 1989 – 1999 were used in the data analysis in Vigo and Aberdeen to estimate average CPUE and length distributions by species and area. Data processing is on progress to obtain relevant outputs to perform environmental modelling and provide information to task 6.

Fishing locations and observed effort was analysed by area, as well as abundance by species and interspecies comparisons. A more detailed description of data analysis is given in the GIS section.

Task 4: Catch and effort data

4.1. Estimate the monthly CPUE by species in international waters and inside the FICZ. *(See Annex V for tables and graphics)*

ANAMER has provided historical data on catches 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 fishing fleet in those fishing grounds (Table 18). ANAMER also collated information on effort of its fleet from the same period that allowed the estimation of the total effort by the Spanish fleet in the mentioned area.

All the information collected was processed in a database in order to get CPUE estimations based in commercial activity. Conversion factors, provided by the IEO, were introduced in spreadsheets with data landings to obtain target species catches estimations. All tasks related with information checking and estimations were carried out by MG Otero, ANAMER's subcontracted company in charge of these activities.

Hence, ANAMER has provided to the project data of three different types:

? Landings. - Landings in kg of target and by-catch species by commercial category have been provided by ANAMER. The commercial categories used are the different market sizes present in the Spanish Market to consumers and frozen seafood industry. These data have been checked and introduced in spreadsheets to produce finally results of monthly and yearly landings by species and commercial category. The historical series goes from 1983 to 2000. Further estimations have permitted to transform these landings of processed commercial categories into whole fish weight by means of conversion factors. Next, with conversion factors, based in the ANAMER share of the whole Spanish fleet operating in the area, the whole catch of hakes by the Spanish fleet was estimated (Figure 9).

? Effort. - Data on effort by boat and by month comprising historical series from 1983 to 2000 were provided by ANAMER. These data have been checked and introduced in spreadsheets to produce finally results of monthly and yearly effort in number of vessels and thousands of effort days (Figures 10 and 11). Further calculations based in the analysis of effort by vessel categories (TRB) provided effort data related to tonnage vessel size (Figure 12).

? Observer data. – Along the duration of the project, ANAMER provided 5 observers representing a total 600 observer days and 1520 hauls recorded. The observers collected fishery, biological and environmental information in accordance with instructions received by researchers from IEO, including length and biological samples as well as collection of samples (stomachs, otoliths, etc) following the instructions done by IEO researchers.

  ANAMER has also contributed to the project providing vessels to the embarkment of the observers and with the logistics for their deployment and transshipment in collaboration with its associated companies in Stanley (Sulivan Shipping Services and Atlantis) and its subcontractor in Vigo (M.G. Otero). M.G. Otero has also made the statistical treatment and analysis of the data to estimate monthly and yearly catch of the Spanish fleet, and effort by vessel and by ship categories (tonnage and power) in close co-ordination with IEO.

Table 18 Estimation of total Hake catch (kgs) by the whole Spanish fishing fleet (based in ANAMER data)

	YEAR															
MONTH	**1983**	**1984**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
JANUARY	0	55766	0	0	4571074	5321187	898512	0	3412384	4184801	1757110	2640313	2260733	1443364	4979736	6071174
FEBRUARY	0	234062	0	0	325413	914614	1599904	1209712	11476	4081	3111518	524772	1588510	0	0	11923
MARCH	0	140164	133164	815223	107913	68996	1846352	0	0	172188	614559	0	0	0	755802	1177738
APRIL	0	1050634	126155	405083	456458	933701	7606000	178160	1231657	218596	925462	1258393	247109	425837	1318392	0
MAY	2014455	1595597	100505	6265834	6018160	1229808	6522144	3606752	478103	3373925	2598038	5493721	353818	979013	1401657	904910
JUNE	1551387	608738	803935	14768920	4352120	7396412	5819072	15764928	655007	3101782	4554384	1587328	760389	1994614	1639713	14149
JULY	441280	480064	4086531	11112461	4983399	12510845	22885728	10511312	10453395	1306584	3042034	1022606	2036197	4698170	3039323	3291547
AUGUST	1455636	843817	7089128	4848110	3382139	18541493	6430288	13587072	2437281	3349713	1795758	913060	833083	2720292	591793	5306779
SEPTEMBER	526195	352722	6651735	8128933	1541972	13455326	11225520	289785	1756790	4453453	0	836431	1859163	0	4365779	712885
OCTOBER	411863	37565	3980557	6876985	9623999	7152921	7813984	2848458	138553	17528	2220877	1478006	0	2349980	0	565757
NOVEMBER	114986	1691245	6603034	7984032	16840403	23599568	11958528	10578195	759083	6083771	6204345	2774263	4553754	3572150	693948	0
DECEMBER	98412		785753	13313640	10337983	10560370	9243936	12248195	9358061	8681915	11845800	8449124	5476072	1808083	4222423	3310142
TOTAL	6614214	7090375	30360496	74519222	62541034	101685240	93849968	70822569	30691789	34948337	38669886	26978015	19968828	19991502	23008564	21367004

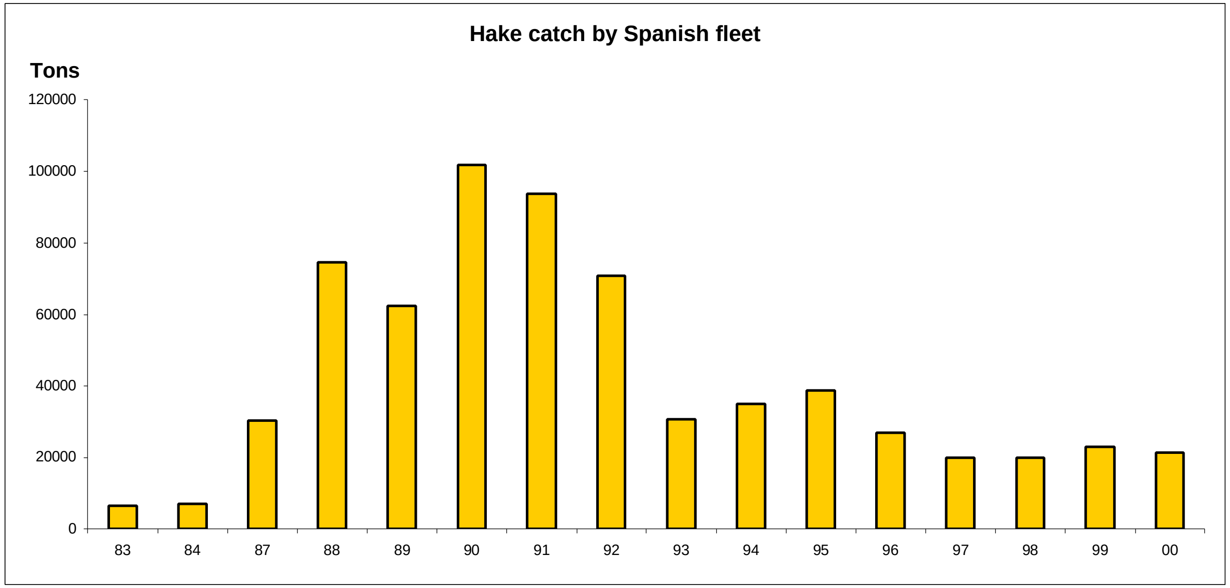


Figure 9. Estimation of total Hake catch (Tons) by the whole Spanish fishing fleet (based in ANAMER data)

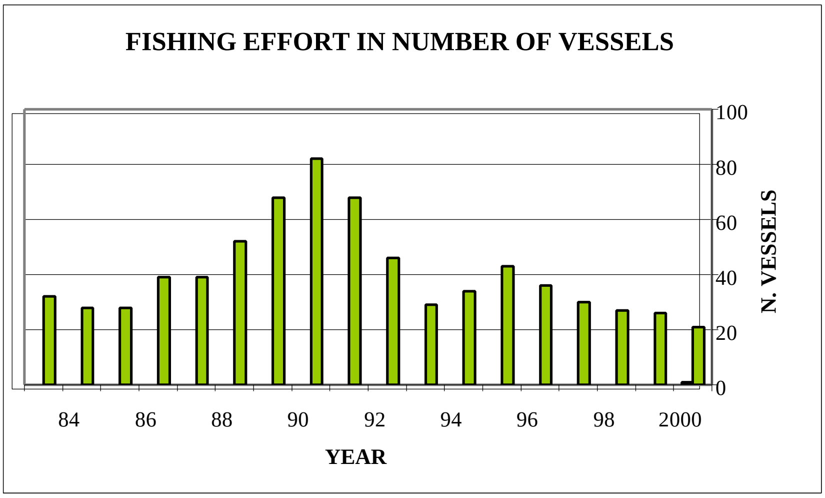


Figure 10. Fishing Effort in number of vessels

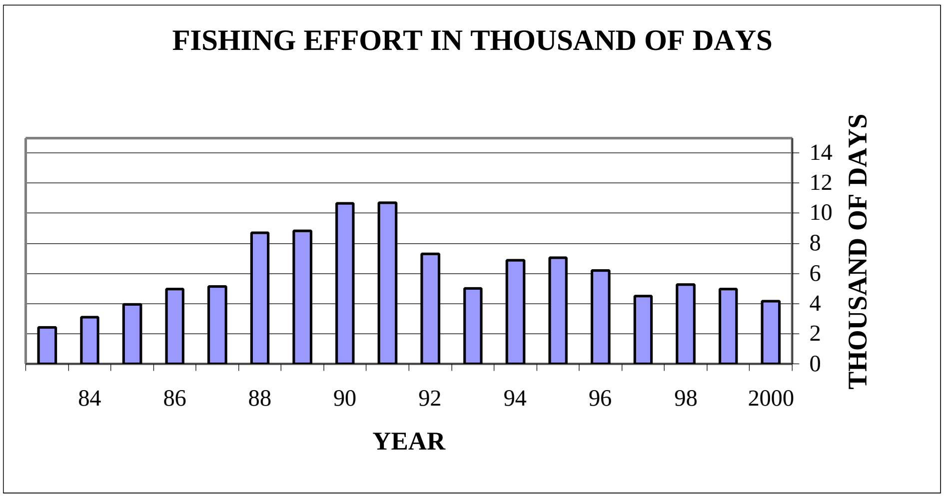


Figure 11. Fishing Effort in thousand of days

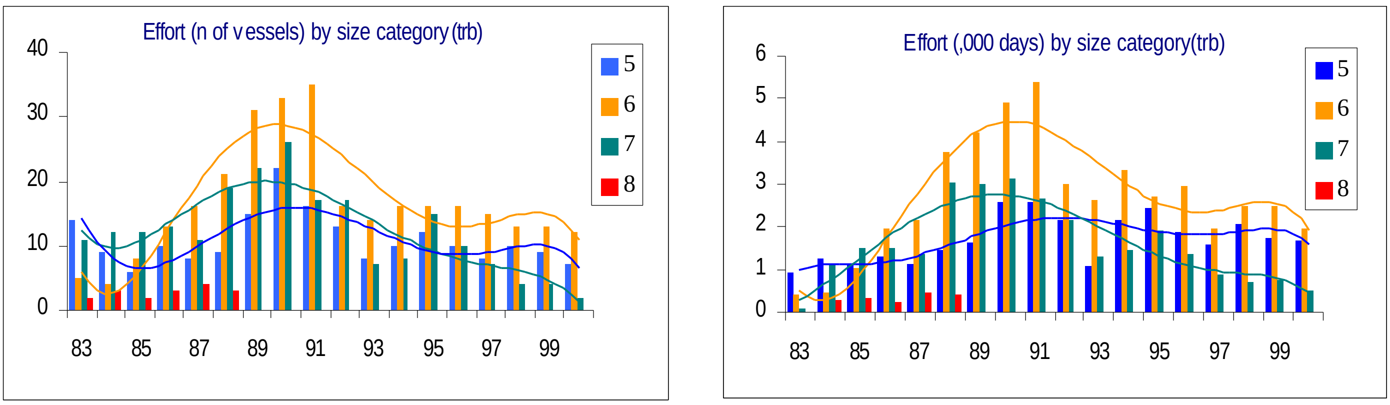


Figure 12. Trends in Fishing Effort by size vessel category in number of vessels and thousand fishing days. Vessel categories: 5 < 500 TRB, 6 > 500 < 1000 TRB, 7 > 1000 < 2000 TRB, 8 > 2000 TRB

4.2. compare the CPUE obtained in 4.1 with the data obtained by the on-board observers.

This work was carried out by AU team, with assistance from IEO team. Comparisons between CPUE estimations from on-board observers and from commercial data were made in year 2001. A database, based on MS ACCESS? , and a GIS (geographical information system), based on ARCVIEW? , have been developed for data assembly, integration and management. Environmental and fishery data have been integrated in the database and GIS. The GIS was used to describe and model effects of sea temperature and currents on hake distribution, condition indices and growth rates. *(See Annex VI for maps and graphics)*

DATA COLLECTION AND INTEGRATION

Environmental data

Environmental data from the area between 30ºS – 63ºS and 42ºW – 70ºW, including SST, bathymetry, sea surface level residual, SBT, SSS, SBS, wind direction and strength, and surface roughness, have been integrated in the database and GIS. Data were obtained from two sources: downloaded from the websites of data centres and from the fishery data provided by IEO (Vigo).

SST data

? Reynolds monthly mean SST data were downloaded from NCAR (National Center for Atmospheric Research, USA). The spatial resolution of the data is 1? longitude by 1? latitude. The data are the output of a model using remotely sensed data, survey data, and the distribution of ice. Data were integrated in the ACCESS database as tables, and in GIS as grids, contour lines at 0.5?C degree intervals, and point coverages.

? AVHRR weekly global gridded SST data (MCSST) images are downloaded from the NASA web site. The data are derived from the NOAA AVHRR for both the ascending pass (daytime) and descending pass (night time). The data are weekly composites in HDF (Hierarchical Data Format). The data are given on an equal-angle grid of 2048 pixels longitude by 1024 pixels latitude. The data are from 1982 and onwards.

Bathymetric data

? ETOPO5: 5-minute gridded bathymetry data for the world. These data were obtained from on-line access to NOAA National Geophysical Data Centre. This is the best bathymetric data available for the study area. The data covering the project area were integrated into the GIS and ACCESS database. The data were integrated in the ACCESS database as a table, and in the GIS as a grid.

? GEBCO (General Bathymetric Chart of the Oceans) bathymetry data for the world in vector structure. The contour lines are 0m, 200m, 500m, 1000m, and at 500m intervals subsequently. The GEBCO data were entered into GIS to construct the coastlines. The data were exported in DXF format and input in the GIS as a contour line coverage.

Sea level residual data

? Sea level residual data are downloaded from NASA web site. The data were defined as the sea surface height, minus the mean sea surface or the geoid, and minus the effects of tides and inverse barometric pressure. It is given by:

Residual Height = Sea Surface Height – Geophysical Surface – Tide Effects – Inverse Barometer

The data are 5-day averages with 1? longitude by 1? latitude spatial resolution. Data are from 1993 onwards.

Basic statistical analyses were carried out to calculate the monthly average sea level residual, variance, standard deviation, etc. The data, together with the statistical analysis results, were integrated in the ACCESS database as tables and in the GIS as grids, contour line coverages and point coverages.

Other environmental data

The other environmental data provided along with fishery data include SBT, SSS, SBS, cloud, wind direction and strength, fishing depth, and sea surface roughness.

<u>Fishery data</u>

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. IEO data refer to all hauls monitored by observers (i.e. a sample of total fishing effort). Observer effort varied from year to year.

<u>Fishing locations and observed effort</u>

The locations of hauls from 1989 to 2001 are displayed in Figures 1 and 2, and show that fishing activities are located in 3 areas. The North area is from 44?S northwards. The Middle area is between 44?S and 47? 30’S. The South area is from 47? 30’S southwards and the Falklands Islands area. 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 13 and 14 for IEO and FIGFD data separately.

<u>Fishery abundance</u>

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

Figure 3 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.

<u>*CPUE*</u>

Monthly CPUE (catches per unit effort, kg/hr) are 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. Regarding *M. australis* in the south area, CPUE increased from 1991, but dropped dramatically from 1996.

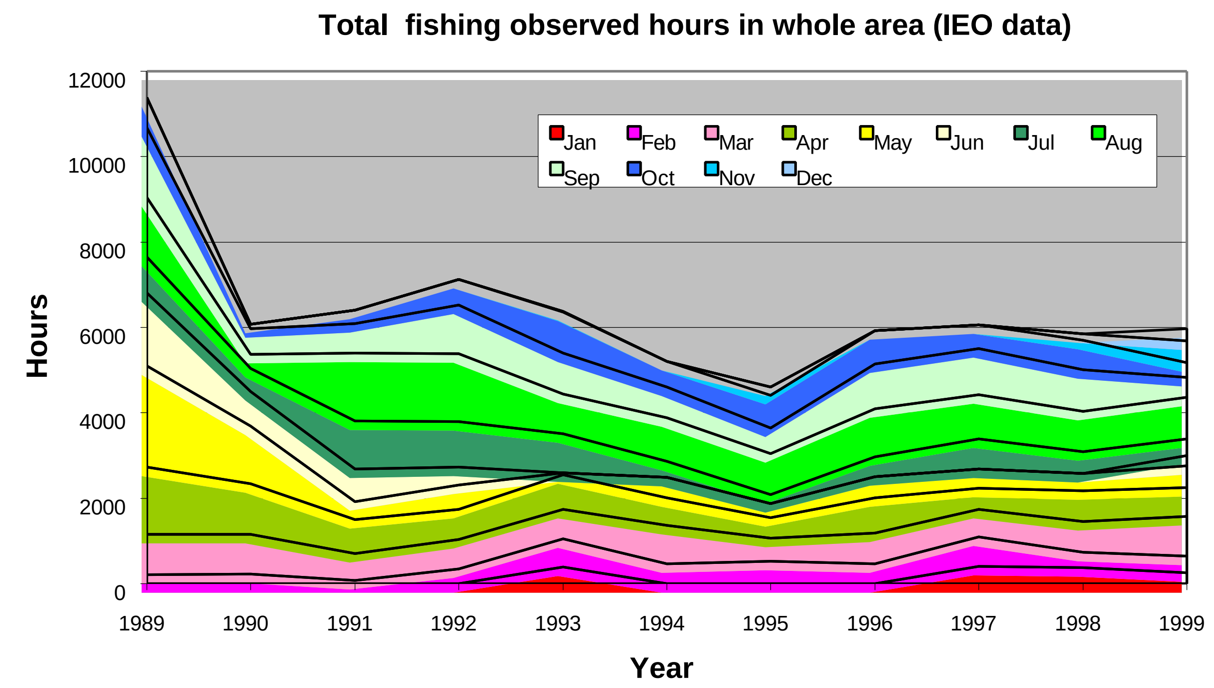


Figure 13. Total fishing observed effort in the whole area (IEO data)

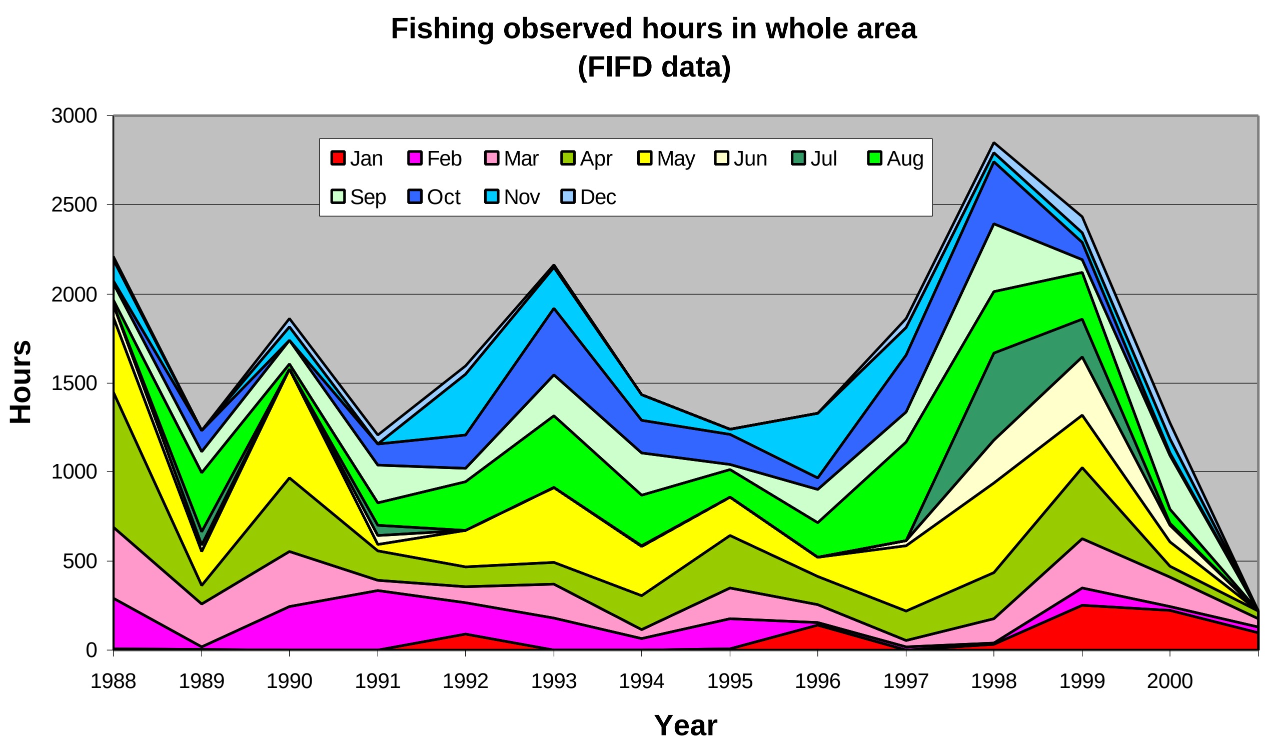


Figure 14. Total fishing observed effort in the whole area (FIGFD data)

The relationship between fishery abundance and environmental factors

Primary analyses have been carried out using GIS visualization and data exploratory methods, to visually analyse the distribution of fishery abundance (CPUE) in relation to meso-scale oceanographic factors using sea level residual (SLR) data and other environmental data such as SST. Data on SLR and SST were used to explore the possible impact of environmental factors on the spatial pattern of hake abundance and on migration. Long-term monthly and yearly mean SLR (1993–99), and the respective standard deviations (SD), based on 5-day mean SLR data, are calculated, integrated in the GIS and interpreted as grids.

The relationships between SST and hake CPUE were analysed visually. Long-term monthly average SST are calculated for 1989–99 and displayed as contour lines with 0.5? C degree intervals. Long-term monthly average CPUE was also calculated for 1989-99 and with a spatial resolution of 0.5? longitude and 0.5? latitude.

Analysis Methods

Spatial and temporal distribution of hake abundance, the spatial and temporal fishing pattern, and the environmental influence on fish distribution are analysed. Spanish (IEO) fishery data and FIGFD fishery data are used in analysis. Firstly, we calculate the ratio of hake catches to total catches of all species by each haul, and define the hauls as hake target hauls if the ratio is equal to or greater than 0.5. CPUE is used as fish abundance index, which is calculated by total hake catches subdivided by total fishing hours of each haul. Monthly mean CPUE is also calculated by summing hake catches divided by the sum of hours at 0.5 by 0.5 degree rectangle.

Visual and statistical analyses are carried out to understand the spatial and temporal fishing patterns, such as the distribution of hake target fishing area, the spatial and temporal trend and shift of fishing effort, spatial and temporal changes of the ratio of hake target fishing effort to total fishing efforts, the spatial and temporal changes of the ratio of hake catches to total catches of all species.

Visual analysis is based on a geographical information system (GIS), which is developed with support of ESRI (Environmental Systems Research Institute, Inc) GIS software ArcView®. Fishery data are imported from the Access database into ArcView® using SQL (structured query language), and integrated in the GIS as shapefiles. Both monthly total fishing hours and hake target fishing hours of all recorded hauls at 0.5 by 0.5 degree rectangle are calculated and displayed in time-series maps. Time-series maps of fishing hours by single hauls with different hake catch ratio from 0 to 1 are also made. Correlation is calculated between fish abundance and environmental factors, and between fishing efforts in different sub-areas, for investigating the influence of marine environment on fish abundance and distribution, and the trend of fishing activity.

Results and discussion

4.2.1. Fishing locations and efforts

4.2.1.1 IEO data

The fleet fished in three separate areas, as shown in Figures 1 and 2, the north area, which is also defined as area 42, the middle area, which is also defined as area 46, and the south area, which is around the Falkland Islands. As listed in Table 19 Spanish (IEO) fishery data include 15343 recorded hauls in total. 1151 recorded hauls, i.e. 7.5 percent of total hauls, in the north area. 5474 recorded hauls, i.e. 35.7 percent of total hauls, in the middle area. 8718 recorded hauls, i.e. 56.8 per in the south area. Although there are more than 50 percent of hauls are located in the south area, only 7.21 percent of hauls are hake *Merluccius hubbsi* target. Whereas, 53.71 percent of hauls are hake target in the middle area, and 14.30 percent hauls are hake *Merluccius hubbsi* target in the north area.

Spatial shift of hake *Merluccius hubbsi* fishing locations in different seasons, as shown in Figure 15, is remarkable. Very limited hauls are hake *Merluccius australis* target, as listed in table 19 and shown in Figure 16.

Table 19. Fishing hauls recorded by IEO (IEO data: 1989 – 1999)

Area	Total hauls	*Merluccius hubbsi* target		*Merluccius australis* target	
		Hauls	%	Hauls	%
North area	1151	164	14.2	0	0
Middle area	5474	2940	53.71	0	0
South area	8728	629	7.2	21	0.2
Total	15343	3733	24.3	21	0.14

Hake fishing are the major fishing activities in some months in the whole area, and middle area is the most important hake fishing site.

Spearman's rank correlation was calculated between monthly total fishing hours in the middle area and the south areas. Table 20 lists the results:

Table 20. Spearman's rank test

	Number of months	p-value	Correlation
Around year	98	0	-0.323
May, Jun. Jul. Aug. Sep.	41	0	-0.614

Correlation tests show significant negative correlation between hake target fishing efforts in the middle area and the south area, especially in hake fishing season in winter.

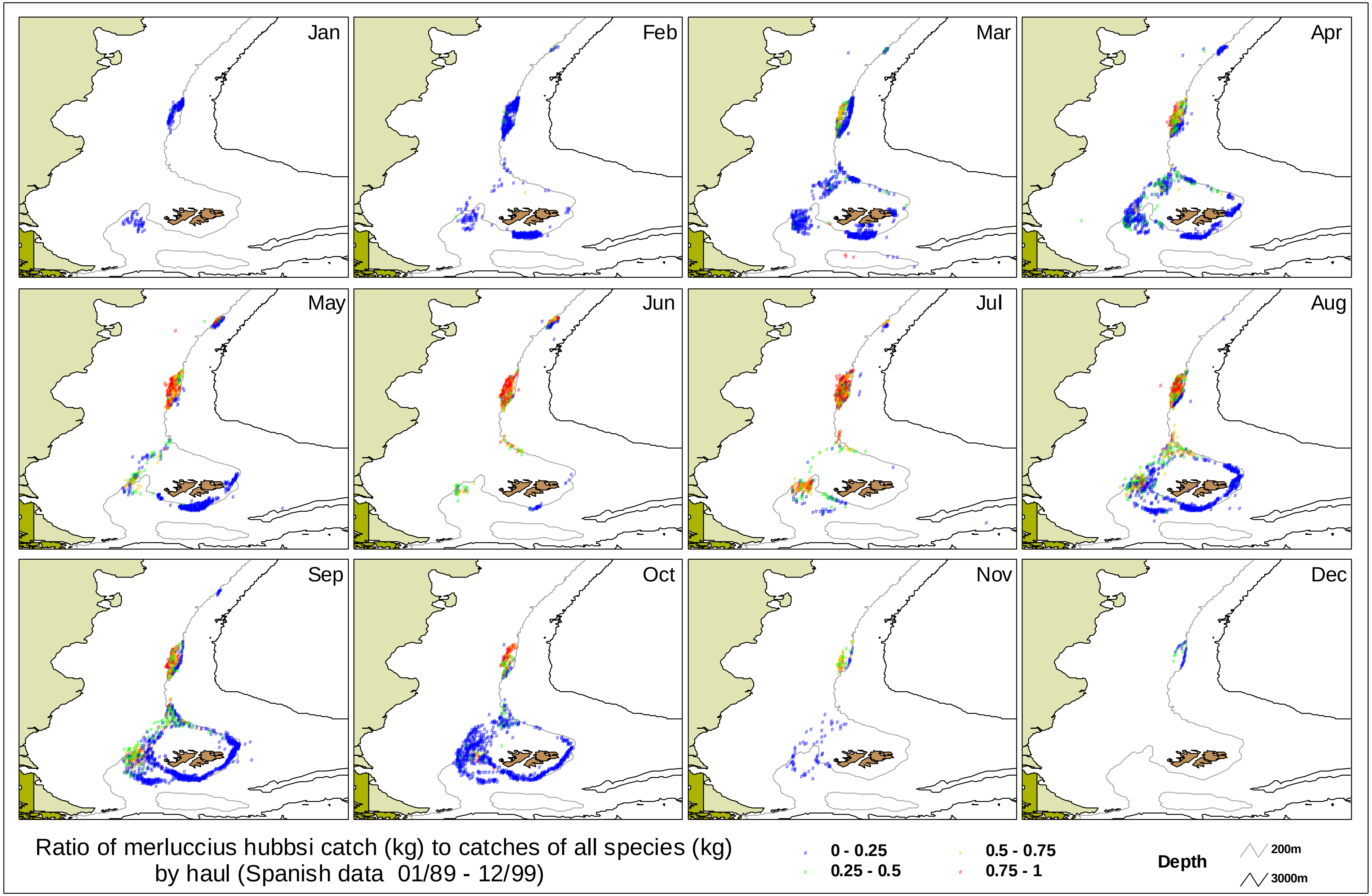


Figure 15. Ratio of *M. hubbsi* to catches of all species (Spanish data)

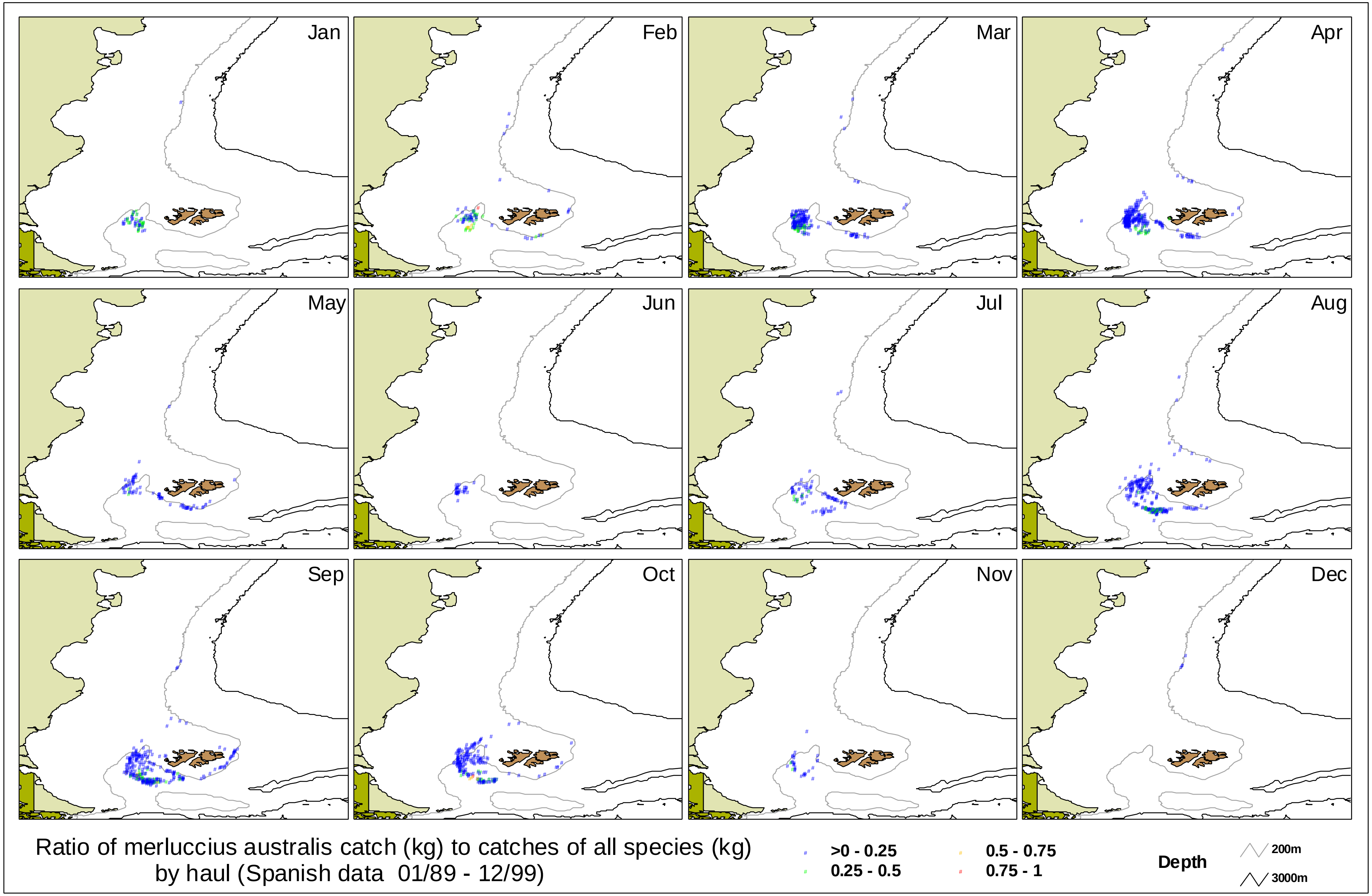


Figure 16. Ratio of *M. australis* to catches of all species (Spanish data)

4.2.1.2 FIGFD data

FIGFD data record comprises both Spanish flag vessels and other of different nationalities vessels fishing in this area. The data used in the project have 5749 recorded hauls from January 1988 – April 2001. Figure 2 shows the location of fishing hauls. As listed in Table 21, of 5749 total hauls, only 6 recorded hauls in the north area, 269 recorded hauls, i.e. only 4.7 percent of total hauls, in the middle area, and 5474 recorded hauls, i.e. 95.2 per in the south area. Therefore, we assume that the haul records in the north and middle areas are not completed comparing with the south area. Thus we mainly use the data located in the south area in the analysis and modelling. Although there are more than 95 percent of hauls are located in the south area, only 480 hauls (8.8 percent of total hauls in this area) are *Merluccius hubbsi* target, 14 hauls are *Merluccius australis* target. 122 hauls are *Merluccius hubbsi* target in the middle area.

Table 21. Fishing hauls recorded by FIGFD (01/88 – 04/01)

Area	Total	*Merluccius hubbsi* target		*Merluccius australis* target	
		Hauls	%	Hauls	%
North area	6	2	33.3	0	0
Middle area	269	122	45.4	1	0.37
South area	5474	480	8.8	14	0.26
Total	5749	604	10.5	15	0.26

Figure 17 shows the spatial distribution of fishing hauls with different ratio of hake *Merluccius hubbsi* catches to the catches of all species. Similar as Spanish data, winter is the main season for hake fishing, and the middle area is the major hake fishing site. In the south area, hake were fished mainly in the west part of this area. Figure 18 shows the spatial distribution of fishing hauls with different ratio of hake *Merluccius australis* catches to the catches of all species.

Compared with Spanish data, the correlation between monthly total fishing hours in middle and the south area is not significant, shows there is no shift of fishing hours between middle area and south area (Table 22)

Table 22. Spearman's rank test

	Number of months	p-value	Correlation
Around year	109	0.961	-0.005
May, Jun. Jul. Aug. Sep.	43	0.636	0.073

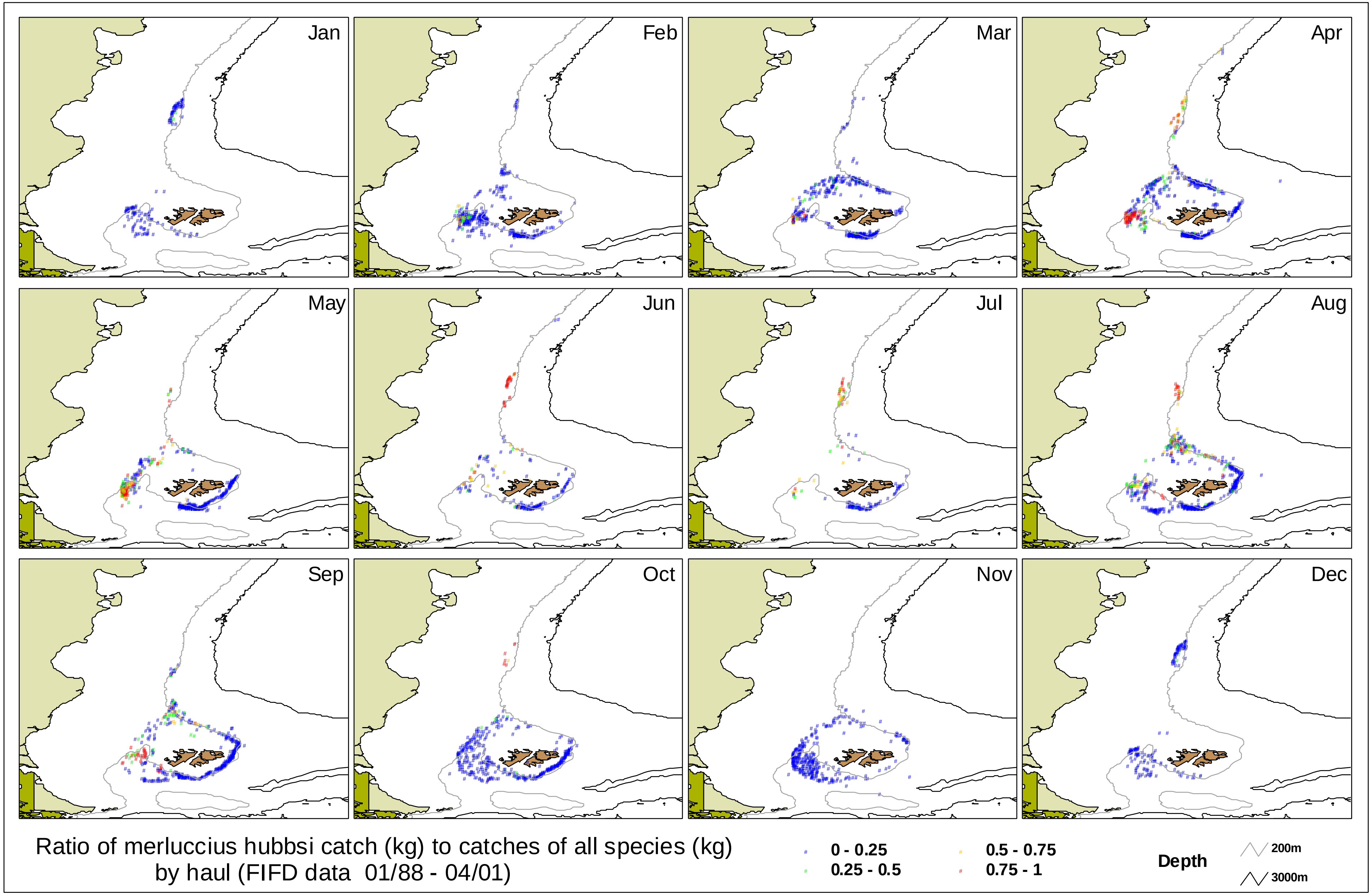


Figure 17. Ratio of *M. hubbsi* (FIGFD data)

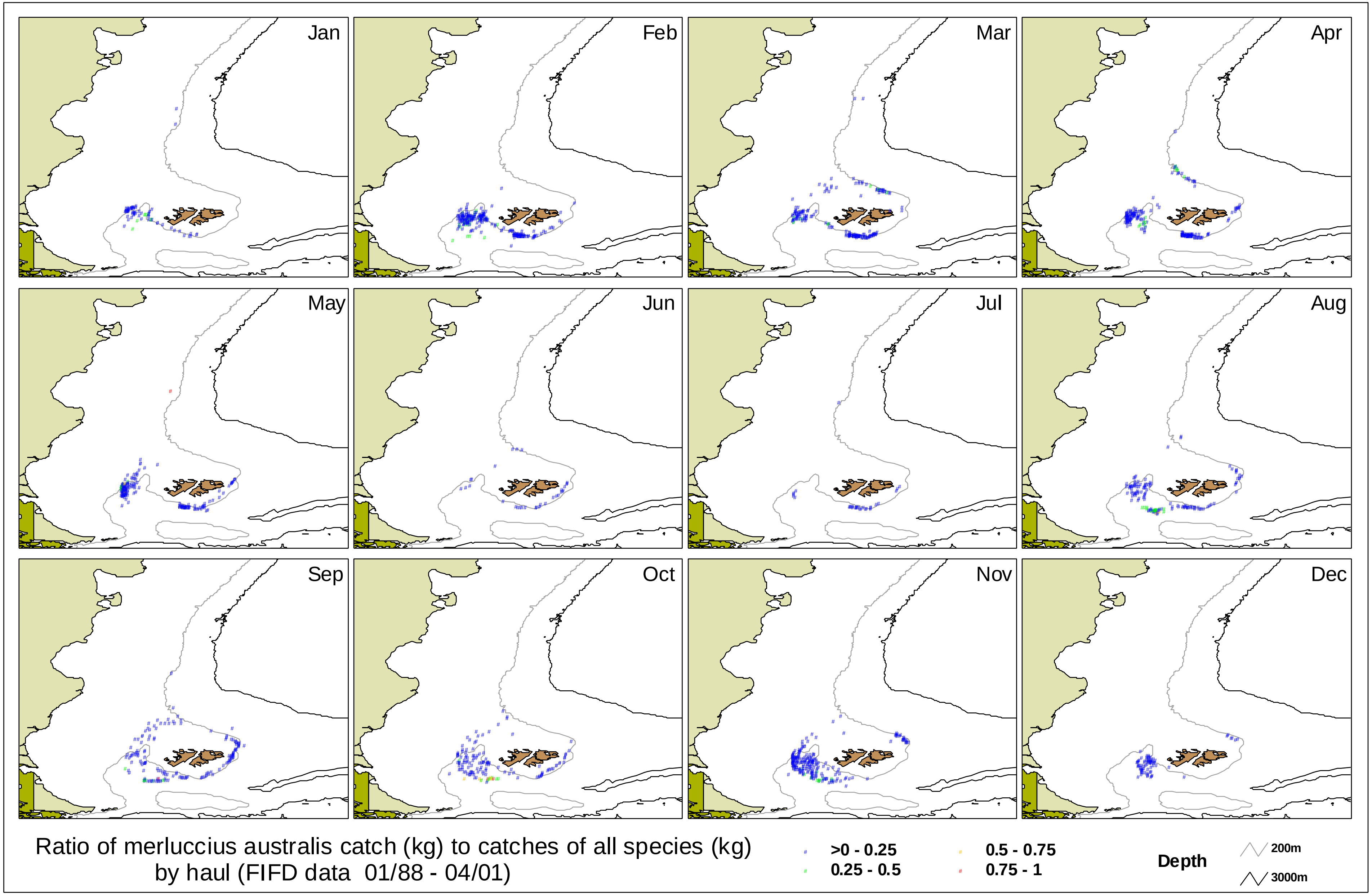


Figure 18. Ratio of *M. australis* (FIGFD data)

4.2.2. Environmental influence on fish abundance and distribution

Spearman's rank test is used for calculating the correlation between fish abundance and moon/cloud index, sea temperature, and depth. Only hake target hauls are used in the calculation

Table 23 lists the correlation between fish abundance and moon/cloud index. The calculation is based only on Spanish data, because there is no moon/cloud index record in FIGFD data. In Spanish data, cloud status is divided into 8 classes: 1 represents clear sky, 8 represents full cloudy sky. Moon status is divided into 4 classes: 1 represents full moon, 4 represents no moon. The calculated correlation represents the relationship between CPUE and cloud index, at the same moon situation. The correlations between fish abundance and cloud index at different moon condition are overwhelming negative, indicating that higher catches in cloudy weather condition.

Tables 24 and 25 lists the correlation between *Merluccius hubbsi* CPUE and sea temperature. In north and middle areas, fish abundance is negatively related to sea temperature, indicating that high fish abundance is related to the strong northward cold Falklands currents (Malvinas current) carries nutrient-rich water in this area.

Table 26 lists the correlation between *Merluccius hubbsi* CPUE and sea depth in whole area and each sub-area. The table shows that fish abundance is positively related to sea depth in summer, but mixed in winter.

The correlations between *Merluccius australis* CPUE and sea temperature and depth in whole area were also calculated using Spearman's rank test method (Table 27). Fish abundance is significantly positive related to SST in the first half of a year and in September, negatively related to SST in August and September. However, Fish abundance is overwhelming negatively related to SBT, except May. The correlation between fish abundance and depth is significantly positive in January – march, July, and September, and negative in November and December.

Table 23. Spearman'rank test for the correlation between *Merluccius hubbsi* CPUE and cloud index (1- 8, 1 represents clear sky, 8 represents full cloudy sky) at different moon condition (moon index 1- 4, 1 represents full moon, 4 represents no moon).

Moon		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	*r*	-	-	-	-0.11	-0.13	-0.19	**-0.30**	0.28	0	-	-	-
	p	-	-	-	0.70	0.69	0.55	**0.03**	0.08	0.99	-	-	-
	n	-	-	-	13	10	10	**52**	40	16	-	-	-
2	*r*	-	-	0	-	0.26	0.37	0.09	-0.11	**-0.66**	-	-	-
	p	-	-	0.97	-	0.34	0.14	0.44	0.37	**0.02**	-	-	-
	n	-	-	8	-	15	17	69	71	**14**	-	-	-
3	*r*	-	-	-0.14	0.57	-0.01	-0.19	0.06	**-0.27**	**-0.54**	-0.21	-	-
	p	-	-	0.68	0.06	0.97	0.32	0.65	**0.05**	**0.01**	0.57	-	-
	n	-	-	8	12	33	28	58	**52**	**26**	7	-	-
4	*r*	-	-	-	-0.14	-0.07	-0.05	**-0.35**	0.03	-0.08	-	-	-
	p	-	-	-	0.55	0.75	0.80	**0.01**	0.87	0.75	-	-	-
	n	-	-	-	18	24	30	**62**	39	15	-	-	-

Table 24. Spearman Rank correlation test between *Merluccius hubbsi* CPUE and SST. Single haul (hake targeted) data are used (FIGFD 01/88-04/01, IEO 01/89-12/99)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whole	r	-	-0.06	-0.01	**-0.18**	**-0.13**	**-0.10**	**0.09**	**0.24**	-0.01	-0.09	0.21	-
	p	-	0.74	0.93	0	0	0.03	0	0	0.82	0.28	0.18	-
	n	-	29	186	491	474	436	973	841	414	152	42	-
North	r	-	-	-	-	**0.45**	-0.11	0.01	-	-	-	-	-
	p	-	-	-	-	0	0.29	0.96	-	-	-	-	-
	n	-	-	-	-	55	87	15	-	-	-	-	-
Middle	r	-	-0.16	0	**-0.17**	-0.03	-0.11	**-0.08**	**0.20**	-0.08	-0.11	0.21	-
	p	-	0.54	0.97	0	0.56	0.06	0.03	0	0.26	0.23	0.18	-
	n	-	15	164	428	327	311	805	599	211	122	42	-
South	r	-	0.40	**0.57**	-0.06	**-0.49**	0.14	0.06	**0.13**	0.09	0.01	-	-
	p	-	0.23	0.02	0.66	0	0.38	0.46	0.04	0.21	0.94	-	-
	n	-	10	19	62	92	38	153	242	203	30	-	-

Table 25. Spearman Rank correlation test between *Merluccius hubbsi* CPUE and SBT. Single haul (hake targeted) data are used (FIGFD 01/88-04/01, IEO 01/89-12/99)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whole	r	-	-0.39	**0.41**	**-0.12**	-0.07	**-0.15**	-0.06	-0.03	-0.06	0.08	-	-
	p	-	0.09	**0**	**0.01**	0.16	**0.01**	0.13	0.55	0.39	0.44	-	-
	n	-	20	**176**	**477**	381	**339**	602	400	218	95	-	-
North	r	-	-	-	-	**0.52**	0.12	0.40	-	-	-	-	-
	p	-	-	-	-	**0**	0.29	0.27	-	-	-	-	-
	n	-	-	-	-	**54**	75	9	-	-	-	-	-
Middle	r	-	-0.31	0.03	**-0.19**	**-0.21**	**-0.23**	**-0.19**	-0.07	-0.21	-0.07	-	-
	p	-	0.29	0.70	**0**	**0**	**0**	**0**	0.32	0.03	0.57	-	-
	n	-	12	130	**376**	**278**	**235**	**445**	233	108	67	-	-
South	r	-	-	0.04	**-0.25**	**-0.68**	-0.20	**0.17**	**0.15**	0.09	0.04	-	-
	p	-	-	0.79	**0.01**	**0**	0.29	**0.04**	**0.05**	0.35	0.82	-	-
	n	-	-	43	**98**	**49**	29	**148**	**167**	110	28	-	-

Table 26. Spearman Rank correlation test between *Merluccius hubbsi* CPUE and depth. Single haul (hake targeted) data are used (FIGFD 01/88-04/01, IEO 01/89-12/99).

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Whole	r	-	**0.60**	**0.39**	**0.32**	**0.25**	0.03	**-0.27**	**-0.33**	-0.04	0.05	0.01	-
	p	-	0	0	0	0	0.46	0	0	0.43	0.56	0.93	-
	n	-	38	211	601	586	450	975	857	420	153	42	-
North	r	-	-	-	-	0.20	**0.36**	-0.29	-	-	-	-	-
	p	-	-	-	-	0.15	0	0.28	-	-	-	-	-
	n	-	-	-	-	55	87	15	-	-	-	-	-
Middle	r	-	0.04	0.09	**0.14**	**-0.20**	-0.09	**-0.10**	**-0.11**	**-0.18**	-0.06	0.01	-
	p	-	0.89	0.23	0	0	0.10	0	0.01	0.01	0.50	0.93	-
	n	-	15	164	455	331	313	805	599	212	123	42	-
South	r	-	**0.63**	**0.52**	**0.30**	**0.18**	-0.16	0.08	**-0.14**	0	0.07	-	-
	p	-	0.01	0	0	0.01	0.25	0.34	0.03	0.95	0.72	-	-
	n	-	19	44	143	200	50	155	258	208	30	-	-

Table 27. Spearman Rank correlation test between *Merluccius australis* CPUE and sea temperature depth. Single haul (with catches) data are used (FIGFD 01/88-04/01, IEO 01/89-12/99)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SST	r	**0.41**	**0.51**	**0.21**	**0.24**	**0.22**	**0.49**	0.02	**-0.38**	**0.24**	0.05	0.11	**-0.42**
	p	0	0	0	0	0	0	0.84	0	0	0.33	0.12	0.01
	n	115	324	497	589	251	61	122	425	456	335	205	39
SBT	r	**-1**	**-0.52**	**-0.08**	**-0.10**	**0.60**	**-0.06**	**0**	**-0.17**	**-0.46**	**-0.45**	**-0.87**	**0**
	p	0	0	0.20	0.02	0	0.74	0	0.01	0	0	0	0
	n	65	126	295	488	118	35	88	267	285	154	59	16
Depth	r	**0.63**	**0.21**	**0.46**	-0.01	0	0	**0.42**	0.05	**0.18**	-0.03	**-0.15**	**-0.26**
	p	0	0	0	0.88	0.95	0.99	0	0.26	0	0.58	0.01	0.02
	n	137	383	503	672	322	66	122	434	489	365	282	80

4.3. use of data to obtain results and to feed task 6

All this information was used to feed task 6 (assessment).

Objective 2. Assembly, collation and maintenance of already existing fishery and biological data. Creation of a common database and development of specific software

Task 5. Database assembly and maintenance.

5.1. maintenance of already existing databases of biological and fishery data.

IEO Vigo has been compiling a historical database developed by a observers program carried out since 1989 onwards. This data collection allows us to obtain both fishing operation information and to study the behaviour of the different target and non-target species.

In order to store and manage all this information a specific software was developed in 1991. This sofware was implemented in *C* code and has been used as standard tool as far now. Data collated by fishing trip are organised in diferent Betrieve structures.

5.2. development of an specific database and analysis software

IEO team analysed the algorithms and developed a new software during the first half of the first year of the present project (Figures 19 and 20). This new application keeps the own processing data characteristics of the previous one and permits a better data management as well as support new tools for analysing the relevant information.

Microsoft Acces database structure was used to allow to obtain any other non-specific outputs by developing both new Visual Basic Applications (VBA) and SQL queries. MS Access structure also allows us to deal online selected output ans results throught ASP webpages.

This new software was named as Falkland Project and it was presented in the workshop on assessment held in London (July 2001). Since then, it has been the standard tool both for recording new data and querying all kind of information. However, to facilitate the use of this yearly data series, a management procedure was created. This procedure, called as ReportBuilder, allow to process data in different years.

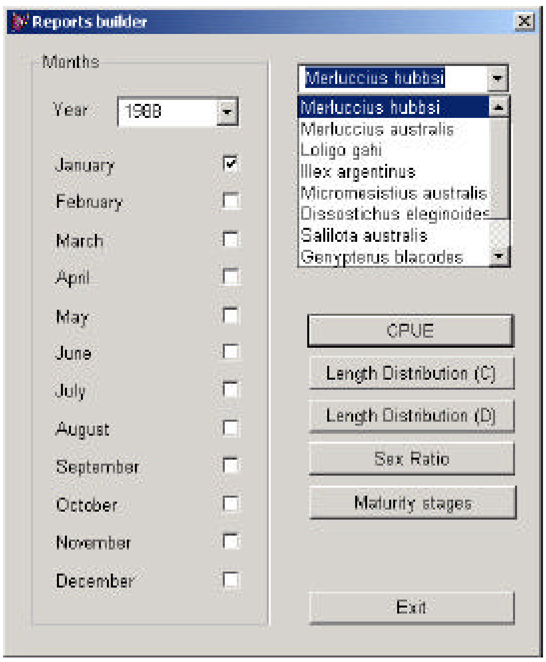


Figure 19. Interface of the *ReportBuilder*

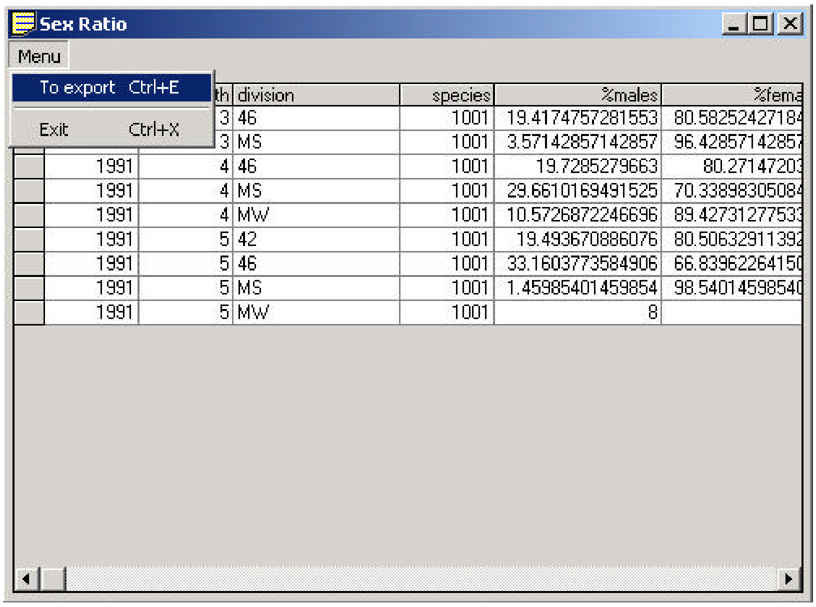


Figure 20. Example of *Sex Ratio* output

Hence, Report Builder created standardized outputs which cover the main objectives of this project. The species considered in this application and its code are sown in Table 28.

Table 28. Scientific name and code of the species

Scientific name	**code**
Merluccius hubbsi	1001
Merluccius australis	1002
Macruronus magellanicus	1003
Genypterus blacodes	1004
Salilota australis	1005
Micromesistius australis	1006
Dissostichus eleginoides	1007
Patagonotothen spp	1010
Loligo gahi	3001
Illex argentinus	3002

The following results may be produced:

- Reports on hauls, fishing effort, catches, length distributions and biological samples.
- Outputs about CPUE by month, division, length distributions weighted to haul catch and discard, sex-ratio and maturity stages.

ReportBuilder may be also implemented to achieve any other non-standardized output by queries throughout MS Access and VBA Modules. However, due to the large amount of stored data, a continuous analysis of most used functions of ReportBuilder is always needed in order to minimize the processing computer time and to improve the reliability of the procedure.

A website for dissemination of results has been also created (Figure 21). It was developed by following DHTML and ASP standard criteria and several levels of access ensure the confidentiality of some data.

The related link is*:* http://oceanovigo.vi.ieo.es/proyectos/study99016/default.htm

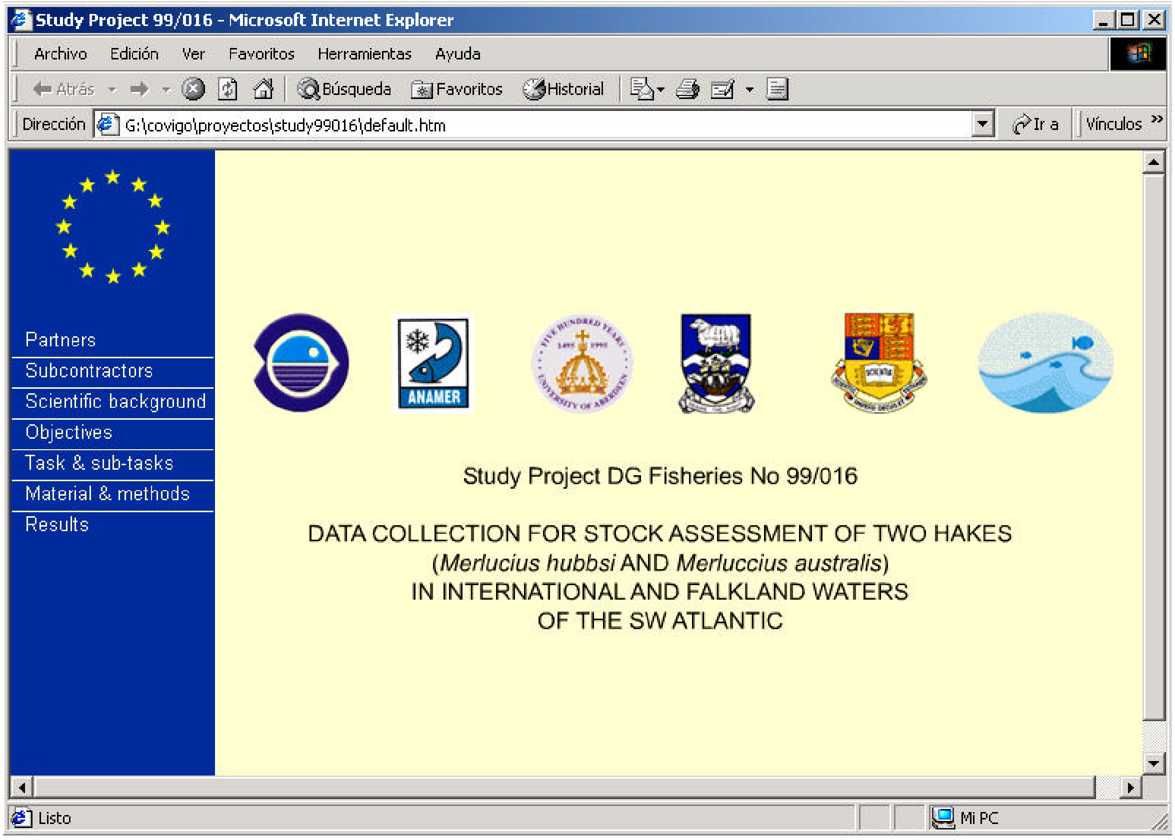


Figure 21. Home page of the Project Website

5.3. Assembly and integration of new data.

Fishery and biological data collected by a total of 82 observers during the period 1989 – 2001 (table 1) was provided by IEO and ANAMER and integrated in the database. A set of algorithms was created to convert and integrate the previous database files from the period 1989-1999. BTR files were exported to text files and then we applied the conversion application. On the other hand the analogous procedure was developed to convert and integrate the FIGFD database to combine the different partners information in a common structure.

Having made the final selection of fields to be retained in the common database, observer data for the Spanish fleet (ANAMER and Falkland Islands) will be copied into this database prior to the stock assessment workshop. Hence, historical data series analyzed were (Figure 22):

- FIGFD: years 1988-2001 (observer data)
- IEO: years 1989-2001 (observer data)
- ANAMER: 1983-2000 (landings and effort); 200-2001 (observer data)

The different tables which comprise the database are indexed by a series of key fields. These key fields were used to establish a series of sequential relationships, permitting to maintain not only the integrity of the registers included in the different tables, but also the execution of complex queries in SQL and VBA languages (Figure 23)

Source	Description	Brought	Used
FIGFD	Haul records	5749	5749
	Catch records	52023	39129
	Biological sample	8285	8285
	Length sample	21869	21869
IEO	Haul records	6036	6036
	Catch records	37201	37201
	Biological sample	174562	174562
	Length sample	62654	62654

	Description	Nº of Recordsets
COMMON DB	Haul records	11785
	Catch record	76330
	Biological sample	182847
	Length sample	84523

Figure 22. Registers integrated in the common database

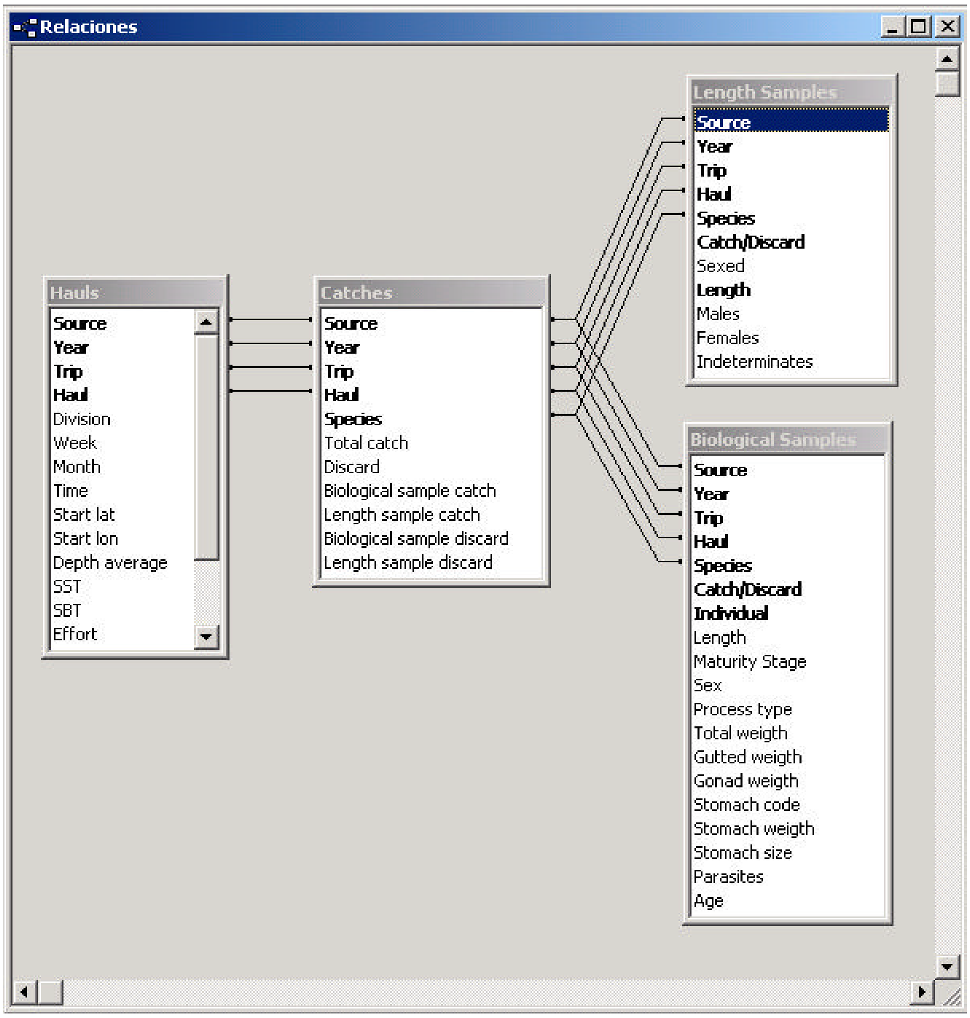


Figure 23. Relationships among tables and fields of the database

Objective 3. Preliminary assessment of target species

Task 6: Stock assessment

A number of hypotheses were examined for the relationship of *M. hubbsi* caught around the Falkland Islands (Area A), in high seas waters (Area B) and in Argentine waters (Figure 24). These hypotheses were:

H1. A is a separate stock, unaffected by activities in Argentina or by stock B; the alternative hypotheses is that it is not a separate stock, and may be linked to either fish and fishing in area B (H3) or in Argentina (H4).

H2. B is a separate stock. The alternative hypothesis is that B is part of the general Argentine stock (considered here under H2) or that it is linked to fish from area A (H3).

H3. Fish from A and B are linked, and together form a single separate stock. This is one of the alternative hypotheses in H1 and H2. The alternative hypothesis is that they are not linked. A further alternative, that they are both linked to fish from Argentina is not considered here. However, if there proved to be confirmatory evidence that H3 was true, this further hypothesis might be worth investigating.

H4. A is linked to fishing in Argentina but not to fishing in area B. This is one of the alternative hypotheses to H1.

There are, of course a number of other possibilities, including those addressing area C. However, there are much fewer data from area C than the other areas, and it was considered by the workshop highly unlikely that fish in this area were separate from the general Argentine stock. These alternative hypotheses were therefore not considered further.

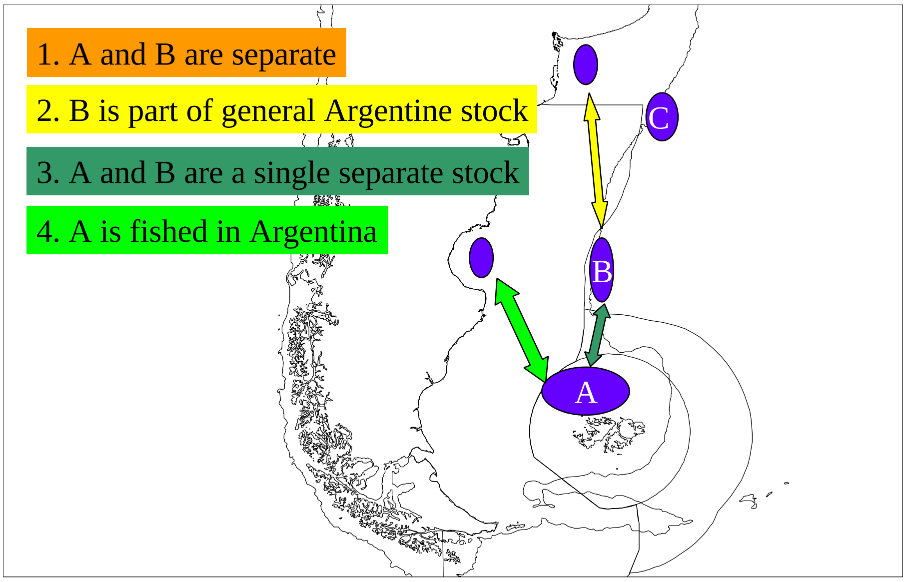


Figure 24. Schematic of the main hypotheses considered in the assessment.

Hypothesis 1: Area A is a separate stock that warrants an independent assessment. It is not linked to Area B, or to Argentine waters, although it may be distributed there occasionally.

Generating a tuning series for area A

An analysis of the appropriate tuning series for area A was presented in the report of the Vigo workshop. At that time it was noted that hake targeting behaviour had apparently changed over time. The frequency of daily catches containing >50% hake is plotted (as "sample size") by year in Figure 25. This roughly follows trends in the standardised CPUE series. Clearly there is a relationship between the availability of hake and the number of catches containing >50% hake. Since the sample size from which the tuning series was derived varied from year to year, it was appropriate to weight the tuning series. The inverse standard error was used as a weighting factor in the assessment models.

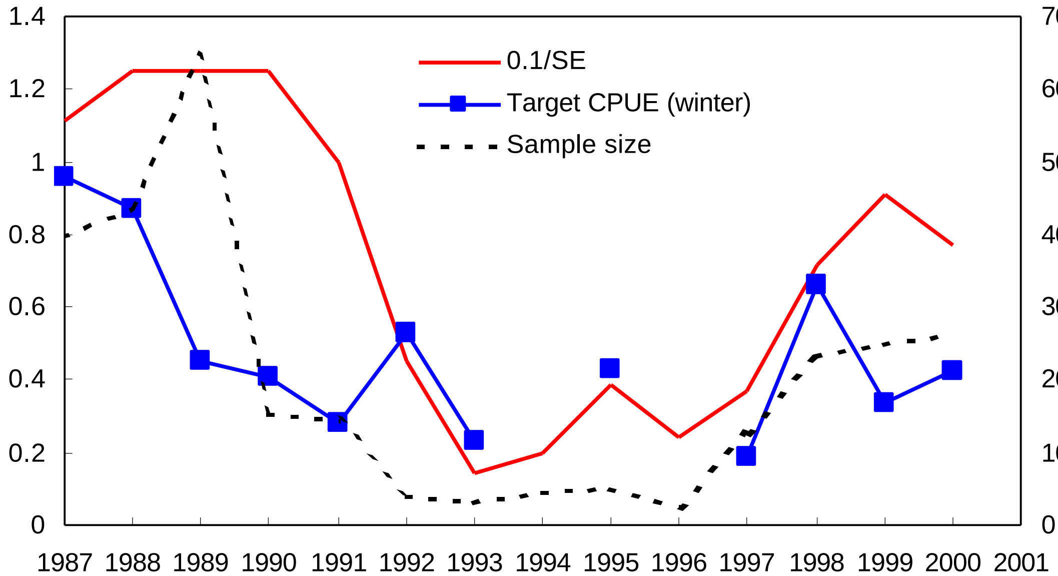


Figure 25. Trends in the target CPUE series for ES/FK vessels fishing in the Falkland Islands hake fishery

Assessment: A new assessment was conducted with the following input data.

? Catch data: Total catch of hakes (*M. australis* and *M. hubbsi*) from the Falklands, with the catch of *M. hubbsi* being estimated by FIGFD observer-derived proportions of the two species in the catch (see section 2.3 above).

? CPUE data: The weighted FIGFD Spanish/Falklands flag vessel CPUE tuning series (targeting April – Sept. North of 51ºS: 50%) was used.

? Catch in numbers/weight at age: From FIGFD data.

? Selectivity coefficient, M (0.3) from Argentine assessment (INIDEP Documento Cientifico 3, May 1994) and section 2.4 from the stock assessment Annex .

Two methods were used. The first was a Schaefer production model fitted in CEDA (MRAG Ltd) (Table 29 and Figure 26). The second was an ADAPT cohort analysis (VPA) implemented in Excel with bootstrapped confidence limits (Figure 27). Using the same terminal F value and selectivity vector from the VPA, the current level of fishing mortality was used as a constant to project the spawning stock biomass forward over a 20 year period. This was presented with 95% confidence limits and estimated catches in Figure 28.

Table 29. Point estimates and 95% confidence limits for Hake spawning stock biomass using CEDA analysis with an initial proportion of 0.75 and a time lag set at 2 years.

Unexploited biomass (K)	93,648 tonnes
B_{1987}	70,036 tonnes
Upper 95% CI for K	70,240 tonnes
Lower 95% CI for K	143,900 tonnes
Population growth rate (r)	0.173
Upper 95% CI for r	0.05
Lower 95% CI for r	0.34

a. b.

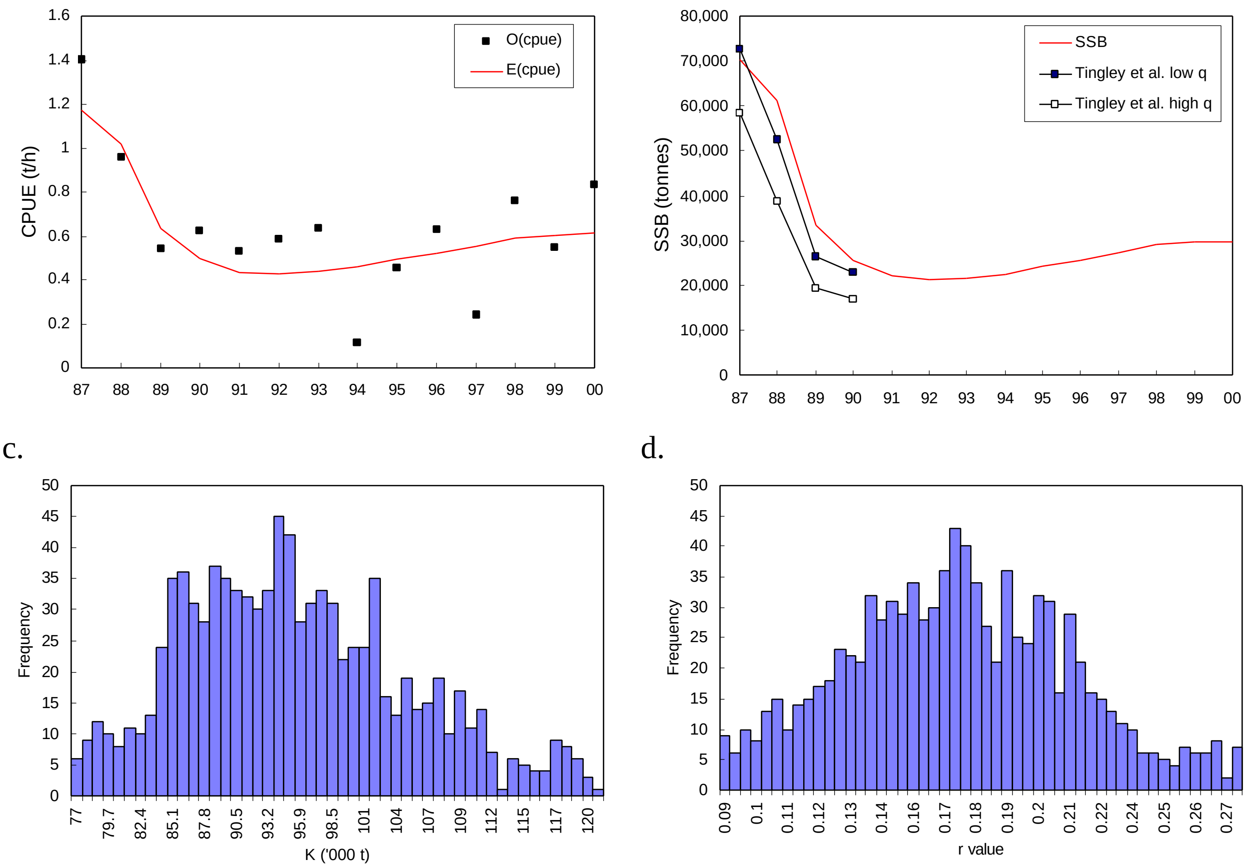


Figure 26. Hypothesis 1: stock is exclusive to Falkland Island waters only. Output from CEDA analysis showing a). the distribution of observed and expected cpue values, b). biomass estimates between 1987 and 2000, including previous estimates from Tingley et al., (1995) c). range of values obtained for the unexploited biomass (K value) during bootstrapping, and d). range of values obtained for the population growth rate (r values) during bootstrapping.

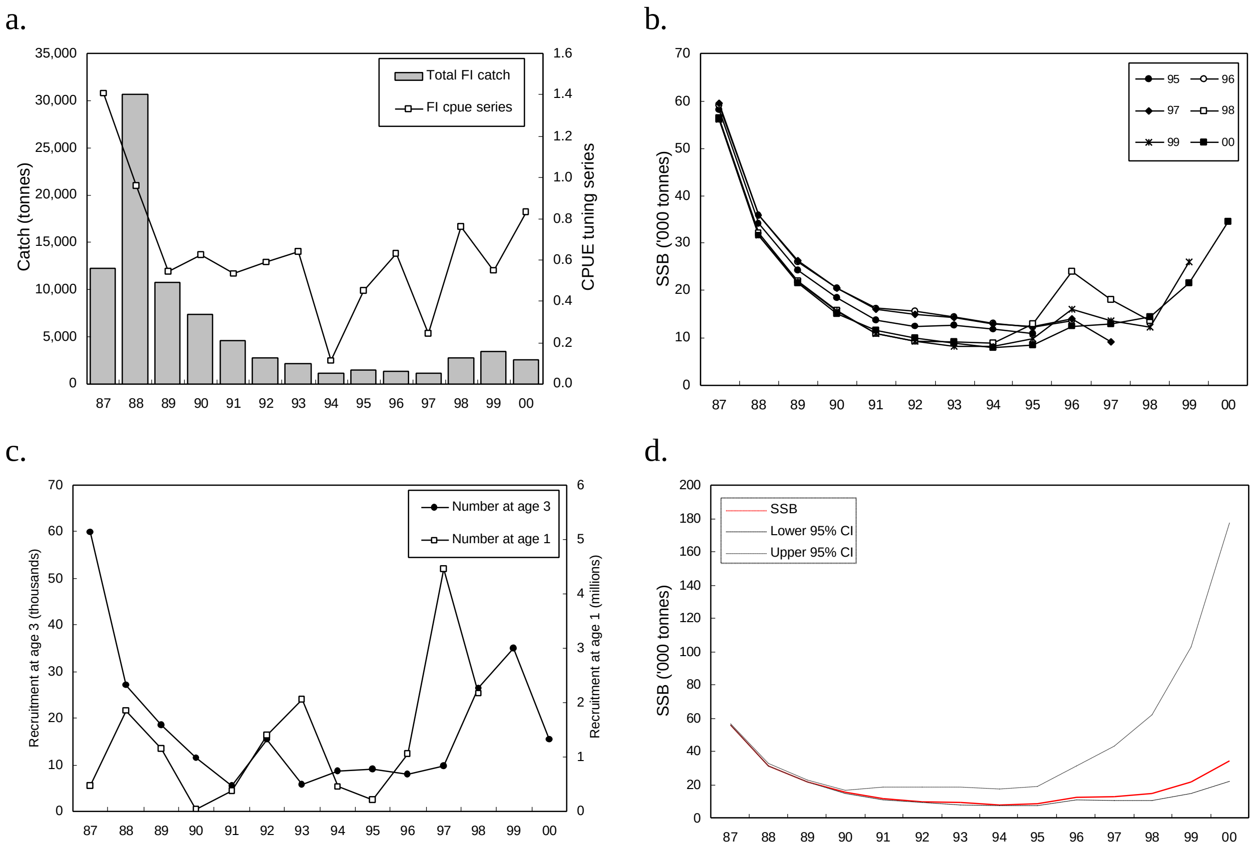


Figure 27. Hypothesis 1: stock is exclusive to Falkland Island waters only. Results of a VPA analysis showing a). total annual catch and tuning cpue series used in the analysis b). retrospective analysis of spawning stock biomass for years 1987 to 2000 c). number of recruits entering the fishery at age 3 and the estimated number of fish at age 1 d). estimates of spawning stock biomass fitted with the upper and lower 95% confidence limits.

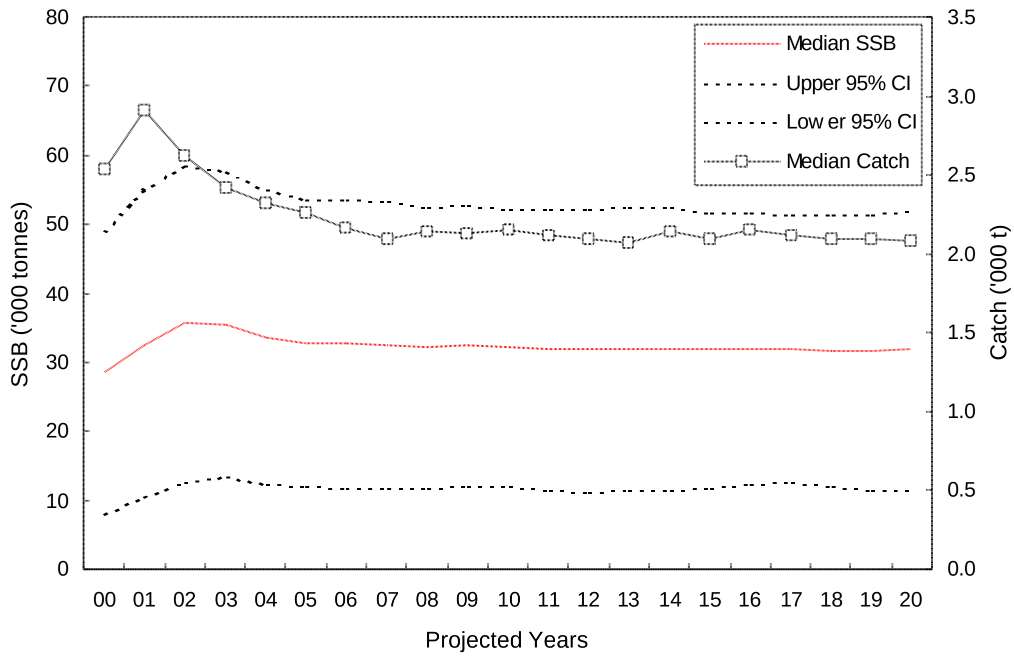


Figure 28. Projection of median spawning stock biomass over a 20 year period with 95% confidence limits and projected total catches over the same period, from the results of the cohort analysis.

Discussion

The results are quite consistent with the results of an assessment performed in 1995 by Tingley et al (1995) and with the preliminary assessment conducted for the second meeting of the hake workshop. Although the former authors were faced with a classic "one way trip" their estimates of stock size are quite similar to those from the present assessment.

One problem with the VPA assessment is that the projection does not suggest that the stock will recover to previously high levels under current estimates of recruitment. This could indicate a strong stock-recruitment relationship, or it could suggest that recruits are being fished elsewhere, a possibility that is explored further in Hypothesis 4(b).

Hypothesis 2. Stock B is separate or is part of the general Argentine stock.

Examination of this hypothesis proceeded through examination of CPUE trends. Unfortunately, the results of the meristic/morphometric analysis were unavailable to the meeting, so this was the only method through which to examine the relationships between stocks. Consequently the relationships between all three areas was examined here, although some of this discussion is relevant to H3 rather than H2.

Generating a tuning series for Area B

Spanish vessels fishing in high seas (areas 46 and 42) mainly target either hake or *Illex argentinus* squid. In general, hake catches and *I. argentinus* catches are separated in space and time. In order to produce an index of hake abundance for high seas areas, it is necessary to account for the behaviour of vessels, as those targeting squid are likely to underestimate hake abundance. In addition, since hake is a seasonally migrating species, local abundance is likely to change on a seasonal basis. Peak concentrations at spawning sites in Argentine waters are recorded in November, suggesting a spring and summer migration away from high seas areas. For this reason, as for the FICZ tuning series, only data for the winter period (April to September) were used.

The catch composition by depth in area 46 from IEO observer data was studied with the aim of identifying criteria for separating catches into those targeting hake and those targeting squid. Figure 29 shows that >70% of the total winter catch from depths <150m is *M. hubbsi*, and that other species dominate catches from greater depths. In fact, the narrow depth zone between 101 and 150m was the source of 93% of the reported *M. hubbsi* catch in area 46 for the winter months. CPUEs from this zone were therefore used as the tuning series from zone B. It was not possible to standardise for vessel effects as no vessel-specific information was given. The tuning series was weighted by total effort

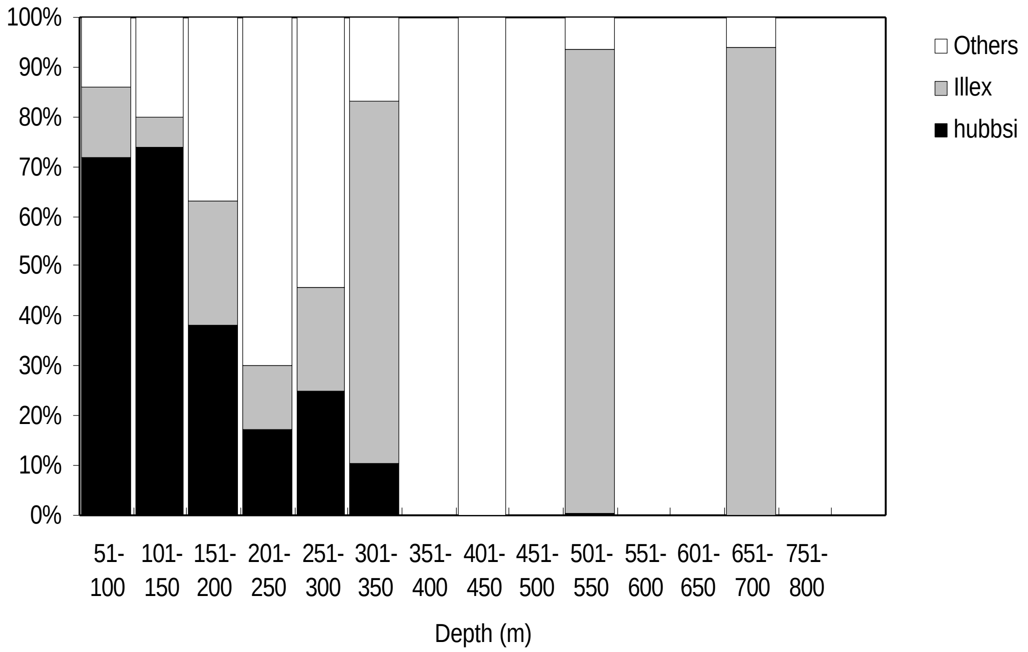


Figure 29. Proportion of Illex and hake in catches from IEO observer data in area B, by depth.

<u>Comparing the CPUE series from areas A and B to see if any areas display similar trends</u>

Interannual trends in annual average CPUE for *M. hubbsi* in each fishery area were compared (using IEO data) graphically (Figure 30) and with correlation analysis (Table 30). Although there appears to be something of an inverse relationship between CPUE in area 46 and areas further south, there were no statistically significant correlations. No relationships were found between hake CPUE and CPUE for *Illex argentinus* or with June or December SST anomalies (46.5^{o} S, 58.5^{o} W). *Illex* CPUE in area 46 was significantly positively correlated with the June SST anomaly. Hake CPUE in area 46 was well-described by a multiple regression model including overall annual CPUE, effort in area 46 and the December SST anomaly. However, the short time series available precludes adequate testing of this model.

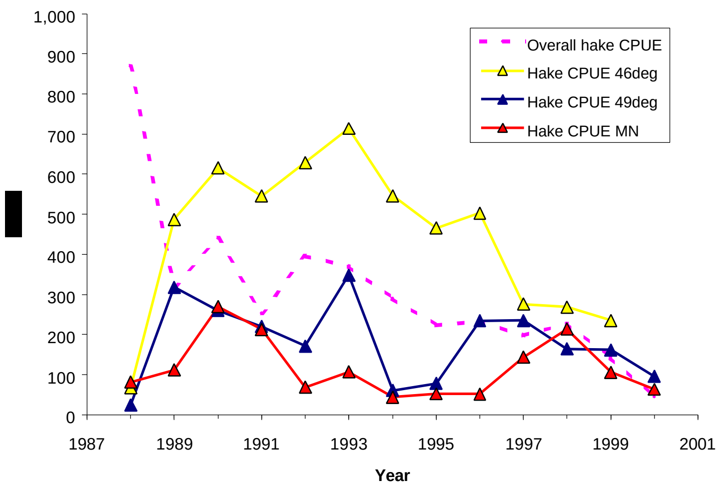


Figure 30. Comparison of CPUE series generated from raw IEO observer data.

Table 30. Correlation coefficients for CPUE series generated from raw IEO observer data.

Correlations (N=11 to 13 years)

	MhCPUE46	MhCPUE49	MhCPUEMN	MhCPUEover	SST June	SST Dece	MhEff46	IaCPUE46	Rv
Mh CPUE46	1.000								
Mh CPUE49	0.529	1.000							
Mh CPUEMN	0.034	0.418	1.000						
Mh CPUEover	-0.254	-0.172	0.040	1.000					
SST June	-0.045	0.073	0.212	-0.454	1.000				
SST Dece	0.272	0.521	-0.481	-0.303	-0.045	1.000			
Mh Eff46	0.198	0.535	0.267	-0.437	0.583	0.228	1.000		
Ia CPUE46	-0.485	0.254	-0.007	-0.359	0.643	0.389	0.236	1.000	
Rv	-0.320	-0.060	0.283	0.547	-0.234	-0.217	-0.030	-0.208	1.000

<u>Comparing the CPUE series from area B and Argentina to see if the areas display similar trends</u>

The CPUE series from sections H1 and H2 are included in Table 31 with estimates for spawning stock biomass of Argentine hake (at 1 January) from the February 2001 Argentine assessment. These series are standardised to 1990 in Figure 31.

Table 31. Standardised CPUE series for areas A and B, together with the SSB (1 Jan) from the Argentine 2001 Assessment.

	Area A CPUE	Area B CPUE	Argentine assessment Biomass
1986			1085
1987	1.405		1072
1988	0.961	46.6	895
1989	0.543	543	665
1990	0.625	664	384
1991	0.533	552	387
1992	0.589	664	386
1993	0.638	899	393
1994	0.114	640	404
1995	0.454	599	402
1996	0.631	697	426
1997	0.242	434	445
1998	0.763	344	397
1999	0.549	343	389
2000	0.835		331

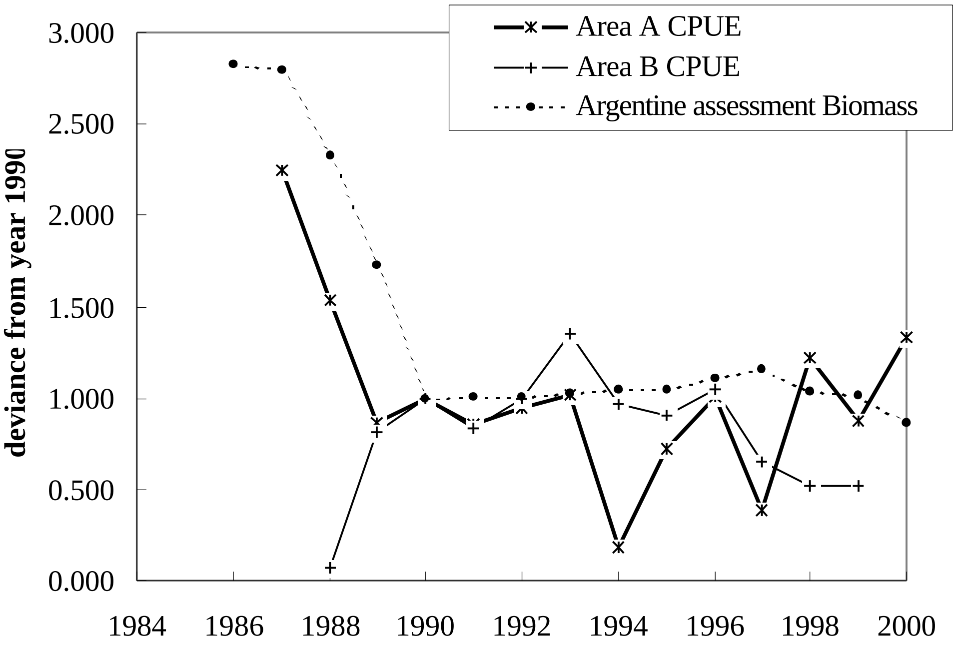


Figure 31. CPUE trends in areas A and B, and trends in SSB from the 2001 Argentine hake assessment, standardised to 1990.

There is clearly a correlation between the Area A CPUE and the Argentine assessment in the first few years of the series, as the stock undergoes its initial decline. There is no correlation between the two series after 1990 ($r^2 = 0.0$). There is also no significant correlation between the area A and area B series, especially if the 1998 point is removed (it could be considered to be an artificially low point in a developing fishery); r = -0.38 including 1988, and 0.048 excluding it (n=12 and 11 respectively). This is the same as the result obtained from using the raw IEO observer data in section 3.2.2. However, despite the apparently similar trends between the Argentine biomass and area B CPUE, there is no significant correlation between them.

The Argentine biomass is at 1 January and could relate to the CPUE series for the coming year or a past year, since both the CPUE series from areas A and B are winter series. If it is assumed to relate to the past year it is shifted one year backwards in Figure 30 and becomes entirely coincident with the decline in CPUE of area A. The correlation coefficient for area B CPUE against Argentine biomass also becomes more positive (r=0.557, n=11, p=0.07).

Discussion

These results are do not provide conclusive evidence that the Argentine fishery, area A and area B are either linked or not linked. The weak negative correlation found between the CPUE series from the two areas A and B might be taken as evidence that they are separate stocks, but it could also result from them being the same stock that is distributed differently between years. Similarly, there is some evidence that the trends in CPUE in area B mirror trends in the Argentine hake stock biomass, but the correlations are not significant. The most significant result is the almost coincident decline in area A CPUE and Argentine assessment biomass, but there is not a similar coincidence in trends after 1990.

We therefore continue to explore some of the hypotheses.

Hypothesis 3: A and B are a single separate stock

Previous section was unable to find good reasons to consider A and B to be from the same stock. Nevertheless there was also no concrete evidence that A and B were separate. We therefore conducted an assessment similar to that for H1.

Generating catch data for area B

The total Spanish fleet landings of hakes was estimated from ANAMER fleet landings (Figure 32). The catch of hakes within the Falkland's zones by the Spanish fleet was calculated and two months added to approximate landing date from catch date. The difference is assumed to be Spanish catches in international waters.

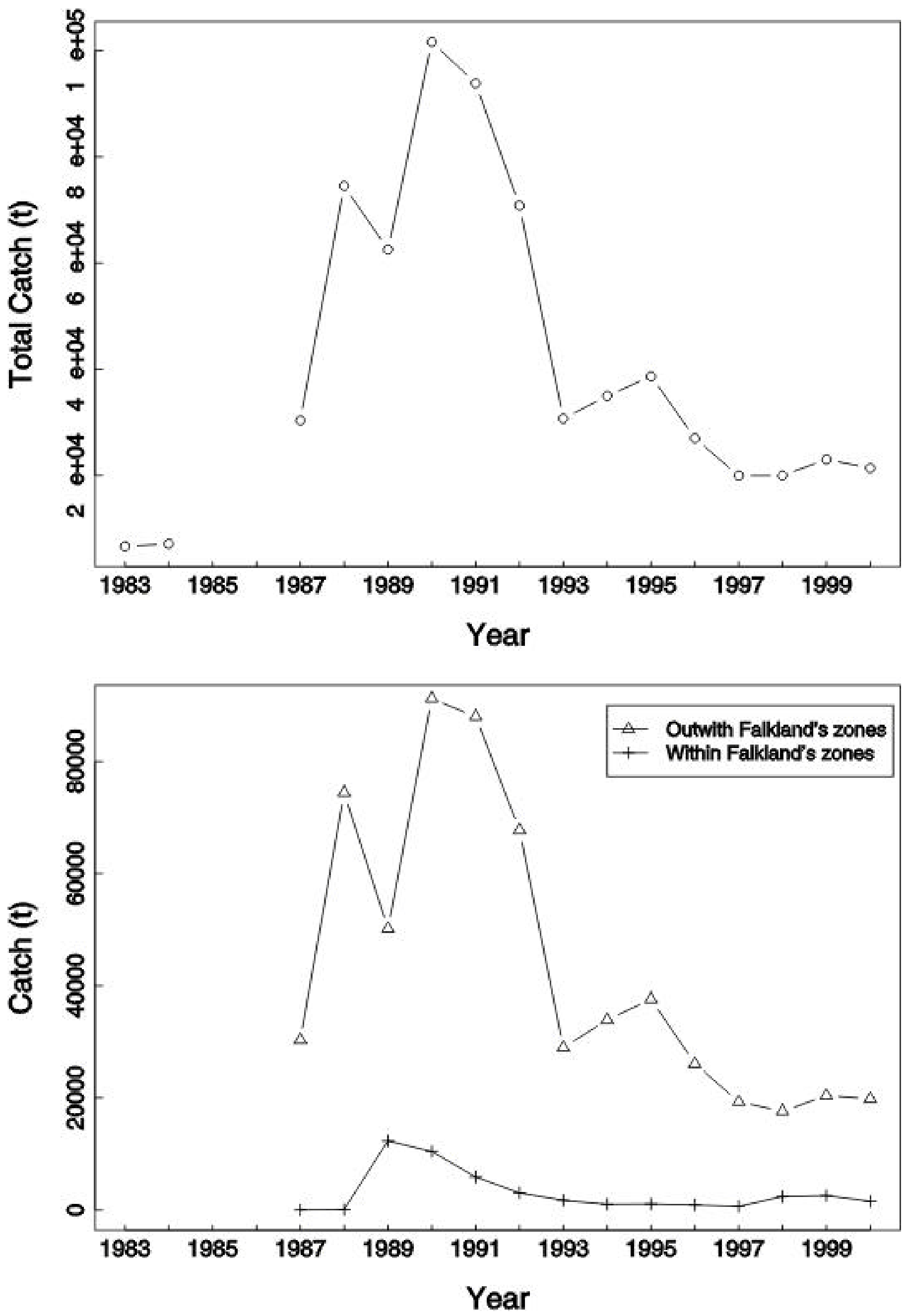


Figure 32. Total Spanish fleet landings of hake (top) and catches taken from the Falkland's zones by the Spanish fleet (bottom).

Total catches in the areas north of the Falkland's zones were estimated by adding out of zone hake catches reported to FIGFD by non-Spanish vessels to the estimated catch by the Spanish fleet in international waters (Table 32)

Table 32. Estimated total catches of hake in Area B.

Year	*Kg*
1987	30,334,436
1988	74,424,462
1989	501,883,22
1990	91,233,947
1991	87,983,646
1992	67,752,407
1993	28,960,295
1994	33,916,959
1995	37,590,267
1996	26,077,534
1997	19,324,015
1998	17,590,780
1999	20,425,475
2000	19,818,156

Assessment:

Inputs were as follows:

? Catch data: FIGFD Falklands catch data (from the assessment of area A under Hypothesis 1) + the estimates of hake catches in area B from the analysis in section 3.3.1.

? CPUE tuning data: Two series were used, one the Falklands CPUE series used in the area A assessment, and the other the high seas CPUE derived in section 3.2.1, both weighted by inverse variance.

? Catch in numbers, weight at age, maturity etc: the same ratios of these inputs as in the assessment for area A, but adjusted for the different catch data.

The only assessment that was performed here was the ADAPT cohort analysis (Figure 33).

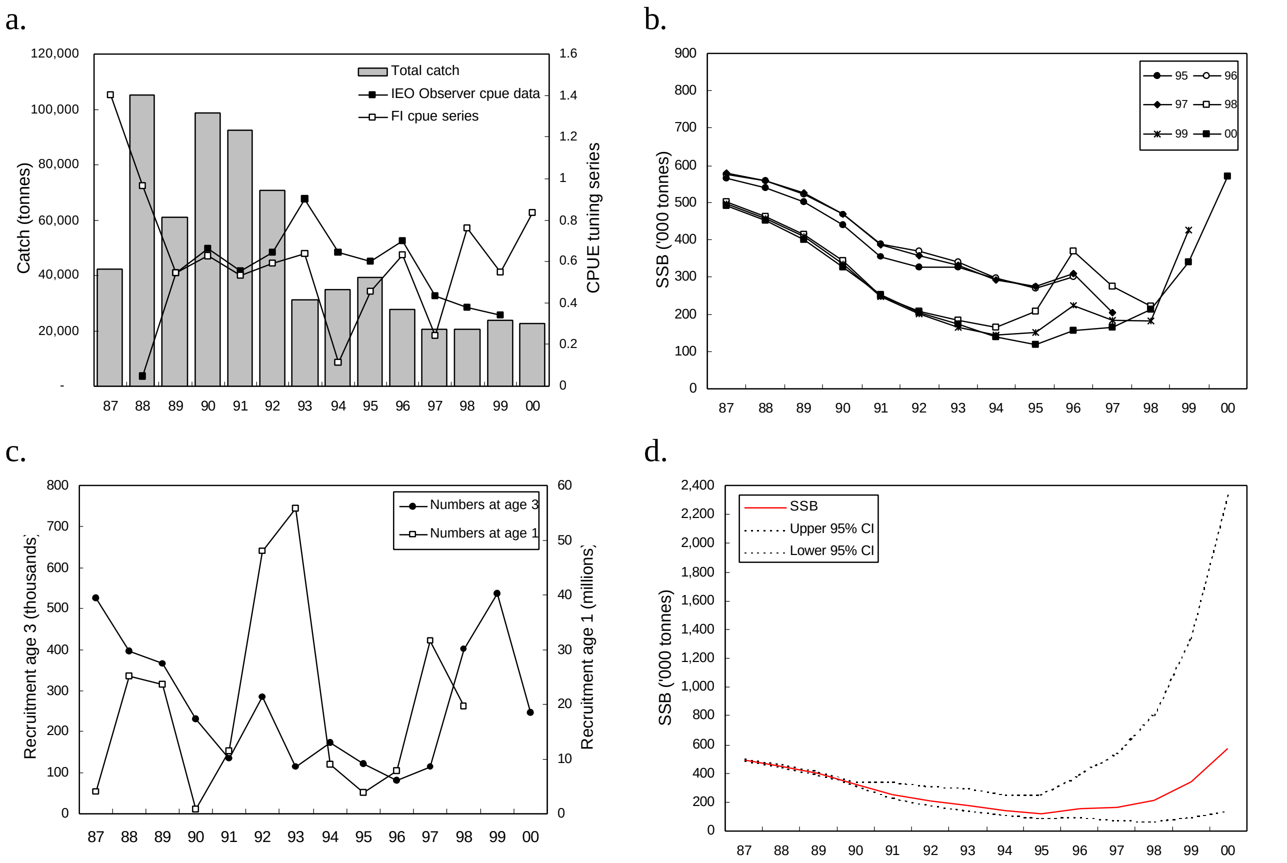


Figure 33 Hypothesis 3: stock in Falkland Island waters (A) is part of northern stock (B) found at both latitudes 42ºS and 46ºS. Results of a VPA analysis showing a). total annual catch from both areas (A and B) and two sets of tuning cpue series using both the FI and Spanish data b). retrospective analysis of spawning stock biomass for years 1987 to 2000 c). number of recruits entering the fishery at age 3 and the estimated number of fish at age 1 d). estimates of spawning stock biomass fitted with the upper and lower 95% confidence limits.

Discussion

The workshop noted that lengths and ages are available for out of zone (OOZ), and it might be possible to include these to refine the assessment of H3 at a future date.

The VPA suggests that stock has now recovered to very high levels. But these levels have not been seen in the fishery. This suggests that the hypothesis is probably false.

Hypothesis 4: Stock A is fished in Argentina.

Two alternatives were considered under this hypothesis. The *M. hubbsi* stock clearly spends the winter feeding around the Falkland Islands. It departs in early summer (October) in pre-spawning condition and returns in early autumn to area A in post-spawning condition. Spawning has not been found in area A. However, there are known spawning areas in the summer in Argentine waters in the Gulf of San Jorge. It therefore seems possible that the Falklands stock breeds there. Furthermore, very young fish (0+ and 1+) are not found around the Falkland Islands. They, also, may be in nursery areas close to the Argentine coast, possibly in the south of San Jorge Gulf.

Two different possibilities were therefore considered: (a) that mature adults are taken in Argentine waters (San Jorge Gulf) in the summer, or (b) that juveniles are taken as a bycatch in inshore fisheries in that Gulf in their first year.

Hypothesis 4(a): *Stock A is fished in Argentina as spawning adults in the summer.*

Catches in the summer in the hypothesised spawning area

Spawning hakes are known to have been targeted in this area for some time, and in 1998 Argentina introduced a Closed Juvenile Patagonian Area (CJPA) over the spawning grounds (Table 33a). In consequence the catches of spawning adults in spawning grounds are known and have declined markedly since the introduction of the closed area.

Table 33a. Estimated catches of adult spawning hake in the CJPA.

Year	Catches (tonnes)
1991	275,000
1992	300,000
1993	320,000
1994	260,000
1995	250,000
1996	210,000
1997	115,000
1998	20,000
1999	25,000
2000	10,000

Seasonally directed fishing in the spawning areas takes place from October to March, with the highest catches occurring in November and December (Table 33b). Length frequency data from this directed fishery shows the majority of fish caught to be 39cm or above with the majority aged 2yrs or over. These data could also be put into an assessment.

Table 33b. Seasonally directed fishing on spawning fish.

Year	Catch (tonnes)
1992	2,000
1993	2,500
1994	7,500
1995	7,500
1996	14,000
1997	16,000
1998	7,500
1999	9,000
2000	1,000

Assessment:

An assessment of area A was undertaken, which was identical to the one undertaken under hypothesis 1 with the addition of spawning stock catches estimated for the years 1996-1999. These were taken from Table 33a.

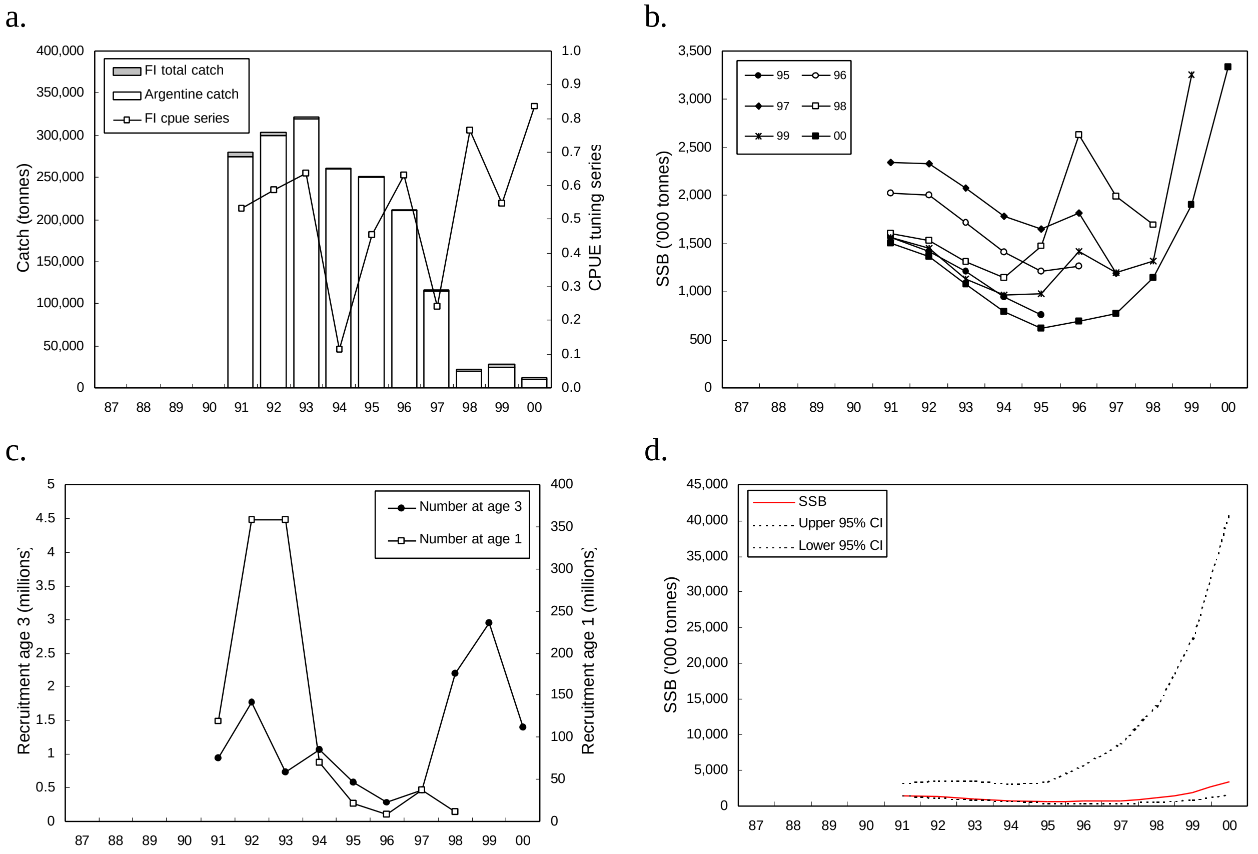


Figure 34. Hypothesis 4: The majority of the stock is retained within Falkland Island waters, but a seasonal fishery in Argentina exploits part of the spawning stock biomass. Results of a VPA analysis showing a). annual catches taken from the Falkland Islands and part of the Argentine stock and the Falkland Islands tuning series used in the analysis b). retrospective analysis of spawning stock biomass for years 1991 to 2000 c). number of recruits entering the fishery at age 3 and the estimated number of fish at age 1, and d). estimates of spawning stock biomass fitted with the upper and lower 95% confidence limits.

Discussion.

The VPA suggests that stock has now recovered to very high levels. But these levels have not been seen in the fishery. This suggests that the hypothesis that the catches in table 33a are all from stock A is probably false. It is still possible that some of the spawning animals from stock A are taken at their spawning time, but we have no means of determining the catches that are relevant to stock A.

This hypothesis is not, therefore, meaningful in providing an assessment of the stock.

Hypothesis 4(b): *Stock A is fished in Argentina as juveniles in the inshore shrimp fishery.*

Analysis of bycatch in the shrimp fishery

Sources used:

1. Pettovello, A. D. 1999. By-catch in the Patagonian red shrimp (Pleoticus muelleri) fishery. Mar. Freshwat. Res., vol. 50(2): 123-7.
2. U: Gandini, PA; Frere, E; Pettovello, AD; Cedrola, PV. 1999. Interaction between magellanic penguins and shrimp fisheries in Patagonia, Argentina. Condor, vol. 101(4): 783-789.
3. Argentine assessment report, 2001.

These authors estimate that the bycatch of hake in the shrimp (Patagonian red shrimp: Pleoticus muelleri) fishery around San Jorge Gulf are significant. (2) suggests 89% of the bycatch is hake, (1) 66% by biomass. Using length frequency distributions presented by the authors, we estimate from (1) that mean size was 23.6 cm (range 17-37cm: mostly 1 year old animals and younger). (2) 14.8cm (range 12->18). These data were collected mostly in 1997, but for (2) also in 1995 and 1996.

Catches in the southern part of the San Jorge Gulf were 8,351 t in 1997 (Table 34).

Table 34. 1997 catches of juvenile *M. hubbsi* in the red shrimp fishery in the South of San Jorge Gulf from Pettovello (1999).

summer	404 t
autumn	339 t
spring	7,608 t
	Total 8,351 t
	Total for whole of Gulf of San Jorge = 16,079 t

This equates to 67,894,309 individuals using the size estimate from (1) and 253,060,606 using the size estimate from (2). For the whole of the catch in the Gulf, estimates are 130,723,577 and 487,242,424.

Shrimp catch in 1997 was 6,479 t, 3241 (approximately ½ from San Jorge Gulf) (Figure 35). Assuming that the same proportions of shrimp were caught in San Jorge Gulf in all other years for which there are FAO total catch estimates, and that the same proportion of small hake were caught as were reported in 1997 by ref (1), we can estimate the total catch of 1 year old hake in this fishery.

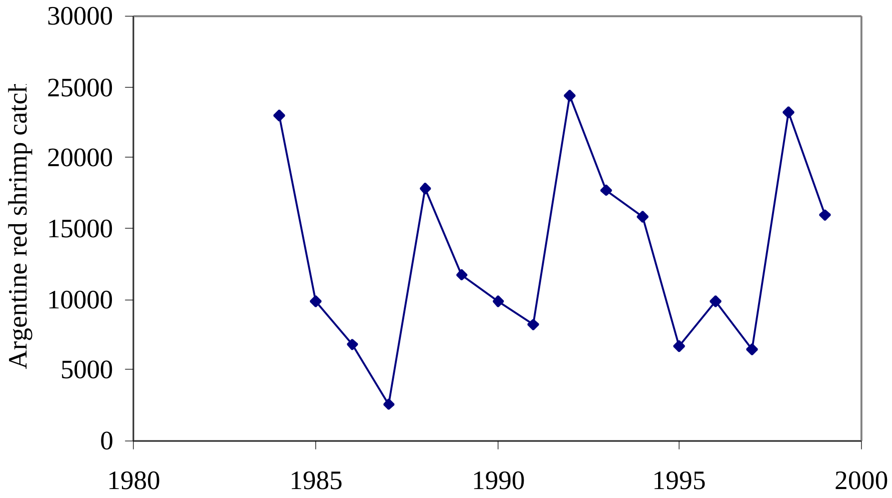


Figure 35. Inshore shrimp catch in Argentina (Source: FAO catch data).

Table 35. Estimates of total catch of age 1 hake in the San Jorge Gulf shrimp fishery. Column 2 is the FAO statistics for the whole of Argentina. Column 3 is the total estimate hake catch in the whole of San Jorge Gulf, using the same catch proportions as reported by reference (1) in 1997, and the mean weight of fish reported by reference (2). Column 4 gives numbers estimated for the Southern Gulf only. The italicised numbers were used in the assessment.

	Argentine red shrimp (FAO)	large size hake		small size hake	
		San Jorge	*South San Jorge*	San Jorge	South San Jorge
		1997 hake catch 16079	*1997 hake catch 8351*	*1997 hake catch 16079*	*1997 hake catch 8351*
		Millions of age 1 hake caught	*Millions of age 1 hake caught*	Millions of age 1 hake caught	Millions of age 1 hake caught
1984	22,994	464	*241*	1,729	898
1985	9,835	198	*103*	740	384
1986	6,768	137	*71*	509	264
1987	2,541	51	*27*	191	99
1988	17,800	359	*187*	1,339	695
1989	11,680	236	*122*	878	456
1990	9,852	199	*103*	741	385
1991	8,218	166	*86*	618	321
1992	24,397	492	*256*	1,835	953
1993	17,645	356	*185*	1,327	689
1994	15,826	319	*166*	1,190	618
1995	6,705	135	*70*	504	262
1996	9,874	199	*103*	743	386
1997	6,479	131	*68*	487	253
1998	23,203	468	*243*	1,745	906
1999	15,888	321	*166*	1,195	621

The Argentine assessment (3) estimates in 1998 that the outrigger shrimp fleet, in the whole of San Jorge Gulf, took 750,000,000 year 1 animals, of which 700,000,000 were discarded. Of all the estimates above for the whole of the Gulf, this is most similar to 468M (shaded).

The Gulf of San Jorge acts as a nursery ground for stocks of *M. hubbsi* that are the subject of the main Argentine fishery. Therefore, it is unlikely that all these young fish are part of any stock in area A. We therefore used the estimated number of 1+ fish caught in the southern part of the Gulf only (italics in Table 35) in the following assessment.

Assessment:

An assessment of area A was undertaken, which was identical to the one undertaken under hypothesis 1 with the addition of the estimated catch of 1+ animals from the above table to the assessment.

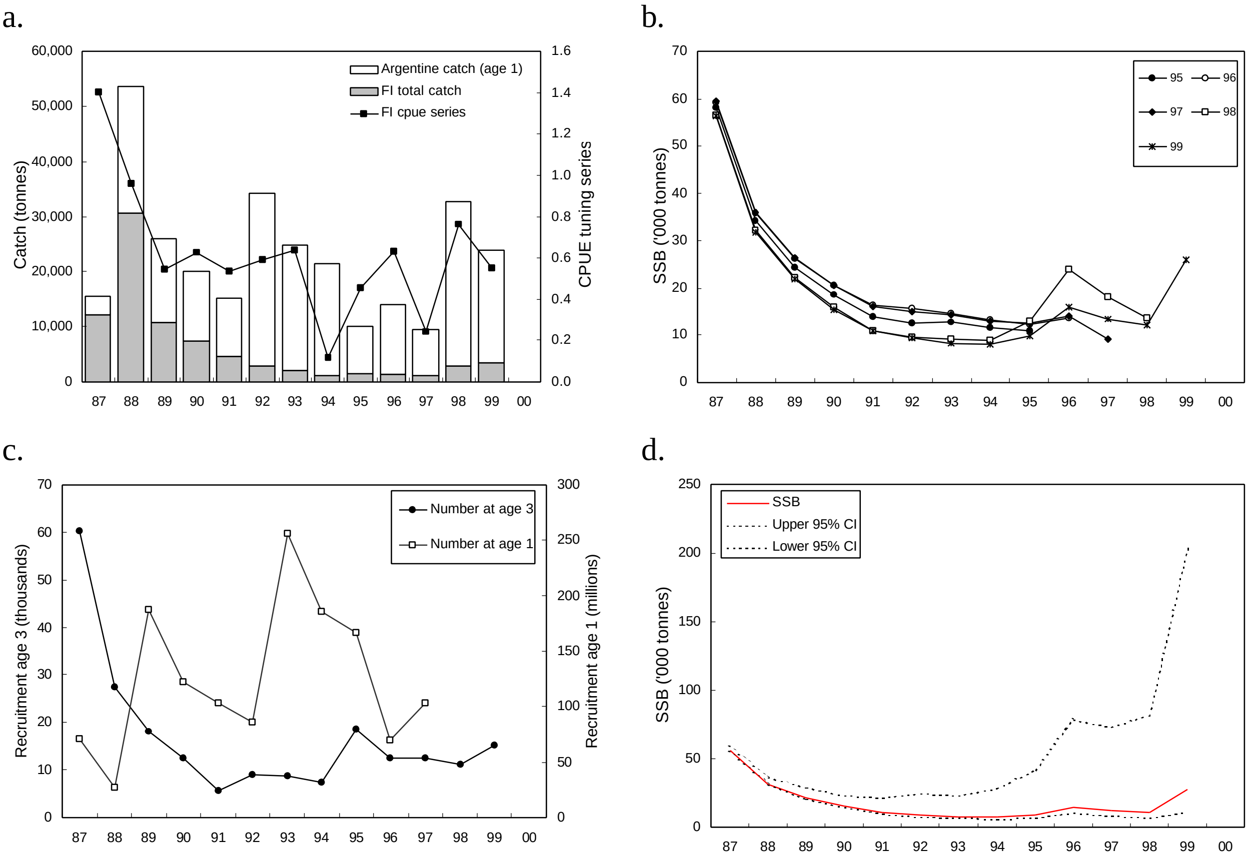


Figure 35. Hypothesis 4: The majority of the stock is retained within Falkland Island waters, but a seasonal fishery in Argentina exploits a number of the juveniles (age 1). Results of a VPA analysis showing a). total annual catch from the Falkland Islands and the estimated number of juveniles retained as a bycatch in the Argentine shrimp fishery. The Falkland Islands tuning series was used in the analysis b). retrospective analysis of spawning stock biomass for years 1987 to 2000 c). number of recruits entering the fishery at ages 1 and 3, and d). estimates of spawning stock biomass fitted with the upper and lower 95% confidence limits.

Discussion

The same problem as was encountered with hypothesis H4a is also relevant to H4b: although the recruits can be included, they are probably not all from stock A and we do not know the relevant proportions. However, we have assumed that only those fish caught in the south of the Gulf might be part of the stock fished in area A.

This hypothesis could explain some of the variability in recruitment that is seen in the assessment of H1. It may also explain why the projection from H1 was not able to realise the pre-exploitation biomass under current recruitment levels – in effect, recruitment is being depressed by the high level of juvenile mortality in the red shrimp fishery. Figure 36 clearly shows the volume of this fishery.

Co-ordination and dissemination activities

MEETINGS

The following meetings took place along the project:

- A first coordination meeting was held in the facilities of IEO Vigo in April 2000, involving all the Spanish participants and representatives of the University of Aberdeen and RRAG.
- There was a second meeting in Aberdeen University in July 2000 during the CIAC Symposium to minimize direct cost to this project. The meeting involved representatives of IEO, the University of Aberdeen, RRAG and FIGFD.
- A third coordination meeting was held at IEO and ANAMER buildings in Vigo in December 2000, involving all the Spanish participants and representatives of the University of Aberdeen and RRAG.
- A fourth meeting was held in Faro in March 2001 involving representatives of IEO, the University of Aberdeen and RRAG, alongside other project meetings, thus minimising direct cost to this project.
- A final coordination meeting and the workshop on preliminary hake stocks assessment took place in London in July 2001 at RRAG facilities, involving all the RRAG and FIGFD participants and representatives of IEO and of the University of Aberdeen.
- Other several minor meetings were held in Vigo between IEO and AU participants alongside other project meetings
- There were additional national meetings.

DISSEMINATION OF RESULTS

The following articles have been published in the magazines "Pesca Internacional" and "Industrias Pesqueras" edited by the Spanish fisheries sector in Vigo:

- "*Industria e investigación, unidos en la explotación racional*" (Pesca Internacional, Num. 4, January 2001)
- "*Necesidad de un organismo multilateral para la gestión de las pesquerías en el Atlántico Sudoccidental*" (Industrias Pesqueras, Num. 1775-1776, April 2001)
- "*IEO y ANAMER finalizan un proyecto de evaluación de stock de merluza*" (Pesca Internacional, Num. 16 January 2002)
- "*Campaña en el Atlántico de ANAMER*" (Pesca Internacional, Num. 3, December 2000)
- "*Atl. Sudoccidental: Más datos sobre la merluza*" (Pesca Internacional, Num. 18, March 2002)
- "*Atlántico Sudoccidental, punto de encuentro*" (Pesca Internacional, Num. 20, May 2002)

A poster describing the project objectives and tasks was prepared and distributed among ANAMER associated companies.

A talk on the project objectives, tasks, activities, results and collaboration between fishing industry and research centres will be given to representatives of the Spanish fisheries sector by the project co-ordinator at ANAMER facilities.

A note about the project was published in January 2002 in the monthly information booklet of IEO and in its website – see http://www.ieo.es/agenda.html

A Web page have been established for dissemination of some of the results of the project – see http://oceanovigo.vi.ieo.es/proyectos/study99016/default.htm

PUBLICATIONS

A Poster describing a possible spawning area for Southern blue whiting was sent to the ICES ASC in September 2001.

A Poster on the use of GIS to the study of fisheries in the SW Atlantic was presented in a Workshop on remote sensing held at Vigo University in October 2001.

A paper with the title "SERIE HISTÓRICA DE DATOS COMERCIALES Y BIOLÓGICOS SOBRE LAS DOS ESPECIES DE MERLUZA *(Merluccius hubbsi* y *M. australis)* EN TORNO A LAS ISLAS MALVINAS Y AGUAS INTERNACIONALES DE LA PLATAFORMA PATAGÓNICA. 1989-2000" was submitted to the IEO statistics review "DATOS Y RESUMENES" and it is now in press. Two more papers on cephalopods and by-catch finfish species are expected to be submitted to the same review in the first half of 2002.

The following abstracts have been sent to the ICES Annual Science Conference to be held in October 2002 in Copenhagen:

- Assessment of the Falkland Island population of Argentine hake *Merluccius hubbsi*
- The trophic relationships of several commercial finfish species from the southwest Atlantic.
- Morphometric and meristic variation in Argentine hake (*Merluccius hubbsi*) and southern hake (*Merluccius australis*) from the southwest Atlantic.
- The spatio-temporal pattern of hake (*Merluccius hubbsi*) abundance and environmental influence in the Patagonian shelf area
- Trends in the pattern of discarding in the hake (*Merluccius hubbsi* and *Merluccius australis*) fishery in the SW Atlantic
- Analysis of the evolution of catch and effort in the Spanish hake fisheries in the Patagonian shelf
- Overview of the Spanish fisheries in the Patagonian Shelf

Additionally, a considerable amount of additional data analysis is on progress. The aim is to complete analysis and publication over the next 12 months, including the following papers already in writing:

1. *The spatial and temporal pattern of hake M. hubbsi fisheries by Spanish fleets in the Patagonian shelf area.*
2. *The spatial and temporal fishery pattern of Spanish fleets in Patagonian shelf area*
3. *The fishery, assessment and stock structure of hakes around the Falkland Islands*
4. *Seasonal distribution and migrations of Merluccius hubbsi and M. australis in Falkland Islands waters*

It is also expected to produce other papers on hake diet, morphometrics, stock differences and discard patterns by the Spanish fleet in the Patagonian Shelf.

Acknowledgements

We thank the ANAMER associated companies and other Spanish fishing enterprises, as well as skippers, officers and crews for their collaboration with the scientific observers programme of IEO since 1989 and particularly with this project, supplying vessels for deployment of observers and for providing data on fishing activity. We thank all scientific observers participating in the IEO observers programme, especially Ángeles Armesto for her collaboration with the faunal guide. In Vigo, we thank Adolfo Ortega for his quiet collaboration with us from many years ago. Particular thanks are due to José Antonio Cordeiro in Stanley, for his friendly assistance since 1989 boarding observers and shipping samples and equipment.

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