Cooperative Research (CRAFT)

PROMOTING HIGHER ADDED VALUE TO A FINFISH SPECIES REJECTED TO SEA

Contract number Q5CR-2002-71709

Final Report

(Period 01/01/2003 - 31/12/2004)

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PROJECT PROGRESS SUMMARY

Section 1: PROJECT IDENTIFICATION Information to be provided for project identification	**NOT CONFIDENTIAL**

Title of the project: ***PROMOTING HIGHER ADDED VALUE TO A FINFISH SPECIES REJECTED TO SEA***			
Acronym of the project: ***ROCKCOD***			
Type of contract **Co-operative Research (CRAFT)**			**Total project cost** (in euro) 880.199 €
Contract number **Q5CR-2002-71709**	**Duration** (in months) 24 Months		**EU contribution** (in euro) 439.654 €
Commencement date 1 January 2003		**Period covered by the progress report** 1 January 2003– 31 December 2004	
PROJECT COORDINATOR			
Name: José Ramón Fuertes Gamundi	**Title: Mr**		**Address: Puerto Pesquero P.O. Box 1078 E-36200 Vigo, Spain**
Telephone: +34 986 433844	**Telefax: +34 986 439218**		**E-mail address:** **direccion@arvi.org**
Key words (5 maximum - Please include specific keywords that best describe the project.). Fisheries, Discards, SW Atlantic, Ecosystem, Seafood industry			
World wide web address (the project's www address) http://www.arvi.org/I+D+I/principalIrockcod.asp			

List of participants Provide all partners' details including their legal status in the contract i.e., contractor, assistant contractor (to which contractor?).

Industrial partners

ANAMER (Leader, Industrial Partner). SPAIN

SULIVAN SHIPPING SERVICES LTD (ANAMER associated company). FALKLAND ISLANDS

MG OTERO CONSULTORES SL (ANAMER Subcontractor). SPAIN

OPTIMAR FODEMA SA (Industrial Partner). SPAIN

ARMADORA PEREIRA SA (Industrial Partner). SPAIN

ARGOS LTD (Industrial Partner). UK

NECTARBECK LTD CROWN SEAFOODS (Industrial Partner). UK

PEZ AUSTRAL SA (SPONSOR). SPAIN

Research partners

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INSTITUTO ESPAÑOL DE OCEANOGRAFÍA IEO (RTD Performer). SPAIN

ABERDEEN UNIVERSITY UNIABDN (RTD Performer). UK

NORTH SEA FISHERMEN'S ORGANIZATION (NSFO) (UNIABDN Subcontractor). UK

Section 2: Project Progress Report **NOT CONFIDENTIAL**

(2 pages maximum.. Use short sentences. Be factual. Avoid technical terms as much as possible)

Objectives:

This project aimed to the development of the research and the technology necessary to promote higher added value to fishing activity. This is to be achieved by obtaining profit from a finfish species ("Rockcod", *Patagonotothen* spp.) not known to consumers and currently discarded by the EU fishing fleet operating in the South West Atlantic, in order to supply the EU seafood industry with a good quality raw material for human food manufacturing. Use of this species, caught as a by-catch in the existing fisheries targeting hakes and cephalopods, should also increase the profitability of the fleet, contribute to maintaining employment and help to counterbalance the negative effects of fishing activity and discards in the ecosystem. The main scientific-technological objectives and expected achievements were the following:

- Description of the fisheries
- Improved knowledge of the biology of the species
- Biomass assessment
- Estimation of catches and discards
- Analysis of the spatial and temporal distribution of the resource. Fishery forecasting and testing
- Sensorial, Microbiological, Nutritional and Biochemical Evaluation of Rock cod
- Development of the technical modifications on board commercial vessels
- Development of new processed products from frozen Rock cod

Results and Milestones:

WP 1 Co-ordination.

i) setting up of the Steering Committee

ii) kick-off meeting (Feb 2003), as well as first and second annual co-ordination meetings (Dec 2003 and Sept 2004, respectively)

iii) several meetings held between different partners concerning co-ordination of Fisheries, Characterisation and Suitability activities, including design of the observers' sampling protocol, collection, shipment , traceability and delivery of samples, and freezing and machinery trials.

WP 2 Fisheries, biology, distribution and assessment.

i) first and second progress report Fisheries Co-ordination

ii) selection, training and deployment of observers and monitoring of their activities. Collection, shipment, traceability and delivery of samples to Stanley, Vigo and Aberdeen. Creation of database structure, data processing and collation, data analysis and obtention of results.

iii) preliminary description of the European fisheries in the SW Atlantic and description of the rockcod fisheries around the Falkland islands and on the High Seas.

iv) length at sexual maturity for P. ramsayi was found to be 27.56 and 24.85 cm LT for male and female fish respectively. This would suggest that they mature at the ages of 5 to 7 years respectively. The diet of rockcod is composed mainly of crustaceans, polychaetes, isopods, amphipods, and seaweeds. Diet composition shows significant differences by size, sex and area.

v) analysis of the spatial and temporal variability distribution of the resource. Fishery forecasting: Although the predictive models developed have high residual deviance, the give average fitted values compared with the original CPUE values. This may indicate that the models are feasible for predicting average fish abundance levels.

vi) preliminary analysis of stock status of Rockcod within Falklands Island waters. Projections from the ASPMs, for what they are worth, suggest that average catches of between 700 and 3000 tonnes annually would be sustainable in the long term.

WP 3 Characterisation of the raw fish as food.

i) first and second progress report Characterisation Co-ordination

ii) P. ramsayi showed a low fat content and high protein content. This species showed low levels of cholesterol, high levels of vitamin E in comparison to other fish species, and low levels of carbohydrates. The fatty acids profile showed a high content of PUFA, specially EPA and DHA. This study also demonstrated that there is not risk associated to the accumulation of toxic metals

iii) in relation to mineral content, values agreed with those reported for other species and demonstrated that this species is a good source of minerals. Levels of amino acids were in agreement with data reported in literature for other fish species

iv) from the point of view of its nutritional composition and organoleptic characteristic, Patagonotothen ramsayi shows high quality. Its consumption is out of risk as for the contamination of heavy metals and parasites. This species has a shelf life of 6-9 month frozen at –18ºC. From a public health point of view no nematodes (Anisakis and Pseudoterranova) that are able to infect humans were found in the flesh of P. ramsayi although they were found in other organs

WP 4 Technological suitability.

i) first and second progress report Suitability Co-ordination

ii) the overall quality and nutritional valued of whole *P. ramsayi* was maintained stable during 6 months at -20ºC. The quality was low after 9 months at –20ºC mainly due to the development of rancidity.

iii) the size of the fish is the main problem for the European market. The only solution is landing larger fish (>33cm).

Milestone M1: *First Co-ordination Meeting* (**Finished**). The kick-off meeting was held on the 6th February 2003.

Milestone M2: *Gathering and sending of fish samples* (**Finished**). Shipment of samples to Port Stanley, Vigo and Aberdeen for biological and sensorial, microbiological and biochemical trials.

Milestone M3: *Fisheries Data collection* (**Finished**). Collection and collation of historical fishery data available at IEO and FIFD, as well as compilation of new data was completed at the end third quarter 2004.

Milestone M4: *Midterm Review* (**Finished**). The first consolidated report was accepted in March 2004.

Milestone M5: *Determination of shelf-life under frozen conditions* (**Finished**). Trials showed good sensory quality after frozen storage.

Milestone M6: *Fisheries description and assessment* (**Finished**). Preliminary description of European fisheries in the Patagonian Shelf. Description of Rockcod fisheries mainly focussing in variations on the spatio-temporal distribution and regarding oceanographic features. Assessment of Rock cod stocks and economic potential.

Milestone M7: *Overall characterisation, evaluation of consumer's acceptance and overall feasibility* (**Finished**). Review of overall results concerning characterisation, consumer's acceptance and overall feasibility was made within the frame of WP4

Benefits and Beneficiaries:

The project would contribute to increase the profitability of the fleets and of the food fishing industry, maintenance of employment and conservation of marine ecosystems.

The main industrial needs related to the above mentioned problems are:

- The EU fishing fleet needs to find new species to increase its profitability.
- The EU food fishing industry needs to be furnished of adequate amounts of row material to produce goods to supply the markets.

This makes necessary to deep in the knowledge of the biology of the species, relationships between its distribution and environmental issues, biomass assessment, characterisation of the new product to be used for human consumption and development of new technologies for its processing and marketing.

Future Actions (if applicable):

Updating of the project's website with final results will be finished after approval of final report (http://www.arvi.org/I+D+I/principalIrockcod.asp).

An important result related with this project thay will require future actions is the contract signed in 2004 between the Fondo de Regulación y Organización del Mercado de los Productos de la Pesca y Cultivos Marinos (FROM), belonging to the Spanish General Directorate for Fisheries and the Spanish National Association of Fish Can Producers (ANFACO). This contract aims to provide technical assistance for the establishment of a quality and safety plan for marketing of fish can products. Among other targets, comprises the use of new fish species in the fish canning industry and will include the rockcod (*Patagonotothen* spp.) in the study. Several canning companies are participating in this pilot plan and will be the final users of the results.

Another actions to be undertaken in the future refer to dissemination activities of the results achieved during this project for awareness of fishing industry and consumers to make better use of marine living resources.

Application for fundings for a campaing aiming to promote the comsuption of discarded species among European consumers will be considered.

1. OBJECTIVES AND EXPECTED ACHIEVEMENTS (AS IN THE TECHNICAL ANNEX)

This project aims to develop the research and the technology necessary to promote higher added value to fishing activity. This is to be achieved by obtaining profit from a finfish species (Rockcod, Patagonotothen spp.) not known to consumers and currently discarded by the EU fishing fleet operating in the South West Atlantic, in order to supply the EU seafood industry with a good quality raw material for human food manufacturing. Use of this species, caught as a by-catch in the existing fisheries targeting hakes and cephalopods, should also increase the profitability of the fleet, contribute to maintaining employment and help to counterbalance the negative effects of fishing activity and discards in the ecosystem.

The main scientific-technological objectives and expected achievements are the following:

- *Description of the fisheries*
- *Improved knowledge of the biology of the species*
- *Biomass assessment*
- *Estimation of catches and discards*
- *Analysis of the spatial and temporal distribution of the resource. Fishery forecasting and testing*
- *Sensorial, Microbiological, Nutritional and Biochemical Evaluation of Rock cod*
- *Development of the technical modifications on board commercial vessels*
- *Development of new processed products from frozen Rock cod*

2. PROJECT WORKPLAN (AS IN THE TECHNICAL ANNEX)

Introduction

This proposal will assess abundance trends and suitability for exploitation of a discarded species to be exploited by the EU fishing fleet and its potential to supply the seafood industry with a new marketable product. The project will provide advice on the likely long-term biological and socio-economic consequences of different levels of exploitation. The project encompasses certain areas of interest to the European fishing fleet operating in the SW Atlantic (i.e. FICZ/FOCZ and International Waters outside the Argentinean EEZ). The partnership includes representation from Spain, Norway and UK.

The project is divided onto 4 work packages including co-ordination and will last 24 months. The scientific and technical work packages will run sequentially. Each work package will be co-ordinated by one of the partners in the project.

The subject species of the project (Rock cod, Patagonotothen spp.) can be included in the category Unquantifiable Discarded Species for which a lack of data creates an unknown level of biological and ecological impact. Hall (1996) showed the lack of data for most discarded species around the world. Hence, one of the most important objectives of the scientific work should be the creation of a database to allow the assessment of this environmental impact with already existing and new data acquired during the project.

Project structure, planning and timetable (as in the technical annex)

WPL	**Workpackage list**					
Work-package No[1]	**Workpackage title**	**Responsible & Participants No**[2]	**Person months** [3]	**Start month** [4]	**End month**[5]	**Deliverable No**[6]
1	***Co-ordination and dissemination***	**A1, A2, A5, B1, B4**	**13**	**1**	**24**	**1,2,5,6,7,8,13, 21,23,24,25, 26,27,28**
2	***Fisheries, biology, distribution and assessment***	**B4, A1, A3, A4, B2, B3, B5**	**48,5**	**2**	**22**	**14,16,17,18,19**
3	***Characterisation of the raw fish as food***	**B1**	**6**	**6**	**16**	**3,9,11,12**
4	***Technological suitability of Rockcod for an industrial processing line***	**B1, A2, A5**	**9**	**5**	**23**	**4,10,15,20, 22**
	TOTAL		**76,5**			

[1] Workpackage number: 1 – n.

[2] Number of the contractor leading the work in this workpackage.

[3] The total number of person-months allocated to each workpackage.

[4] Relative start date of the work in the specific workpackage, month 0 marking the start of the project, and all other start dates being relative to this start date.

[5] Relative end date, month 0 marking the start of the project, and all end dates being relative to this start date.

[6] Deliverable number: Number for the deliverable(s)/result(s) mentioned in the workpackage: D1 - Dn.

Deliverables list for the whole period

Deliverable No[7]	Deliverable title	Delivery date[8]	Nature[9]	Dissemination level[10]	Status	Dissemination target
1	First Co-ordination meeting report	2	R	CO	Finished. Included in the First Progress Report	Project Partners
2	Consortium Agreement	6	O	CO	Finished. Sent to the Commission in 2004	Project Partners
3	Organoleptic characteristics of Rockcod with especial focus in off-flavours	9	O	CO	Finished	Seafood Industry
4	Rockcod suitability for physical processing (fillet, gut, etc.)	10	O	CO	Finished	Fishery Industry
5	First progress report Fisheries Co-ordination	11	R	CO	Finished. Included in the First Progress Report	Project Partners
6	First progress report Characterisation Co-ordination	11	R	CO	Finished. Included in the First Progress Report	Project Partners
7	First progress report Suitability Co-ordination	11	R	CO	Finished. Included in the First Progress Report	Project Partners

[7] Deliverable numbers in order of delivery dates: 1 -n
[8] Month in which the deliverables will be available. Month 0 marking the start of the project, and all delivery dates being relative to this start date.
[9] Please indicate the nature of the deliverable using one of the following codes:

R = Report
P = Prototype
D = Demonstrator
O = Other

[10] Please indicate the dissemination level using one of the following codes:

PU = Public
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).

8	First consolidated annual periodic report	12	R	CO	Finished. Included in the Second Progress Report	Project Partners
9	Safety and possible toxicological risks associated to Rockcod consumption report	13	R	CO	Finished	Seafood Industry
10	Modifications needed for machinery on board	15	O	CO	Finished	Fishery Industry
11	Nutritional characteristic of the fish species as food report	16	R	CO	Finished	Seafood Industry
12	Spoilage characteristics of the fish during conservation and processing report	16	R	CO	Finished	Seafood Industry
13	Final report Characterisation Co-ordination	16	R	PU	Finished. Included in the Second Progress Report	Project Partners, Seafood Industry
14	Implementation of an actual Database	18	O	CO	Finished	Project Partners, Fishery managers
15	Shelf-life of whole Rockcod and Rockcod fillets under frozen conditions report	19	R	CO	Finished	Seafood Industry
16	General review of assessment and management practices of the Fisheries	20	R	CO	Finished	Project Partners, Fishery managers
17	Fishery forecasting	21	O	CO	Finished	Project Partners, Fishery managers
18	Analysis of the spatial and temporal distribution of the resource	21	O	CO	Finished	Project Partners, Fishery managers
19	Estimate of Fishery long-term sustainable yield	22	O	CO	Finished	Project Partners, Fishery managers
20	High quality and healthy processed products from Rockcod results	22	O	CO	Finished	Seafood Industry
21	Final report Fisheries Co-ordination	22	R	PU	Finished. Included in the Second Progress Report	Project Partners, Fishery managers

22	Consumer's acceptance degree results	23	O	PU	Finished	Seafood Industry, Consumers
23	Final report Suitability Co-ordination	23	R	PU	Finished. Included in the Second Progress Report	Project Partners, Fishery managers
24	Final Report	24	R	PU	Finished	Project Partners, Fishery managers
25	Brochures for dissemination about project	6, 22	R	PU	Finished	Fishery & seafood industries
26	Meeting minutes	6,12,18,24	R	CO	Finished	Project Partners
27	Annual cost statements	12, 24	R	CO	Finished	EC Services
28	Technical Implementation Plan (TIP)	24	R	PU	Finished	Project Partners, Fishery managers

Milestones list

Milestone No	Milestone title	Timing	Type	Status	Criteria
M1	First Co-ordination meeting	2	Meeting	Finished	
M2	Gathering and sending of fish samples	4	Timeline	Finished	
M3	Fisheries Data collection Completed	18	Data	Finished	Date of reports delivery
M4	Midterm Review	15 - 16	Meeting	Finished	Review overall progress and measure against goals in Tech. Annex
M5	Determination of shelf-life of whole Rockcod under frozen conditions.	19	Data	Finished	Expected shelf-life of at least 12 months
M6	Fisheries description and assessment of Rock cod stocks and economic potential	22	Meeting and data reviews	Finished	General review of assessment and management practices of the Fisheries and Fishery forecasting
M7	Overall characterisation of Rockcod as food and evaluation of consumer's acceptance and overall feasibility	23-24	Meeting and data reviews	Finished	Final meeting review of overall results and exploitation potential assessment

WORKPACKAGE 1

CO-ORDINATION AND DISSEMINATION OF RESULTS

Description of the workpackages

WORKPACKAGE NUMBER 1: CO-ORDINATION AND DISSEMINATION OF RESULTS

Phase: final report

Start date: 1

Completion date: 24

Current status: finished

Co-ordinated by ANAMER (A1) Person Months (4+1) with assistance of MG Otero

Other Partners (Person/Months): A2 (1), A5 (1), B1 (1) and B4 (5).

Deliverables Nº: 1,2,5,6,7,8,13,21,23,24,25,26,27,28.

Milestones Nº: 1, 4.

Objectives (as in the technical annex)

This workpackage encompasses the tasks required for scientific and technical co-ordination: monitoring and management of scientific and technical progress and general day-to-day communication within the project. Periodic meetings with partners will be organised to discuss and clarify any problems that might arise. Mid-term and final reports will be issued for different aspects of the research, monitoring of deliverables and other project results. This workpackage will ensure harmonisation of data collection, analysis and reporting. Partners will need to work closely together to produce compatible data and joint analyses.

The general co-ordination of the project will be carried out by ANAMER assisted by its subcontractor MG Otero Consultores S.L. Since the project will involve close collaboration with scientific and technical research, the scientific research will be carried out in close collaboration with IEO.

A steering committee consisting of the WP co-ordinators with the additional participation of the main co-ordinator, ANAMER, helped by MG Otero Consultores SL, will be created. Continuous information exchange will be favoured and meetings will be held throughout the project period. The methodology will be found in section 4 (Project Management and Co-ordination).

A Consortium Agreement covering the intellectual property of project results will be redacted during the kick off meeting and subsequently signed by partners.

DISSEMINATION OF RESULTS (Leader ANAMER (A1), Person/Month (1), with assistance of MG Otero and NSFO)

- *Brochures about project will be disseminated among associated members of ship-owners companies.*
- *Articles describing project objectives, tasks and results will be published in specialised magazines, at national and international level.*
- *Posters describing the project objectives, tasks and results will be prepared and distributed among associated members of ship-owners companies.*
- *Talks on the project objectives, tasks, activities and results will be given to representatives of the ship-owners companies.*

- *Notes about the project will be published in all the partners' websites.*
- *A Web page will be established for dissemination of some of the results of the project.*

Methodology and study materials (as in the technical annex)

1. Management capability of the co-ordinator

The general co-ordinator of the project - ANAMER- will be responsible for the co-ordination between all the partners and the European Union, and will carry out the management of the project (Workpackage 1) assisted in this tasks by its subcontractor MG Otero, who have experience in elaboration of proposals and in participation in former EU funded projects related to fisheries. More specifically, during years 2000 and 2001 MG Otero has participated subcontracted by ANAMER in a project funded by the DG FISHERIES to study hake stocks in the SW Atlantic (Falkland islands and International Waters). During this mentioned project, among other tasks, MG Otero carried out co-ordination between fishing companies and Research Institutes (IEO, UNIABDN, FIFD and ICON) participating in the project.

Besides its participation in co-ordination activities, MG Otero will supply and contract scientific observers for on board data, and sample collection and forecast testing. MG Otero will provide a Bachelor in Biology with experience in these fisheries for co-ordination activities, to give training courses to observers about their work on board the vessels, and for data analysis.

The management approach foresees a further work programme definition during the kick-off meeting, including planning the periodical meetings. Informal communication between the partners will be encouraged (specially by e-mail). Progress reports from each leader will be required at predefined intervals, identifying variance against work programme objectives and giving detail of corrective action and deliverables. Formal reports will be sent to the EC, to meet the 6 monthly patterns expected by the Commission together with financial statements.

A specific project management workpackage is included in the work programme to allow the management procedures. This workpackage covers all the manpower needed for the overall co-ordination of the project, including measures needed to ensure the exploitation and dissemination of results. Preparation of the detailed planning for the tasks and the preparation of the task reports is included in the manpower for the respective technical task. This workpackage will also consider updating of the exploitation plan and organising the actions necessary to protect the intellectual property. This will be reviewed at each formal meeting.

The co-ordination workpackage encompasses the tasks required for scientific and technical co-ordination: monitoring and management of scientific and technical progress and general day-to-day communication within the project. Also under this heading are workshops for different aspects of the work, annual co-ordination meetings and co-ordination of the production of deliverables and other project results. This workpackage will ensure harmonisation of work and reporting and will develop the fishery and biological database. Partners will need to work closely together to produce compatible data and joint analyses. Since the project will involve close collaboration with scientific and technical research, the scientific research will be carried out in close collaboration with IEO.

2. ***Structure, administration and competence***

To accomplish the main scientific objective of the ROCKCOD project a multidisciplinary consortium is needed. For this purpose, the project counts with the participation of 10 partners representing SMEs and RTD Performers such as industrial fishing and processing companies, national research institutions and universities, besides a governmental body from the Falkland/Malvinas Islands. All of them will contribute to new machinery design and format presentations of the new product, assembly and analyses of historical and new data on fishing activity, biology of the species, environmental and socio-economic parameters, and to depict their possible interactions.

3. ***Project Co-ordinator***

Overall co-ordination of the project will be the responsibility of ANAMER who will also be the main interface between the Consortium and the European Commission, with strong collaboration of MG Otero, as project manager reporting to the project co-ordinator. He will consolidate the project planning, progress reports, milestone assessments, cost statements and budgetary overviews etc, using the inputs from the other partners and will co-ordinate the communication between partners.

4. ***Steering Committee***

In order to facilitate the management of the project, a Steering Committee composed of Work Package co-ordinators is proposed. ANAMER/MG Otero for WP 1, IEO for WP 2, and CSIC/IIM for Work Packages 3 and 4 will constitute the membership of the Steering Committee. ANAMER and MG Otero will be in charge of keeping all the partners fully informed about the project status, the planning and all other issues which are important for the partners in order to avoid any confusion and maintain the vitality of the mutual co-operation. Interactive management meetings and technical meetings have an important role in the communication strategy. All information such as meeting's minute, visit reports, task reports, relevant publications, etc, will be addressed to the project consortia. Continuous information exchange will be favoured and meetings among partners will be held for major project organisation.

5. ***Milestone reviews***

Overall progress in all workpackages will be reviewed at the project co-ordination meetings. During these meetings, the progress of the project and the outlook for exploitation of the results will be critically reviewed and compared to the planning and criteria described in the work-programme. Depending on the progress and the results achieved, a change in the work-programme may be proposed. Alternatively, in case of insufficient technical results or poor outlooks for future exploitation of the results, it can be decided to discontinue the project. For the mid-term and final assessment a special review meeting will be organised with the steering committee.

6. ***Communication strategy***

The communication strategy aims to keep all the partners fully informed about the project status, the planning and all other issues which are important to the partners in order to obtain maximum transparency for all involved and to increase the synergy of the co-operation. Interactive management meetings and technical meetings take an important role in the communication strategy. All information (like minutes of meetings, visit reports, task *reports, relevant publications etc) will be communicated to the Workpackage Co-ordinator and to the Project Co-ordinator, who will decide whether to channel this information to the other partners or not, when appropriate.*

All Partners are principal contractors and will have access to all reports and results. Changes in the working programme and other information concerning the consortium and the project will be communicated to all partners. Each partner will designate a contact person responsible for communication. All Partners are equipped with computers, Internet access and e-mail accounts. Standard communication will be done by e-mail. The exchange of documents and news will be done by a uniform system, Microsoft Office Windows. The official language within the consortium will be English as all documents and protocols will be written in this language.

7. Methods for monitoring and reporting progress

Each partner will report every 6 months to the corresponding Workpackage Co-ordinator about the progress of the work on the basis of a regularly updated detailed planning. These progress reports will contain a review of:

- *compliance with the work programme*
- *percentage of completion, estimated time of completion*
- *technical progress and results achieved (deliverables)*
- *work planned for the following period*

In addition, once a year they will submit the individual cost statements derived from the project execution. The Workpackage Co-ordinators and representatives from Research Institutions will then summarise the overall project status and planning and send it to the Project Co-ordinator, who will finally prepare the corresponding annual management, progress and cost statement reports, taking care of their distribution to the Commission in time. A final project report will review the scientific and technical achievements of the project and main deliverables.

8. Meetings

Meetings will be held every year (3) in total, including the kick-off meeting at different places easily accessible to all partners. Their organisation will be assigned to either Project Co-ordinator or Workpackage Co-ordinators. A preliminary chronogram with possible locations will be generated in the kick off meeting. Meeting organisers will be responsible for its organisation and the elaboration of the minutes. They will consider technical revisions, including changes in the program, interpretation of obtained results, further investigations and reporting to the EU. There will be a balanced weighting of all Partners. Decisions will be made by majority. If fundamental problems occur, the co-ordinator will have to decide in consultation with the Commission. These periodical meetings will ensure the proceeding of the work. If a partner fails to perform or report his results, he will be required by the co-ordinator to make up for it.

The meetings will be organised in a way that travel and subsistence costs are kept at a minimum. A mid-term and final project meeting should be held with participation of all contractors and the Commission.

The European Commission will be informed about the meetings at least eight weeks in advance.

9. ***Project management tasks***

A specific project management Workpackage is included in the work programme to implement to management procedures described above. This task describes all the requirements and demands on the workforce for the overall project co-ordination, including the measures required to assure the exploitation and dissemination of results.

Final report Co-ordination

This Final Report of the CRAFT Project **Q5CR-2002-71709** *"Promoting higher added value to a finfish species rejected to sea*" refers to activities developed during the whole project life from 1st January 2003 to 31st December 2004, under the workpackages included in the proposal.

The main objective of the project was to develop the research and the technology necessary to promote higher added value to fishing activity by obtaining profit from a finfish species (Rockcod, *Patagonotothen* spp.) not known to consumers and currently discarded by the EU fishing fleet operating in the South West Atlantic, in order to supply the EU seafood industry with a good quality raw material for human food manufacturing.

General activities carried out: the Steering Committee, composed by the WP co-ordinators with assistance of MG Otero, was in charge of monitoring and definition of the main co-ordination actions carried out during the whole project's life.

1 *Steering Committee*

As the ROCKCOD project acceptance was confirmed at the end of December 2002 and the start of the first annual fishing season was in January 2003 (February inside the Falkland Islands Interim and Outer Conservation Zones, FICZ and FOCZ respectively), an interim Steering Committee (SC) was set up by e-mail in the first days of January 2003. The interim SC was composed by the WP co-ordinators (i.e. José Ramón Fuertes, ANAMER; Julio Portela, IEO; Isabel Medina, IIM) with assistance of MG Otero and worked for monitoring of project activities, exchange of information, relations between partners, etc.

Due to the imminence of fishing activities in the Patagonian Shelf and the urgent need of deployment of observers, it was agreed after consultation with all partners to fix the kick-off meeting to the 6th of February 2003 in Vigo on the 6th of February 2003, at ANAMER facilities.

2 *Meetings*

2.1 Kick-off meeting

As stated in point 1 (Steering Committee), the kick-off meeting was held on the 6th of February 2003 at ANAMER facilities in Vigo, Spain, with attendance of representatives from all partners with exception of representative from NECTARBECK LTD-Crown Seafoods, who apologized for not being able to attend to the meeting and sent a note to the Coordinator with his needs about fish samples to carry out its share of the project. Previously, a draft agenda for the meeting was circulated to all partners for discussion. The agreed agenda was used during the meeting to address debates and presentations made by some of the participants.

Significant issues related to the project activities such as dates and logistics for deployment of observers, sample collection and sampling protocols, historical catch and effort data, administrative details, etc, were discussed during the meeting. The composition of the interim Steering Committee formed by partners from Vigo was agreed by all the presents.

The agenda and minutes of the meeting as well as presentations in PowerPoint format made by participants, were included in ANNEX I of the First Progress Report.

2.2 First co-ordination meeting

The First annual co-ordination meeting took place on the 2nd of December 2003 at ANAMER facilities in Vigo, Spain, with attendance of representatives from all partners. Previously, a draft agenda for the meeting was circulated to all partners for discussion. The agreed agenda was used during the meeting to address debates and presentations made by some of the participants. The Commission scientific officer responsible for the project was invited to participate in the meeting.

The agenda and minutes of the meeting, as well as presentations in PowerPoint format made by participants were included in ANNEX I of the First Progress Report.

2.3 Second co-ordination meeting

The second co-ordination meeting took place in Vigo at ANAMER facilities on September 21st with attendance of representatives from all partners, coinciding with the ICES Annual Science Conference held in the same city from 22-25 September.

Previously, a draft agenda for the meeting was circulated to all partners for discussion. The agreed agenda was used during the meeting to address debates and presentations made by some of the participants.

Significant issues related to project activities carried out during the second year project such as co-ordination matters, data and sample collection, fisheries description, biology, GIS, assessment, characterisation of the raw fish, technical suitability, administrative details, etc, were discussed during the meeting.

The agenda and minutes of the meeting as well as presentations in PowerPoint format made by participants, were included in ANNEX I of the Second Progress Report.

2.4 Fisheries co-ordination meetings

Several short meetings for co-ordination of observers' deployment and samples logistics were conducted during 2003 and 2004 by MG Otero and IEO at facilities of ANAMER and Armadora Pereira, as well as by email with staff from Argos Ltd, FIFD and Sulivan Shipping Services Ltd, ANAMER' subsidiary company in Port Stanley. Two short meetings were held the 4th of June and the 3rd of December in Vigo between staff from MG Otero, IEO, Argos Ltd and Armadora Pereira to discuss about progress of the activities.

Another activity held in 2003 comprised contacts between FIFD and IEO for elaboration of the sampling protocol included in WP 2, which was distributed among FIFD, IEO and ANAMER observers to standardise their activities.

During 2003 one observer from ANAMER and another one from IEO were sent to the fishing grounds at the end of February. Observers from FIFD began their activities at the start of the first annual fishing season in February 2003. Two more IEO observers were sent in early August at the start of the second fishing season and finished work in early November. FIFD observers also continued their activities during the second season until the end of October.

In 2004 one observer from IEO was sent to the fishing grounds in January 2004. Observers from FIFD began their activities at the start of the first annual fishing season in February 2004. One ANAMER observer and three more from IEO were sent in mid July and early August at the start of the second fishing season and finished work in early December. FIFD observers also continued their activities during the second season until the end of October.

First and Second progress report Fisheries Co-ordination are included in this report (Final Report Fisheries Co-ordination)

2.5 Fish characterisation co-ordination meetings

The 4th of June 2003 a meeting was held among personnel from IIM, OPTIMAR FODEMA, IEO and MG Otero, to examine the samples brought by "Argos Pereira" for characterisation and technological trials. Several short meetings were held between same partners during second half of 2003 to discuss about sample collection, tracking and deliverance.

Short meetings for co-ordination of activities related with WP3 and contacts by e-mail with partners participating in tasks included in this workpackage were made along the second year project. Staff from IIM, OPTIMAR FODEMA, IEO and MG Otero, participated in discussions related to sample collection and shipment, tracking and deliverance.

First and Second progress report Fisheries Co-ordination are included in this report (Final Report Characterisation Co-ordination)

2.6 Fish suitability co-ordination meetings

A visit to one of Argos vessels participating in the project (Argos Pereira), was made on the 5th of June 2003 with attendance of personnel from Argos Ltd, OPTIMAR FODEMA, IEO and MG Otero. During this visit a consultation was made by the Argos Ltd representative to OPTIMAR FODEMA engineers about the possibility of an automatic grading system for Loligo.

Another visit to "Argos Pereira" was made on the 10th of June 2003 by OPTIMAR FODEMA engineers, ANAMER observer and Pereira and MG Otero staff to discuss about freezing and machinery tests made by the observer during his trip. Several short meetings for co-ordination of activities related with WP4 and contacts by e-mail between personnel from IIM, Argos Ltd, OPTIMAR FODEMA, IEO and MG Otero took place during 2004 to discuss about freezing and machinery tests made by the observer during his trip.

First and Second progress report Fisheries Co-ordination are included in this report (Final Report Suitability Co-ordination)

2.7 Non-professional test panel

Previous to the First annual co-ordination meeting and coinciding with the second annual co-ordination meeting two hedonistic tests were prepared to taste Rockcod dishes at Spanish style, with attendance of all participants in the meetings. A third non-professional test took place after the talk about project results given on the 15th December 2004 to shipowners and media. Staff from the Spanish Directorate for Fisheries also participated in the test panel. This kind of test is used in opposition to the Professional test panel results to obtain information expected to be similar to that of the average consumer. The test must get the consumer preference about the preparations. The aim of the test is to obtain the following information:

1. Do you like/dislike this fish?
2. Do you like any preparation in particular?
3. Indicate any problem that as a consumer the fish presents to you.

Both tests took place at the Restaurant of Vigo Don Pepe, Ctra. De Camposancos 347. Tel 986 46 09 13. Fax 986 46 20 65. www.cateringdonpepe.com. e-mail: info@cateringdonpepe.com.

Five different preparations were presented to the participants, two fried, two cooked and one baked. For fried preparations fillets and muscle bars were used and for the other ones the whole fish headed, gutted and scaled was utilized.

The fish taste was well accepted and over all the muscle texture in mouth was very appreciated. The fish presented a consistent structure in all the dishes what evidenced its capacity for withstand different cooking treatments.

On the other hand, when the whole fish was used a problem arose; the fish presents tiny bones in the abdomen. Although these bones disappeared in a preparation with a slightly marinade treatment this represent a problem to solve maybe with an special cut to the fillets that eliminate this part of the fish.

3 *Model X*

The Model X was sent to the Commission after signature by all partners.

4 *Consortium Agreement*

The Consortium Agreement signed by all partners was sent to the Commission in 2004

5 *Dissemination of Results*

During the whole project life a series of articles were published in local, regional and international newspapers and specialized magazines, as well as interviews and reports were broadcasted by local, regional and national TVs and radio stations:

- An article entitled "*Estudio pionero del aprovechamiento de los descartes*" was published during the Exploratory Award phase of the project by the specialized magazine Pesca Internacional edited by the Vigo Shipowners Co-operative, in its issue of July 2002.
- An article entitled "*EU could help rock cod research: possible new South Atlantic fishery*" was published by the specialized magazine Fishing News International edited by Heighway, Agra Europe, in its issue of November 2002.
- An article entitled "*Galicia investiga la explotación del «marujito» para consumo humano*" was published by the regional newspaper La Voz de Galicia in its issue of 7th February 2003.
- An article entitled "*Investigadores vigueses estudian una nueva especie para la flota que faena en Malvinas*" was published by the regional newspaper Faro de Vigo in its issue of 7th February 2003.
- During the kick-off meeting several interviews with project participants were broadcasted by local TV and radio stations.
- An interview with the scientific co-ordinator of the project was broadcasted by the regional TV (TVG) the 28th June on its main weekend news programme.
- An article entitled "*ANAMER lidera un proyecto cofinanciado por la UE para el aprovechamiento de un descarte en Malvinas*" was published by the specialized magazine Pesca Internacional edited by the Vigo Shipowners Co-operative, in its issue of December 2003.

- An article entitled "*Proyecto ROCKCOD: si el fletán tuvo éxito, esta especie podría tener aún más* " will be published by the specialized magazine Europa Azul in its issue of January 2004.
- An interview with ANAMER representative and the scientific co-ordinator of the project was broadcasted by the national TV station (TELE-5) in two different news magazines on the 15th of December.
- A brochure about project objectives and activities during the sixth first months edited by ANAMER for dissemination among the fishing industry is in press. A draft of the brochure was included in ANNEX II of the first year progress report.
- An article entitled "*Los armadores vigueses comenzarán a comercializar pronto el marujito*" by the local newspaper Atlántico Diario in its issue of 11th December 2004.
- An article entitled "*Los armadores potenciarán comercialmente el marujito*" was published by the regional newspaper La Voz de Galicia in its issue of 11th December 2004.
- Two articles entitled "*Los armadores comercializarán un nuevo pescado del Atlántico sur*" and "*Vigo aspira a colocar en el mercado una especie que captura en Malvinas*" were published by the local newspaper Faro de Vigo, in its issue of 16th December 2004.
- Two articles entitled "*Los científicos apuestan por el Rockcod*" and "*Puesta en sociedad de don Marujito*" were published by the specialized magazine Pesca Internacional edited by the Vigo Shipowners Co-operative, in its issue of January 2005.
- During the second co-ordination meeting several interviews with project participants were broadcasted by local TV and radio stations.
- A brochure about project results and activities during the second year project edited by ANAMER for dissemination among the fishing industry is in press. A draft of the brochure was included in ANNEX II of the second year progress report.

A talk on the main results achieved during the project was given at ANAMER' facilities on the 15th of December 2004 with attendance of associated companies' staff and media (TV, radio and press). The talk was given by IEO and IIM researchers participating in the project, covering aspects such as spatio-temporal distribution and potential of the resource, nutritional value, biology, processing, etc.

Information about project objectives, tasks, results and participants is downloadable from the project's website (http://www.arvi.org/I+D+I/principalIrockcod.asp).

Task 1.1 (*General co-ordination*)

The Steering Committee, composed by the WP co-ordinators with assistance of MG Otero, was in charge of monitoring and definition of the main co-ordination actions carried out during the whole project's life.

The Steering Committee, set up in January 2003, worked by email for monitoring of project activities during the whole project's life. Its first resolution after consultations with all partners was to hold the kick-off meeting in Vigo on the 6th of February 2003, at ANAMER facilities. The first annual and second co-ordination meetings were also held at ANAMER on the 2nd December 2003 and on the 21st September 2004. Minutes corresponding to these meetings were included in the first and second progress reports;

A talk on the main results achieved during the project was given at ANAMER' facilities on the 15th of December 2004 with attendance of associated companies staff and media

(TV, radio and press). The talk was given by IEO and IIM researchers participating in the project, covering aspects such as spatio-temporal distribution and potential of the resource, nutritional value, biology, processing, etc.

Other dissemination activities included articles published in local, regional and international newspapers and specialized magazines, as well as interviews and reports were broadcasted by local, regional and national TVs and radio stations.

Task 1.2 (*Fisheries co-ordination*)

This task included several meetings and contacts by e-mail between ANAMER, MG Otero, IEO, FIFD, Armadora Pereira and Argos Ltd. for logistics of observers, and shipment and tracking of samples. Other activities comprised contacts between ANAMER, MG Otero, IEO, FIFD, Armadora Pereira and Argos Ltd for monitoring of observers' activities, data collection and collation, updating of the database, analyses and reporting. Final report Fisheries Co-ordination is included in this report.

Task 1.3 (*Characterisation co-ordination*)

A number of meetings and contacts by e-mail between ANAMER, MG Otero, IIM and IEO were made for monitoring of tasks included in WP 3 and for traceability and delivery of the samples. Final report Characterisation Co-ordination is included in this report.

Task 1.4 (*Suitability co-ordination*)

Activities included in this task comprised some meetings with OPTIMAR FODEMA, ANAMER, MG Otero, Armadora Pereira, Argos Ltd, and IIM for discussions on freezing and machinery trials included in WP 4. Final report Suitability Co-ordination is included in this report.

Final Report Fisheries Co-ordination (Deliverable # 21)

WP 2 Fisheries, biology, distribution and assessment (Lead by IEO)

Objective: The lack of good data on the population dynamics of the species, which is the target of the project, will be taken into consideration. This work-package will therefore try to improve these items by producing a description of the fisheries in the area and of the main biological features, distribution and stock assessment of the species that is the objective of the project.

Task 2.1 (*Data collection*)

This task was the basis of the project and has provided all the fishery, biological (samples included) and environmental data required for tasks integrated in WP 2, 3 and 4. We would like to stress the importance of the participation of fishing partners in this task including ANAMER and its associated company in Stanley, Sulivan Shipping Services Ltd, as well as its subcontracted company MG Otero which contribution for logistics of observers and shipment of samples was of crucial importance for the project. The selfless collaboration of FIFD and IEO was also of great importance for the success of this task. The report for the whole project is included in section WP2, Task 2.1.

Main activities related to this task during the whole project's life referred to:

1. Design of the observer sampling protocol for WP 2 by FIFD;
2. Selection, training and deployment of observers to fishing vessels. Logistics of the observers' programmes carried out by FIFD and IEO with additional participation of ANAMER, Sulivan Shipping Services Ltd and MG Otero;
3. Collection of samples and fishery, biological and oceanographic data.
4. Shipment of samples to Stanley, Vigo and Aberdeen for subsequent tasks to be developed by IEO, FIFD, UNIABDN, IIM, OPTIMAR FODEMA and Crown Seafoods. For the achievemnt of this task it was of great importance the collaboration of the Patrol Ship from FIFD and the ANAMER' representative in Port Stanley;
5. Monitoring of observers' activities and traceability of samples with participation of FIFD, IEO, ANAMER, Sulivan Shipping Services Ltd and MG Otero;
6. Database structure was discussed and necessary changes were agreed among research partners participating in this WP, using as starting point the database created during the *CEC DG Fisheries Study Project 99/016*.
7. Once the structure of the database was finished, it was circulated between partners. During the first annual meeting (2nd December 2003) it was agreed that historical and new fishery data, aggregated on a weekly basis, should be provided by IEO and FIFD by February 2004, in order to start assessment task (ICON). Implementation of the database. Data processing and collation;
8. Data analysis and results.

Task 2.2 (*Fisheries description*)

A preliminary description of the European fisheries in the studied area was made by IEO and FIFD during the project's fisrt year using information collected during the aforementioned Study Project. During the second year and after analysis by IEO and FIFD of fishery, biological and environmental data collected during the project's lifetime, a description of the Rockcod fisheries in the southwest Atlantic was made, mainly focussing on the study of the variations on the spatio-temporal distribution of *Patagonotothen* spp. using GIS and GAM techniques (Task 2.4). The report for the whole project is included in section WP2, Task 2.2.

Task 2.3 (*Biology*)

A summary of the data collected by FIFD and IEO and main results reached during the whole project including CPUE analyses, length frequencies, length weight relationships, reproductive studies, etc, was made. A description of Fisheries Biology of Patagonotothen spp. on the Patagonian shelf was made by FIFD and IEO. Reports on Processing and reading of Patagonotothen spp. otoliths and Reproductive biology of Patagonotothen species were made by FIFD. Morphometric studies based on multivariate analysis of three independent character sets, namely external morphometrics, fin ray counts and skull bone morphometrics initiated in September 2003, under co-ordination of Aberdeen University (UNIABDN) and participation of IEO were finished during the second year. Diet studies, also co-ordinated by UNIABDN, were made in 2004. The report for the whole project is included in section WP2, Task 2.3.

Task 2.4 (*GIS*)

Collection and integration into a GIS platform of remotely sensed sea surface temperature (SST) data was made in close collaboration between UNIABDN (task responsible) and IEO. Fishery and environmental data provided by FIFD and IEO, as well as SST data derived from the NOAA Advanced Very High Resolution Radiometer (AVHRR) were analysed. Analysis of the spatio-temporal distribution of the resource in relation to physical (depth, latitude and longitude) and oceanographic features (Sea Surface Temperature, SST), as well as fishery forecasts were made. The report for the whole project is included in section WP2, Task 2.4 and Subtask 2.4.1.

Task 2.5 (*Assessment*)

Activities included in this task were initiated by ICON in February 2004 including analyses of catch at age, GLM standardisation of CPUE data, biomass estimates, ASPM – Age-structured production model, yield-per-recruit and stock-recruitment relationship. The report for the whole project is included in section WP2, Task 2.5.

The main results achieved in the frame of WP 2 during the whole project were:

- Selection, training, deployment and monitoring of observers' activities
- Assembling of commercial, biological and environmental data
- Development of the database structure. Integration of historical and newly acquired data on the database

- Collection of samples for biological studies at FIFD, UNIABDN and IEO
- Collection of samples for sensorial, microbiological, nutritional and biochemical analyses at CSIC-IIM and processing trials by Nectarbeck
- First and second progress report Fisheries Co-ordination
- Preliminary description of the fisheries in the Patagonian Shelf
- Description of the rockcod fisheries in the Patagonian Shelf
- Communication to the ICES ASC 2004 entitled "Preliminary study of the variations on the spatio-temporal distribution of a potentially exploitable species (*Patagonotothen* spp.) in the southwest Atlantic, using GIS techniques"
- Age and growth, reproductive biology, morphometric and diet studies
- Length/weight relationships
- Examination of *Patagonotothen* gonads histologically for a description of their maturity stages
- Study of the reproductive biology of Patagonotothen species in the Falkland Islands Conservation Zones and on the high seas to the North of the FOCZ.
- GIS analyses and fishery forecasts
- Assessment: catch at age, estimates of biomass, yield-per-recruit and stock-recruitment relationship

Final Report Characterisation Co-ordination (Deliverable # 13)

WP 3 Characterisation of the raw fish as food (Lead by IIM)

Objective: characterisation of the nutritional and sensorial properties together with the biochemical characterisation that will allow the global quality evaluation of rock cod as a new fish product. The microbiological control of the raw fish will assure the possible risk associated to its consumption.

Activities comprised the study of the sensorial, chemical and biochemical characteristics of different individuals of *Patagonotothen ramsayi* to study their quality and future applications in fish technology.

Frozen samples collected by ANAMER, IEO and FIFD observers during their stay on board commercial vessels, arrived at IIM during the project and were used for different analyses aiming to establish sensorial, microbiological, biochemical evaluation and composition and nutritional value of the target species.

Task 3.1 (*sensorial evaluation*)

> Organoleptic evaluation of fresh fish was carried out on board by the observer according to the Official DOCE (1989). As regards to frozen samples analysed in IIM during the project, all individuals showed good sensory quality after frozen storage. *P. ramsayi* showed good muscle properties with high water retention and firm texture. The report for second the whole project is included in section WP3, Task 3.1.

Task 3.2 (*microbiological evaluation*)

> Microbiological data corresponding to fresh samples of *P. ramsayi* were negative. Data of coliforms, *E. coli* and *Salmonella* were negative. Total microbial content of frozen samples were low: 785 UFC and analyses of coliform colonies were negative. The report for the whole project is included in section WP3, Task 3.2.

Task 3.3 (*composition and nutritional value*)

> *P. ramsayi* showed a low fat content and high protein content. This species showed low levels of cholesterol, high levels of vitamin E in comparison to other fish species, and low levels of carbohydrates. The fatty acids profile showed a high content of PUFA, specially EPA and DHA. In relation to mineral content, values agreed with those reported for other species and demonstrated that this species is a good source of minerals. Levels of amino acids were in agreement with data reported in literature for other fish species. The report for the whole project is included in section WP3, Task 3.3.

Task 3.4 *(biochemical evaluation)*

> For identification purposes, in addition to morphological analysis, the sarcoplasmic protein profiles of fishes were studied. On the basis of these results, a characteristic pattern of sarcoplasmic proteins for each species was determined

and used for identifying samples. The muscle composition of the three species. *P. guntheri* and *P. ramsayi* showed similar protein content. The most important feature was the high content of polyunsaturated fatty acids (PUFA) present in the three species. The most important feature was the high content of polyunsaturated fatty acids (PUFA) present in the three species. Fatty acids esterified to triacylglyerols are known to be more saturated than those of phospholipids.

The content of Hg, Cd, Pb and Cu in *P. ramsayi* was determined. **The study demonstrated that there was no accumulation of these metals, therefore no risk associated to the consumption due to toxic metals.** All samples showed levels of heavy metals considerably low and under the legislated permitted limits: The report for the whole project is included in section WP3, Task 3.4.

The main results achieved in the frame of WP 3 during the whole project were:

- Sensorial and biochemical analyses of *Patagonotothen* spp.
- Organoleptic evaluation of *Patagonotothen* spp
- Microbiological analyses of fresh and frozen samples
- Quality Analysis
- Sensorial Analysis
- Electrophoretic analyses of sarcoplasmic proteins
- Content of C, H and N
- Lipid and phospholipid content
- Sarcoplasmic electrophoretic profiles
- Comparison among species by sex
- Fatty acid analysis
- Saturated, monounsaturated and polyunsaturated content

Final Report Suitability co-ordination (Deliverable # 23)

WP 4 Technological suitability (Lead by IIM)

Objective: to study the suitability of Rock cod for two different industrial processing lines and to produce adequate seafood to supply the European market under different formats.

Task 4.1 (*Physical Suitability*)

The average yield of manual processing of rockcod species was manually established calculating the flesh which can be used after beheaded and gutted. The yields of *P. guntheri* and *P. ramsayi* were 35.6 ±1.7 and 33.5 ± 0.6, respectively. The yield was not very high, but because of the size, *P. ramsayi* (the most abundant species in the area) can be almost totally used for filleting. However, *P. guntheri* is too small for filleting, and the flesh could be only used for minced muscle. The report for the whole project is included in section WP4, Task 4.1.

Task 4.2 (*Development of technical modifications*)

On board two Argos vessels ("*ARGOS PEREIRA*" and "*ARGOS VIGO*"), Argos personnel and the ANAMER observer carried out several processing runs with the target species.

After arrival of "*ARGOS PEREIRA*" in June 2003 to Vigo, the general manager of OPTIMAR FODEMA and one engineer went to examine the processing machine lay out of the vessel. A meeting with MG Otero, IEO and owner vessel representative was carried out. Another meeting related to this task took place in June 2003 at CSIC-IIM headquarters to examine the Rockcod samples received, and to discuss the progress of the investigations in reference to the fish.

Fish freezing:

Using the information collected during the Rockcod Exploratory Award, EXAW 1642, Contract nº QLK5-2001-41642, one of two sample batches gathered showed yellowish taints spread all over the fish body, after several months under freezing conditions; so special attention was paid by the observer during his trip to get a good isolation of the gathered samples using plastic film, prior to the freezing process. Care was also taken in getting a good frozen product in the minimum time. Two different freezing systems were available on board: an Ultrafreezing Tunnel and Contact Trays. The tunnel is the slower system, the product needs 6 hours to get the suitable freezing state. The trays are a quicker method spending 2-3 hours to freeze the product. So the quicker method was used during trials.

Machinery checks:

To process the fish headed, gutted and tailless had no problems. Three commercial sizes could be envisaged:

Length between 24-28 cms.	Weight: >150gr.
Length between 29-34 cms.	Weight: 150-200 gr.
Length bigger than 35 cms.	Weight: higher than 200 gr.

Fillets: The fish has hard scale skin that was easily eliminated by the skin machines. The problem arose with the automatic filleting machine. The report for the whole project is included in section WP4, Task 4.2.

Task 4.3 (Frozen Storage)

This part of the work was aimed to evaluate the aptitude of *P. ramsayi* to be frozen stored. Different individuals corresponding to three different trials, August, October and December 2003, were stored at –20ºC, and analysed during a year. They were studied at 4, 6, 9 and 12 months. A sampling experiment for getting data corresponding to zero point on board was planned. The observer took fresh samples and prepared three types of samples: small pieces of muscle, muscle treated with dichloromethane and muscle treated with perchloric acid depending on the scope of the later analyses at IIM.

Off- flavours were determined with the content of TMA, TVB and ^{i}-TBA. Rancidity was determined by sensory analysis and the determination of PV and ^{i}-TBA. Water retention and texture were studied with the determination of protein solubility. Proteolitic activity was also studied for illustrating the possible degradation of texture.

Moreover, nutritional quality was evaluated within the vitamin E degradation and the variation in the fatty acid composition. Skin-on and skin-off fillets were prepared on board and arrived at IIM after 4 months of frozen storage. All analyses were duplicate and/or triplicate. More than 6500 analyses were carried out.

Task 4.4 (Development of processed products from frozen rockcod)

Sub-Task 4.4.1.

The Rockcod passed all routine quality controls needed to fulfil the Good Manufacturing Practises. Microbiological data corresponding to fresh samples of P. ramsayi were negative. Data of coliforms, E. coli and Salmonella were negative. Total microbial content of frozen samples were low: 785 UFC and analyses of coliform colonies were negative. Al processed batches underwent sensorial tests carried out by skinned testers. None of the tested batches presented off-flavours.

Sub-Tasks 4.4.2. and 4.4.3

Hand made fillets with skin were battered/breaded using an industrial machine. The battered portions were pre-fried in oil, using a combination time/temperature of 15 seconds at 180ºC. The pre-fried portions were deep frozen using a Frigoscandia frozen tunnel, being the combination time/temperature of between 20 to 40 minutes at -45ºC. An Ishida automatic filling-weighing machine was used to put the frozen portions into bags. These bags were maintained at below – 18º C in frozen storage till their preparation as dishes to be tested.

Sub-Task 4.4.4.

The size of the fish is the main problem for the European market. Whole fish of 24 cm, will give a skinless fillet 8-14cm and this is not practical or viable. The only solution is:
Only land the larger fish 33cm + if they are there to be caught.

The main results achieved in the frame of WP 4 during the whole project were:

- Calculation of the average yield
- Processing runs on board commercial vessels
- Meetings for development of technical modifications
- Examination of the processing machine lay out of the vessels
- Analysis of fish processing and freezing systems on board
- Machinery checks

Discussion-Conclusion

Workpackage 1: CO-ORDINATION

Conclusions

The following tasks were carried out during the project: setting up of the Steering Committee, kick-off meeting, first and second annual coordination meetings, monitoring of project activities, as well as several short meetings and contacts by e-mail for co-ordination of observers deployment, fisheries co-ordination, fish characterisation co-ordination, fish suitability co-ordination, Model X signature, Consortium Agreement and dissemination of results.

Deliverable # 1 *First Co-ordination meeting report*: finished. The first annual co-ordination meeting was held at ANAMER on the 2nd of December. The agenda and minutes of the meeting were included in ANNEX I of the First Progress Report.

Deliverable # 2 *Consortium Agreement*: finished. Signed by all partners and sent to the Commission in 2004.

Deliverable # 5 *First progress report Fisheries Co-ordination*: finished. Included in the First Year Progress Report.

Deliverable # 6 *First progress report Characterisation Co-ordination*: finished. Included in the First Year Progress Report.

Deliverable # 7 *First progress report Suitability Co-ordination*: finished. Included in the First Year Progress Report.

Deliverable # 8 *First consolidated annual periodic report*: finished. Accepted in March 2004.

Deliverable # 13 *Final report Characterisation Co-ordination*: finished. Included in this Report.

Deliverable # 21 *Final report Fisheries Co-ordination*: finished. Included in this Report.

Deliverable # 23 *Final report Suitability Co-ordination*: finished. Included in this Report.

Deliverable # 24 *Final Report*: finished. The present report

Deliverable # 25 *Brochures for dissemination about project*: the first one was included in the First Year Progress Report. The draft of the second one was included in the Second Year Progress Report. The final version of second brochure will be included in the definitive version of the Final Report.

Deliverable # 26 *Meeting minutes of the second co-ordination meeting*: finished. Included in ANNEX I of the second progress report.

Deliverable # 27 *Annual cost statements*: finished. Cost statements corresponding to the first year were sent to the Commission with the first progress report in January 2004. Cost statements corresponding to the second year and to the whole project were sent to the Commission with the second progress report in March 2005.

Deliverable # 28 *Technical Implementation Plan (TIP)*: finished.

Milestone # 1 (*First Co-ordination meeting*) was achieved. The First Co-ordination meeting (Kick-off meeting) was held on the 6th of February 2003 at ANAMER facilities in Vigo, Spain.

Milestone # 4 (*Midterm Review*) was achieved. The First annual co-ordination meeting took place on the 2nd of December 2003 at ANAMER facilities in Vigo, Spain, with attendance of representatives from all partners.

Workpackage 2: FISHERIES, BIOLOGY, DISTRIBUTION AND ASSESSMENT

Conclusions

Tasks 2.1, 2.2 and 2.3 (*data collection, fisheries description and biology*) were carried out as scheduled in the proposal. Concerning tasks 2.1 and 2.2, observers from ANAMER, IEO and FIFD were deployed to fishing grounds for collection of fishery and biological information, as well as of biological samples.

In the frame of Task 2.2 (*fisheries description*), a preliminary description of the european fisheries in the studied area was made by IEO and FIFD during the project's first year. During the second year a depiction of the rockcod fisheries in the SW Atlantic was made by IEO and FIFD mainly focussing on the variations on its spatio-temporal and bathymetric distribution. A communication entitled "Preliminary study of the variations on the spatio-temporal distribution of a potentially exploitable species (*Patagonotothen* spp.) in the southwest Atlantic, using GIS techniques" was submitted to the ICES Annual Science Conference held in Vigo in September 2004. Personnel belonging to IEO, FIFD and UNIABDN was involved in all these activities.

Results from Task 2.3 (*biology*) included age and growth studies based on otolith reading (FIFD), reproductive biology of *Patagonotothen* species comprising fecundity, state of maturity and sex ratio of individuals (FIFD), morphometric studies using multivariate analysis of morphometric and meristic characters (IEO, UNIABDN), and diet research describing the trophic role of rockcod in the hake fishery areas of West Falklands/Malvinas and in the High Seas (UNIABDN). Samples collected by observers provided the basic material for these analyses. All this documents are included in this report.

Task 2.4 (*GIS*) was responsibility of UNIABDN with participation of IEO. Spatially referenced commercial fishery data, as well as bathymetric and environmental data were examined using Geographic Information System (GIS) techniques in order to map and represent information about the distribution and the abundance of catches of *Patagonotothen* spp. A document on activities related to this task by both research organisms is presented in this report (GIS). Sub Task 2.4.1 (fishery forecasting) was lead by UNIABDN with participation of IEO and comprised data scanning and statistical modeling using Generalised Additive Models (GAMs).

Task 2.5 (*assessment*) was responsibility of ICON and comprised review of stock assessment methods fundamental to the provision of sound management advice to determine the likely size of the stock, and the catch levels that can be sustained by the stock without overexploiting it. Activities related to task 2.5 included analyses of catch at age, GLM standardisation of CPUE data, biomass estimates, ASPM – Age-structured production model, yield-per-recruit and stock-recruitment relationship.

Deliverable # 14 (*Implementation of an actual Database*) finished. Included in Task 2.1.

Deliverable # 16 (*General review of assessment and management practices of the fisheries*) finished. Included in task 2.5.

Deliverable # 17 (*Fishery forecasting*) finished. Included in the present report (subtask 2.4.1).

Deliverable # 18 (*Analysis of the spatial and temporal distribution of the resource*) finished. Included in the present report (task 2.4).

Deliverable # 19 (*Estimate of Fishery long-term sustainable yield*) finished. Included in the present report (task 2.5).

Milestone # 2 (*Gathering and sending of fish samples*) was achieved. Activities concerning this milestone were carried out during first and second year project.

Milestone # 3 (*Fisheries Data collection Completed*) was achieved. Activities concerning this milestone were carried out during first and second year project.

Milestone # 6 (*Fisheries description and assessment of Rock cod stocks and economic potential*) was achieved. A preliminary description of the European fisheries in the Patagonian Shelf was made during the first year and included in the first periodic report. The description of the rockcod fisheries and assessment of rockcod stocks and economic potential was made during the second year and included in the second periodic report.

Workpackage 3: CHARACTERISATION OF THE RAW FISH AS FOOD

Conclusions

Analyses performed at CSIC-IIM under tasks 3.1, 3.2, 3.3, and 3.4 lead to the following conclusions:

1. Sensorial analysis and quality values regarding to the formation of volatile bases and amines derived from microbial and enzymatic degradation were low. Parameters related to rancidity were also low and did not reveal off-flavours associated to lipid deterioration.
2. Texture of *P. guntheri* and *P. ramsayi* was elastic and firm with high water retention. However, texture of *P. magellanica* species was rapidly deteriorated at 4ºC, probably due to a high proteolitic activity.
3. Microbiological analyses did not show significant contamination in all fish and unfrozen samples.
4. The lipid content of the species ranged among 1-3%. *P. guntheri* was the fattest species. The three species showed a high content of polyunsaturated fatty acids, with high contents of EPA and DHA. Lipids of *P. guntheri* were more saturated than the other species.
5. The seasonal variation was studied in *P. ramsayi*. The lipid content increased along the year and the highest content was detected in samples corresponding to November and December.
6. Females corresponding to May were in maturation sex stage. Females contained slight higher lipid amount than males. They were richer in triacylglycerols than males, therefore they showed a more saturated fatty acid composition than males.
7. *P. guntheri* and *P. ramsayi* showed similar protein content. *P. magellanica* had less protein content and higher water content. Sarcoplasmic electrophoretic profiles of fishes were studied. Profiles of *P. guntheri* and *P. ramsayi* were rather similar. *P. magellanica* sarcoplasmic profile was significantly different.

A document on activities related to this task is presented in this report.

Deliverables # 3 (*Organoleptic characteristics of Rockcod with especial focus in off-flavours*), **# 9** (*Safety and possible toxicological risks associated to Rockcod consumption report*) and **#11** (*Nutritional characteristics of the fish species as food report*) were finished and are included in WP3.

Deliverable # 12 (*Spoilage characteristics of the fish during conservation and processing report*) was finished and is included in WP4.

Milestone # 7 (*Overall characterisation of Rockcod as food and evaluation of consumer's acceptance and overall feasibility*) was achieved. Activities concerning this milestone were carried out during first and second year project.

Workpackage 4: TECHNOLOGICAL SUITABILITY OF ROCKCOD FOR AN INDUSTRIAL PROCESSING LINE

Conclusions

Task 4.1. (*Physical Suitability)*

The yield was not very high, but because of the size, *P. ramsayi* (the most abundant species in the area) can be almost totally used for filleting. However, *P. guntheri* is too small for filleting, and the flesh could be only used for minced muscle.

Task 4.2 (D*evelopment of the technical modifications on board commercial vessels*)

Two different freezing systems were available on board: an Ultrafreezing Tunnel and Contact Trays. The tunnel is the slower system, the product needs 6 hours to get the suitable freezing state. The trays are a quicker method spending 2-3 hours to freeze the product.

To process the fish headed, gutted and tailless had no problems. Three commercial size could be envisaged:

24-28 cm. Weight: >150gr.
29-34 cm. Weight: 150-200 gr.
>35 cm. Weight: 200 gr, or higher.

Fillets: The fish has hard scale skin that was easily eliminated by the skin machines.

Task 4.3 (*Frozen Storage*):

- Off- flavours were determined with the content of TMA, TVB and ^{i}-TBA.

- Rancidity were determined by sensory analysis and the determination of PV and ^{i}-TBA.

- Water retention and texture were studied with the determination of protein solubility. Proteolitic activity was also studied for illustrating the possible degradation of texture.

- Moreover, nutritional quality was evaluated within the vitamin E degradation and the variation in the fatty acid composition.

Task 4.4 (*Development of processed products from frozen rockcod*)

The fish was good tasting, with no odours or off flavours when cooked, similar to the Patagonian Silver Hake (*Merluccius hubbsi*) caught in south-western Atlantic. The Rock Cod has a clean taste that you would expect from colder water fish, the flesh could become softer & mushy if the species were caught in the warmer waters of the mid Atlantic, again like Hake.

The only process open, unless the fish come in larger form, is to put the Headed & Gutted whole fish through a 3 mil mincing machine, to separate the bone and skin. The fish can go into a 7.5 kilo, waxed liner, industrial block, for further processing.

We are finding the product is needing more raw material in the core weight to maintain the minimum fish content in the finished product. (Some 5% more than cod or haddock) This could be due to slightly more oil content in the rock cod and is being absorbed into the coatings.

The size of the Fish is the main problem for the European market. Whole fish of 24 cm, will give a skinless fillet 8-14cm and this is not practical or viable. The only solution is:
Only land the larger fish 33cm + if they are there to be caught.

The fish could be filleted in the Far East, if the logistics of the transportation can be overcome. Bearing in mind the yield will be only 50% of the H&G fish landed. This could set this up if required, to produce skinless boneless blocks of white fish fillets, using the rock cod The current market price would be £2-20 per kilo (3.70 Euro) delivered into the UK.

Deliverables # 4 (*Rockcod suitability for physical processing (fillet, gut, etc.*), **# 10** (*Modifications needed for machinery on board*), **# 12** (*Spoilage characteristics of the fish during conservation and processing report*), **# 15** (*Shelf-life of whole Rockcod and Rockcod fillets under frozen conditions report*), **# 20** (*High quality and healthy processed products from Rockcod results*) and **# 22** (*Consumer's acceptance degree results*) were finished and are included in WP4 of this report.

Milestone # 5 (*Determination of shelf-life of whole Rockcod under frozen conditions*) was achieved. Activities concerning this milestone were carried out during first and second year project.

Milestone # 7 (*Overall characterisation of Rockcod as food and evaluation of consumer's acceptance and overall feasibility*) was achieved. Activities concerning this milestone were carried out during first and second year project.

WORKPACKAGE 2

FISHERIES, BIOLOGY, DISTRIBUTION AND ASSESSMENT

WORKPACKAGE NUMBER 2: FISHERIES, BIOLOGY, DISTRIBUTION AND ASSESSMENT

Phase: final report

Start date: 2

Completion date: 22

Current status: finished

Co-ordinated by IEO (B4) Person/Month (11.8)

Other Partners (Person/Months): A1 (1.5), A3(4.5), A4 (4.6) B2(13), B3 (5.5), B5 (7.6)

Deliverables Nº: 14,16,17,18,19.

Milestones Nº: 2, 3, 6.

Objectives (as in the technical annex)

The lack of good data on the population dynamics of the species, which is the target of the project, will be taken into consideration. This work-package will therefore try to improve these items by producing a description of the fisheries in the area and of the main biological features, distribution and stock assessment of the species that is the objective of the project. The participation of the FIFD, providing historical time series as well as scientific cruises, will be essential. Additionally, logistic assistance from commercial vessels for observer deployment will also be needed.

Methodology and study materials (as in the technical annex)

This workpackage is composed of the following tasks:

Task 2.1. Data collection: (Stock-specific data collection on fishing activity and biology. Leader IEO).

Data on fishing activity (catches, effort and discards) provided by different partners will be collated. Several sources of information will be used: historical and new data collected on board commercial vessels during the project by scientific observers from FIFD, IEO and ANAMER (200 observer days in charge of the project provided by ANAMER's subcontractor MG Otero). Commercial data (catches, landings, effort and discards) from ANAMER, Armadora Pereira and Argos. Biological information on rockcod will be collected during research cruises from FIFD and by observers on board commercial vessels from ANAMER, Armadora Pereira and Argos. These will include length distributions, maturity, etc. Otoliths and stomachs will be collected for subsequent studies of age, growth and feeding of rockcod in different areas and seasons.

Task 2.2. Fisheries description (Description of fishing activities, gears, vessels, etc. Leader FIFD).

This task will be undertaken in the first 6 months of the second year of the project. Review of historical data about fishing activities in recent years provided by FIFD, IEO, ANAMER, Armadora Pereira and Argos will result in a description of the fisheries in the *area with special emphasis in rock cod fisheries. Fishing areas and seasons, fishing gears, characteristics of the vessels, etc, will be included in the description. ICON will produce a general review of assessment and management practices.*

Task 2.3. Biology (Study of Biological issues. Leader FIFD).

The analysis and description of main biological parameters of the species such as fecundity, spawning, growth, diet, etc, falls under this heading task.

Task 2.4. GIS (Analysis of the spatial and temporal distribution of the resource. Leader UA).

A geographical information system for integration of environmental and fishery data (including effort, landings and discards) will be developed based in GIS methods and models for visualisation.

Sub Task 2.4.1 Fishery Forecasting

The GIS will produce analysis and prediction of meso-scale and local dynamics of oceanic environment, its relation to the dynamics of fishery resources, etc. Fishery forecasts will be tested by using commercial vessels from ANAMER, Armadora Pereira and Argos.

Task 2.5. Assessment (Assessment of rock cod stocks. Leader ICON).

Historical catch and effort data collected by FIFD and IEO observers will be combined with new data collected during this project to derive estimates of Catch Per Unit Effort (CPUE). Standardised CPUE will be determined for use in assessments. Two assessment models will be examined: production models using trends in CPUE and age-based models. Stochastic yield per recruit analyses will be performed to determine sustainable exploitation rates. If the assessment models are sufficiently successful (this is not guaranteed with a new species) the current status of the stock with respect to sustainable exploitation rates will be examined. If the assessment is successful, and if the surveys provide a sufficiently robust estimate of stock size, an estimate of long-term sustainable yield will be made.

Task 2.1

Data Collection

Task 2.1. Data collection (Leader IEO)

The most reliable and almost the unique way to collect fishery and biological information on such a distant fishing grounds as those of the Patagonian Shelf (Falkland Shelf and the High Seas), is through scientific observers deployed on board commercial vessels. Two of the partners participating in this project (FIFD and IEO) have been running observers programmes in these waters since 1987 and 1988 respectively.

The processing of the catches on board (head and guts off, filets skinless or not, fish paste, fish sausage, etc) makes not possible to obtain biological data such as length frequency distributions, length weight relationships, etc, as well as biological samples for reproductive, morphometric or diet studies when the vessels land their catches.

At the same time data on fishing activity (catch, effort, position, depth, course, etc) on a haul by haul basis, together with other environmental information (SST, SBT, daylight, clouds, moon phase, etc), is useful for gaining an insight into the spatio-temporal distribution patterns of fish species that are not likely to be provided by skippers or captains of fishing vessels.

The use of scientific observers on board commercial vessels makes it possible to obtain such a kind of information as described above.

During the second year of the project scientific observers were deployed on board commercial vessels in the study area (continuing the work carried out during the 1st year). The observers gathered the fishery and biological information and also collected the biological samples required to accomplish the project objectives.

The spatio-temporal coverage of the observer programme in the second year of the project was improved (as in year 1) with 100 hundred observer days carried out by ANAMER observers provided by its subcontractor MG Otero.

The logistics and monitoring of FIFD observers is relatively simple since they are based in Port Stanley and count with the support of the Fishery Patrol Vessel for their deployment and transhipment of biological samples and other material. Fishing vessels operating inside FICZ and FOCZ are required by the FIFD to accept observers onboard. Observers spend some 15- 20 days at sea and then return to Stanley, where their work is supervised and possible mistakes can be corrected for future trips.

In the case of Spanish observers the logistics for their deployment to fishing vessels is quite different:

- the acceptance of observers onboard is absolutely voluntary and dependent on captain and shipowner decision, so sometimes to find a vessel may take several days or weeks;
- the best way to go onboard of a fishing vessel is meanwhile she is at port either for a fishing licence, repairing or for transhipment of the fish;
- the process for embarkation gets much more complicated if the target ship is already in the fishing grounds, as it requires the location of another boat with accommodation for the observer, going to same area;

- all this complicated process was simplified by the close collaboration of Armadora Pereira (A3) and Argos (A4) vessels coordinated by MG Otero and Sulivan Shipping Ltd.

Five Spanish observers (one contracted by ANAMER and the other three by IEO) were selected and deployed to fishing boats belonging to ANAMER and Argos operating in the SW Atlantic after training courses at IEO. A total of 555 observer days were spent by these observers from the start of their activities on the 15th January until the 26th of November.

Monitoring of FIFD observers was made after their trips when they arrived back in Stanley Also during a trip FIFD observers are required to make two radio schedules per week with the observer co-ordinator to brief him on their progress and to pass biological summary statistics. Spanish observers reported fortnightly to IEO about their activities, indicating number of observed trawls, sampling, etc.

The database structure designed during the first year project after discussions among IEO, FIFD and UNIABDN and implemented by IEO was used to introduce the information collected during this reporting period.

Samples such as whole specimens for morphometric studies and characterization of the raw fish, otoliths, stomachs and gonads for age and growth, diet and fecundity studies were collected by observers during their trips following the sampling protocol. The samples collected were sent to Stanley and Vigo. Once all the samples arrived to IEO, they were allocated among partners (IIM, UNIABDN, OPTIMAR FODEMA and Crown Seafoods) to carry out different studies.

The collaboration of the Patrol Ship from FIFD and the ANAMER' representative in Port Stanley José A. Cordeiro have played an important role in this phase of the project.

As in the first year, an important photographic work was made by the ANAMER observer taking pictures of all species caught during his trip, maturity stages, sex characteristics, etc. This material, included in electronic format in ANNEX III of this report, will be used to produce the second edition of the faunal guide of the Patagonian Shelf and Falkland Islands waters, edited by IEO in the frame of the *CEC DG Fisheries Study Project 99/016*.

Deliverable # 14 Implementation of an actual Database

As agreed during the kick-off meeting, the database structure designed during the former EU funded project *CEC DG Fisheries Study Project 99/016* was used as a starting point for the present project database. The final structure was decided after discussions among IEO, FIFD and UNIABDN and implemented by IEO (Figure 1).

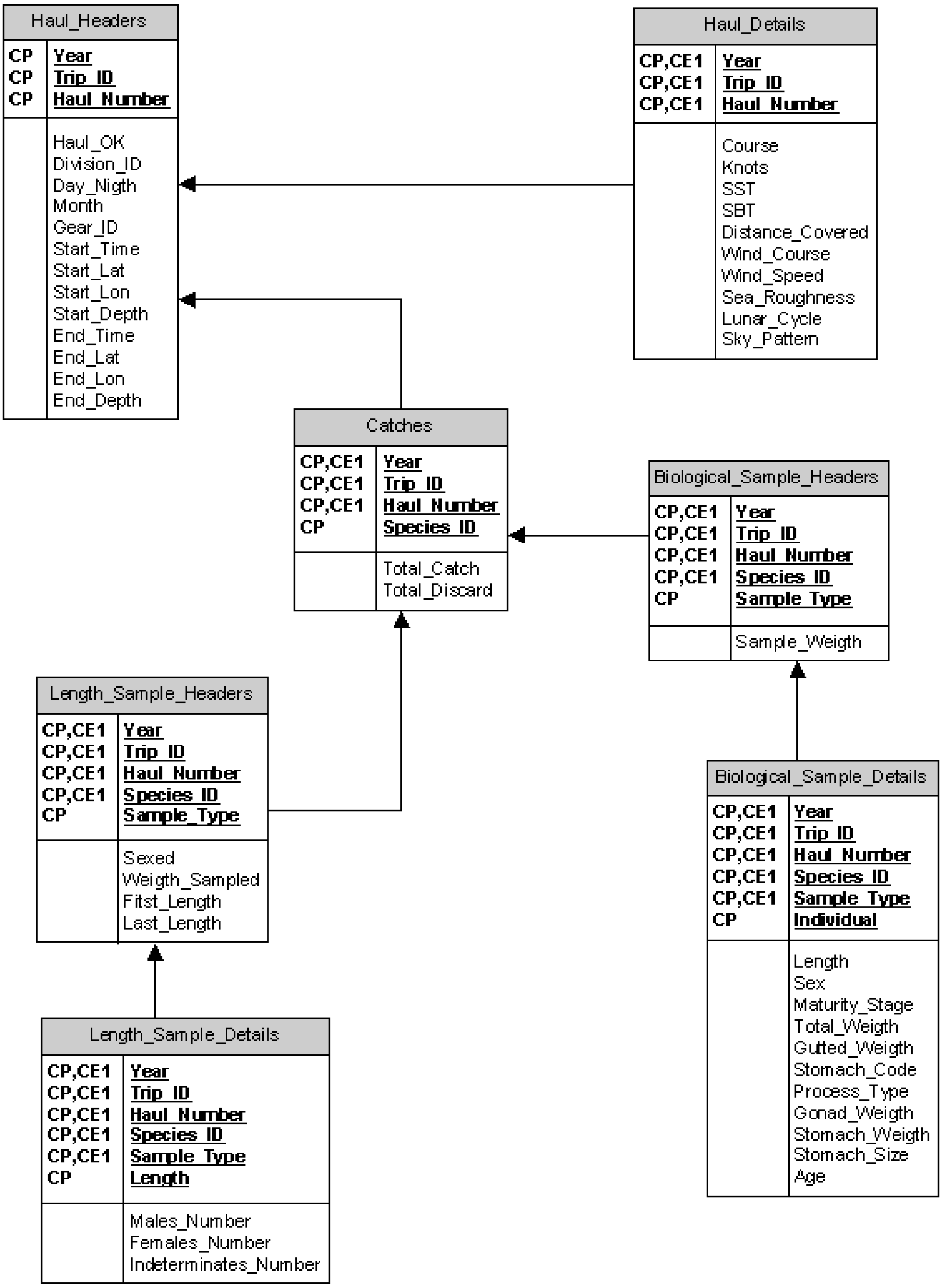

Figure 1: Database structure. CP: Clave Primaria (Primary Key); CE: Clave Externa (Foreign Key)

Task 2.2

Fisheries Description

Task 2.2. Fisheries description. Leader FIFD (Milestone # 6)

A preliminary description of the European fisheries in the studied area was made during the first year using information collected throughout the former EU funded project: CEC DG Fisheries Study Project 99/016. The Steering Committee considered that an important amount of relevant information concerning the target species of the present project (*Patagonotothen* spp.) would be collected during its lifetime, so it was decided that for a better fulfilment of the project objectives, this task should be finished during the second project year, once more data on Rockcod fishery were available for the study. As a result of this, a description of the rockcod fisheries in the SW Atlantic was made by scientific staff from IEO, FIFD and UNIABDN in 2004.

Preliminary description of the European fisheries on the Patagonian Shelf (1st progress report, 2003).

Introduction

The fishing grounds of the Patagonian Shelf support some of the most important fisheries in the world. The greatest abundance of marine resources are found between the 35º and 54º parallels South and, is associated with the Subtropical Convergence formed by the Brazil and Falkland/Malvinas currents. The mixing of the flow of La Plata River and the western branch of the Falkland/Malvinas Current generates areas of high plankton production on the shelf.

Hakes (*Merluccius hubbsi* and *Merluccius australis*) and cephalopods (*Illex argentinus* and *Loligo gahi*) have been found to be the main commercial species, with important amounts of accompanying species in the catches such as Patagonian toothfish (*Dissostichus eleginoides*), Kingclip (*Genypterus blacodes*), Hoki (*Macruronus magellanicus*), Red cod *(Salilota australis*), Southern blue whiting (*Micromesistius australis australis*), etc.

These fisheries are currently among the most important to the European bottom trawler freezing fleet. At present, the European fleet operating in this area is represented by approximately 40 Spanish fishing vessels and another 20 that operate in joint ventures sailing under Falkland flag. Only very few vessels from another EU countries are fishing in this area. It is estimated that the Spanish fleet generates approximately 2,000 direct offshore jobs, and more than 10,000 indirect onshore jobs. The value at first sale of their catches is estimated at around 411 M€ per year.

General description of the area

The fishing grounds off the Patagonian Shelf are actually one of the few areas around the world with important fishery resources but in which there is no effective regulation under any Regional Fisheries Organization. Local assessment and management is made inside the Falkland Islands Interim and Outer Conservation Zones (FICZ/FOCZ) and inside Argentinean EEZ. There is now some bilateral work going on through work-shops in the SAFC and joint research cruises on both Illex and southern blue whiting. These are the SBW bioacoustic survey and the Illex pre-recruit surveys. Fishery resources on the Patagonian Shelf occur and are exploited inside Argentinean EEZ, around the Falkland/Malvinas islands and in the adjacent international waters, representing in many cases a typical example of what are known as straddling stocks.

Commercial fishing by Spanish boats in the Patagonian Shelf started sporadically in early 1960s and continued irregularly until 1983 after which its presence was regular in the area although alternating their activity with the fishing grounds in the South East Atlantic. The crisis in the Namibian fisheries at the end of the 1980s was the reason for the increase of the operations in the SW Atlantic, reaching a maximum activity in 1990. After that, the development of new fisheries by the Spanish fishing fleet in the North Atlantic represented a decline in the total effort on the Patagonian Shelf.

A fisheries regime for the management of the resources around the Falkland/Malvinas islands was implemented on the first of February 1987, which followed the introduction of the Falkland Islands Interim Conservation and Management Zone (FICZ) in October 1986. The Falkland Islands Outer Zone (FOCZ) was introduced on 26th December 1990, extending the FICZ to the north, east and south of the Falkland/Malvinas islands to 200 miles, measured from coastal baselines. The South Atlantic Fisheries Commission (SAFC), composed of delegations from Britain and Argentina with participation of observers from the Falkland Islands as part of the British delegation was set up in 1991. Joint surveys with Dorada and Oca Balda on Southern Blue Whiting and a joint survey on Illex pre-recruits have been made under SAFC agreements.

The argentine EEZ lies to the west of the Falkland Islands conservation zones. A number of important species have a trans-boundary distribution and of those the most important are the squid (*Illex argentinus*) and the Southern blue whiting (*Micromesistius australis australis*). Stocks of both species are shared between the Falkland Islands and Argentina, together with the high seas beyond 200 miles in the case of *Illex* (Anon., 1997).

Physical and oceanographic features in the Patagonian Shelf

The Patagonian Shelf is the widest in the Southern Hemisphere and one of the few areas in the world where the continental shelf extends beyond the 200 nautical mile limit; the continental shelf until 200 m depth has an area of 300,300 nautical square miles even in its majority is less than 100 m depth; the continental slope (200-1000 m) has an approximate surface of 58,000 nautical square miles (FAO, 1983).

The northern part of the platform is narrow increasing its width further to the south, reaching the maximum breadth (869 km) around parallel 51º S. In the northern part, the slope until 50 fathoms is smooth (0.5 m/km) being steeper between 50 and 100 fathoms; in the south, the slope is higher from 0 to 50 fathoms (1m/km) and smoother between 50 and 100 fathoms (0.3 m/km) at the latitude of Puerto Deseado (47º 45’ S – 65º 55’ W).

The Patagonian Shelf is greatly influenced by the Subtropical Convergence formed by the Brazil and Falkland/Malvinas currents. The Falkland/Malvinas current is actually an offshoot of the Antarctic Circumpolar Current, a branch that veers northward along the South American continental shelf (Garzoli & Bianchi, 1987). The boundary between the cold Falkland/Malvinas Current water and warmer inshore water parallels the coast until about the latitude of Buenos Aires, where the Falkland/Malvinas encounters the Brazil Current (Deacon, 1937; Gordon, 1981; Legekis & Gordon. 1982). This interaction creates a very complicated fluid dynamics problem: the flow of the Falkland/Malvinas Current is turned into the South Atlantic Ocean, while the warm Brazil Current waters are pushed toward the coast. The exact location of this boundary varies with the seasons (Figure 2), as seen in sea surface temperature imagery (Goddard DAAC, 1999).

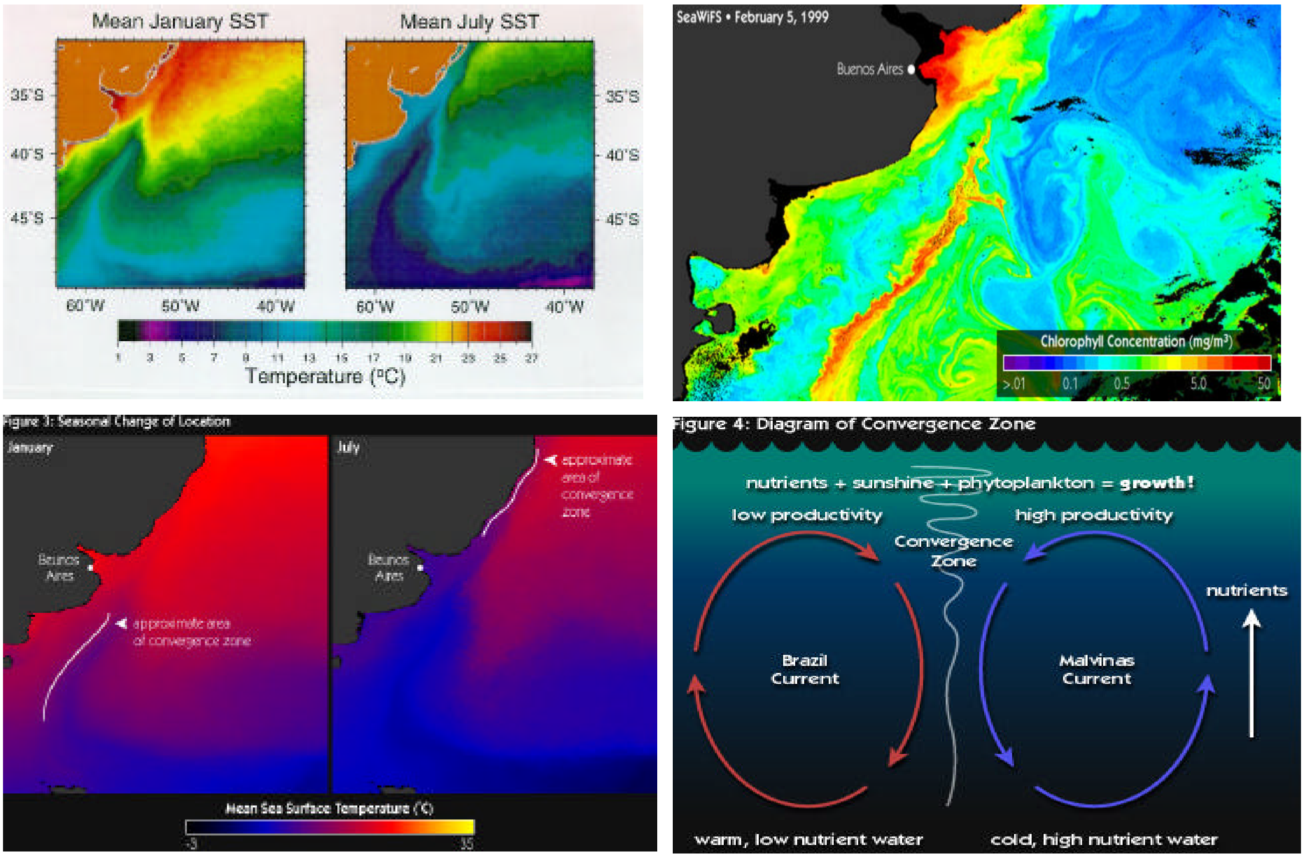

Figure 2: SST Distribution in summer (January) and winter (July). Note the Brazilian current and the Falklands current and the different position of the Convergence Zone.

All these species are highly influenced by the oceanographic conditions of the area including its inter- and intra-annual variability. Shortfin squid (*Illex argentinus*) perform yearly large migratory movements from the South of Brazil to Falklands, maybe related to its life cycle.

There are several relevant publications available, e.g. Agnew, D. J. (2002):

1. The oceanography and topography of the southern Patagonian shelf, with the strong Falkland current deriving from the Antarctic Circumpolar current moving northwards both west and cast of the Falkland Islands, creates an area of very high zooplankton productivity immediately to the north of the islands.

2. Information on the distribution, spawning times and larval distribution of the most important fish and squid species is reviewed in this paper. High densities of macroplanktonic euphausid and hyperiid amphipods, especially in the summer, attract and sustain squid stocks (the pelagic *Illex argentinus* and bentho-pelagic *Loligo gahi*) and pelagic fish (*Micromesistius australis* and *Sprattus fuegensis*).

3. There is an important spawning ground for three fish species having pelagic eggs and larvae (*Micromesistius australis*, *Salilota australis* and *Sprattus fuegensis*) on the shelf break immediately to the south and southwest of the Islands. The shelf surrounding the islands, and west and south towards the Argentine coast, forms a nursery area for the larvae of these and a number of other fish and squid species.

4. Pollution emanating from the oil exploration tranches to the north of the islands or oil-based activities on the north shores of the Islands, although coincident with the area of high plankton productivity, would be unlikely to affect, in any major way the

pelagic ecosystem around the Falkland Islands unless it became entrained in the area of slack water to the north of East Falkland. However, water flows from the Special Co-operation Area over critical spawning areas for a number of fished species (red cod, southern blue whiting and L. gahi) has the potential to affect not only these but the Falkland shelf waters which act as a nursery area for many marine species. Copyright (C) 2002 John Wiley Sons, Ltd.

Waluda, C. M., P. G. Rodhouse, et al. (2001), Waluda, C. M., P. N. Trathan, et al. (1999):

The fishery for Illex argentinus in the Southwest Atlantic is subject to large inter-annual variability in recruitment strength. In this paper we attempt to build a predictive model using sea surface temperature (SST) to examine links between recruitment to the Falkland Islands fishery and environmental variability during the juvenile and adult life history stages. SST data from the National Center for Atmospheric Research (NCAR) were found to be comparable with near-surface data derived from in situ expendable bathy- thermograph (XBT) profiles in the southern Patagonian shelf. Variation in SST during the early life stages appears to be important in determining recruitment of I. argentinus. SST in the hatching grounds of the northern Patagonian shelf during the period of hatching (particularly June and July) was negatively correlated with catches in the fishery in the following season. SST anomaly data from positions in the Pacific and Southwest Atlantic were used to examine teleconnections between these areas. Links were seen at a lag of 2 yr between the Pacific and southern Patagonian shelf, and at about 5 yr between the Pacific and northern Patagonian shelf. This is consistent with SST anomalies associated with El Nino in the Pacific propagating around the globe via the Antarctic Circumpolar Wave (ACW). Predicting cold events via teleconnections between SST anomalies in the Pacific and Atlantic would appear to have the potential to predict the recruitment strength of I. argentinus in the Southwest Atlantic.

Common squid (*Loligo gahi*) is more confined to a relative small area within Falkland waters, named Loligo-box, but with great explosions of abundance in Autumn (March to May). Finfish use to take advantage of the current dynamics, moving southward in summer together with the Brazilian current and northward in winter making use of the subantarctic (Falkland/Malvinas) current.

Spanish Fisheries in the SW Atlantic

These fisheries comprise target and by-catch species with different proportions of discards. Target species may be discarded due to several reasons such as size, poor condition of the fish, etc; by-catch species experienced a reduction in discards since early 90s due to their introduction as marketable species to consumers.

The fishing grounds in the Patagonian Shelf in which vessels flying Spanish flag are operating can be divided in two main fishing zones, one of them around the Falkland/Malvinas islands in what are known as Falkland Islands Interim and Outer Conservation Zones (FICZ and FOCZ respectively) and the second one in the High Seas, outside the Argentinean EEZ.

The activity of the Spanish vessels in the High Seas is reduced to those portions of the continental shelf and slope sticking out of the Argentinean EEZ, i.e. a small patch around 42º S and a bigger area comprised between parallels 43º 30’ and 48º S, namely “Area 42 and 46” respectively. The fishing grounds around the isles have been divided in three sub areas Malvinas North (MN), Malvinas West (MW) and Malvinas South (MS) (Figure 3).

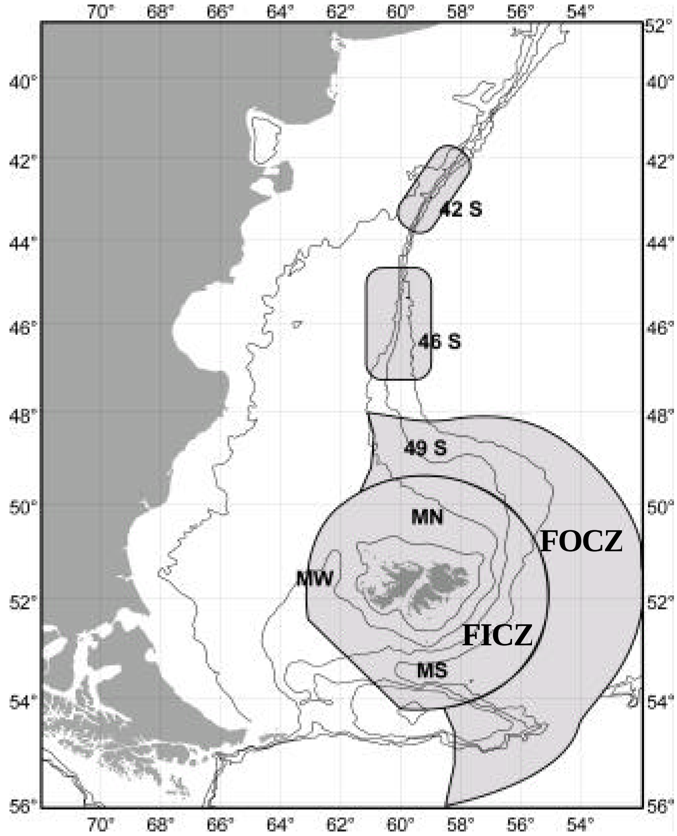

Figure 3: Main fishing areas in the Patagonian Self for the Spanish fishing fleet

- *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 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 work in order to understand possible changes in fishing patterns as well as to evaluate possible emerging target species and their fishery potential.

Catch and effort

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

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Description of the rockcod fisheries in the SW Atlantic (2nd progress report, 2004).

During the second year and after analysis of relevant information concerning the target species (*Patagonotothen* spp.) collected during the project lifetime, a description of the rockcod fisheries around the Falkland islands and on the High Seas was made, mainly focussing on the variations on its spatio-temporal and bathymetric distribution.

This study was presented as a communication to the ICES Annual Science Conference held in Vigo in September 2004, entitled "*Preliminary studies of the variations on the spatio-temporal distribution of a potentially exploitable species (Patagonotothen spp.) in the southwest Atlantic, using GIS techniques*". In this progress report a resume of this work is presented. The whole document is included as Annex III.

Introduction

Fish genus *Patagonotothen* are the most common nototheniids on the Patagonian Shelf and slope and is part of the by-catch species in the bottom trawl fisheries. The genus contains 14 species in the waters off southern South America of which *P. ramsayi* is the most abundant (Ekau, 1982; Norman, 1937; Hart, 1946). The rock cod *P. ramsayi* Regan, 1913 (Nototheniidae) is the most common notothenioid fish inhabiting the Argentine Patagonia south of 35º S and is found at a depth range of about 50 ~ 500 m (Nakamura et al.1986). It is common on the outer shelf and slope (mainly 150 – 400 m) around the Falkland Islands. Its south-eastern geographical range on the Falkland shelf is found in the main fishing ground for the squid, *Loligo gahi* (Laptikhovsky and Arkhipkin, 2003).

Throughout its range off the Patagonian shelf, it occurs at depths from 50 to 960 m. *Patagonotothen ramsayi* is a secondary catch target in the southwestern Atlantic area. Observations made from Polish fishing ships indicated that the greatest concentrations, and thus the best fishing results, were obtained in the southern area of the Burdwood Bank. Despite its low biomass in comparison with other fish and squid caught in this area, *P. ramsayi* occur in concentrations on the Patagonian Shelf which can be of interest to fisheries and this species could be a target fishery (Sosinski and Janusz, 2003).

The marine environment around austral South America is rich in coastal fronts, with different forcing, and temporal and spatial scales. Marine frontal patterns maybe seen as part of the structural complexity of the pelagic realm at the seascape scale. The open ocean circulation is dominated by the opposite flow of the Brazil (subtropical) and the Falkland/Malvinas (subantarctic) currents. Both currents meet, on average, at 36º S. In this area, referred to as the Brazil/Malvinas Confluence, the two flows turn offshore in a series of large amplitude meanders. The shelf-break front is a permanent feature that characterizes the border of the shelf. The inner boundary lies between the 90 and 100 m isobath. The geographical location of the front may vary according to the dynamics of the Falkland (Malvinas) Current, for which cyclical variations—including semi-annual, annual and biannual periods—have been reported (Olson *et al*., 1988; Fedulov *et al*., 1990; Acha *et al*., 2004).

Since early 1980s, an important fishery targeting hakes (*Merluccius hubbsi* and *M. australis*) and cephalopods (*Illex argentinus* and *Loligo gahi*) have been developed by Spanish bottom trawlers off the Patagonian Shelf, also catching important quantities of other bycatch species such as kingclip (*Genypterus blacodes*), hoki (*Macruronus magellanicus*), red cod (*Salilota australis*), etc, which have been gradually introduced into the market with good acceptance by the consumers. Even rockcod was exploited in the past by Polish vessels, this species is almost totally discarded by the Spanish fleet.

The fishing grounds in the Patagonian Shelf in which vessels flying Spanish flag operate (Figure 3) can be divided in two main fishing zones, one of them around the Falkland/Malvinas Islands in what are known as Falkland Islands Interim and Outer Conservation Zones (FICZ and FOCZ respectively) and the second one on the High Seas, outside the Argentinean EEZ. The activity of Spanish vessels on the High Seas is reduced to those portions of the continental shelf and slope sticking out of the Argentinean EEZ, i.e. a small patch around 42º S and a bigger area comprised between parallels 43º 30' and 48º S, namely "Area 42 and 46" respectively. The fishing grounds around the isles have been divided in three sub areas Malvinas North (MN), Malvinas West (MW) and Malvinas South (MS).

DATA AND METHODS

Data used into the GIS

Spatially referenced commercial fishery data, as well as bathymetric data were examined using Geographic Information System (GIS) techniques in order to map and represent information about the distribution and the abundance of *Patagonotothen* spp. catches recorded by IEO and FIFD scientific observers in the Falkland Islands and in the High Seas from 1988 to 2003.

Fishery, bathymetric and SST data were integrated within the GIS (ArcGIS version 8.2). This process allows a visual analysis and also the extraction of more information about the parameters that have an influence in the catches distribution.

1- *Environmental data- SST*

Sea surface temperature (SST) data collected by scientific observers on board commercial vessels were geo-referenced to a base map of the Southwest Atlantic and incorporated into the GIS as grids. SST information was used to analyse the relationship between Patagonotothen spp. abundance and oceanic circulation.

2- *Bathymetry data*

Bathymetric contours of the Patagonian shelf were extracted from GEBCO (General Bathymetric Chart of the Oceans) Digital Atlas. This bathymetry data were entered into the GIS. Bathymetric contours represented here are 0 m, 200 m, 500 m and 1000 m.

3- *Fishery data- FIFD and Spanish data*

Daily fishery data for the present study were collected by observers working for the IEO (Instituto Español de Oceanografía, Vigo, Spain) and FIGFD (Falkland Islands Government Fisheries Department, Stanley) on board commercial vessels over the 17-year period 1988-2003. All of the data were integrated into a MS Access database and used in analysis and modelling. Fishery data were imported and integrated into the GIS as monthly time-series grids at spatial resolution of 0.5 degrees. CPUE (catches per unit effort, kg/hr) was used as an index of abundance in the fishery. This index reflects fish abundance and accounts for changes in fleet activity over the 17-year period. Maps were visually analysed in order to find relations between bathymetry, SST and fisheries data for the same month.

Geographical Information System methods

GIS maps

Patagonotothen spp. raster data sets were created with the GIS on a monthly basis. Each cell in the map is a square that represents a specific portion of an area with a spatial resolution of 0.5 degree longitude and 0.5 degree latitude square. The size of the cell was selected in order to accomplish a detailed analysis of the temporal evolution of the features represented in the maps (CPUE , ratio of catches to the total catches and modal length).

Density surface maps

Patagonotothen spp. density surfaces were created in the GIS as monthly raster layers. Each cell in every layer is assigned a density value based on the number of features (hauls with CPUE > 0 kg/h) within a radius cell of 1.5 degrees. To create a density surface we used the Kernel method that uses a mathematical function to give more importance to features closer to the center of the cell. With this method maps, with patterns that are easier to interpret, were obtained. The GIS defines a neighbourhood (based on the search radius specified, in this case 1.5 degrees) around each cell centre. It then totals the number of features that fall within that neighbourhood and divides that number by the area of the neighbourhood. This value is assigned to the cell. The GIS moves on to the next cell and repeats the same procedure, resulting in the creation of a smoothed surface. Mapping density shows where the highest concentrations of *Patagonotothen* spp. are found on a monthly basis.

Besides the visual analysis of the maps, a rank correlation was carried out between *Patagonotothen* spp. abundance and other variables (month, latitude, longitude, average depth, SST, lunar cycle and sky pattern) in order to quantify the correlations between them.

Statistical analysis and modelling

Generalized additive models (GAMs)

Generalized Additive Models (GAMs) are able to deal with non-linear relationships between an independent variable and multiple predictors and are particularly appropriate to our study.

In order to model the variations of *Patagonotothen* spp. abundance we used GAMs. GAMs were first proposed by Hastie & Tibshirani (1990) and some of the first applications to fisheries data were by Swartzman *et al*. (1992, 1994, 1995). A GAM is a non-parametric regression method with less strict assumptions about normality and linearity than linear regression. This method is an extension of the generalized linear models (GLMs; McCullagh & Nelder, 1989). The principal strength of additive models is their ability to fit complex smooth functions (smooths) to the predictor rather than being constrained by the linearity implicit in GLMs. A GAM, the generalized version of an additive model, is expressed as:

$$g(E[y]) = b_0 + \sum_k S_k(x_k)$$

The right-hand side of the equation is the additive predictor. $ß_0$ is an intercept term and S_k is a one-dimensional smoothing function for the k^{th} spatial covariate, x_k. The degree of smoothing is determined by the degrees of freedom (d.f.) associated with the smoothing function. The larger the degrees of freedom, less smoothing is performed and the function obtained is more flexible.

GAMs were fitted using the "gam" command in S-Plus and using cubic smoothing splines to smooth covariates. Spline smoothers are popular because they have a theoretical justification that can be used to determine the appropriate smoothness for the fit. Smoothing splines are locally cubic splines that minimize a penalized residual sum of squares, drawing a smoothed curve through the data points.

In our model, the expected value of *Patagonotothen* spp. abundance is expressed as a sum of smooth functions of the covariates (month, latitude, longitude, SST and average depth). All data were imported into S-Plus from excel files and configured as data objects. Data were screened to reveal characteristics of data sets and scatter plots were made for each pair of variables. The error distribution used was the Gaussian distribution, which is normally appropriate for describing spatial heterogeneity and abundance data (Maravelias, 1997; Swatzman *et al*., 1994).

To measure the goodness of fit of the model, a pseudo-coefficient of residual determination, PCf, is estimated (Swartzman *et al*., 1992):

$$PCf = 1 - \frac{RD}{ND}$$

where RD is the residual deviance, i.e. the deviance of the full model, similar to the residual sum of squares in a linear model, and ND the null deviance, i.e. the deviance of the model with only the intercept term. PCf values obtained are listed in Table 1.

Table 1. Summary of GAM results for weighted and unweighted models

Unweighted model

ND	RD	PCf
1651276711 (12831 d.f)	1611545572 (12811 d.f)	0,024060861

Weighted model

ND	RD	PCf
6281336497 (12831 d.f)	6137622872 (12811 d.f)	0,022879466

In this work, the fishing effort variable was used as a weighting factor. The amount of fishing effort can be considered as an index of the quality of the sampling, and more effort probably implies more reliability in the data. Therefore, in the weighted model, less importance is assigned to data with low fishing effort and more importance to data with high fishing effort. An unweighted model was also fitted for comparison.

Analysis of biological data

Data on length were collected by observers by measuring total length (TL) of at least 100 individuals in each sample when possible. A scale of four maturity stages was used in order to study the distribution of *Patagonotothen* spp. maturity stages during the year.

Data on modal lengths in each haul were mapped using GIS. Length weight relationships were calculated.

RESULTS AND DISCUSSION (for a more detailed information see *Task 2.4* and Annex III)

Spatial distribution of catches of *Patagonotothen* spp.

CPUE (catch per unit effort, kg/hr) was used as an index of abundance in the fishery. The annual location of hauls and CPUE values (Kg/hr) for *Patagonotothen* spp. as well as the annual CPUE values (Kg/hr) by 0.5º x 0.5º rectangles over the period 1988-2002 were obtained. Rockcod catches in 14 years does not describe a clear spatio-temporal pattern. In general terms we conclude that higher CPUE values were recorded between 1996 and 1999. Over the rest of the period, the CPUE values fluctuate.

Monthly CPUE values demonstrated that fish abundance was higher in the austral summer than in the winter. February, March and April were the months in which higher CPUE values were recorded. From February to May there is an expansion in the distribution of the catches from the western area towards the eastern area.

The distribution of *Patagonotothen* spp. per depth strata gives us an idea about the habitat of the species. Peak CPUEs were recorded in 100-200 m and 200-300 strata. Poor catches were recorded in 0-100, 300-400, 400-500 and at depths bigger than 500 m. Catches in the 0-100 m strata were mainly located in divisions 46, 49 and MS. In the 300-400 m strata catches were located mainly in divisions 42, 46 and MS. Strata 400-500 m and higher than 500 m show few catches at division 42 and MS. Catches located between 100-200 m were found all around the islands and also in the High Seas.

Density maps

Density surface maps show the abundance distribution of this species through the year. Maximum density values were recorded within March, July and August. These values are located in all cases in division 46. April was characterized by the presence of high-density values in division 46 and 49. From August to December there is a clear fall in density values, reaching the minimum in December.

Scatter plots

Scatter plots suggested the following relationships:

1. CPUE shows two peaks located in March and October. Minimum values were found during January, July and December.
2. The relationship of abundance (in terms of CPUE) with the geographic position (latitude and longitude) basically indicates the location of the vessels fishing. *Patagonotothen* spp. was fished all around the Falkland Islands and also in the High Seas, being the maximum abundance found at latitude 46º S and longitude 59º W.
3. *Patagonotothen* spp. abundance seems to be positively related to 100-200 m depth range.
4. Highest *Patagonotothen* spp. CPUE values were associated with SST between 6.3º C and 12º C

Generalized additive models

Generalized additive models (GAMs) were used to model the spatio-temporal distribution of *Patagonotothen* spp. The variables included in the GAM were Sea Surface Temperature (SST), month, latitude, longitude and month average depth .
Results show that:

1. There is a general decrease in abundances that reaches the minimum value in July. From July, GAM plot depicts a slight increasing trend that reaches a peak in October, when the curve undergoes a decrease.
2. Results from the GAM plots related to latitude show an increasing trend from 54º S to 49º S, where the maximum abundance of *Patagonotothen* spp. was found. From latitude 49º S northwards there is a slight decreasing trend that reaches a minimum at latitudes around 46º S and 44º S.
3. Longitude GAM plots show two peaks: one located around 61º W, the other placed at 58º W.
4. In terms of depth, there is a clearly defined maximum value located between 100 and 200 m.
5. The GAM demonstrates that the relationship between CPUE and SST is non linear. Highest CPUE were founded at temperatures around 6.3º C and 12º C.

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Task 2.3

Biology

Task 2.3. Biology. Leader FIFD

Fisheries Biology of *Patagonotothen* spp. on the Patagonian shelf (1st progress report, 2003).

Introduction

With the initiation of the "Rockcod Project" in January 2003 and after its kick-off meeting in February a sampling program was set in place to examine various aspects of the population dynamics, reproductive biology and age and growth of the *Patagonotothen* species inhabiting the waters of the Falkland Shelf. Further samples for the examination of feeding ecology, morphometric and characterization studies have been collected for another RTD partners within the project (UNIABDN and CSIC-IIM respectively).

The genus *Patagonotothen* contains 14 species in the waters off southern South America of which *P. ramsayi* is the most abundant (Ekau, 1982; Norman, 1937; Hart, 1946). Little is known about the biology and ecology of these species and with the onset of the 'Craft Project' it became necessary to examine various aspects of the species' biology with a particular emphasis on parameters that can be used in stock assessment studies.

The aim of this report is to summarise the data collected by the Falkland Islands Fisheries Department (FIFD) and Instituto Español de Oceanografía (IEO) to date.

Patagonotothen species encountered

From the start of the project FIFD observers have encountered five species of *Patagonotothen* on various trawlers in the conservation zones. Theses include *P. ramsayi*, *P. tessellata*, *P. guntheri*, *P. squamiceps*, and *P. elegans* (Figure 4). The latter are listed in order of abundance. Now that there are a number of species available for study the FIFD plans to make an improved key for rockcod identification at sea.

a

b

c

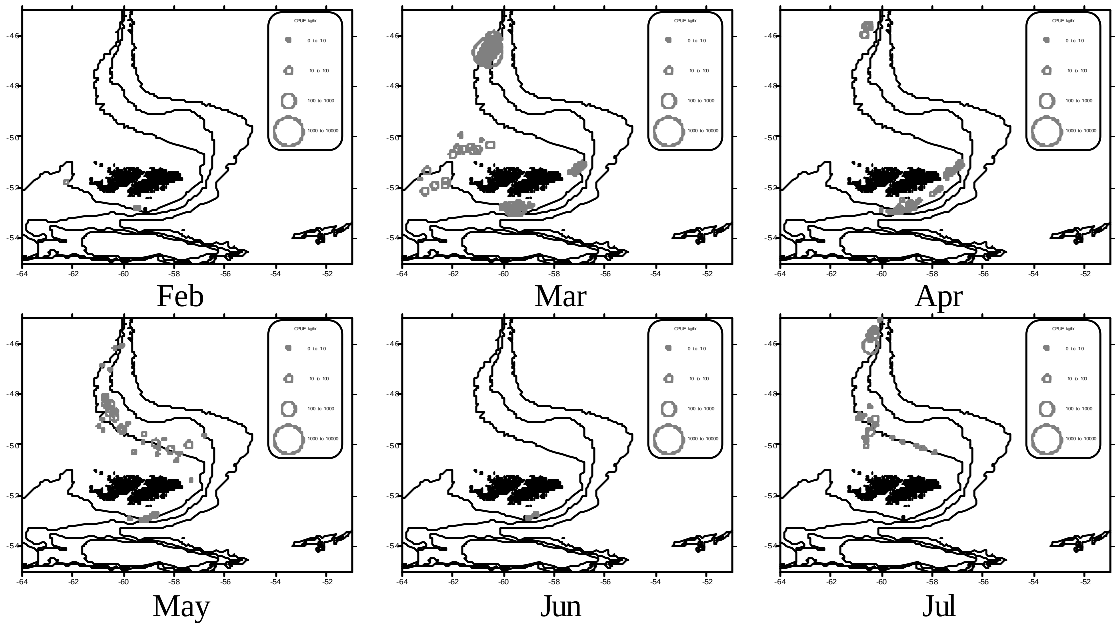
d

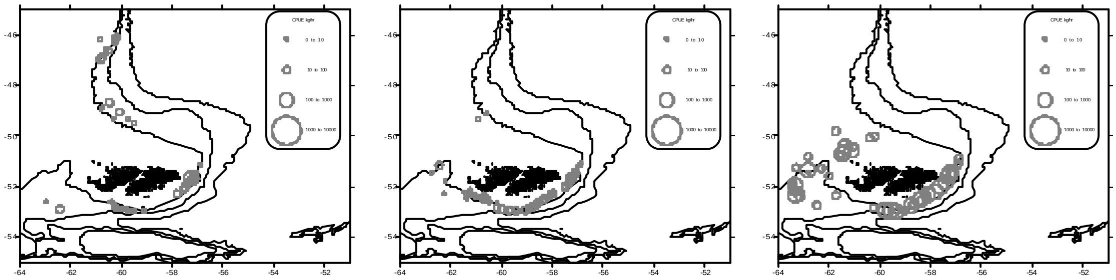
e

Figure 4: a) *Patagonotothen ramsayi* b) *P. tessellata* c) *P. guntheri* d) *P. squamiceps* e) *P. elegans.*

Observed catch per unit effort (CPUE)

The FIFD have observed 631 trawls (positive for rockcod) from 1st February to the end of October 2003 on both commercial and research vessels. Figure 5 illustrates the monthly distribution of the observed CPUE (kg/hr) since the start of the project for *Patagonotothen ramsayi*.





Aug Sep Oct

Figure 5: Distribution of observed CPUE by month for *P. ramsayi* since February 2003 (FIFD data)

Four Spanish observers (one contracted by ANAMER and the other three by IEO), were deployed to the study area and collected information from 2nd March to 11th July 2003 during the first fishing season and from 8th August to 1st of November 2003 during the second fishing season. These observers have recorded information from a total of 852 trawls onboard commercial vessels from ANAMER and Argos Ltd, of which 627 were positive for some of the rockcod species. After their arrival to Vigo all the processed information was checked at IEO in order to find possible errors or mistakes during processing (checking is ongoing with the information collected by the two observers arrived in November).

Observers were provided with laptops for processing the information onboard of the fishing vessels using ad hoc software designed during the *CEC DG Fisheries Study Project 99/016*. Small adaptations were made to this software during the first two months of the project based on suggestions made by IEO observers in 2002.

Figure 6 illustrates density of *Patagonotothen* spp. estimated from CPUE (kg/hour) data recorded by Spanish observers during the first fishing season. The density was estimated by using the POINTDENSITY tool included in ArcGis software for the quadratic KERNEL function (Silverman, B. W., 1986). Pointdensity calculates the density of point features around each output grid cell. A neighbourhood is defined around each grid cell center, and the number of points that fall within the neighbourhood is totalled and divided by the area of the neighbourhood. With the KERNEL option, a smoothly curved surface is fitted over each point.

Density of *Patagonotothen* spp. was calculated using the KERNEL function in order to obtain a smoothly tapered surface to each point. Kernel function was chosen due to the fact that, given the small amount of *Patagonotothen* spp. data for the period of study, it represents the reality with more precision than the SIMPLE function. Figures from 7 to 9 were made using the ArcGis software.

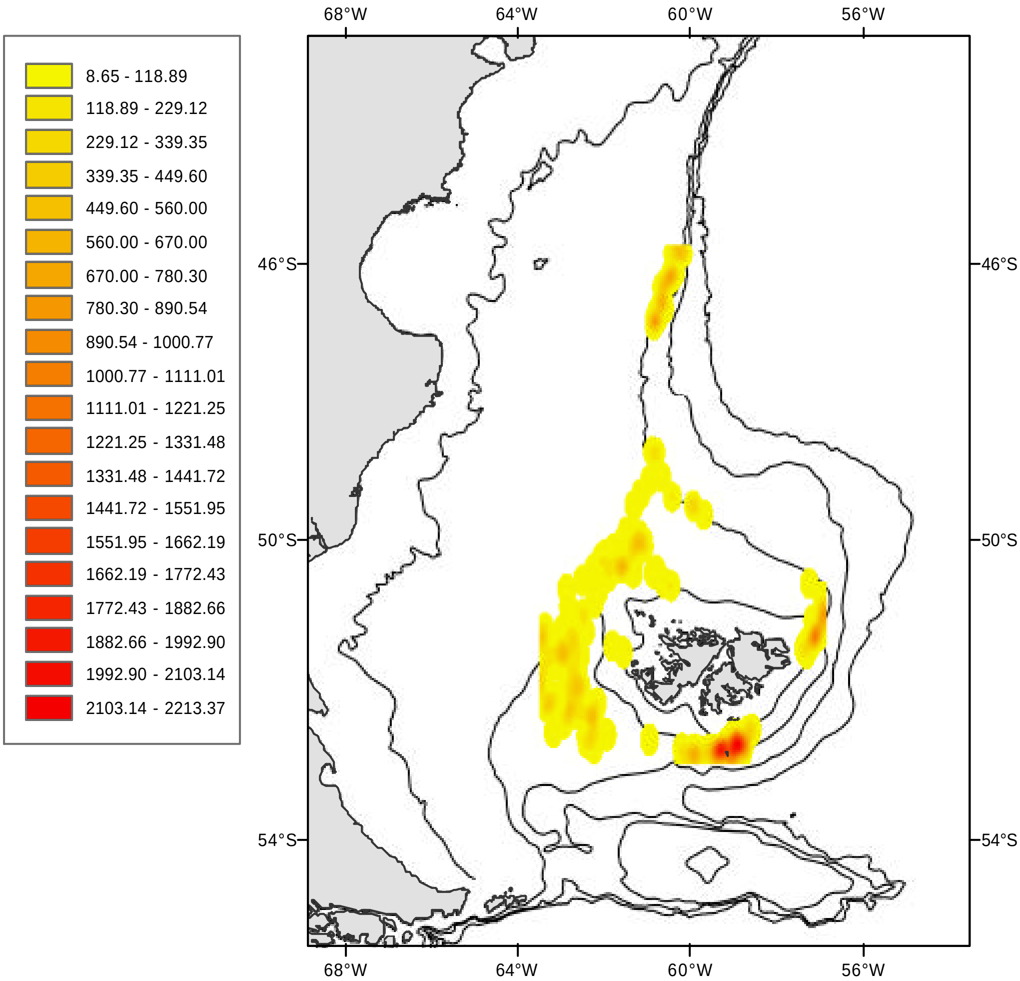


Figure 6: *Patagonotothen* spp. density estimated from CPUE (kg/hour) data recorded by Spanish observers during the first fishing season.

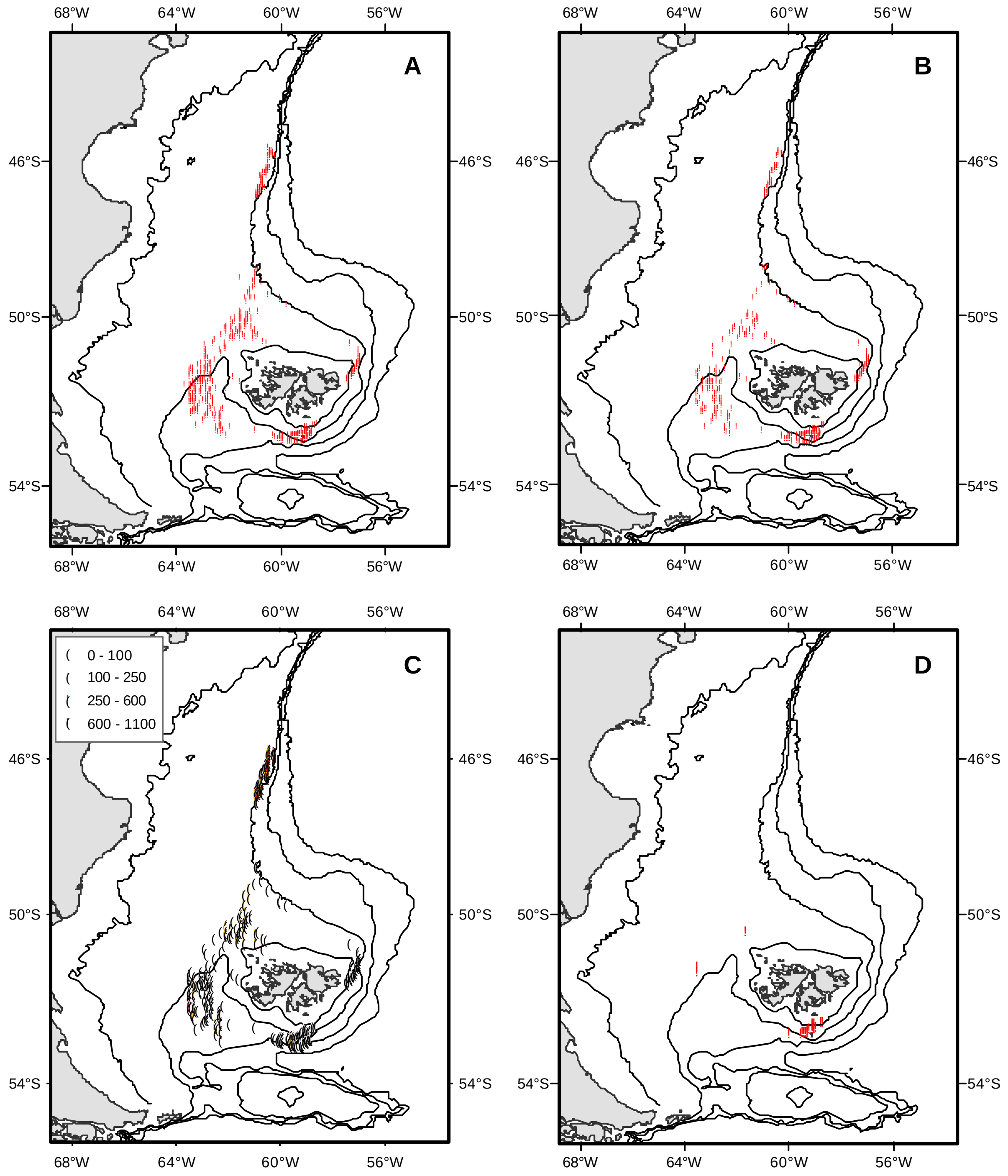


Figure 7: **A**) Location of observed trawls by Spanish observers (1st half 2003). **B**) Location of trawls positive for some of the rockcod species. **C**) CPUE (kg/h) of *Patagonotothen ramsayi*. **D**) Location of trawls positive for *Patagonotothen guntheri*

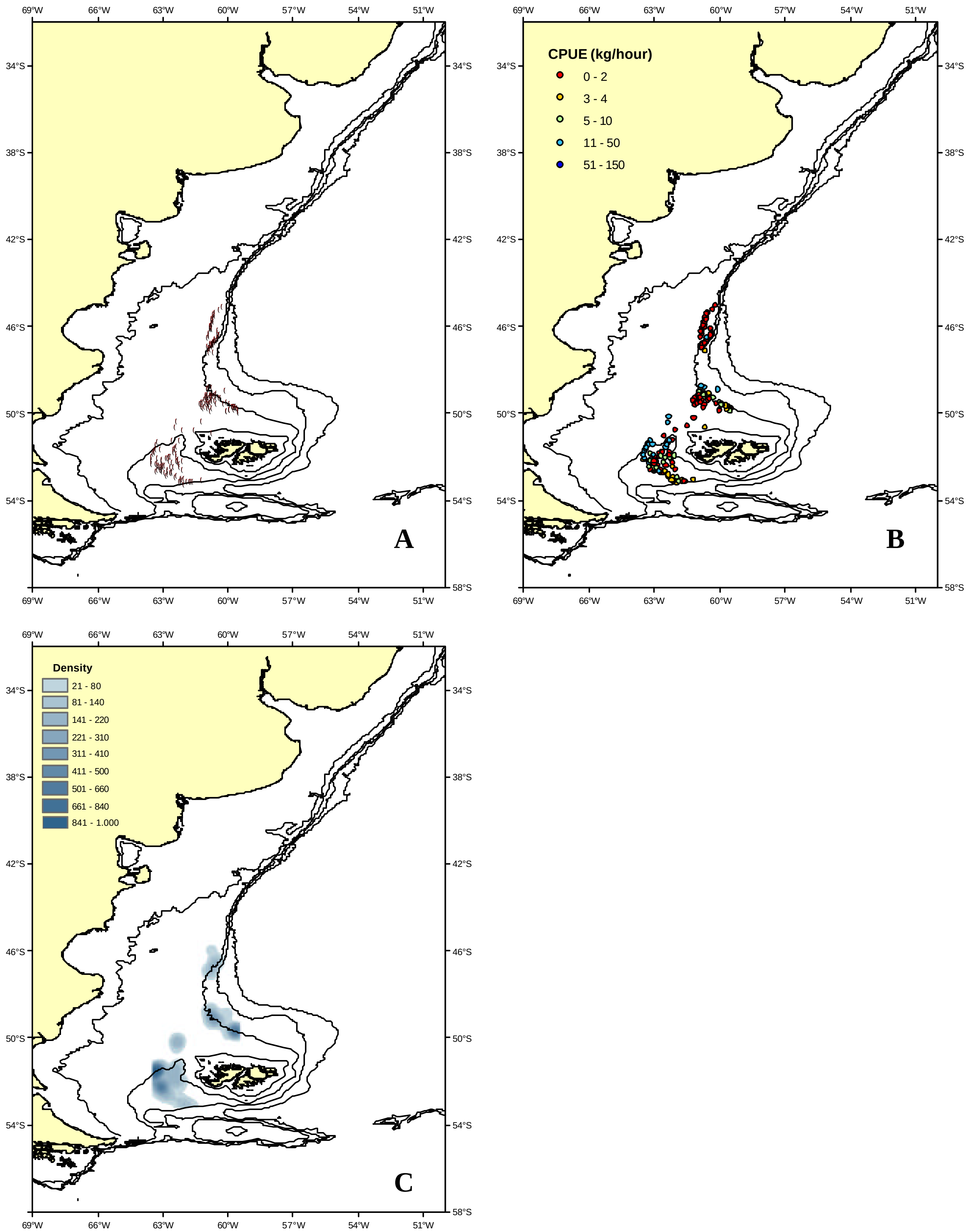


Figure 8: **A**) Location of observed trawls by Spanish Observers (2nd half 2003). **B**) Distribution of observed CPUE (kg/hour) for Patagonotothen spp. **C**) Densities estimated from CPUE data recorded by Spanish observers.

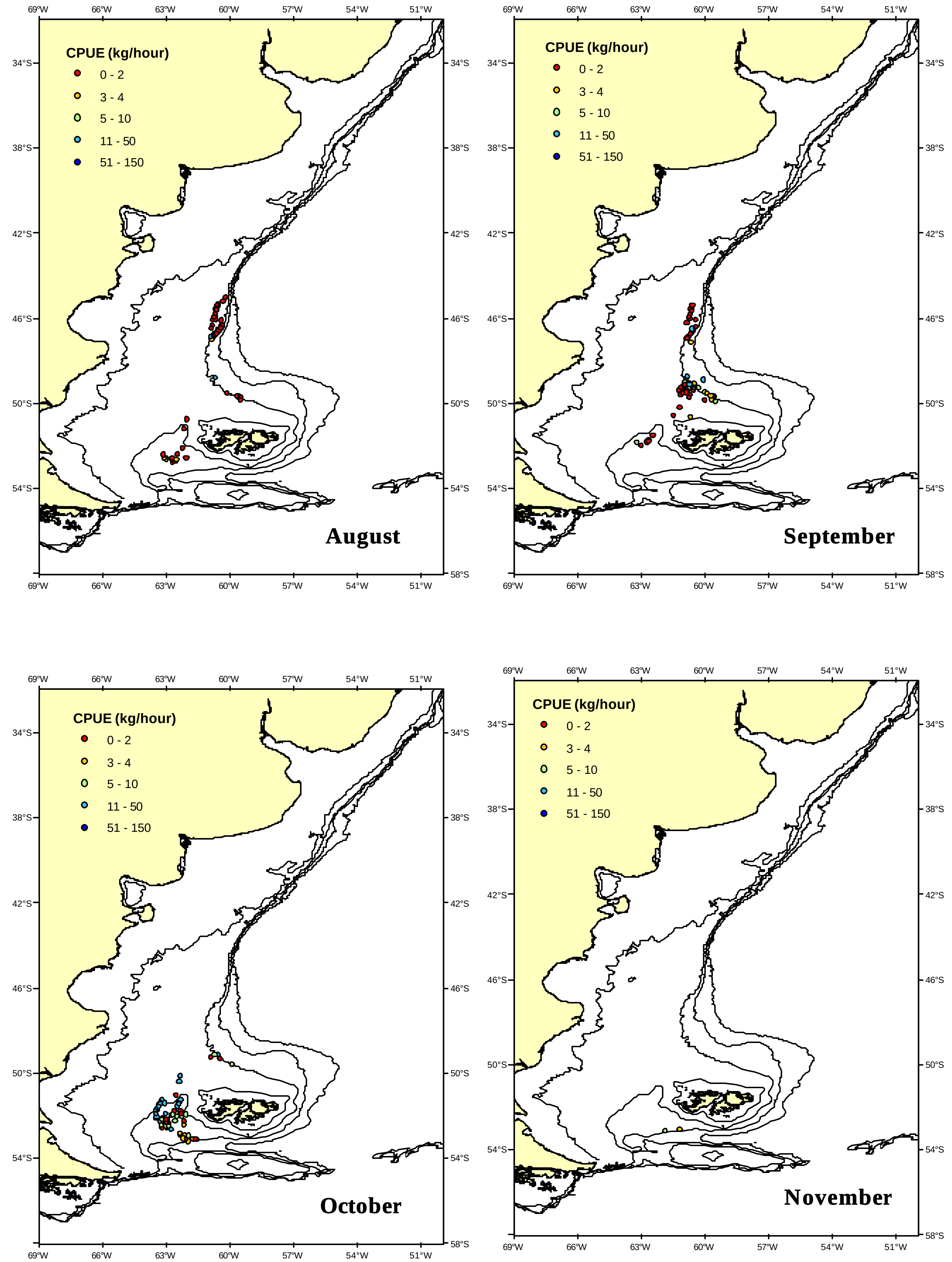
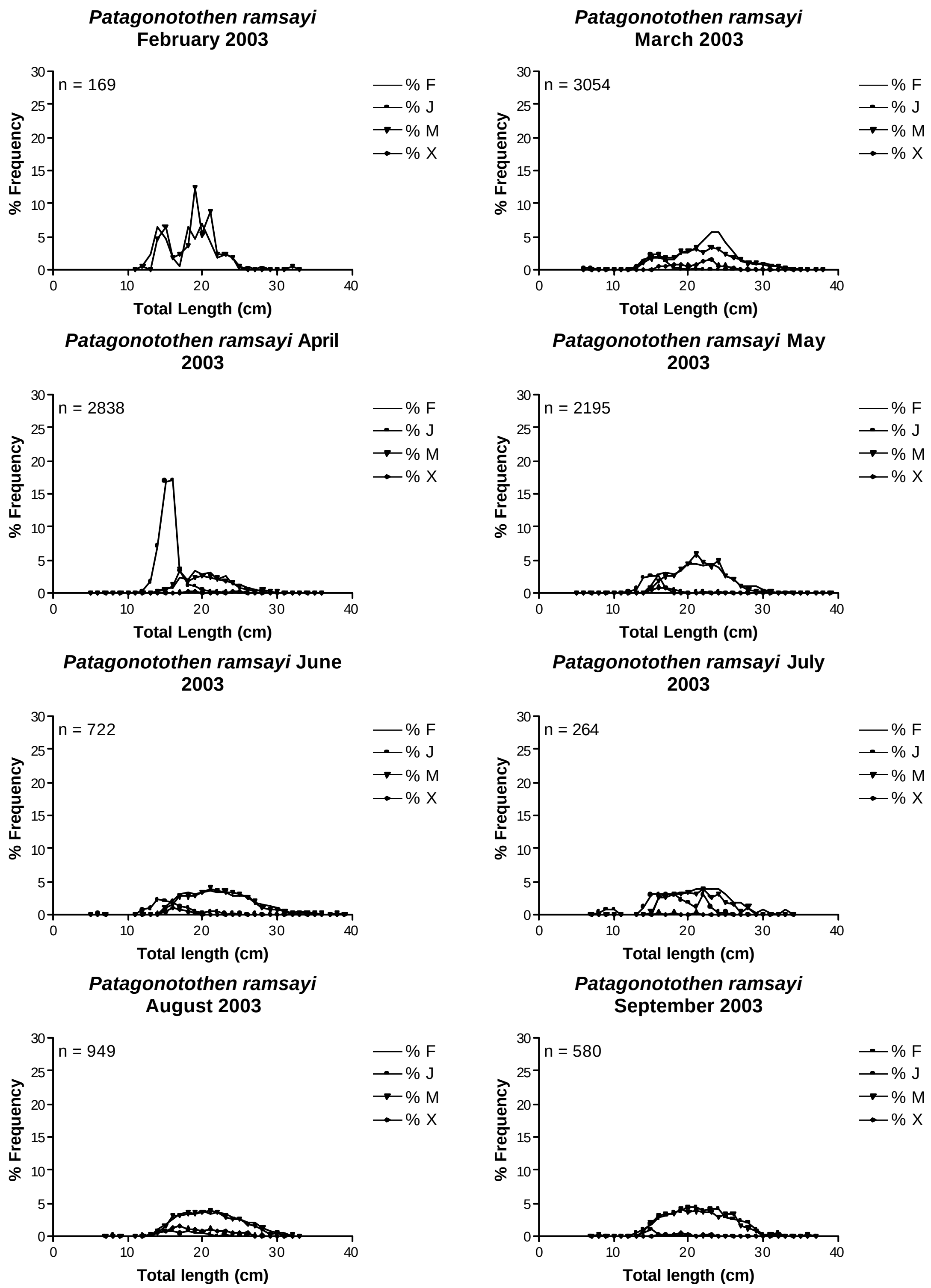


Figure 9: Distribution of monthly observed CPUE (kg/hour) for *Patagonotothen* spp. since August to November 2003 (Spanish observers)

Length frequency Distributions

Since the onset of the first annual fishing season in February to the end of October 2003 the FIFD have collected a total of 17,280 length frequency records for *P. ramsayi*. Figure 10 illustrates the monthly length frequency distributions for this species.



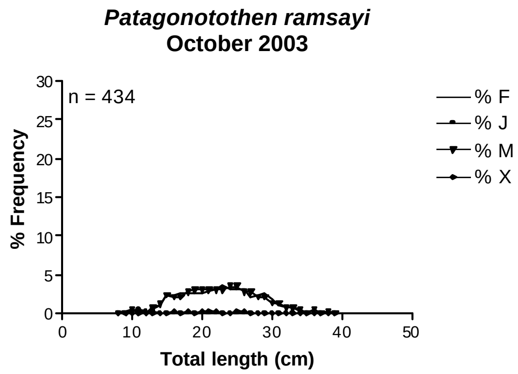
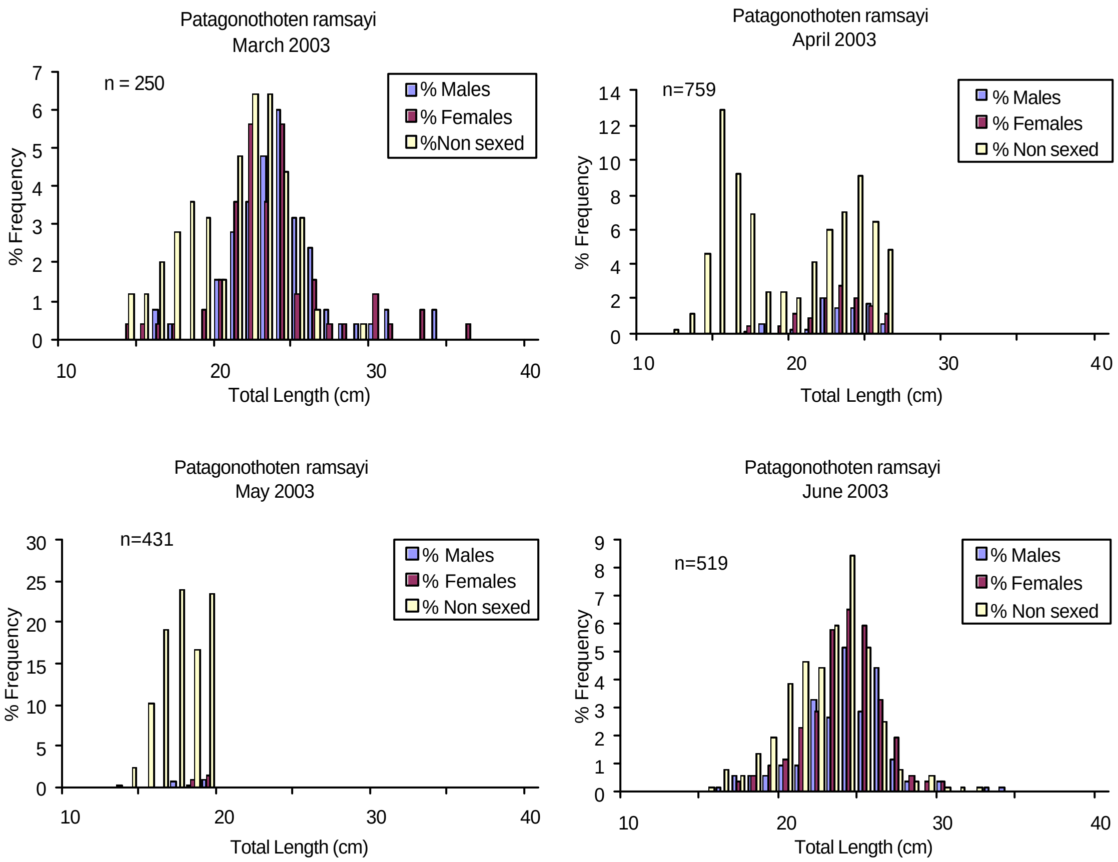


Figure 10: Monthly length frequencies of *Patagonotothen ramsayi* (FIFD data)

Throughout the observation period covered by ANAMER and IEO observers during the first fishing season (2nd March to 11th July 2003) a total of 2,874 length frequency records for *P. ramsayi*. Figure 11 illustrates the monthly length frequency distributions for this species during the first half of the year.



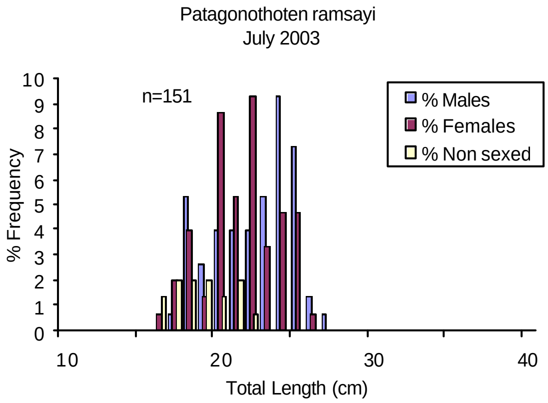


Figure 11: Monthly length frequency distributions for *P. ramsayi* recorded by Spanish observers during the first fishing season.

During the second fishing season, Spanish observers collected a total of 2,516 length frequency records of *Patagonotothen ramsayi* in the period comprised between the 8th of August to the 1st of November. Figure 12 illustrates the monthly length frequency distributions for the second fishing season.

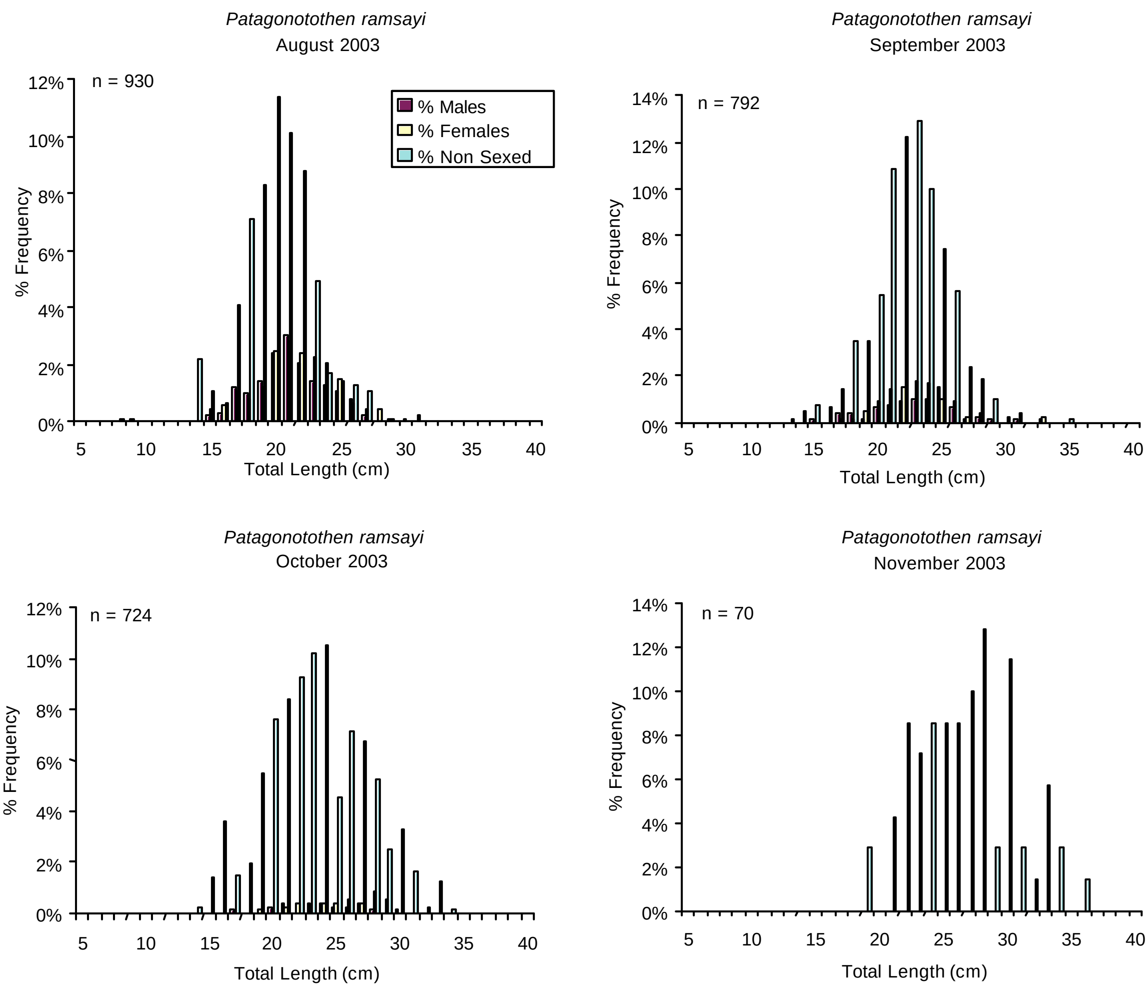


Figure 12: Monthly length frequency distributions for *Patagonotothen* spp. recorded by Spanish observers during the second fishing season.

Length weight relationships

1,200 land based length weight records have been collected and these data include eviscerated and gonad weight.

Otoliths

Since the beginning of February 2003 total of 587 pairs of sagittal otoliths have been collected by FIFD observers from *P. ramsayi*, 79 from *P. guntheri* and 24 from *P. tessellata* for age determination.

Since 2nd March to 11th July 2003 481 pairs of sagittal otoliths of *P. ramsayi* were collected by Spanish observers and sent to Stanley for studies of age and growth by the FIFD.

Reproductive Studies

100 gonads from both sexes and a range of different maturity stage have been collected for histology from the start of the project these will be used to describe the gonad maturities microscopically.

Morphometric studies

A total of 480 adult specimens have been collected for morphometric studies by the University of Aberdeen between February and May 2003 by FIFD observers. Another 400 adult specimens were collected by Spanish observers.

The main aim is to identify evidence for morphometric heterogeneity in rockcod, e.g. are there different stocks in the Falklands and the high seas. It will also be possible to identify measurements which best discriminate between rockcod and other species in the genus *Patagonotothen*. As in the preceding hake Study Project, the methodology is based on multivariate analysis of three independent character sets, namely external morphometrics, fin ray counts and skull bone morphometrics. Ideally all samples should be of one sex and, where possible, taken during the breeding season, when spatial segregation of sympatric stocks is most likely to be seen. The first batch of fish (60) was measured in Vigo in September 2003. The fish were collected by an IEO observer in April 2003. A total of 18 morphometric measurements including total length and 3 counts of fin rays were taken from these samples. The majority of this work will be completed in 2004.

Diet studies

The aims are to quantify the diet of rockcod, evaluate ontogenetic, seasonal, regional and interannual variation, and examine the role of rockcod as prey for other fish. The processing of rockcod stomach contents will commence in 2004. Samples collected by the observers are stored in the IEO center in Vigo and are been sent to UNIABDN for analysis. The information on rockcod as prey will derive mainly from the previous study project on hake.

Just over 240 stomachs have been collected for diet studies by the University of Aberdeen during the second 6 months of the project. Another 366 stomachs were collected by Spanish observers.

Diet: The processing of rockcod stomach contents will commence in 2004 once the samples arrived at UNIABDN.

Morphometrics: The majority of this work will be completed in 2004.

Reference List

Ekau,W. 1982. Biological investigations on *Notothenia ramsayi* Regan 1913 (Pisces, Notothenioidei, Nototheniidae). Arch. Fischwiss. **33:** 43-68.

Hart,T.J. 1946. Report on trawling surveys on the Patagonian continental shelf. Discovery Reports **23:** 223-408.

Norman,J.R. 1937. Coast Fishes. Part II. The Patagonian region. Discovery Reports **16:** 1-150.

Silverman, B. W. 1986. Density Estimation for Statistics and Data Analysis. Chapman and Hall, 1986.

Processing and reading of *Patagonotothen* spp. otoliths for age and growth studies (2nd progress report, 2004).

Introduction

A basic knowledge of how fish grow and the relative numbers of juveniles and mature fish in a population is required to answer questions on how fishing affects a population. It is also useful to know the size and age of a particular species when it reaches sexual maturity. Knowing the average size and size variation at age over several years is important for comparative studies. These changes may be normal or result due to a change in their environment.

Several kinds of hard parts of fish can be used to determine age. Otoliths and scales are the most common. Otoliths are composed of calcium carbonate crystals embedded in an organic matrix. The organic material consists of layers of concentric shells. There is evidence that variation in the amount and thickness of the shells is responsible for ring formation. With some exceptions, opaque zones are laid down during the summer, and translucent zones (hyaline) are formed during winter (Casselman, 1983). Just to confuse matters zones viewed by reflected light appear the reverse of those seen through transmitted light.

As far as we are aware this is the third study to employ otoliths to examine the age and growth of *Patagotothen ramsayi*. Ekau (1982) found that age determination using otoliths proved to be the easiest and most reliable method. He also found that the comparisons of readings between otoliths and scales showed good agreement. Otoliths and scales from southern stations (> 46° S) were found to have well defined growth zones, which were more distinct than those from northern stations (<42 ° S). Ekau (1982) also found that otoliths from the northern areas had a hyaline centre in every case. He also found a maximum age of 11 years on the Burdwood Bank. Polish studies in the South Atlantic revealed that ages of *P. ramsayi* ranged from 1 to 14 years (Sosínski and Janusz, 2003).

The only other work to examine the age and growth of a *Patagonotothen* species was on larval *P. tessellata* where Rae *et al*. (1999) validated their daily growth rings and examined their growth.

The aims of this study were to ascertain whether otoliths could be used to estimate age and growth of this fish, and to determine *P. ramsayi* longevity and growth rates. It was also necessary to validate the annual deposition of growth rings and to compare the readings taken from scales with those taken from otoliths.

Materials and Methods

Sample collection

Since the onset of the current CRAFT project in February 2003 for *Patagonotothen ramsayi*, a regular sampling regime was set in place to investigate the population dynamics and other aspects of the biology of this species (see sample protocols in "Promoting a higher added value to a finfish species rejected to sea", Q5CR-2002-71709, First Midterm Review). On board commercial vessels scientific observers processed samples for length frequency analysis and sub-samples were brought back to the Falkland Islands Government Fisheries Department (FIFD) laboratory for further analysis. On commercial trawlers and the research vessel RV Dorada the length frequency of the catch was analysed by measuring the total length (L_T) (nearest cm below) with every individual assessed for its sex and stage of maturity (macroscopically) using the FIFD maturity scale (See Table 2).

Table 2: FIFD eight stage maturity scale

Maturity Stage	Female	Male
I = Immature	Transparent, colourless or grey straight ribbon	Transparent, colourless or grey straight ribbon
II = Resting	Colour, length & presence of capillaries as for testis. No eggs visible	Translucent, grey-red. Gonads approximately 1/2 length of ventral cavity. Outer edge starting to become pleated/frilly. One or two capillaries present
III = Early Developing	A few eggs visible	Heavily frilled, no milt present
IV = Late Developing	Orange-red. Eggs clearly discernible	Reddish-white. No milt produced under pressure, although visible (may be necessary to cut open to ascertain presence)
V = Ripe	Eggs completely round. Some already translucent and ripe	Extremely pleated. White and full with drops of milt produced under pressure
VI = Running	Roe runs freely when slight pressure is applied	Milt runs freely when slight pressure is applied
VII = Spent	Purple/red, not completely empty. No opaque eggs left in the ovary	Purple/red, not completely empty
VIII = Recovering Spent	Red and empty. A few eggs in state of resorption	Red and empty

The eight-stage maturity scale used here was modified from Nikolsky (1963) where stage 3 is divided into an early and late developing stage. In the laboratory the total length, wet mass (M_T, nearest g below) and eviscerated weight were ascertained. Sex and maturity were assessed and the gonads were removed and weighed (M_G). On board vessels and back in the FIFD laboratory otoliths and scales were removed. Later on in the project scientific observers were asked to remove otoliths and scales from large and small animals and these were then introduced to the study non-randomly.

Otolith and scale processing

On board or in the laboratory otoliths and scales, were removed, rinsed in water to remove any tissue, blood or mucous and stored dry, in pairs, in paper envelopes. Initially otoliths were stored in a vial of water for at least 24 hours. They were then examined under a zoom microscope on a dark back-ground. It became clear early on that some otoliths from larger animals were difficult to read because they were too thick and opaque. This was also evident in a smaller number of smaller fish. In this case different approach was necessary. The most effective method was to grind the otoliths into what was effectively a transverse section of about 200~300 µm. This was achieved by laying a microscope slide onto a hot plate with a few crystals of a thermo-plastic cement called Crystal Bond™ (Aremco Products, Inc.) until the plastic melted. The otolith was then placed into the melted plastic and positioned with its distal surface face down on the microscope slide. Once in the plastic the otolith was then moved so that its nucleus was in position at the edge of the slide and allowed to set. Once set the otolith was the ground down to the edge of the slide using a Buehler Metaserve 2000 Grider/polisher. The slide was then heated again and once the plastic had melted the otolith was turned round and positioned with its ground surface on the slide. The otolith was placed on the grinder again and was ground down to the nucleus effectively producing a transverse section firstly using 600 then 1000 grit sand paper (Figure 13).

Scales were removed from a collection randomly and were washed in freshwater to clean there surfaces of skin and mucous. Once cleaned, they were rinsed in 70% ethanol, dried and mounted on slides with cover slips. Scales were read using transmitted light.

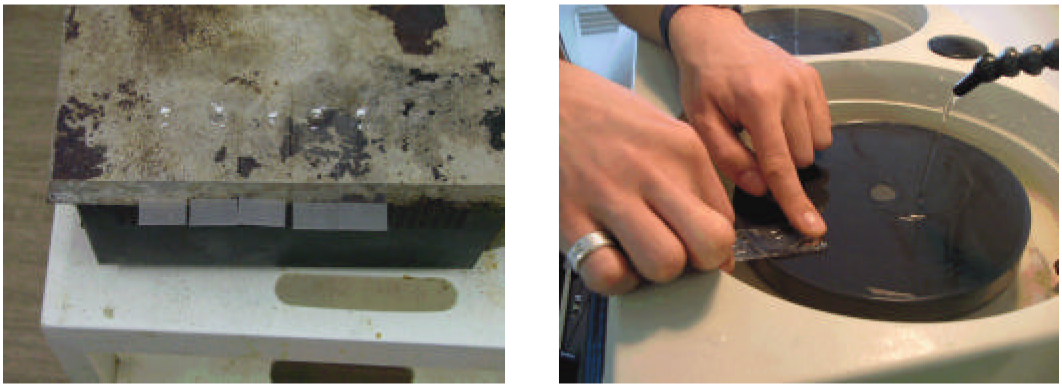


Figure 13: a) Crystal bond heating on the hot plate b) Grinding a *Patagonotothen ramsayi otolith*

Once the otolith was ground to the required thickness the section was then covered with a drop of immersion oil and viewed with dark-field transmitted light.

Comparisons of reading between otoliths and scales

Reading taken from otoliths and their corresponding scales were compared using the index of average percent error (IAPE, Beamish and Fournier, 1981):

$$IAPE = \frac{1}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{\left|Xij - Xj\right|}{Xj}\right]$$

where N is the number of fish aged, R the number of times each is aged, X_{ij} the ith age determination of the jth fish and Xj the average age calculated for the jth fish. Readings were also compared using simple regression and a paired t test.

Validation of annual growth bands

Marginal increment analysis was employed to validate the annual periodicity of growth ring deposition in the otoliths. Otoliths that were determined to be between 3 and 5 years were chosen because their translucent zones were sufficiently far apart to note whether they had occurred on the margin of the otolith. With this the assumption is that margins in fish older than five and younger than three years lay their margins down at the same time of year. Ideally all ages should be validated but in this case the translucent zones were too close together to be able to accurately assess when they were forming on the edge of the otolith. Twenty of these otoliths were pooled into the months that they were collected. Unfortunately, samples were not collected in January or December for 2003 and 2004 due to lack of scientific observation on commercial vessels. The periodicity of band depostion was then assessed by the monthly prevalence of translucent zones at the edge of the otoliths.

Growth

Length at age data were fitted with a non-linear least squares regression to the von Bertalanffy growth model:

$$\boldsymbol{L_t = L_8 (1 - \exp[-K(t - t_0)])}$$

Results

Sample collection

From the onset of the study in February 2003 scientific observers collected a total of 3145 otoliths of which 1277 were read. Figure 14 illustrates sample locations of *P. ramsayi* that were used in this particular study.

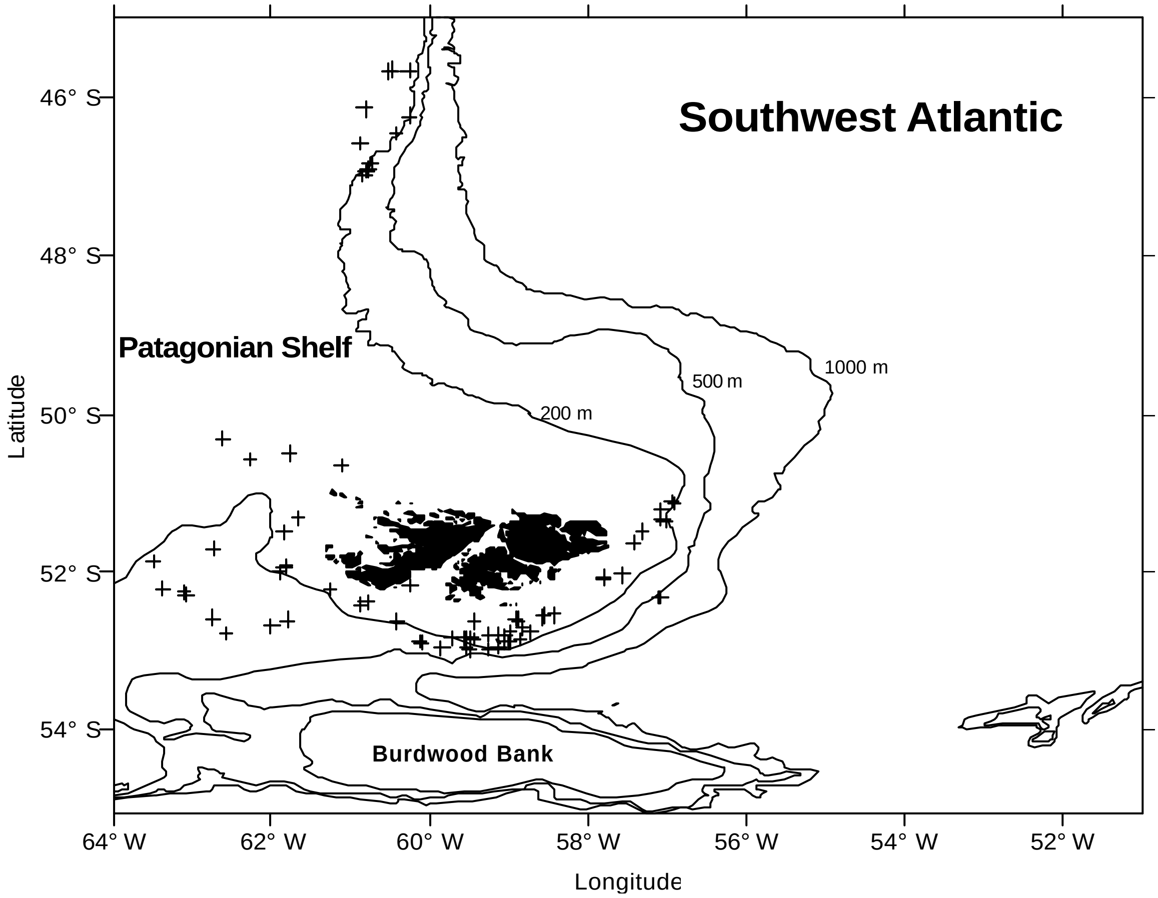
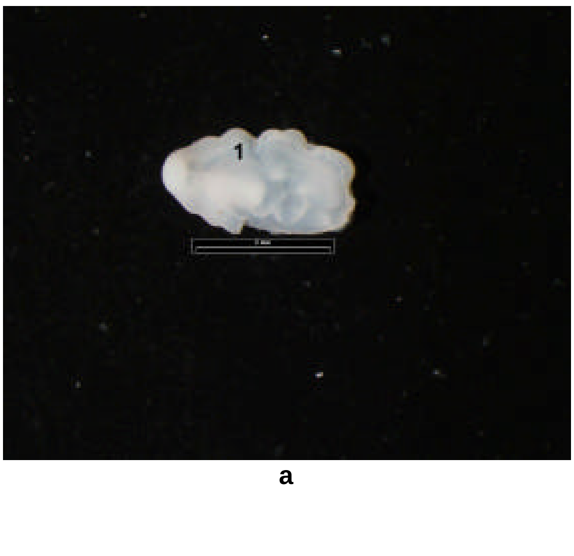


Figure 14: Sample locations of *P. ramsayi* caught between caught between February 2004 and December 2003 that were used for this particular age and growth study.

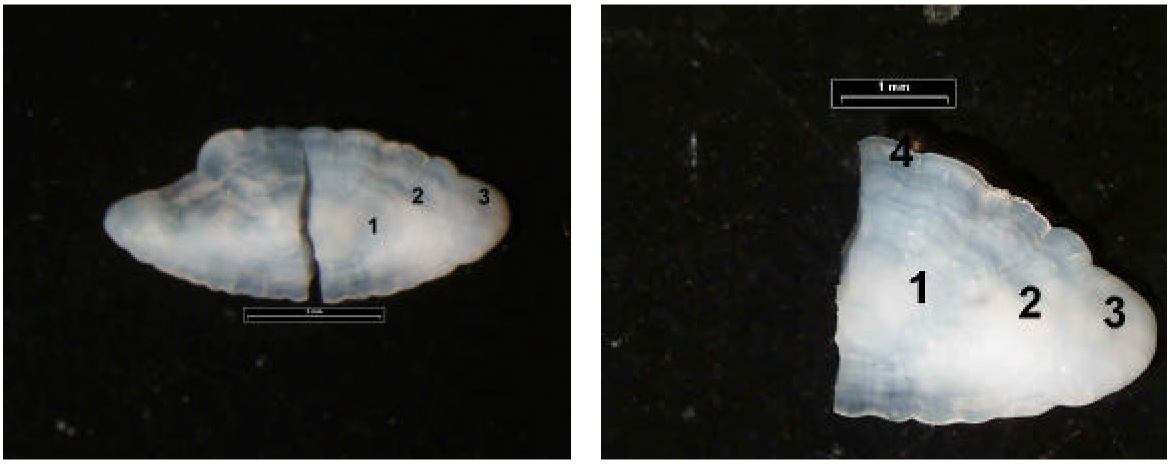
Otolith readability and processing

The clarity of the pattern of zonation in the otoliths a varied a great deal, however zone counts were determined from 97% (n = 1239) of the otoliths examined. The remaining three percent were considered to be impossible to read due to irregular calcium deposits and problems interpreting zones. Of the otoliths that were readable 81% were read whole while 19% were considered to be too thick and had to be ground down to a transverse section. Figure 15 illustrates the banding on whole otoliths and Figure 3 illustrates the banding on otoliths that had been ground.



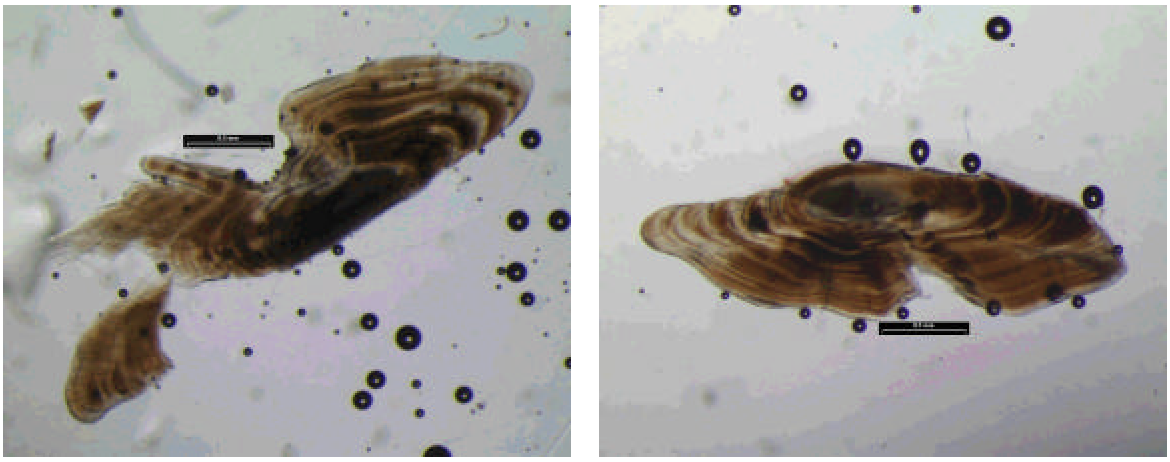
a

b

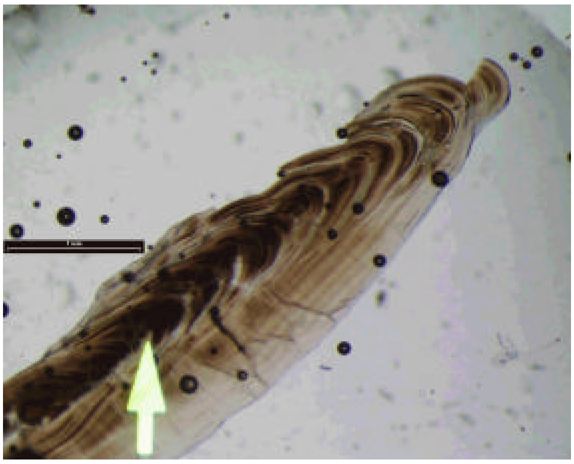


c d

Figure 15: *Patagotothen ramsayi* otoliths (whole) showing banding a) 1yr b) 2yrs c) 3yrs d) 4 yrs



a b



c

Figure 16: Section otoliths of *Patagonotothen ramsayi* a) 7 yrs b) 8 yrs c) longitudinal section 14 yrs. Arrow indicates the 1st ring.

Validation

Determining whether an otolith margin was opaque or translucent was difficult when examining whole otoliths. The analysis was made easier by examining otoliths, between 3 and 5 years, that had been sectioned using the grinding method. The proportions of otoliths with translucent margins in each month's sample are illustrated in Figure 17. Although there was no sample for December and January 2003 and 2004, the data indicate that the opaque margins are laid down from September through to May (Figure 4a). The translucent zones were sometimes seen in October but the majority are formed between May and August (Figure 4b). Figure 18 illustrates the monthly prevalences of translucent zones on the edge of the otolith. This would suggest that one opaque and one translucent zone are deposited per year in *P. ramsayi*.

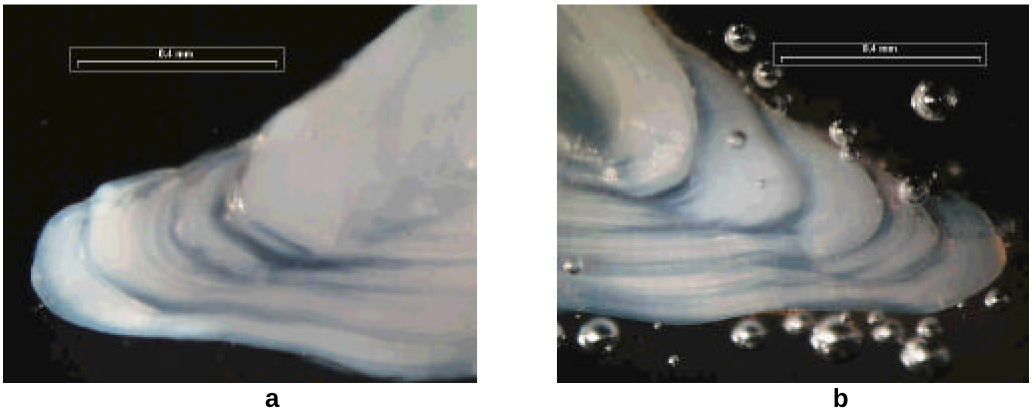


Figure 17: a) Transverse section of a *Patagonotothen ramsayi* otolith with a translucent margin b) with an opaque margin.

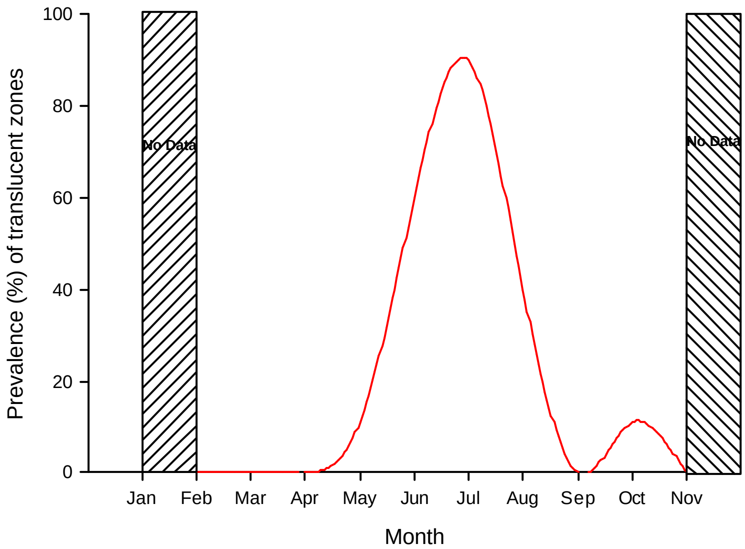


Figure 18: Marginal increment analysis for *Patagonotothen ramsayi* for individuals of between 3 – 5 years.

Scales

Scales were initially quite difficult to read until the correct transmitted light conditions were found. Once established the scales revealed strong growth rings that were relatively easy to count (Figure 19). Comparisons of readings from otoliths and scales from the corresponding fish showed good agreement with an IPAE of 4.36 (n = 141). Figure 20a shows a histogram of the difference between reading taken from otoliths and scales and illustrates that there was a 78% agreement. Scales seemed to overestimate age by one year in 13.5% of the sample and could be attributed to the difference in interpretation between the two. There was no statistically significant difference between the two readings ($P>0.05$, t = 1.27, df. = 140). Figure 20b illustrates a correlation analysis between readings from otoliths and scales and also illustrates a regression line between the two.

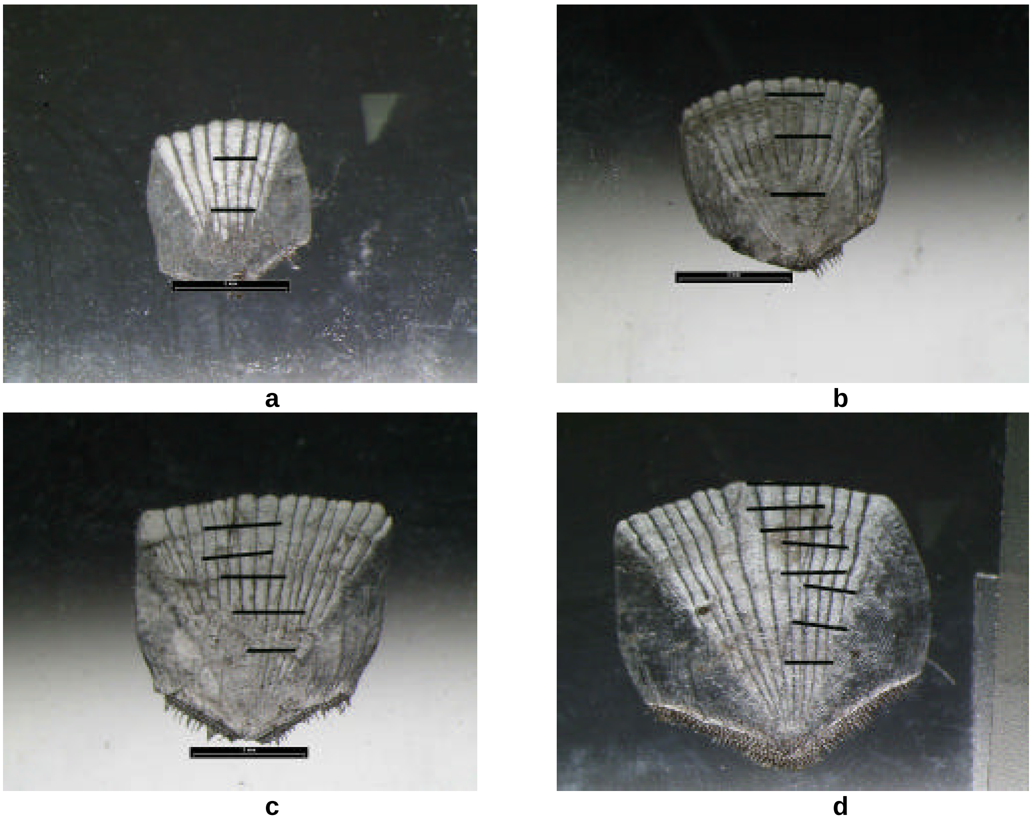
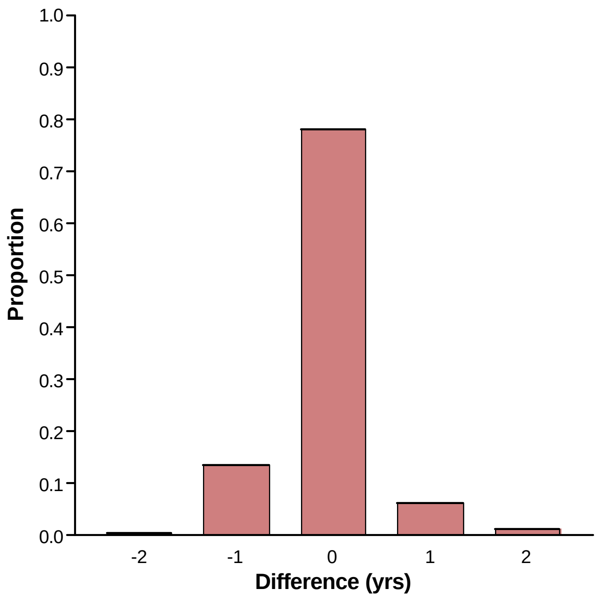


Figure 19: Scales from *Patagonotothen ramsayi* of different ages a) 2yrs b) 3 yrs c) 5 yrs and d) 8 yrs.



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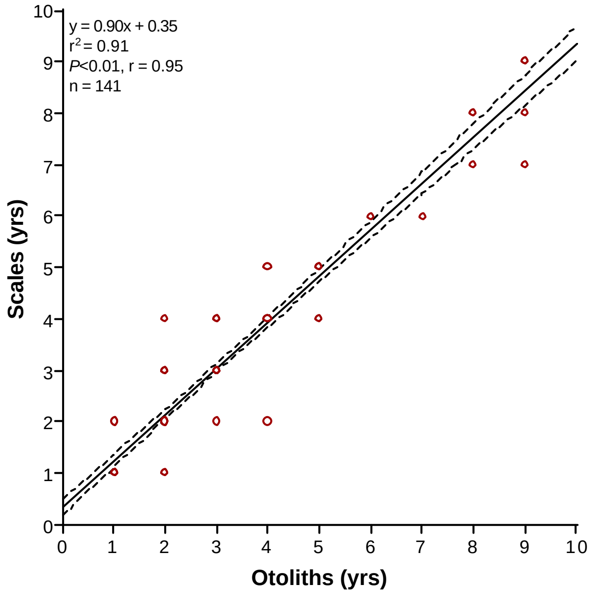


b

Figure 20: a) Histogram illustrating the difference in ages determined from scales and otoliths of *Patagonotothen ramsayi* (n = 141) b) correlation analysis between ages determined from otoliths and scales

Growth

Calculated von Bertalanffy growth parameters are presented in Table 3. This illustrates that *P. ramsayi* is a relatively slow growing species that attains about 5~6 cm in its first year after which it grows about 3 cm per year until age 4. After this growth rapidly slows to 2 cm per year until age 7 and then down to approximately 1 cm per year.

Table 3: Observed age length for *Patagonotothen ramsayi* examined during this study and studies conducted by Sosinski and Janusz (2003), and Ekau (1982).

Study	**Sample No.**	L_8	***K***	t_0
This study				
Combined	1239	33.77	0.25	-1.07
Males	414	37.00	0.16	-2.28
Females	591	35.02	0.21	-1.68
Sosinski and Janusz				
Combined Falkland	749	38.25	0.21	-0.68
Combined Burdwood	290	44.60	0.15	-0.68
Ekau				
Males	284	35.56	0.35	-0.23
Females	346	44.35	0.22	-0.06

It would seem that males had a slower growth rate than females but attain a larger size in our study. Because juvenile animals were difficult to sex we were unable to determine the sex of 0 – group fish. Therefore the minimum age determined for both male and female fish was 1 year and could be the reason why we have relatively high negative values for t_0. The combined sample included males, females and juvenile fish. Table 4 presents an observed age length key for the combined sample examined during this study and Figure 21 illustrates the calculated von Bertalanffy for our combined sample, for Sosinski and Janusz's (2003) study for the Burdwood Bank and the Falklands Shelf, and for Shilbanov (1989) study on *P. guntheri shagensis*.

Table 4: Observed age length key of *Patagonotothen ramsayi* collected during this study.

	Age (yrs)																
TL (cm)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**Total**	**% Frequency**
4	3															**3**	**0.24**
5	14															**14**	**1.13**
6	5															**5**	**0.40**
7	2															**2**	**0.16**
8		1														**1**	**0.08**
9		1														**1**	**0.08**
10		2														**2**	**0.16**
11		4														**4**	**0.32**
12		9														**9**	**0.73**
13		20	1													**21**	**1.69**
14		29	9													**38**	**3.07**
15		30	32													**62**	**5.00**
16		34	37													**71**	**5.73**
17		6	55	1												**62**	**5.00**
18		1	60	6												**67**	**5.41**
19			65	7												**72**	**5.81**
20			47	41												**88**	**7.10**
21			35	87	2											**124**	**10.01**
22			9	86	2											**97**	**7.83**
23			7	51	13											**71**	**5.73**
24			3	20	39	6										**68**	**5.49**
25				8	25	24	1									**58**	**4.68**
26				1	11	27	17									**56**	**4.52**
27				1	4	13	18	7	1							**44**	**3.55**
28						4	9	13	3	1						**30**	**2.42**
29						2	6	8	11	6	1					**34**	**2.74**
30						1	2	9	7	12	2					**33**	**2.66**
31							3	3	13	12	1					**32**	**2.58**
32							1	5	2	6	7	8				**29**	**2.34**
33									4	1	3	1	8			**17**	**1.37**
34										1	1		6	1	4	**13**	**1.05**
35													2		2	**4**	**0.32**
36														1	4	**5**	**0.40**
37															2	**2**	**0.16**
Total	**24**	**137**	**360**	**309**	**96**	**77**	**57**	**45**	**41**	**39**	**15**	**9**	**16**	**2**	**12**	**1239**	**100**
Mean	**5.25**	**14.4**	**18.2**	**21.7**	**24.4**	**25.9**	**27.4**	**29.1**	**30.2**	**30.6**	**31.8**	**32.1**	**33.6**	**35**	**35.3**		
SD	**0.79**	**1.72**	**2.13**	**1.45**	**1.17**	**1.21**	**1.55**	**1.56**	**1.48**	**1.23**	**1.32**	**0.33**	**0.72**	**1.41**	**1.16**		

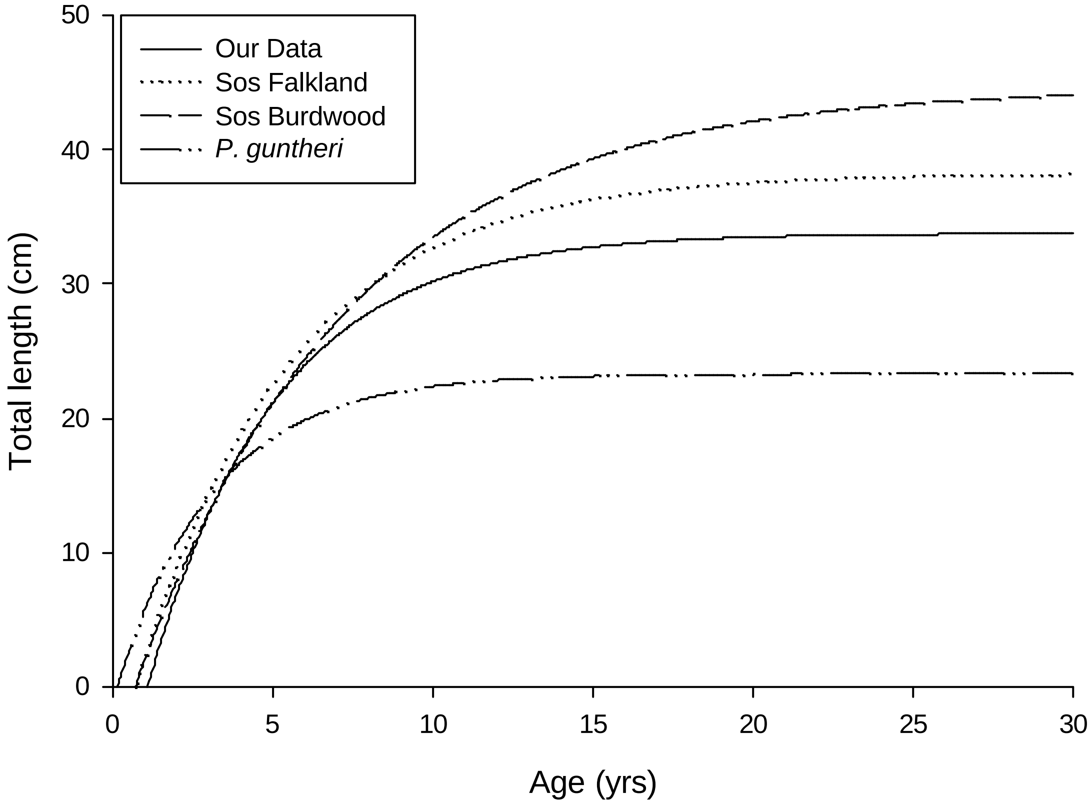


Figure 21: von Bertanalanffy derived growth curves for *Patagonothen ramsayi* examined in the present study and those derived from Sosinski and Janusz (2003) for the Burdwood Bank and the Falkland Islands Shelf. The growth curve for *Patagonotothen guntheri shagensis* was after Shlibanov (1989).

Discussion

Patagonotothen ramsayi lays down one translucent zone every year and counts of these zones are likely to be a valid method for ageing. There are several reasons why "marginal increment analysis" may provide misleading results and in many ways is one of the most difficult validation methods to carry out properly. This is due to technical difficulties associated with viewing partial increments affected by variable refraction through the edge of the otolith, which thins as the margin is approached, and this is made worse by light reflection off the curved surface (Campana, 2001). To reduce this effect we used transversely sectioned otoliths examined with transmitted light and we only used otoliths that were determined to be between 3 and 5 years. This the assumption was that margins in fish older than five and younger than three years are layed down at the same time of year. Ideally all ages should be validated but in this case the translucent zones were too close together to be able to accurately assess when they were forming on the edge of the otolith in older fish. Mark-recapture of chemically marked wild fish is one of the best methods of validating the periodicity of growth increment formation. The method is based on the rapid incorporation of calcium – binding chemicals such as oxytetracycline, alizarin, calcein or strontium, applied at the time of tagging, into bones, scales, spines and otoliths (Campana, 1999). The result is a permanent mark, visible under fluorescent light in the growth increment being formed at the time of tagging. The number of growth increments formed distal to the chemical mark is then compared to the time at liberty after tagging. Unfortunately, *P. ramsayi* do not seem to survive well after capture and the numbers required for tagging to ensure at least some returns would have been too large. Also due to the duration of the project (~2 years) the likelihood of recapture after one year would have been low and therefore this method was not thought be practicable.

The validation of the first or innermost growth increment is one of the most important components of any age and growth study. Without correctly identifying the first increment age determinations will be consistently wrong by a constant amount. Unfortunately we were unable to complete this for this report and these data will be presented later in a publication. Although the first increment was not validated we are sure that we have correctly identified it.

Scales and otoliths showed good agreement with an IPAE of 4.36, which would suggest that they could be successfully employed for ageing *P. ramsayi*. Ekau (1982) also found that scales and otoliths showed good agreement. However, the latter study and the present one agree that otoliths were more reliable and easier to process.

This species is reasonably slow growing with a maximum observed age of 14 years. This contrasts with the growth and longevity another notothenioid occurring of the Falkland Islands shelf. *Eleginops maclovinus* is a large notothenioid that has a high growth rate at an average of 10 cm/year for the first six years of its life with a maximum observed age of 11 years (Brickle *et al*., in press). There have only been two other studies on the age and growth of *P. ramsayi* however no attempt was made to validate the increments in either study. Sosínski and Janusz (2003) examined the age and growth of *P. ramsayi* on the Falkland Islands Shelf and on Burdwood Bank (Figure 21). They found that *P. ramsayi* caught from the Burdwood Bank had lower growth rates and a greater longevity than those caught from the Falkland Islands Shelf and the lower temperatures on the Bank could explain this. Comparisons the growth rates for *P. ramsayi* caught on the shelf during this study and those of Sosínski and Janusz (2003) showed similar growth rates, however L_8 in the latter was higher, 38.25 cm as opposed to 33.77 cm for combined animals (juveniles of undetermined sex, male and females). Although studies on age and growth are at times difficult to compare because of the difference in individual interpretation, especially when the structures are difficult to read, it would appear that Sosínski and Janusz (2003) study produced similar results. However, they used whole otoliths soaked in water for ten minutes before reading whereas the present study sectioned otoliths that were thought to be too thick to read whole. This situation was particularity evident on older fish and therefore their study may have underestimated age in older fish. Ekau (1982) examined age and growth of *P. ramsayi* from samples taken all over the Patagonian Shelf with exception of Burwood Bank. His von Bertalanffy growth parameters are presented in Table 3. However, close examination of his age length key would suggest that he also underestimated age but to a higher degree. If he pooled samples collected south of 46°S and north of 42°S or just used samples from the latter then the large size at such young ages might explain this (5 yrs at 32.5 cm) (no geographical data is supplied). One would expect increased growth rates with higher ambient temperatures. Ekau (1982) examined whole otoliths in glycerine with reflected light against a dark background.

Growth rates for males and females are different. In our study males seemed to have a lower growth rate but attained a greater maximum size, which is the opposite to Ekau (1982). It was suggested that male *P. ramsayi* is a nest builder and is responsible for parental care and they are sexually dimorphic during the breading season (Ekau, 1982; Sosínski and Janusz, 2003) (Reproductive Biology of *Patagonotothen ramsayi* (Regan, 1913) around the Falkland Islands, Southwest Atlantic) so it is possible that a larger male size will lead to better breeding success through mate choice this could therefore explain the difference in growth. Another species, *P. guntheri shagensis,* from Shag Rocks in South Georgia has a much lower growth rate and also a lower maximum size of 23 cm (Shilbanov, 1989). In interesting study would involve the comparison of age and growth *P. guntheri* in the Falkland Islands with *P. guntheri shagensis* at South Georgia.

Further studies will include the validation of the first increment by examining the daily rings within the microstructure of the otolith.

Reproductive biology of *Patagonotothen* species in the Falkland Islands Conservation Zones and on the high seas to the North of the FOCZ (2nd progress report, 2004).

Introduction

The study of how fish reproduce forms a basic and important part of fish biology, especially for those that support important fisheries. Knowledge of the state of maturity and sex ratio of individuals in a population is useful, and estimates of fecundity are important in studies of population dynamics, productivity, or populations estimates (Scott, 1979; Wootton, 1979).

Data on the reproductive biology of *P. ramsayi* was almost non-existent until 1982. Ekau (1982) found that from July to September most specimens caught north of 42°S were in maturity stage II (after Mainer, 1908) and their otoliths exhibited a hyaline nucleus. In contrast to this a larger proportion of fish on the Burdwood Bank were already at stages IV and V and their otoliths exhibited opaque nuclei. Ekau (1982) suggested that this might indicate a difference in the time of spawning from austral autumn in the north to austral spring in the south. He also noted that specimens at maturity stages IV and V exhibited distinct sexual dimorphism where the anal fins, ventral fins and the throat of the males turn deep black.

Sosinski and Janusz (2003) summarised Polish ichthyological studies conducted on *P. ramsayi* from 1979 – 1993 and also reported fish in the north matured in the autumn and fish in more southerly areas matured in spring and therefore spawn in these months. They also provided data on length at maturity and suggested that length at maturity in the northern areas (<42°S) occur two months earlier.

Other than the above there is no data on the reproductive habits and fecundity of *P. ramsayi* available in the literature. Rae and Calvo (1995) examined the fecundity and reproductive habits of *Patagonotothen tessellata* (Richardson, 1845) from the Beagle Channel, Argentina and reported that females spawn twice per year and fecundity was positively correlated to fish length and fish weight with a mean fecundity of 25,932 eggs (range 7,634-62,033). From observations in the field and experiments conducted in aquaria they reported that *P. tessellata* males build nests in rock depressions where the eggs are spawned and fertilized. They found that the nesting activity coincides with massive spawning periods. Inside a nest either a single mature male, or a mature male together with several ripe females, or a male with several eggs masses were found. They also found that whilst the development of embryos within a single mass was well synchronised there were considerable differences between different egg masses. Only males that had prepared nests were able to mate successfully. Rae and Calvo (1995) found that a single male could fertilize egg masses spawned by several ripe females within the same reproductive period. Once the females had spawned they would then leave the nest. Males on the other hand were found to be responsible for parental care and were observed aerating the eggs with their pectoral fins and opercula during development. Once the eggs had hatched the males left the nests, and according to Rae and Calvo (1995) they did not feed during incubation.

The aims of this study was therefore to gain an insight into the reproductive biology of *P. ramsayi* on the Patagonian Shelf between 45°S and 52°S paying particular attention to their reproductive cycle, length at sexual maturity and their fecundity.

Materials and Methods

Sample collection

Since the onset of the current CRAFT project in February 2003 for *Patagonotothen ramsayi*, a regular sampling regime was set in place to investigate the population dynamics and other aspects of the biology of this species (see sample protocols in "Promoting a higher added value to a finfish species rejected to sea", Q5CR-2002-71709, First Midterm Review). On board commercial vessels scientific observers processed samples for length frequency analysis and sub-samples were brought back to the Falkland Islands Government Fisheries Department (FIFD) laboratory for further analysis. On commercial trawlers and the research vessel RV Dorada the length frequency of the catch was analysed by measuring the total length (L_T) (nearest cm below) with every individual assessed for its sex and stage of maturity (macroscopically) using the FIFD maturity scale (See Table 1).

Table 1: FIFD eight stage maturity scale

Maturity Stage	Female	Male
I = Immature	Transparent, colourless or grey straight ribbon	Transparent, colourless or grey straight ribbon
II = Resting	Colour, length & presence of capillaries as for testis. No eggs visible	Translucent, grey-red. Gonads approximately 1/2 length of ventral cavity. Outer edge starting to become pleated/frilly. One or two capillaries present
III = Early Developing	A few eggs visible	Heavily frilled, no milt present
IV = Late Developing	Orange-red. Eggs clearly discernible	Reddish-white. No milt produced under pressure, although visible (may be necessary to cut open to ascertain presence)
V = Ripe	Eggs completely round. Some already translucent and ripe	Extremely pleated. White and full with drops of milt produced under pressure
VI = Running	Roe runs freely when slight pressure is applied	Milt runs freely when slight pressure is applied
VII = Spent	Purple/red, not completely empty. No opaque eggs left in the ovary	Purple/red, not completely empty
VIII = Recovering Spent	Red and empty. A few eggs in state of resorption	Red and empty

The eight stage maturity scale used here was modified from Nikolsky (1963) where stage 3 is divided into an early and late developing stage. In the laboratory the total length, wet mass (M_T, nearest g below) and eviscerated weight were ascertained. Sex and maturity were assessed and the gonads were removed and weighed (M_G). The gonadosomatic index (I_G) was calculated as

$$I_G = (M_G/M_T) \times 100$$

Sex ratio and length frequency analysis

The sex ratios and length frequency dynamics of *P. ramsayi* were analysed on a monthly (pooled over two years, 2003 and 2004) basis to ascertain whether sex or length related migration were masking the true sex ratio of the L_T of the population. The sex ratios of mature individuals (>= 25 cm L_T, maturity stages IV, V, and VI) between May and August (pooled for 2003 and 2004) were also examined as an indicator of nest preparation and nest guarding in males. In all cases there were no data for December for both 2003 and 2004 due to lack of scientific observation on vessels.

Length at maturity

Patagonotothen ramsayi were considered to be sexually mature at stage III. To estimate the length at 50% maturity (L_{M50}) a three-parameter logistic model was fitted to the data

$$y = \frac{a}{1 + \left(\frac{x}{x_o}\right)^b}$$

where y is the percentage of mature animals, x is L_T (cm), x_0 is the L_T at 50% maturity, a the asymptotic value and b is the shape parameter.

Fecundity estimation

A total of 37 *P. ramsayi* ovaries collected between 2003 and 2004 were examined for the purposes of this particular study, including those from three maturing females at stage III, 30 mature females at stage IV and from four spawning individuals at stage V. To estimate the total number of eggs in the ovary, three samples of 150 – 250 mg (depending on the egg size) were taken randomly from different parts of the gonad. This number of sub-samples from the ovary was considered to be sufficient for a good estimation: even one sample gave a reasonable estimation of the total oocyte number in the ovary, as the initial estimation of fecundity was within the 95% confidence limits of the final estimation when the sample number had risen to six (Figure 22).

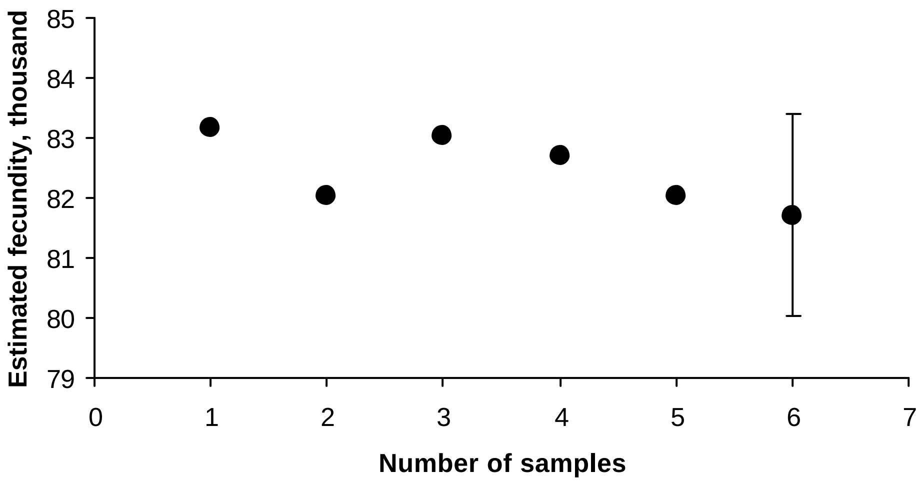


Figure 22: Changes in the precision of fecundity estimation in a female at stage IV (L_T = 23 cm) with increasing sample numbers.

In each sample, oocytes were separated from a network of blood vessels and counted using a Bogorov camera. The egg diameters of 30-35 eggs per sample (total ~ 100 per ovary) were measured across their major axis. Resorpting oocytes were counted separately but were not taken into account when estimating fecundity.

Gonad histology

A total of 126 gonads collected over the study period where fixed in 10% buffered formaline saline (10% BFS, males) and Bouin's solution (females) for later histological analysis. The sex of each specimen was determined both macroscopically and microscopically. Whole gonads were weighed and then cut into 2 to 5 pieces depending on their size to obtain sections from different locations in the ovary, and later embedded in paraffin wax. Sections of 5 – 7 µm thick were cut on a microtome and mounted on slides. They were stained with routine Mayer's haematoxylin and eosin stains. The sections were then mounted with either DPX or Canada Balsam.

Results

Sample collection

A total of 38,667 *P. ramsayi* were sampled on board commercial trawlers and research cruises by scientists and scientific observers between February 2003 and November 2004. Figure 23 illustrates the sampling locations on the Patagonian Shelf.

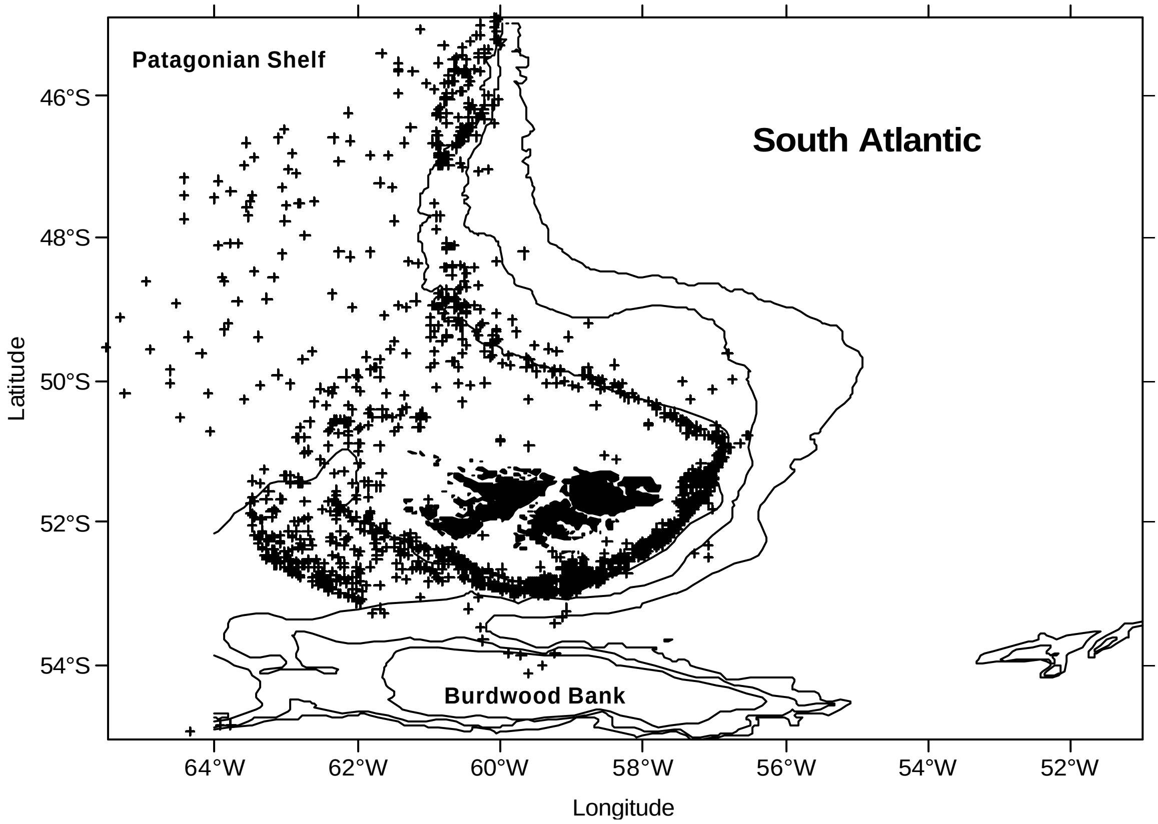


Figure 23: Sample locations for *Patagonotothen ramsayi* between February 2003 and November 2004

Length frequency analysis and sex ratio

The sex ratio of *P. ramsayi* with increasing length for all animals sampled over the study period was approximately 50% males and 50% females (Figure 24).

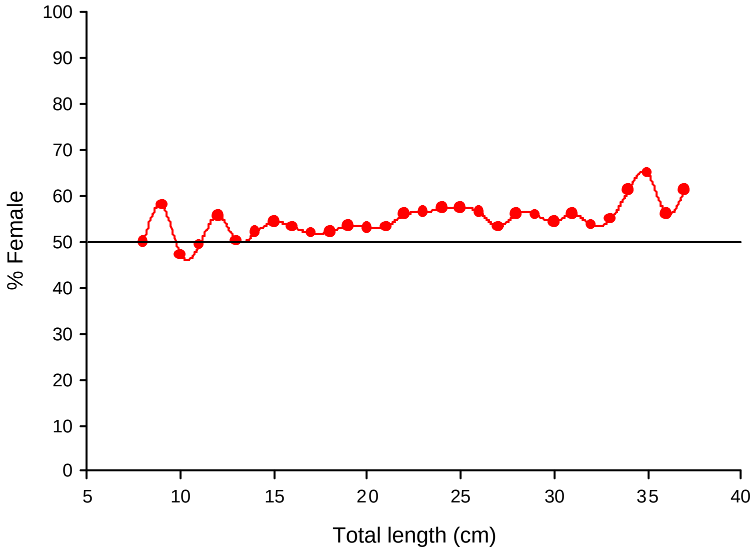
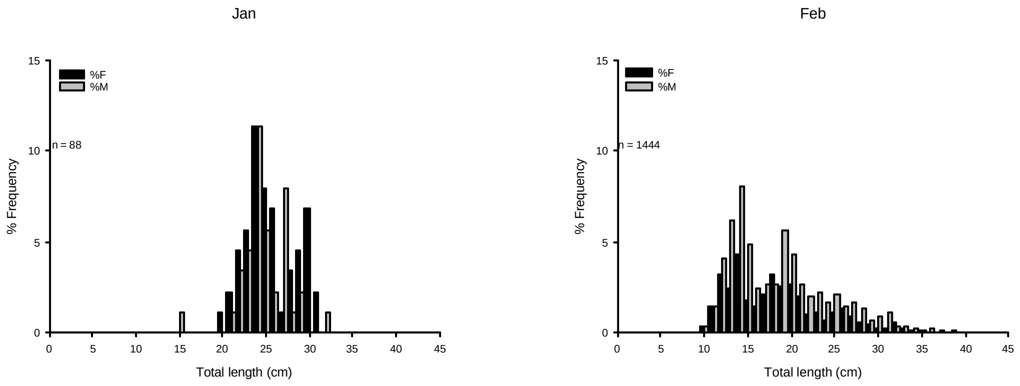
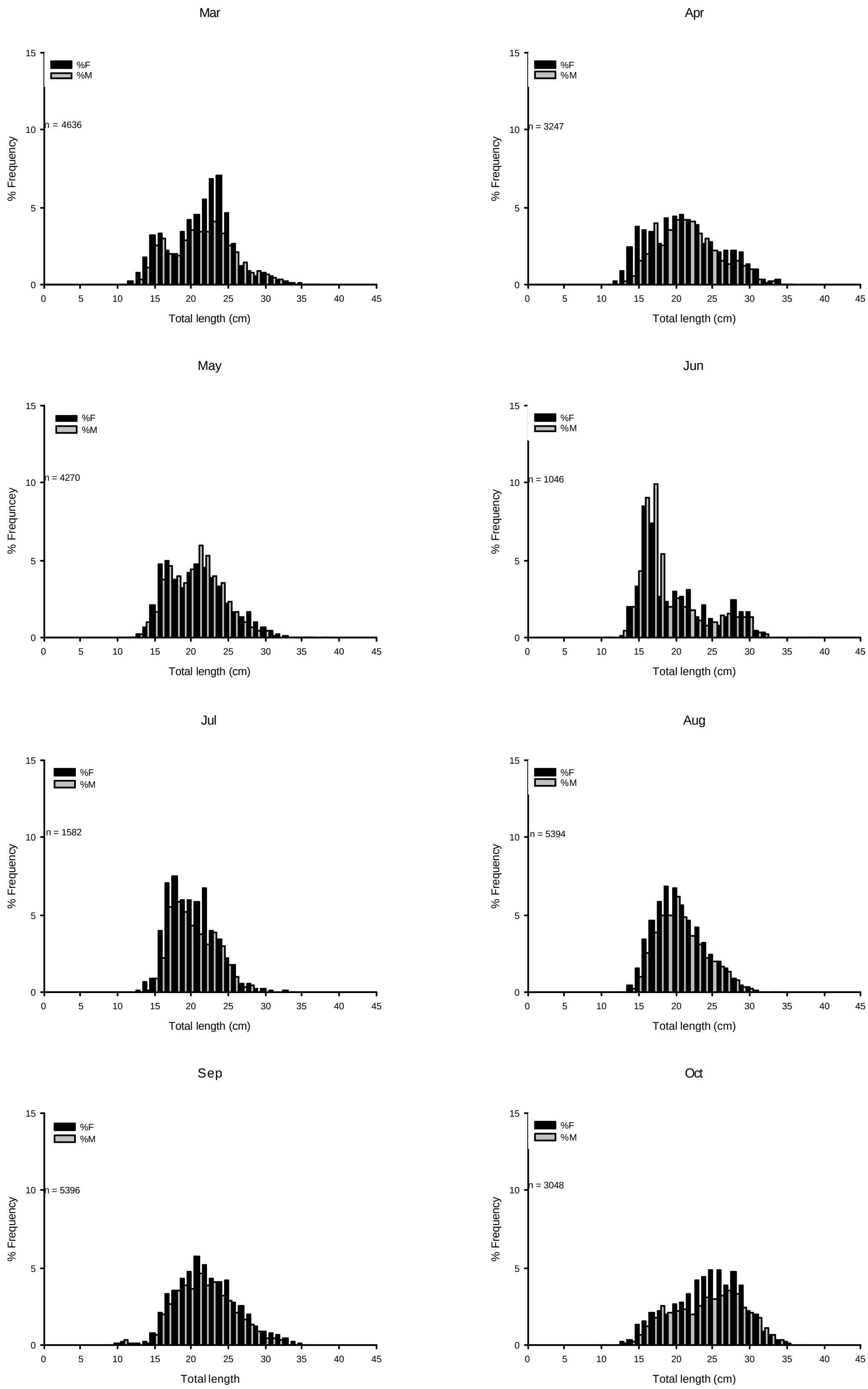


Figure 24: Sex ratio of pooled *Patagonotothen ramsayi* versus total length

Pooled monthly length frequency analysis illustrated that the sex ratios are about equal with a small male bias between January and June. From July onwards there is a female bias and this is most evident in animals of greater than 20 cm L_T. Then in November this situation changes whereby there is a pronounced male bias in the sample population especially in animals over 27 cm L_T (Figure 25). This may indicate that larger males re-enter the sample population before the smaller individuals.




Mar
%F
%M
n = 4636
% Frequency
Total length (cm)
Apr
%F
%M
n = 3247
% Frequency
Total length (cm)
May
%F
%M
n = 4270
% Frequncey
Total length (cm)
Jun
%F
%M
n = 1046
% Frequency
Total length (cm)
Jul
%F
%M
n = 1582
% Frequency
Total length (cm)
Aug
%F
%M
n = 5394
% Frequency
Total length (cm)
Sep
%F
%M
n = 5396
% Frequency
Total length
Oct
%F
%M
n = 3048
% Frequency
Total length (cm)

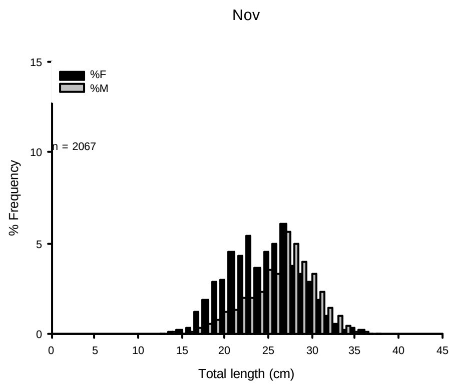


Figure 25: Pooled monthly length frequencies for *Patagonotothen ramsayi* sampled between February 2003 and November 2004

The sex ratios of mature individuals (>= 25 cm L_T, maturity stages IV, V and VI) were examined monthly. The sex ratio in May, June and July showed an extreme female bias. After July the percentage of females in the sample population decreased down to just over 50% in September (Figure 26). This indicates that only a small number of males are in the sample population between June ~ August after which their proportion increases in September. There were no data for the other months of the year because mature animals were not found in these months.

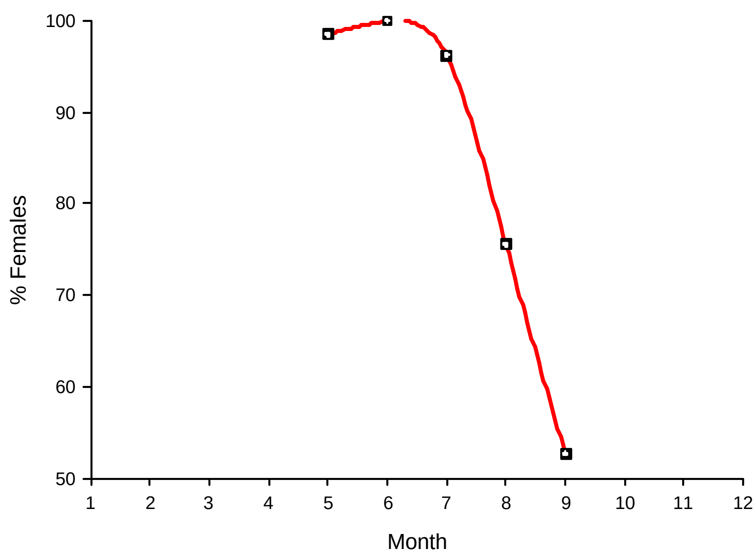
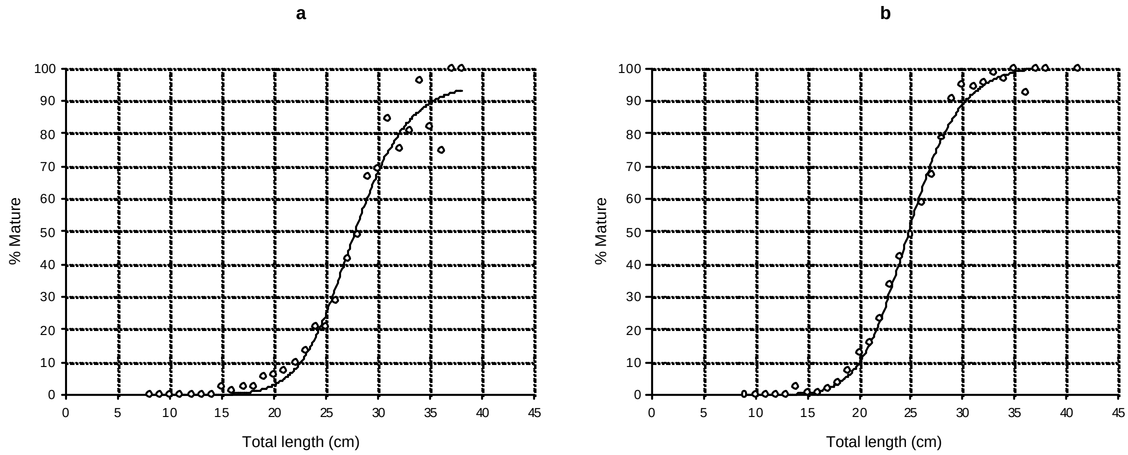


Figure 26: Monthly sex ratio of *Patagonotothen ramsayi* for mature animals greater than 25 cm L_T

Length at maturity

Male and female *P. ramsayi* were considered sexually mature (greater or equal to maturity stage III) at 27.56 cm L_T and 24.85 cm L_T respectively. The length at maturity for combined sexes (males and females) was calculated to be 26.05 cm L_T (Figure 27).



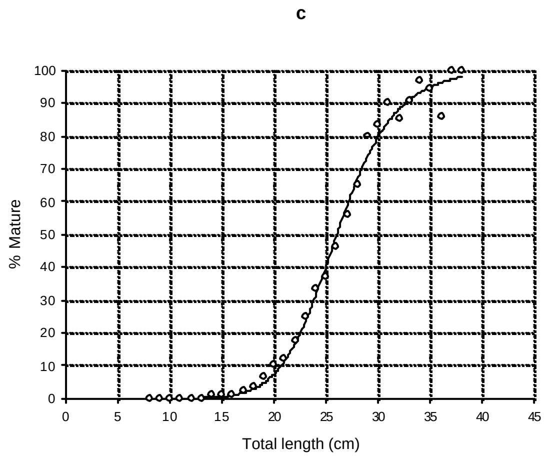


Figure 27: Length at sexual maturity for *Patagonotothen ramsayi*; a = males, b = females, and c = males and females combined.

Fecundity

Formation of total fecundity during maturation

Resorpting oocytes were found in all three females at maturity stage III that were examined (100%), in 21 of 30 females at stage IV (70%), and in two of four females (50%) at stage V. Usually the resorpting oocytes did not exceed 3% of the total number of yolk oocytes but in some animals, during early maturation, this figure was as high as 10% of the oocyte stock. There was a significant negative correlation (P<0.001, Spearman r = -0.573) between mean egg size and the percentage of resorpting oocytes indicating that the intensity of atresion decreases with maturation (Figure 28)

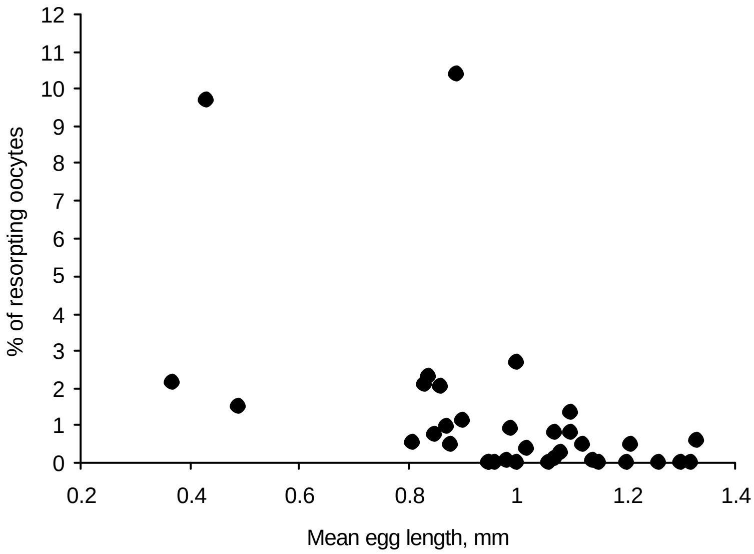


Figure 28: Changes in the occurrence of resorpting oocytes with increasing egg size in *Patagonotothen ramsayi*

Oocyte maturation

The oocyte length distribution in the ovary was found to be unimodal during all stages of maturity (Figure 29) indicating that *P. ramsayi* is a total spawner as opposed to a batch spawner. Upon reaching 0.95 – 1.15 mm, the oocytes are ready to ovulate. The size of hydrated oocytes is 1.0 – 1.45 mm. Egg size was found to increase with increasing fish length at maturity stage V (Figure 30). When examining the eggs under a microscope it was found that their perivitelline space was rather small suggesting that the egg masses of *P. ramsayi* are benthic (see Figure 21a).

Fecundity

Counting the number of hydrated oocytes in females with a maturity stage V, as well as the total number of yolk oocytes in females at stage IV (70%), where oocyte modal size exceeded 1 mm and resorption was no longer observed in the ovary was the method used to estimated fecundity.

The total fecundity in fish ranging 20 – 31 cm L_T varied between 24,300 and 76,700 eggs and this value increased with increasing female size. The total number of oocytes in less advanced females at maturity stage IV was much higher (Figure 31) because of continuing oocyte atresion and reached as much as 160,000 in fish of 30 – 31 cm L_T. This therefore suggests that oocyte atresion during maturation reduced the fecundity by at least 50%.

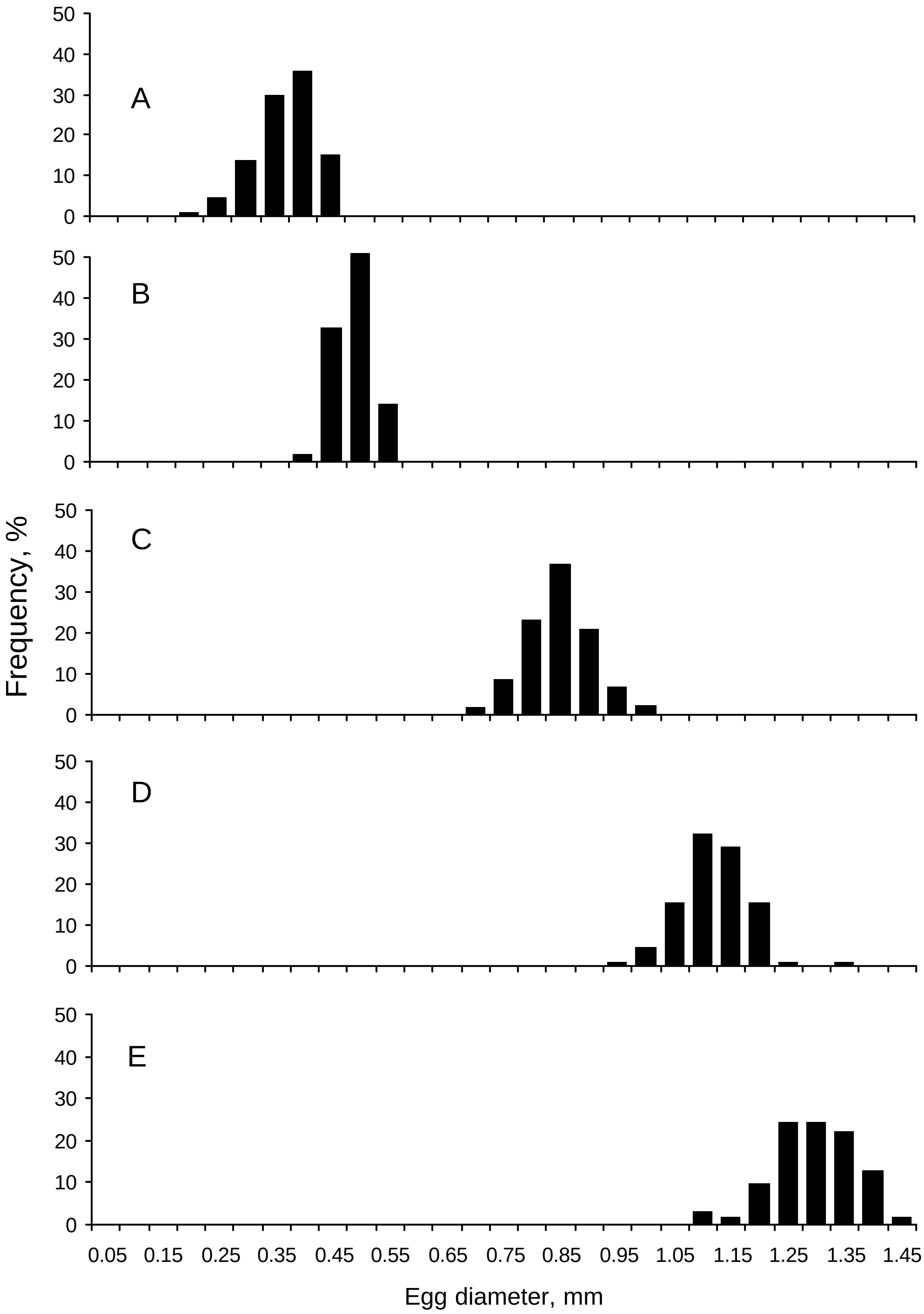


Figure 29: Changes in length frequency of yolk oocytes during maturation of *Patagonotothen ramsayi*. A – 30 cm L_T, stage III, B – 25 cm L_T, stage III, C – 23 cm L_T, stage IV, D – 32 cm L_T, stage IV, E – 27 cm L_T, stage 5

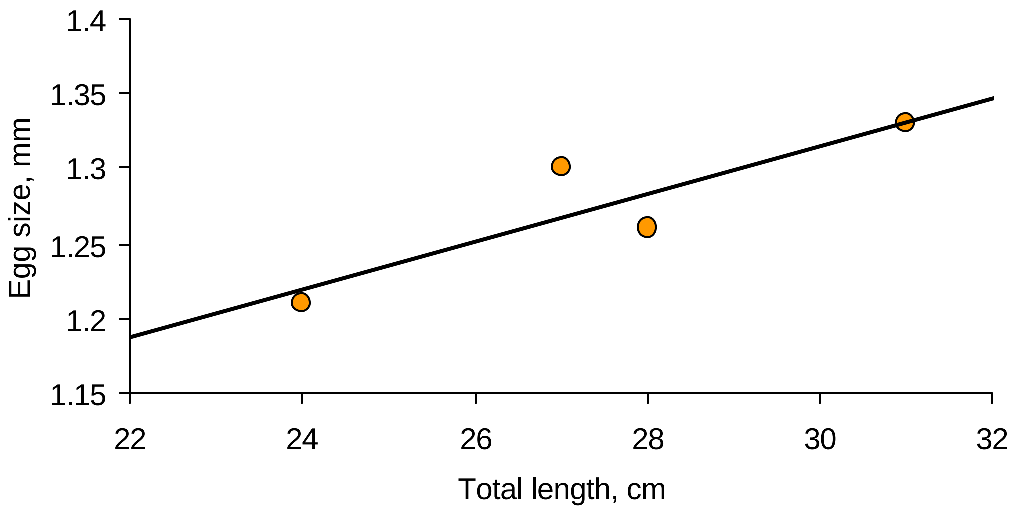


Figure 30: Increase in hydrated egg size with increasing length at maturity stage 5 in *Patagonotothen ramsayi*

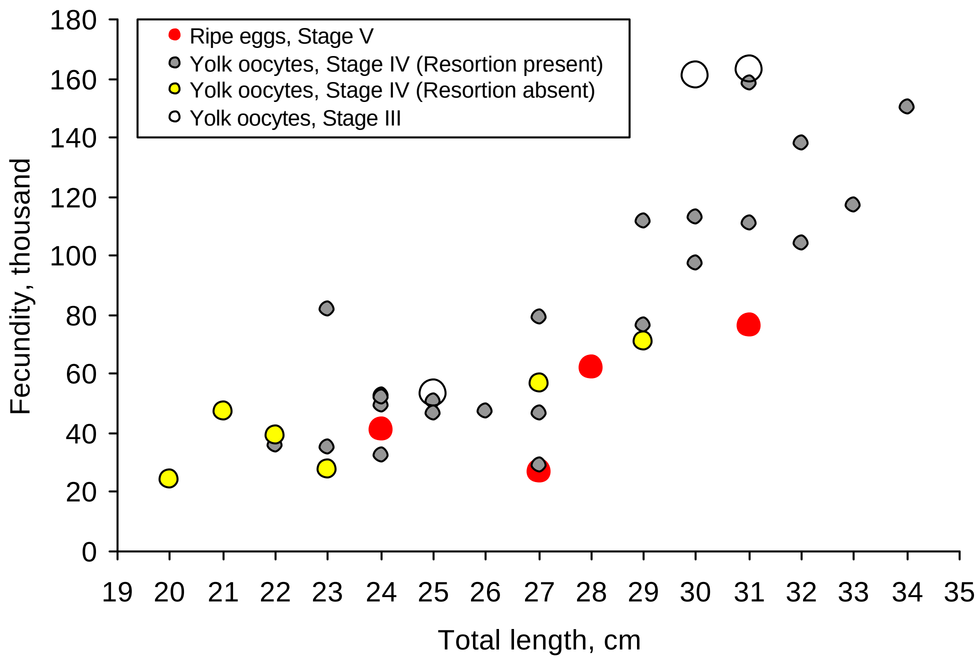


Figure 31: Total fecundity of *Patagonotothen ramsayi* at different maturity stages

The timing of spawning

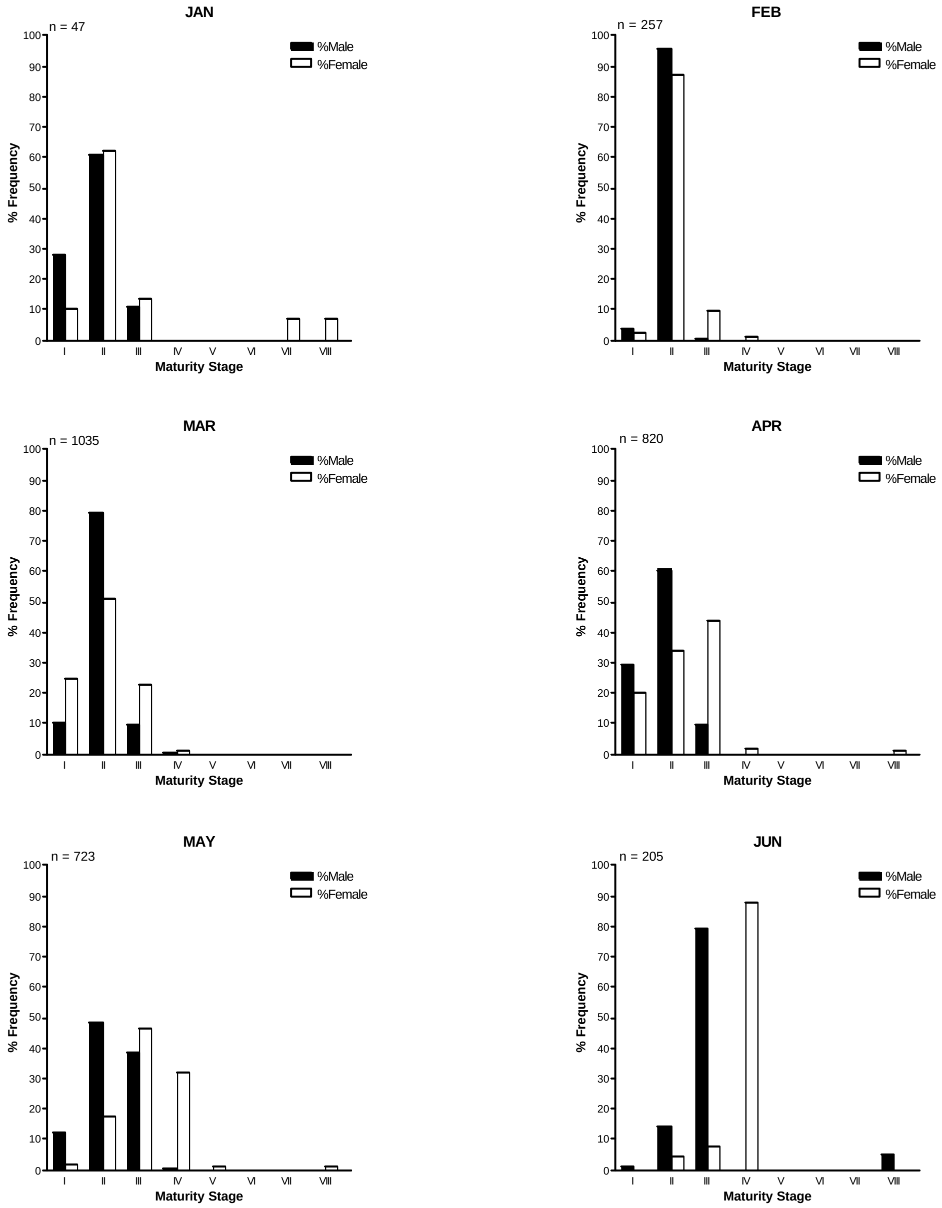
Four spawning females at stage V with hydrated eggs were caught at night between 22:00 and 08:00, between August and September, at depths ranging 250 – 392 m. This might suggest that spawning takes place during darkness for *P. ramsayi*

Annual reproductive cycle

Males and females start to mature from May onwards, and the main spawning period seems to occur between June and August when the majority of female and male maturity stages V and VI are encountered in the sample population. In October and

November large numbers of post spawning (Stages VII and VIII) animals are found in the sample population after which there is a greater proportion of resting animals. Monthly changes in the frequency of occurrence of various maturity stages are illustrated in Figure 32.

The mean (± SE) GSI calculated for males and females greater than or equal to 25 cm L_T is illustrated in Figure 33. In each case there is a peak in mean GSI in June of 10.27% M_T and 0.35% M_T for males and females respectively after which there is a steady decline until 0.05% M_T in males. The decline in GSI for females is less pronounced until September (7.34% M_T) after which it declined drastically to 0.74% M_T.



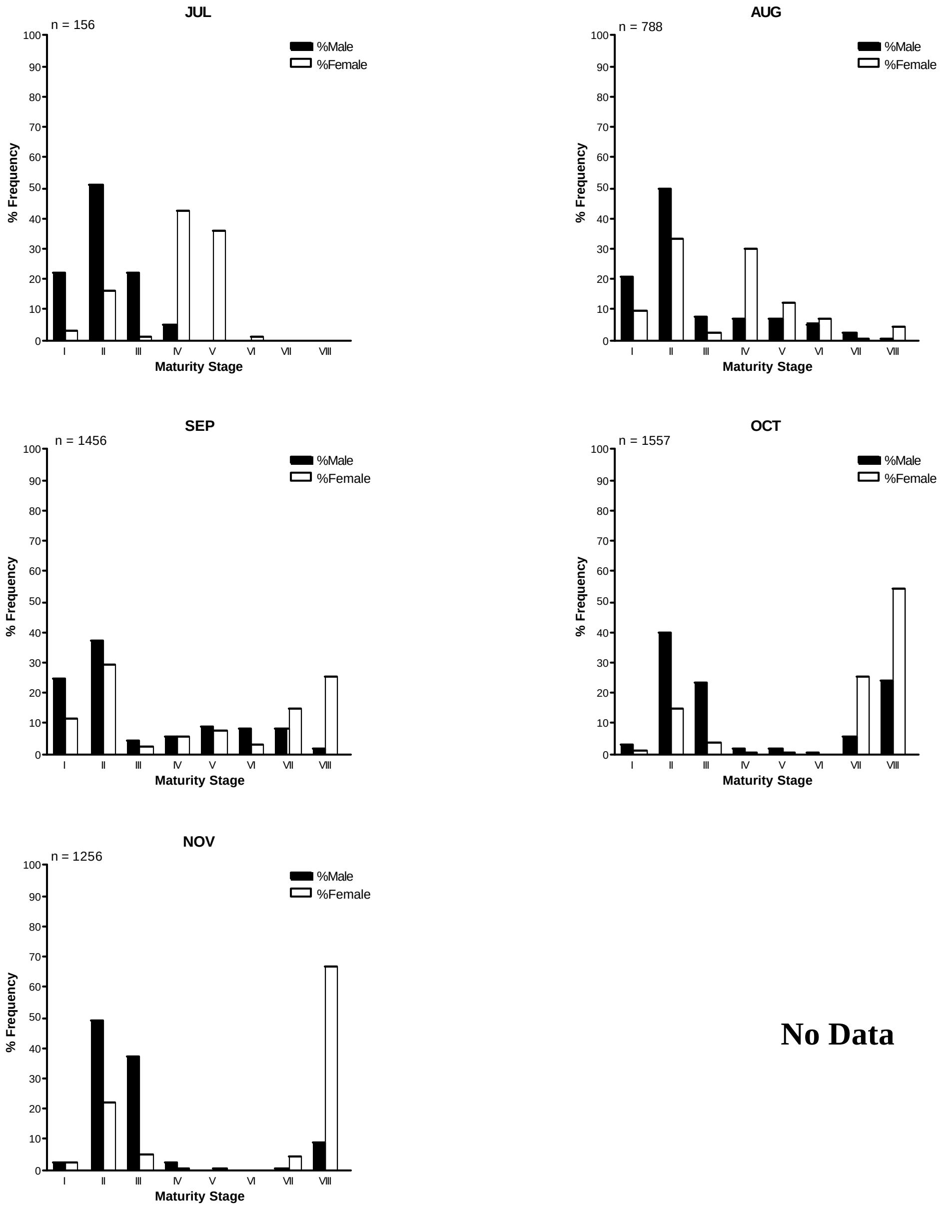


Figure 32: Monthly changes in the frequency of occurrence of various maturity stages of the gonads of *Patagonotothen ramsayi*

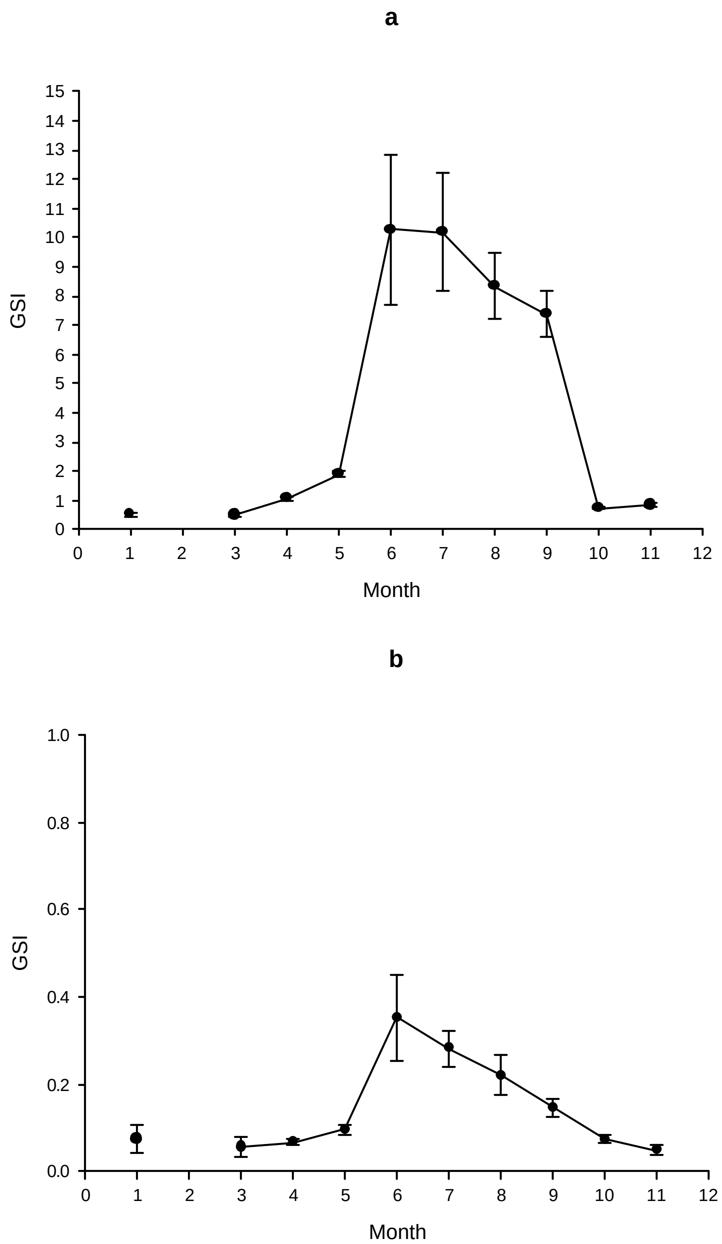
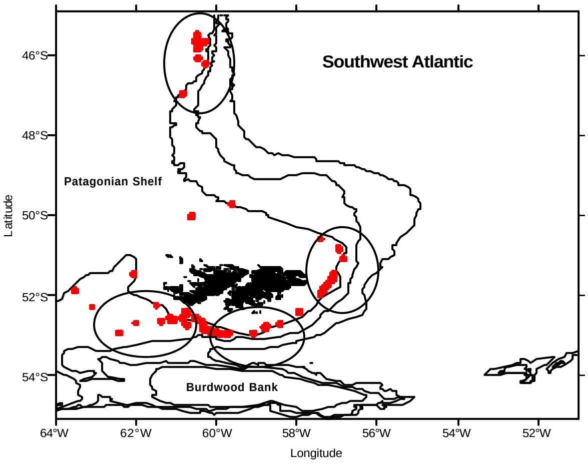
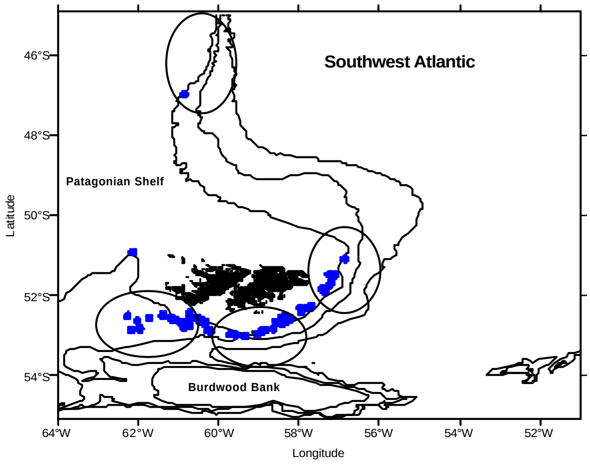


Figure 33: Month GSI (% M_T) for *Patagonotothen ramsayi* females and b males

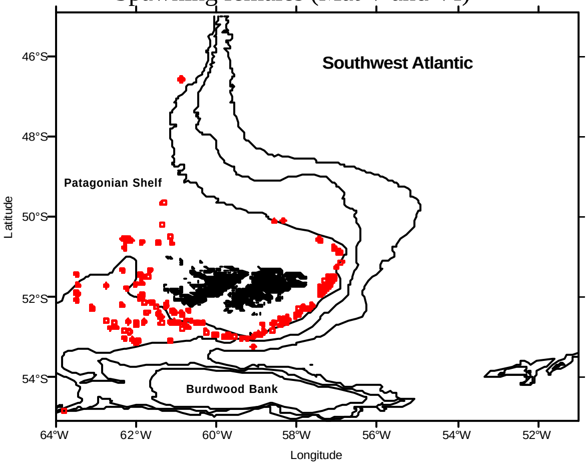
Mapping the areas of occurrence of different maturity stages around the Falkland Islands would suggest *P. ramsayi* spawn (maturity stages V and VI) on the shelf breaks. Post spawning animals tend to move over a larger area to forage and recover. While immature, resting and maturing animals are found all over the shelf on their feeding grounds (Figure 34). Juveniles of less than or equal to 5 cm L_T were found in depths of less than 120 m with over 92% (n = 129) found at 52m or less. Larvae are found in near bottom pelagic waters (our data), which would suggest that they could be carried inshore by off shoots of the Falkland current (see Arkhipkin, 2003 for a description of the hydrography in the area).



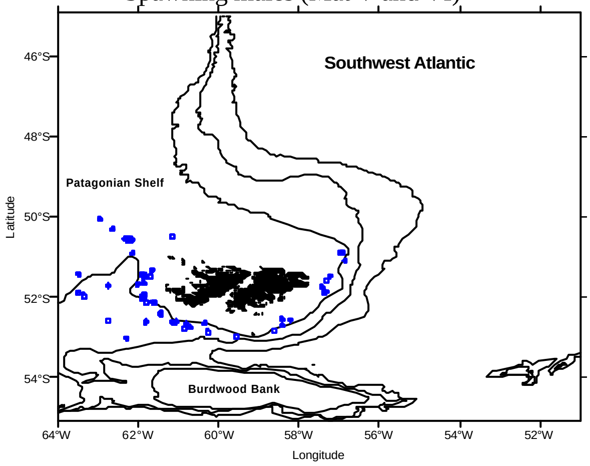
Spawning females (Mat V and VI)



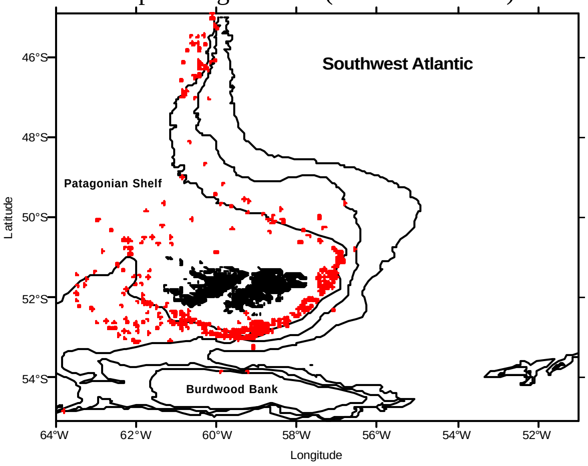
Spawning males (Mat V and VI)



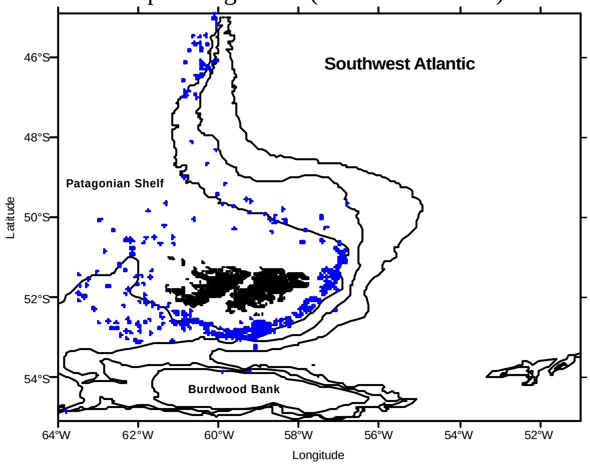
Post Spawning females (Mat VII and VIII)



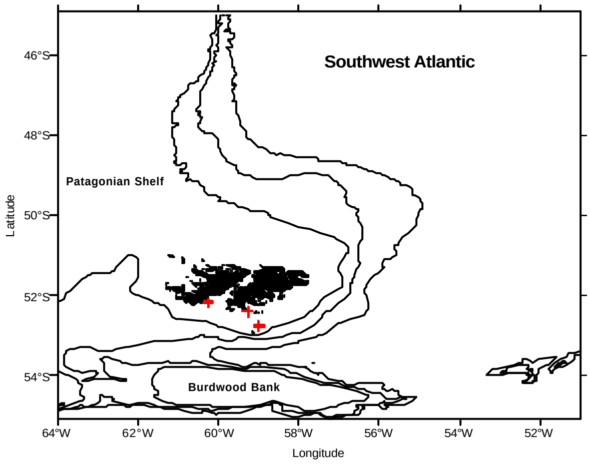
Post Spawning males (Mat VII and VIII)



Immature and maturing females (Mat I,II,III,IV)



Immature and maturing males (Mat I,II,III,IV)



Juvenile individuals <= 5 cm L_T

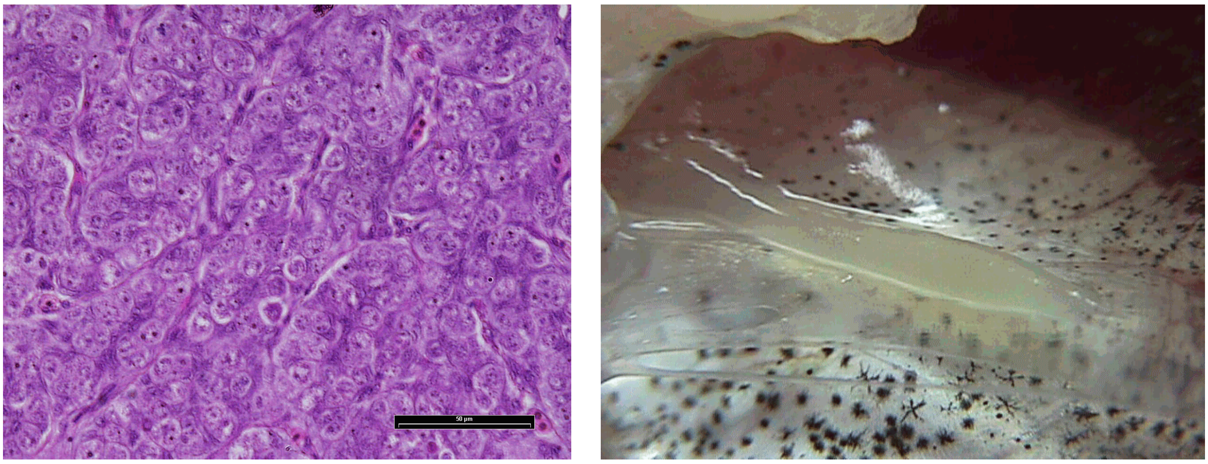
Figure 34: Charts illustrating the areas of occurrence of the different maturity stages of *Patagonotothen ramsayi*.

Gonad histology

The ovaries and testis were divided into six categories based on their histological characteristics.

Testes

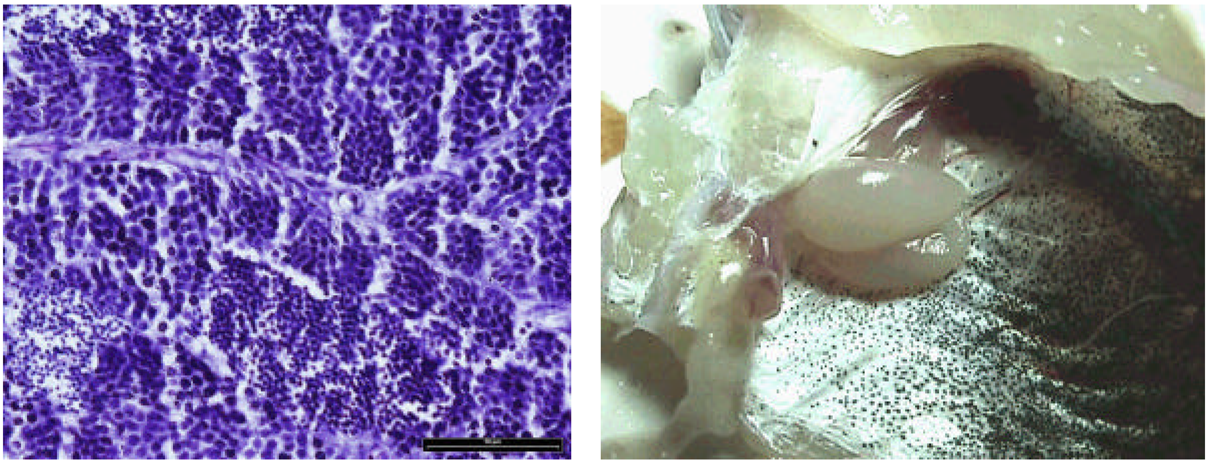
Immature stage (Stage I) (Figure 35a and b). Typical immature testes were thread like and pink in colour. Histologically the densely packed tubules contained layers spermatogonia and almost no lumen.



a b

Figure 35: a) Histological section of an immature testis of *Patagonotothen ramsayi* b) Macroscopic photograph of an immature testis

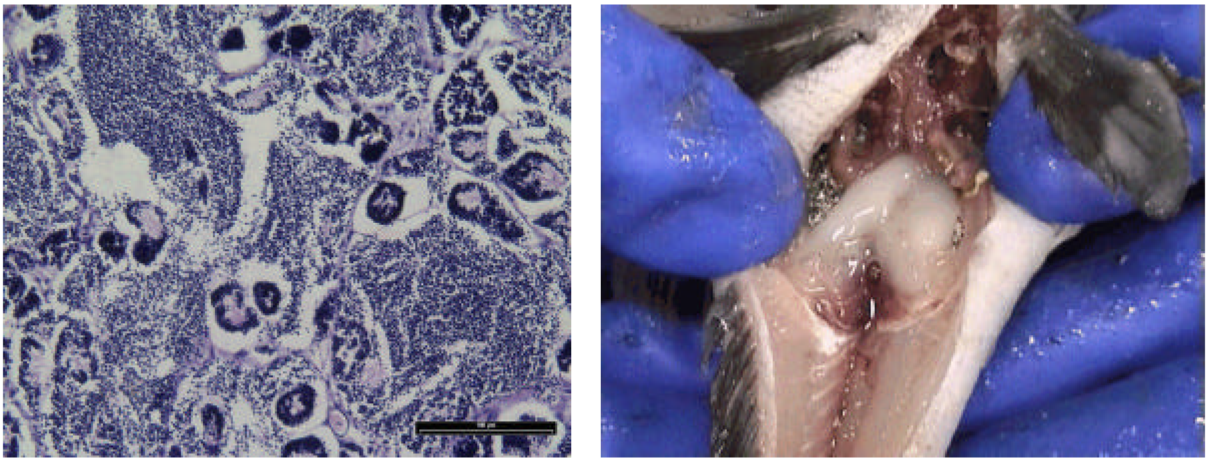
Developing stage (Stage III and IV) (Figure 36a and b). Macroscopically testes are usually larger than in the previous category and in this case they were more rounded in shape and pinkish/white. Histologically this stage contained abundant spermatogonia, numerous spermatocyte cysts and some spermatozoa were attached to the walls lobule. Some spermatozoa were also found free within the lobule lumen.



a b

Figure 36: a) Histological section of a developing testis of *Patagonotothen ramsayi* b) Macroscopic photograph of a developing testis

Mature/spawning stage (Stage V and VI) (Figure 37a and b). Macroscopically these are much larger than in the previous category and in this case the testes were more rounded in shape and white in colour. Sperm oozes out of the testis when under pressure. Histologically this stage has similar stages of spermatogenesis except these gonads are characterised by having their lumens packed with spermatozoa.



a b

Figure 37: a) Histological section of a mature testis of *Patagonotothen ramsayi* b) Macroscopic photograph of a mature testis

Spent stage (Stage VII and VII) (Figure 38). These testes tend to be purple/red and quite flaccid. Histologically this stage contained abundant spermatogonia, numerous spermatocyte cysts but will large empty lobule lumens.

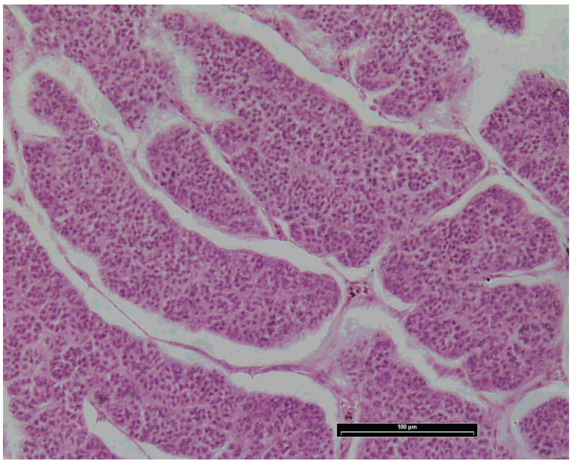
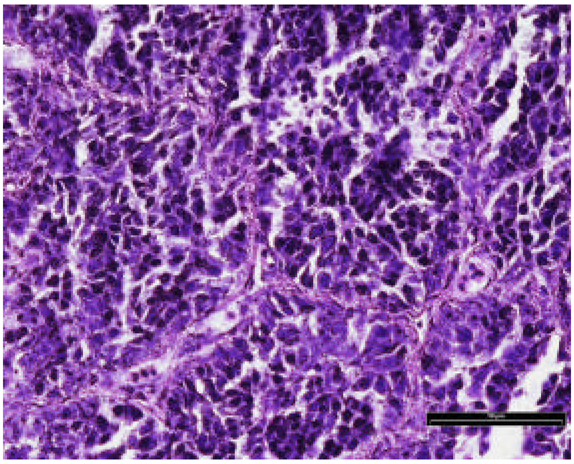
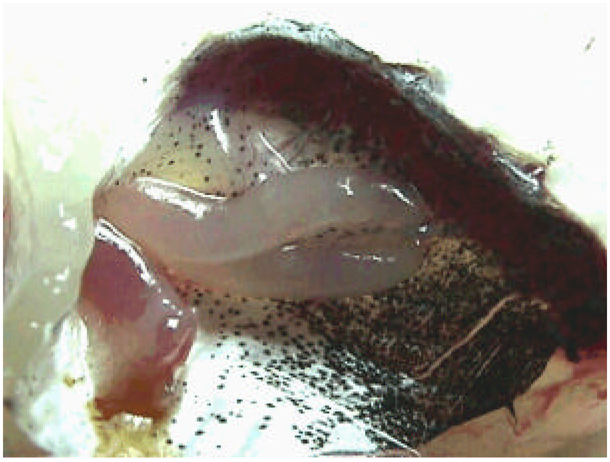


Figure 38: Histological section of a spent testis of *Patagonotothen ramsayi*

Resting stage (Stage II) (Figure 39a and b). These are generally larger than the immature stage and are pink to white in colouration. Histologically they are characterised by large numbers of spermatogonia and spermatocyte cysts. However there are few spermatids and no or very few spermatozoa in the lobules.



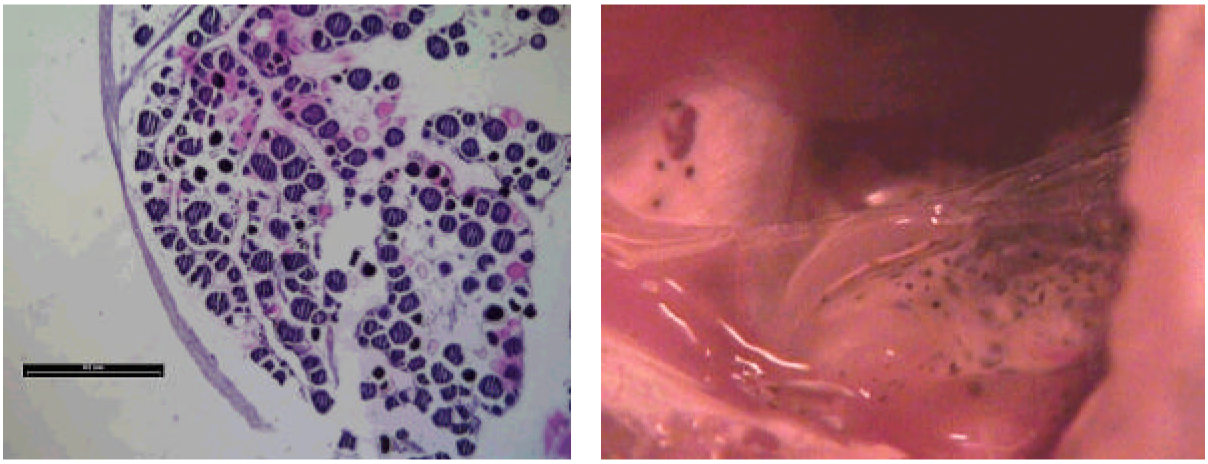


a b

Figure 39: a) Histological section of a resting testis of *Patagonotothen ramsayi* b) Macroscopic photograph of a resting testis

Ovaries

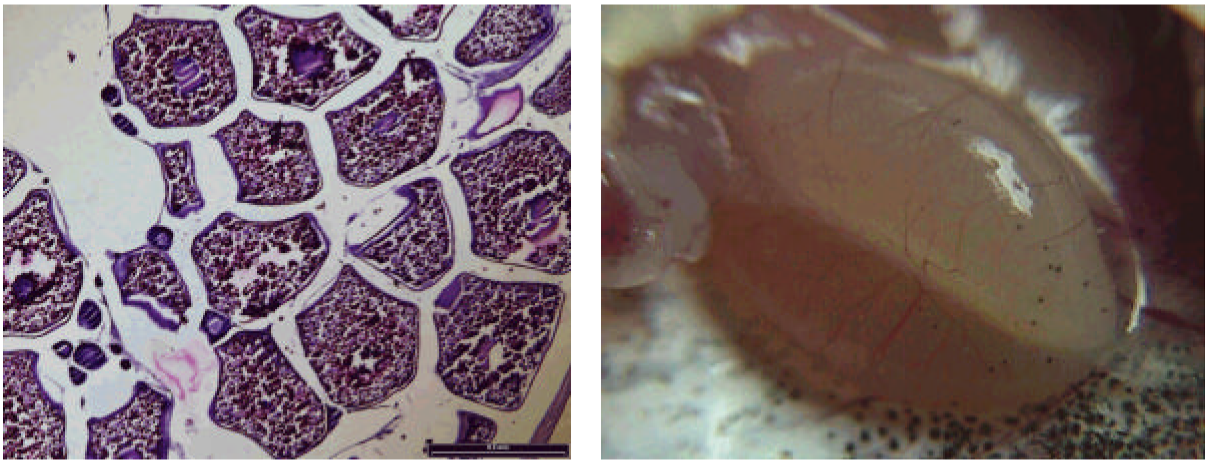
Immature stage (stage I) (Figure 40a and b). The ovaries at this stage are transparent and colourless. Histologically they are characterised by having only previtellogenic and protoplasmic oocytes.



a b

Figure 40: a) Histological section of an immature ovary of *Patagonotothen ramsayi* b) Macroscopic photograph of an immature ovary

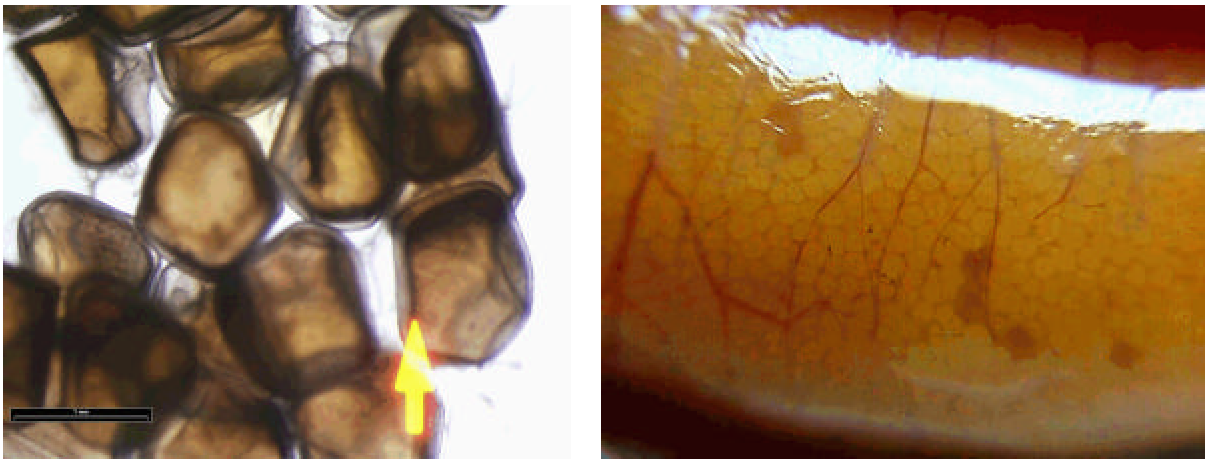
Developing stage (stage III and IV) (Figure 41a and b). In this stage the ovaries are pink and contain numerous capillaries on the surface. Histologically the oocytes are in early stages of yolk accumulation with vitelline droplets forming in the cytoplasm.



a b

Figure 41: a) Histological section of a developing ovary of *Patagonotothen ramsayi* b) Macroscopic photograph of a developing ovary.

Mature/spawning stage (stage V and VI) (Figure 42a and b). The ovaries in this stage were orange in colour considerably larger than in the previous stage. This stage was impossible to process histologically as most of the oocytes were fully hydrated and ovulated and thus contained no structure to hold the eggs in place whilst sectioning samples on the microtome. However, photomicrographs of fixed (10% Buffered formol saline) eggs revealed that most oocytes were hydrated and ovulated. The oocytes were also found to contain a very small perivitelline (see arrow in Figure 21a) space suggesting they were benthic as opposed to pelagic.



a b

Figure 42: a) Hydrated oocytes of *Patagonotothen ramsayi* with the arrow illustrating the preivitelline space b) Macroscopic photograph of a mature ovary

Spent stage (Stage VII and VIII) (Figure 43). In this stage the ovaries are pink/purple in colouration and flaccid. Histologically they contain oocytes in atresia, many postovulatory follicles and previtellogenic oocytes.

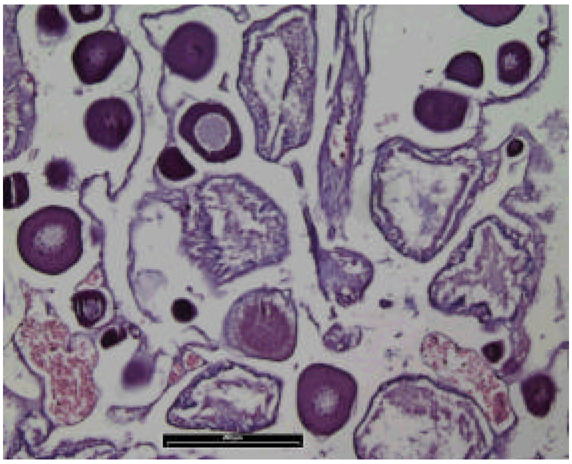
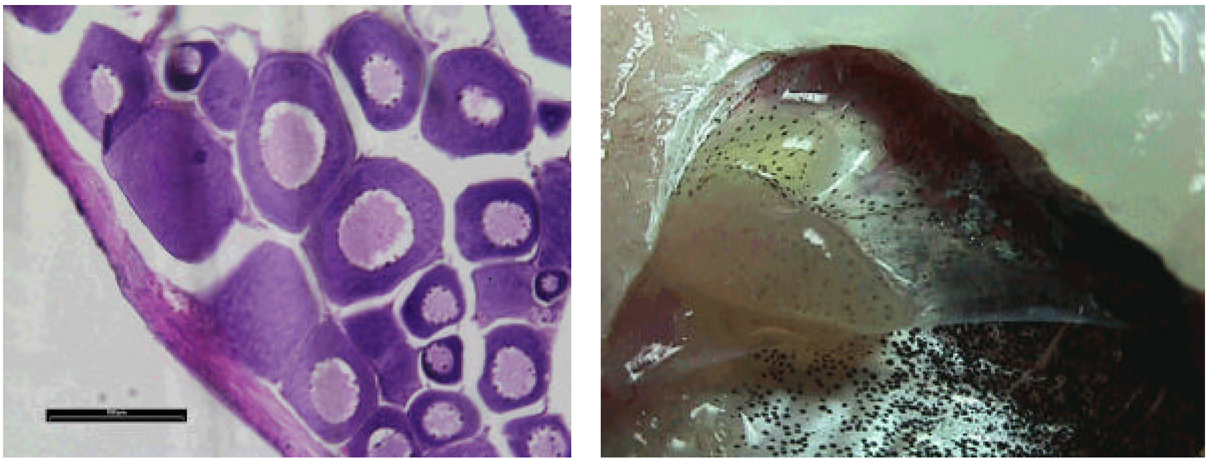


Figure 43: Histologicial section of a spent *Patagonotothen ramsayi* ovary.

Resting stage (stage II) (Figure 44a and b). Translucent to pink in colouration with only a few capillaries on the surface of the ovary. Histologically they contain a few oocytes in late atresia and a combination of previtellogenic and protoplasmic oocytes.



a b

Figure 44: a) Histological section of a resting *Patagonotothen ramsayi* ovary b) Macroscopic photograph of a resting ovary

Discussion

Pooled monthly length-frequency analysis and particularly the sex ratios of mature fish (stages IV, V and VI) suggest that an absence of males in the population during May, June and July could be an indication of nest preparation and nest guarding in male *P. ramsayi*. The hypothesis is that while male *P. ramsayi* are preparing nests and nests guarding their catchablilty decreases because they do not tend to be in the water column. The length-frequency data (Figure 4) for September and October however show that females predominate over most size classes with the exception of animals over 33 cm L_T in October. In November males in the larger size classes (>27 cm L_T) predominate. This might indicate that the larger males are more successful at competing for mates than the smaller males and therefore start to reproduce earlier and leave their nests earlier after the eggs have incubated then hatched. Smaller males become more prevalent in the population during January to February. The eggs of *P. ramsayi* contain a small perivitellogenic space suggesting that they are benthic. This is in contrast to another abundant local notothenioid, *Eleginops maclovinus*, which have pelagic eggs and these are characterised by containing a large perivitellogenic space (Brickle et al, In press). Nesting behaviour has been found in other species of *Patagonotothen* namely *P. tessellata*, *P. sima* and *P. cornucola* (Rae, 1989, 1993; Rae and Calvo, 1995). Rae and Calvo (1995) stated that parental behaviour in *P. tessellata* is usually associated with territorial behaviour and sexual dimorphism. Sexual dimorphism has also been reported for *P. sima* and *P. corucola* at times when females are markedly extended with eggs in July to September indicating that the dimorphism occurs during the spawning period (Gosztonyi and Lopez-Arbarello, 2000). Large specimens of sexually mature *P. ramsayi* also seem to be sexually dimorphic during the spawning season where their anal and ventral fins and the throat of the males turn a deep black colour which may suggest territorial behaviour and competition for mates (Ekau, 1982; Sosinski and Janussz; FIFD unpublished data)

Length at sexual maturity for *P. ramsayi* was found to be 27.56 and 24.85 cm L_T for male and female fish respectively. This would suggest that they mature at the ages of 5 to 7 years respectively. Sosinski and Janusz (2003) concluded that length at maturity was between 17 and 18 cm but they considered fish to be mature at stage II on an eight-stage maturity scale. In our study we considered fish to be sexually mature at greater or equal to stage III between July and November. Sosinski and Janusz (2003) included fish that were virgins in their resting stage (stage II). Our data suggests that *P. ramsayi* are slow developers taking 5 to 7 years to reach their lengths at sexual maturity.

Oocyte resorption occurs in *P. ramsayi* as it occurs in other teleost fish including the nototheioids (Ivankov, 1985; Calvo *et al*, 1999; Murua, *et al*, 2003). It is most intense during the early stages of maturation and sharply decreases before spawning. This type of oocyte atresion has also been observed in other polycyclic total spawners such as the whitespotted char, saffron cod (Ivankov, 1985) and Norwegian spring-spawning herring (Kurita *et al*, 2003). A reduction in fecundity at maturation varies among teleost fish from 8% to 85%, and 50% to 65% decrease in the number in of yolk oocytes found in *P. ramsayi* is similar to many other polycyclic spawners (see Ivankov, 1985; Kurita *et al*, 2003).

Fecundity and egg size in *P. ramsayi* are similar to those of other *Patagonotothen* species, but the paucity of the data prevents any detailed comparisons. There are approximately fourteen species of *Patagonotothen* and they are very common in the shallow waters around southern South America (Froese and Pauly, 2004), but the reproductive biology of this genus is surprisingly understudied. *Patagonotothen guntheri* is the only other commercial species and it is smaller than *P. ramsayi* attaining 23 cm L_T (De Witt *et al*, 1990). Because of its smaller size it has a lower total fecundity of 6,000 – 28,000 eggs but has a similar relative fecundity of 200 – 280 eggs/g. Egg size in this species is also similar to that of *P. ramsayi*, 1.0 – 1.4 mm (Lisovenko, 1987; CCAMLR, 2000).

Another relatively abundant rockcod species around the Falkland Islands, *P. tessellata*, also smaller than *P. ramsayi* attaining a maximum size of 25 cm L_T (FIFD data), has a lower fecundity: 7,634 – 62,033, with a mean egg number of 25,932 in fish ranging between 15 – 24 cm L_T (Rae and Calvo, 1995). The relative fecundity (RF) of this species is described by the regression equation RF = 271 + 20241* L_T (Rae and Calvo, 1995). This would suggest that the relative fecundity (no primary data presented in Rae and Calvo, 1995) in this species is about 300 – 320 eggs/g, which is slightly higher than both *P. ramsayi* and *P. guntheri*.

In total spawners, as opposed to batch spawners, the whole reserve of oocytes is spawned in a unique event over a short period of time as part over a single episode (Murua, *et al*, 2003). If *P. ramsayi* does possess parental behaviour and nest guarding, as is indicated, it is likely that females are able to dispatch their fecundity in the nests of several males during a very short individual spawning period.

Similar sized notothenioid fish (mature females 13 – 38 cm L_T) from the Antarctic seasonal pack-ice zone with slightly larger eggs (1.2 – 1.6 mm) (e.g. *Notothenia cyanobrancha, N. anguistifrons, Gobionotothen acuta* and *Lepidonotothen kempi*) have total fecundities of between 5,600 – 86,000 eggs and relative fecundities of 100 – 350 eggs/g (Kock and Kellerman, 1991). These are very similar to those reported from *Patagonotothen* species and suggests that both small high Antarctic and sub-Antarctic notothenioids follow the same reproductive strategies displaying both r and k strategies with high relative fecundities, small egg size and parental care.

It is concluded that males and females start to mature from May onwards, and the main spawning period seems to occur between June and August when fish migrate from their feeding grounds over a wide area of the shelf to the shelf breaks, it is here that the males build nests. Large numbers of post spawning animals then start to spread back to their feeding grounds to forage and recover.

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Introduction

Multivariate analysis of morphometric and meristic characters is a widely accepted tool for defining population units which, although superseded by molecular genetics techniques as the tool of choice, remains useful, e.g. in the absence of adequate resources to develop and apply genetic markers. Analysis of meristics and morphometrics has been 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, whereas morphometric characters are those obtained by measurements of body parts.

Morphometric and meristic differences arise when populations are relatively discrete, e.g. because they occur in different areas or use different breeding grounds, so that there is relatively little gene flow. Under such circumstances, natural selection or genetic drift can lead the two populations to differ genotypically and phenotypically. However, phenotypic differences can also arise due to differing environmental conditions in each geographic area (Mamuris *et al*, 1998) and it is thus desirable to have data from more than one independent character set to confirm that the observed differences have a genetic basis.

This study discusses the results of a morphometric and meristic study of *Patagonotothen ramsayi*. from around the Falkland islands, with the aim of determining the stock structure of this species. There have been no previous studies of population structure of this species.

Materials and Methods

Sampling and sampling measurements:

Whole *Patagonotothen ramsayi*. were collected from fishing vessels operating around the Falkland islands during April and September 2003 (see Table 5).

Table 5. Summary of fish sampled: area, species, mean length (mm), number sampled.

Sample	Area	Species	Length mean (mm)	Number sampled
1	Falkland South	*Patagonotothen* spp	278,25	60
2	Falkland North	*Patagonotothen* spp	194,36	149
				209

Samples were frozen and stored until analysed. Analysis took place at the Instituto Español de Oceanografía in Vigo (Spain). Measurements were taken always by the same person and all specimens were randomly selected for the person and measured once. Selection of external morphometric and meristic characters was based on previous work on southwest Atlantic gadoids (e.g. Sardella, 1984; Perrota and Sánchez, 1992; Murta, 2000). The following data sets were collected for each fish (see Tables 6 and 7):

1- 18 external morphometric measurements including total length.
2- 3 counts of fin rays.

Table 6. Morphometric measurements taken from *Rockcod* in the Southwest Atlantic.

Number	Code	Measurement (mm)
EXTERNAL MEASUREMENTS		
1	**AM**	Total length
2	**AK**	Pre-caudal length
3	**AE**	Head length
4	**NO**	Pre-orbital length
5	**CD**	Eye diameter (pupil)
6	**OP**	Orbital diameter
7	**PQ**	Post-orbital length
8	**AF**	Pre-dorsal length
9	**NS**	Pre-anal length
10	**NQ**	Pre-pectoral length
11	**QR**	Pectoral fin length
12	**FG**	Length of 1st dorsal fin
13	**HI**	Length of 2nd dorsal fin
14	**ST**	Length of anal fin
15	**AB**	Length of mouth
16	**XX´**	Body height
17	**ZZ´**	Body width
18	**YY´**	Height of caudal peduncle

Table 7. Meristic counts taken from *Rockcod* 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

Data analysis

When all samples for all populations have been taken from the same age class there is no need to eliminate the size effect in the data set. Otherwise, an important stage in the data preparation for morphometric analyses is to eliminate any size effect in the data set when comparing fish of different sizes. Variation should be attributable to body shape differences, and not related to the relative size of the fish. Therefore, transformation of absolute measurements to size-independent shape variables is the first step of the analyses.

Table Standardisation of the fish external morphometrics was carried out using a general linear modal to find the slope for each particular measurement (Table 8). The standardised measurement Y^1 for each of the variables is then:

$$Y' = Y - b\left(X - \overline{X}\right)$$

Where:

Y = original observation

b = regression slope between fish length and each morphometric variable

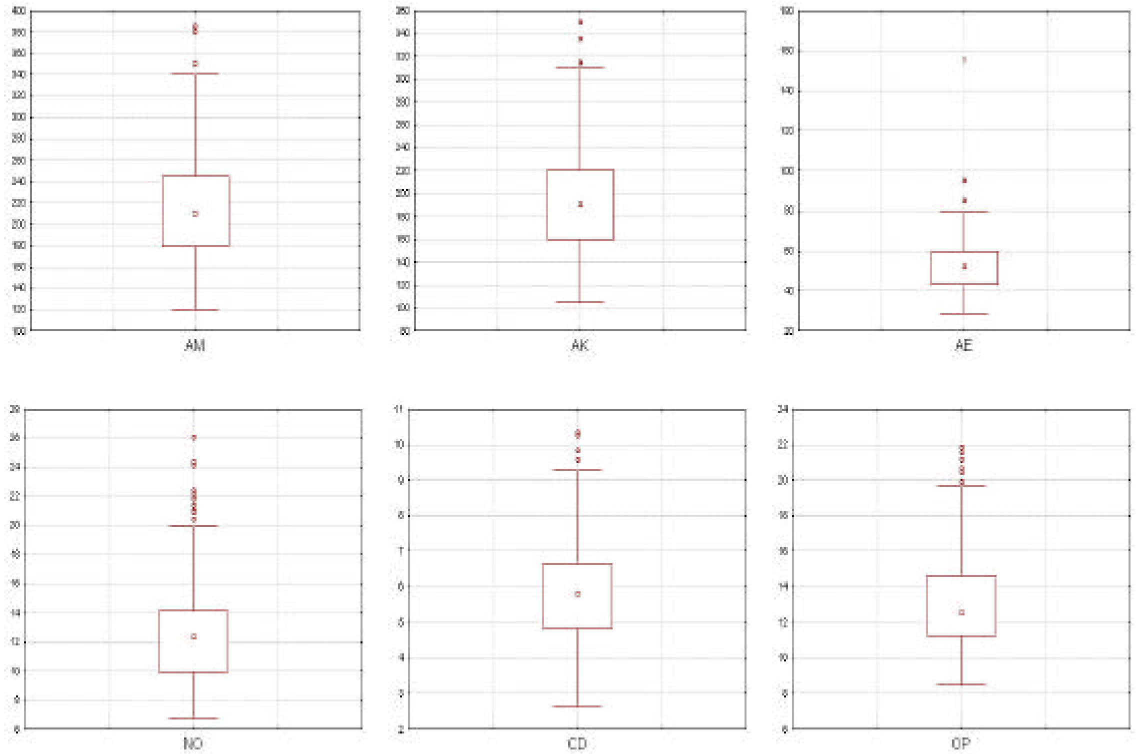
X = total length.

$\overline{X}$ = overall mean total length

Principle component analysis (PCA) of the morphometric measurements was then carried out using STATISTICA software. Plots of second axis versus first scores were examined for evidence of segregation of fish from different areas.

A previous analysis of each morphometric variable using box plots showed the outliers that were removed from the following analysis. The box plots in Figure 45 include the removed outliers.

Principal component analysis of standardised morphometric characteristics of *Patagonotothen* spp. and summary statistics of standardised morphometric data are shown in table 9 and 10.



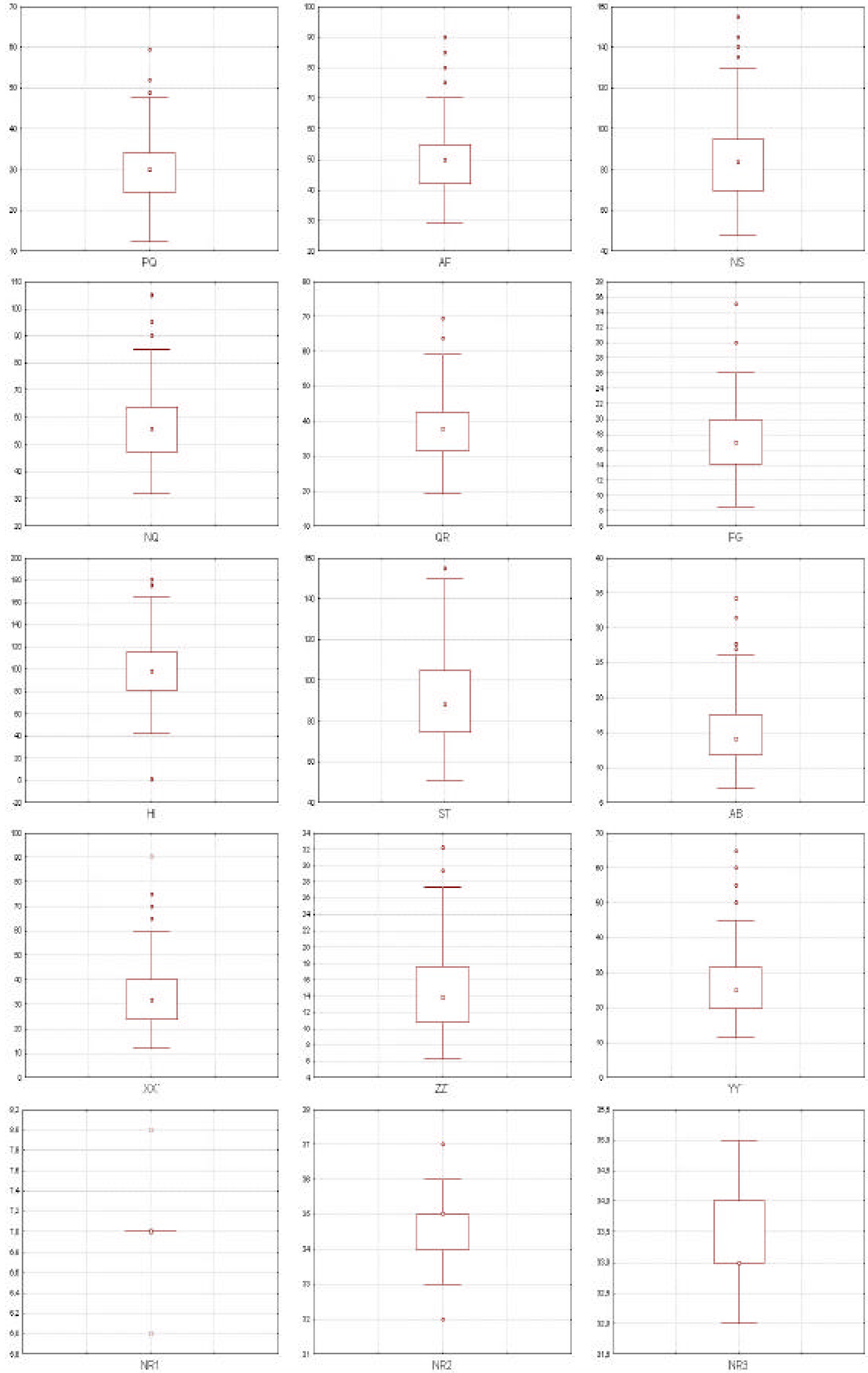


Figure 45. Box-plots for each morphometric and meristic variable.

Table 8. Slope coefficient for each morphometric measurement.

Number	Measurement	Slope Constant
EXTERNAL MEASUREMENTS		
1	Total length	-
2	Pre-caudal length	0.8725
3	Head length	0.2102
4	Pre-orbital length	0.0593
5	Eye diameter (pupil)	0.0235
6	Orbital diameter	0.0047
7	Post-orbital length	0.1305
8	Pre-dorsal length	0.1976
9	Pre-anal length	0.3771
10	Pre-pectoral length	0.2243
11	Pectoral fin length	0.1618
12	Distance to 1st dorsal fin	0.0753
13	Distance to 2nd dorsal fin	0.4832
14	Length to anal fin	0.4243
15	Length of mouth	0.0825
16	Body height	0.2404
17	Body width	0.1001
18	Height of caudal peduncle	0.0188

Results

External morphometrics

A total of 18 morphometric measurements were recorded for each fish. All samples were used in analysis of external morphometric characters. Principal component analysis was initially applied to untransformed external morphometric data, i.e. measurements not standardised for fish length. PCA results showed that the first principle component explained 90.26% of the variability. The first axis was, as expected, dominated by the effect of body size.

Using standardised data, we ensured that the size-corrected variables were not themselves correlated with body size. Figures 46 and 47 show the results of principal component analysis of untransformed and transformed morphometric data. It can be seen that, even when correct for size differences, the two samples appear distinct, providing tentative support for the existence of more than one stock.

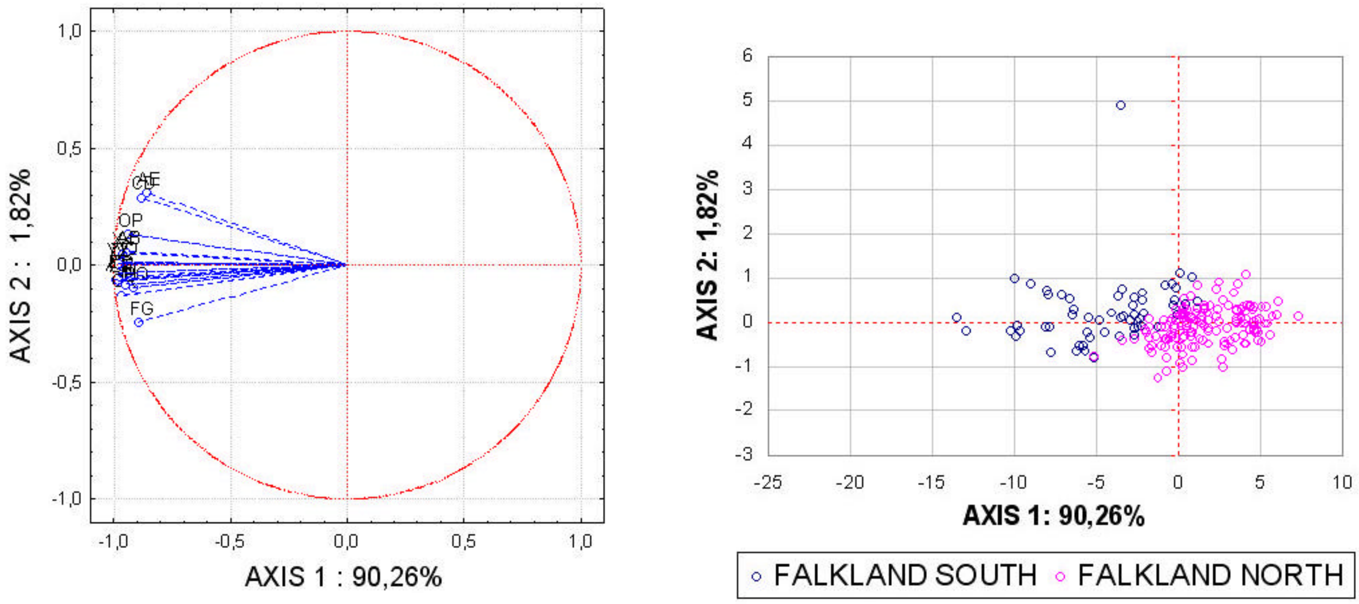


Figure 46. Plot of scores on principal component axes 1 and 2, using non-standardised external morphometric data taken from Falkland North samples (n=149) and Falkland South samples (n=60).

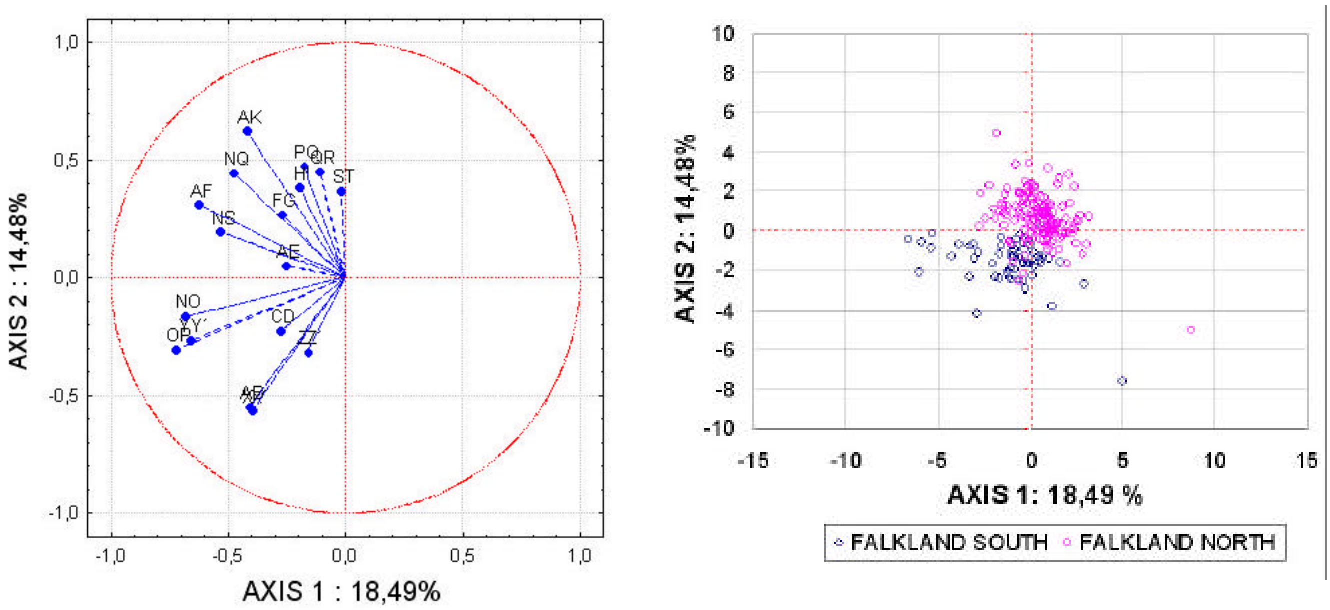


Figure 47. Plot of scores on principal component axes 1 and 2, using standardised external morphometric data taken from Falkland North samples (n=149) and Falkland South samples (n=60).

Table 9. Principal component analysis of standardised morphometric characteristics of *Patagonotothen* spp. in Falkland North (n=149) and Falkland South (n=60). The first ten components accounted for 81.58 % of the variance. Values in the body of the table are component loadings. Values considered significant (| r | > 0.6) are marked in bold.

Variable	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10
AK	-0.421	**0.621**	0,171	0.072	0.045	0.110	-0.203	-0.049	0.116	0.008
AE	-0.252	0.050	0.199	**-0.633**	-0.089	0.382	0.061	0.392	0.126	-0.306
NO	**-0.682**	-0.164	0.114	0.109	0.300	-0.116	0.020	-0.020	0.128	-0.070
CD	-0.276	-0.225	-0.015	-0.144	0.305	0.623	0.384	-0.391	-0.173	0.144
OP	**-0.721**	-0.303	-0.364	-0.078	-0.430	0.002	0.010	-0.132	-0.008	0.004
PQ	-0.176	0.474	0.017	-0.460	-0.021	-0.343	0.326	0.054	0.229	0.317
AF	**-0.626**	0.309	0.070	0.134	0.241	-0.283	-0.087	-0.289	-0.058	-0.115
NS	-0.530	0.195	-0.088	-0.135	0.239	0.025	-0.211	0.314	-0.409	0.463
NQ	-0.478	0.443	-0.192	-0.162	0.317	-0.050	-0.020	-0.057	0.094	-0.353
QR	-0.108	0.448	-0.088	0.396	-0.146	-0.108	0.596	0.228	-0.350	-0.200
FG	-0.271	0.269	-0.229	0.573	-0.050	0.358	0.036	0.273	0.408	0.153
HI	-0.195	0.383	0.499	0.120	-0.330	0.249	-0.253	0.013	-0.272	-0.037
ST	-0.019	0.369	0.574	0.030	-0.360	0.068	0.082	-0.309	0.111	0.073
AB	-0.407	-0.550	0.278	0.267	0.142	0.049	0.063	0.099	0.210	0.091
XX´	-0.397	-0.567	0.274	0.093	0.033	-0.110	-0.042	0.155	-0.165	-0.221
ZZ´	-0.161	-0.318	**0.684**	-0.025	0.012	-0.230	0.202	0.113	0.057	0.135
YY´	**-0.660**	-0.266	-0.319	-0.100	-0.564	-0.095	-0.010	-0.069	0.003	0.050

Eigen value	3.143	2.461	1.623	1.308	1.195	1.043	0.824	0.788	0.758	0.720
% of variance	18.49	14.48	9.55	7.69	7.03	6.14	4.85	4.64	4.46	4.24
Cumulative % variance	18.49	32.96	42.52	50.22	57.25	63.39	68.24	72.88	77.34	81.58

In the principal component analysis. the scores of the first three components accounted for 18.49%, 14.48%, and 9.55% of the total variance respectively or 42.52 % altogether. Examination of the relative magnitudes of the variable coefficients for each principal component allowed the identification of the relative contribution of each variable to the corresponding component. The variables that contributed most to the loading on the first axis were pre-orbital length (NO), orbital diameter (OP), pre-dorsal length (AF) and height of caudal peduncle (YY). The variable that loaded most heavily on the second axis was pre-caudal length (AK). The variable that contributed most to the separation along the third axis was the body width (ZZ´).

Screeplot of explained variance (%) by the first 10 principal components are represented in figure 48 and plot of scores on principal component axes 1 and 2 using meristic data taken from Falkland North samples (n=149) and Falkland South samples (n=60) are shown in figure 49.

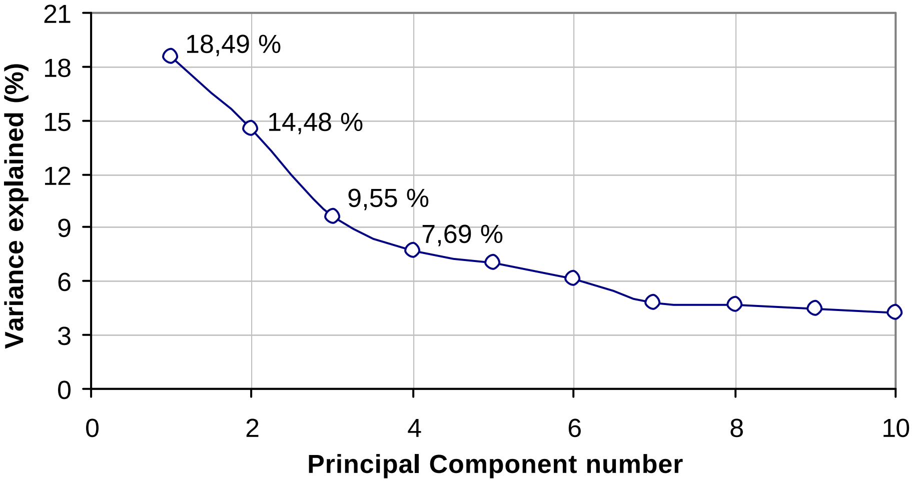


Figure 48. Screeplot of explained variance (%) by the first 10 principal components.

Table 10. Summary statistics of standardised morphometric data.

Variable	Mean	Std. Dev.
AK	195.7933	5.162298
AE	53.2111	7.570228
NO	12.6904	1.166130
CD	5.8283	0.727380
OP	13.0803	2.558426
PQ	30.0049	3.125502
AF	50.9035	2.473603
NS	85.7524	4.833979
NQ	56.7985	2.881476
QR	38.3249	2.163800
FG	17.3261	2.237556
HI	100.4645	9.109886
ST	90.8504	4.030361
AB	15.3060	1.757492
XX	34.4505	4.027057
ZZ	14.7637	1.153279
YY	26.9340	9.481957

Fin ray counts

The first PCA axis explained 50.69 % of variation in the three external meristic variables**.** PCA plots indicated that these variables do not provide a reliable way of distinguishing between the two samples.

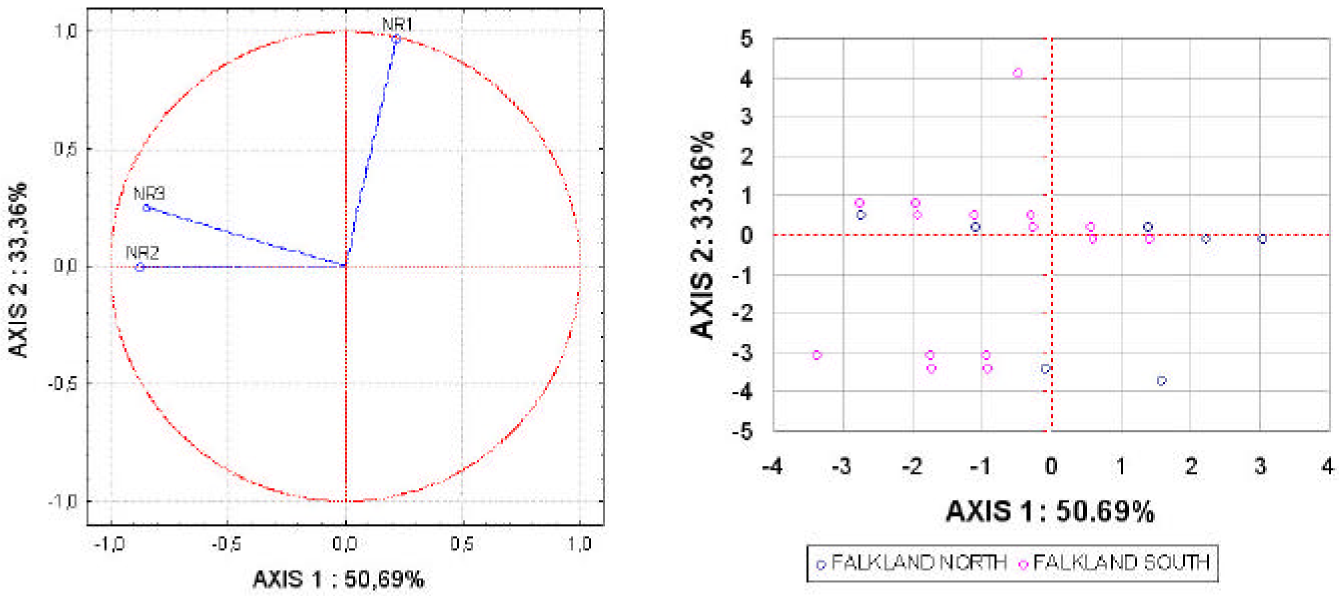


Figure 49. Plot of scores on principal component axes 1 and 2, using meristic data taken from Falkland North samples (n=149) and Falkland South samples (n=60).

Discussion

Multivariate analysis of external morphometrics and fin ray counts has been used successfully on other fish species as a tool for separating groups from distinct geographical regions and also for differentiating between stocks.

In the present study, analysis of external morphometric variations in *Patagonotothen ramsayi* from the Falkland Waters indicated the possible presence of two stocks. one located on Falkland North and the other one located on Falkland South. The study also indicated several physical characteristics that can be used to distinguish *Patagonotothen ramsayi* from the two putative stocks. It will be necessary to examine additional samples and to obtain independent evidence from additional character sets before the existence of more than one stock can be confirmed.

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Diet studies (2nd progress report, 2004).

Introduction

The Southwest Atlantic supports important fisheries for finfish and squid (FAO 1997) and is now one of the 10 most important fishery areas in the world (FAOSTAT 2004). The main target species are squid (notably *Illex arentinus* and *Loligo gahi*) and finfish such as southern blue whiting (*Micromesistius a. australis*), hakes (*Merluccius* spp.), kingclip (*Genypterus blacodes*), red cod (*Salilota australis*), hoki (*Macruronus magellanicus*) and Patagonian toothfish (*Dissostichus eleginoides*) (Falkland Islands Government 2003, 2004). The bottom-trawl fisheries for squid (mainly *Loligo gahi*) and hakes generate a bycatch of various notothenid fish species (Laptikhovsky 2004). *Patagonotothen ramsayi* (Notothenidae) is one of the major species in the discard fisheries in this area, especially around the Falkland Islands (Lucas 1997).

The suborder Notothenioidei includes 122 species in 43 genera and eight families, the majority occurring in the Antarctic (Eastman 2000, Eastman & Eakin 2000). The genus *Patagonotothen* is widely distributed over the Atlantic shelf of South America, with only one species (*P. guntheri*) occuring in the Antarctic (Eastman 2000, Eastman & Eakin 2000). *Patagonotothen ramsayi* (Regan, 1919) is found on the Patagonian shelf, in the Magellanic Province (Eastman 1993), and is locally abundant on the outer shelf and slope around the Falkland islands (Arkhipkin et *al.* 2001). *P.ramsayi* is a demersal-pelagic fish and its distribution is thought to be affected by the Subantartic Current (Cousseau & Perrota 2000), and the Antarctic Polar Front (Stankovic et *al.* 2002).

P. ramsayi feeds on a wide range of planktonic and benthonic organisms. Previous studies have found crustaceans to be the most important prey (Laptikhovsky & Arkhipkin 2003). Mianzan *et al*. (1996) found ctenophores and hydromedusae to be important prey in rockcod caught along the Argentine coastline. Discards from fisheries were also found to be important in their diet (Laptikhovsky 2004).

The aim of this study is to describe the trophic role of rockcod in the hake fishery areas of West Falklands/Malvinas and in the High Seas around 46º South and 49º South. Its diet was analysed and dietary variation in relation to size, sex and area evaluated. The occurrence of rockcod in the stomach contents of other fish species was also examined.

Methods

Diet of rockcod

Observers on Spanish commercial fishing vessels operating in the Southwest Atlantic, collected stomachs of several different demersal fish species during May-September in 2001 and 2003. Biometric data (length, weight, sex and maturity) were collected for the majority of the sampled fish. The samples were frozen on board (-30ºC - -40ºC) and shipped to Aberdeen (UK) for further analysis.

Samples included 171 stomachs of *P.ramsayi*. Stomachs were thawed. Full stomach weight (FSW), empty stomach weight (ESW), and contents weight (CW) were noted. The stomach contents were washed and separated using a sieve (355 µm mesh-size).

Prey species were identified to the lowest possible taxonomic level using a reference collection and published catalogues (e.g. Boltovskoy 1999, Boschi *et al*. 1992, Clarke 1986, Cusseau & Perrota 2000, Ieno 2000, Roper *et al*. 1984). Intact invertebrates that could not be identified immediately were stored in 70% ethanol for later identification. If the stomach contents were well-digested, prey were identified from hard remains (otoliths, vertebrae and skull bones of fish, exoskeletons of crustaceans, mandibles ["beaks"] of cephalopods, etc.). Some prey could be identified only to broad groups, e.g. fish, crustaceans, isopods.

Each intact prey item was counted and weighed (0.1 g). When possible, total length (TL) of fish and dorsal mantle length (DML) of squid were measured. For digested prey, fish otolith length (OL) and cephalopod lower beak rostral length (LRL) were measured using a binocular microscope fitted with an eyepiece graticule.

If a prey item was completely intact, i.e. the skin was still in perfect conditions and showed no signs of digestion, it was classified as representing "net feeding". We also distinguished "discard feeding", i.e. when the fish had taken material thrown overboard during processing operations, such as remains of filleted fish, or kitchen refuse. Data on net feeding and discard feeding were not included in the main analyses due to the low frequency of occurrence (1.24%FO and 3.73%FO respectively).

The size of prey was then estimated by applying published regressions. For the squid *Loligo gahi* and rockcod *P.ramsayi*, regressions are taken from Nyegaard *et al.* (2004); all measurements in mm:

$$L.\ gahi:\ DML = 7.198 \times LRL - 0.368$$
$$P.\ ramsayi:\ TL = 4.273 \times OL_O - 4.916$$

Diet was summarised overall and by (a) sex, (b) fishing area and (c) length class (=20 cm, 21-25, 26-30, 31-35). For each category, we calculated the coefficient of emptiness (V) = N_e / N_s, where N_e is the number of empty stomachs, and N_s is the number of stomachs analysed;

For individual prey categories, dietary importance was summarised using several commonly applied indices (see Hyslop 1980, Amundsen *et al*. 1996, Pierce & Boyle 1991, Cortés 1997, La Mesa *et al*. 1997, Koen Alonso *et al.* 2000, Arkhipkin *et al.* 2001, Nyegaard et *al.* 2004):

%Frequency of Occurrence (%F) = 100 × N_i / N_f, where N_i is the number of stomachs containing prey type *i* and N_f is the number of non-empty stomachs (or N_s-N_e);

Percentage abundance by number (%N), which is the total number of individuals of prey type *i* in the sample of stomachs, divided by the total number of individuals of all prey types, expressed as a percentage;

Percentage abundance by weight (%W), which is the total estimated biomass of prey type *i* in the sample of stomachs, divided by the total estimated biomass of all prey types, expressed as a percentage;

The dietary coefficient "Q", which is the product of the percentage by weight and the percentage of the total number for each prey type;

The Index of Relative Importance (IRI) = (%N+%W)*%FO

For analysis of dietary variation by length, sex and area, some prey taxa were grouped into higher categories: i) species were grouped by genus; ii) animals attached to the substrate were grouped as "sessile forms"; iii) all squids were grouped together, as were all gammarids, all euphausiids and all fish; iv) crustacean taxa with a IRI value less than 1 were grouped with unidentified crustaceans. Isopods were not grouped due to their high frequency of occurrence.

Statistical analysis was carried out using MINITAB Release 12.23, for Windows (1999). Analysis of variation in dietary importance for the main prey categories used Mann-Whitney (sex) and Kruskal-wallis (length and area) tests.

Rockcod as prey

To quantify the importance of rockcod as prey of other demersal fish species, particularly those targeted by fisheries , additional data collected during 1999-2000 were also used. The species studied were: Argentinean hake *Merluccius hubbsi* (N=1037), hoki *Macruronus magellanicus* (N=91) Patagonian toothfish *Dissostichus eleginoides* (N=94), kingclip *Genypterus blacodes* (N=269), red cod *Salilota australis* (N=81) and southern blue whiting *Micromesistius a. australis*).

Results

Diet of P. ramsayi

In total 2621 prey items were found, belonging to 56 distinct prey taxa. No empty stomachs were found (V=0.00%). Net feeding (FO%=1.21%, n=2) and discard feeding were both infrequent (FO=5.42%, n=9).

The percentage of frequency of occurrence (%FO) of unidentified classes of prey (e.g. unidentified crustaceans, worms, fish, and miscellaneous) of prey was 32.12%, within 18.87% was not possible to identified due to advanced digestion of items, and was grouped as miscellaneous in the general diet (Table 11).

The diet of *Patagonotothen ramsayi* included a wide range of prey types. However, the main bulk of the recognizeable stomach contents comprised crustaceans: the zooplanktonic species *Themisto gaudichaudii* and the benthic *Serolis* sp.. Although we did not find any gelatinous plankton in the stomach contents, Mianzan *et al*. (1996) and Laptikhovsky and Arkhipkin (2003) recorded them as a dietary component of rockcod on the Argentinian coast and south east of the Falkland Islands respectively.

Crustaceans were the most important class of prey (overall FO=83.13%), and FO of crustaceans was above 80% for all size classes of rockcod and both sexes. However, when data were grouped by area, it was seen that in the most northerly area (46ºS, n=11), crustaceans were less frequent (FO=36.36%) and fish more important (FO=81.82%) (Fig. 50). *T. gaudichaudii* was the dominant prey category (IRI=1836) followed by isopod *Serolis* spp. (IRI=898.4) (Table 11).

Ontogenetic (size-related) dietary variation

Crustaceans were the most important prey of all sizes classes of rockcod, with FO≥80%. Differences in relation to group size were found in relation to secondary food items. In large rockcod (31-35cm, n=8) fish were important in the diet (FO=50%), while small fish (=20cm, n=15) frequently fed on echinoderms (FO=40%) (Fig. 51). Rockcods between 21-25cm (n=87) had often eaten worms (FO=49.43%) while the 26-30cm class (n=55) frequently took worms (FO=36.36%) and echinoderms (>25%).

Looking into crustacean items, *T.gaudichaudii* and *Serolis* spp. were the dominant prey in medium sized fish (Table 12). On the other hand, small *P.ramsayi* (=20cm) fed mainly in isopod valvifers (IRI=2806, FO=53.33%). Large rockcod (31-35cm) were mainly piscivorous (IRI=4215, FO=50%), although it was not possible to identify the species that they consumed.

Discard feeding occurred in few specimens, but contributed significantly to the prey biomass in the 26-30cm length class of *P.ramsayi* of length (W=43.88%; IRI = 417.37; Table 12)

Diet of male and female fish

Differences by sex (FO%) were not found in most of prey items and only echinoderms occurrence was higher in females (32.22%FO) than in males (17.14%FO) (Fig. 51). Only Echinoderms showed differences between sexes.

Within crustaceans it was found that females fed mainly on amphipods and *Serolis* spp. (isopods). However, isopods valvifers were found in higher ratio in males (IRI=433.99) than in females.

Piscivorous diet occurred with higher ratios in females of *P.ramsayi* than in males (IRI=284.36, 36.01%W), and also predation in brittle stars (IRI=254.91, 24.44%FO).
Worms were found important with similar ratios between sexes (27.14%FO, males; 26.67%FO, females).

Geographic variation in diet

Prey distribution by areas showed differences between 46ºS area and souethern areas (Fig. 51). Fish was found as the most important prey in this area (81.82%FO), mostly *Patagonotothen* spp. (IRI=4396.53). However, the sample size for thi area is small. Within other areas it was in very low occurrence (49º=7.69%, MN=0%, MW=10.81%). Other items were found with lower but similar ratio (Fig. 51).

Ophiurids were found especially important in areas 46ºS (IRI=1462.04, FO=36.36%) and MN (IRI=4224.5, FO=50%), where the sample size was small.

In both, 49ºS and MW areas *T.gaudichaudii* was the mainly prey with an IRI of 2317.22 and 2070.15 respectively (Table 14).

In these two areas were found a variation in the second mainly prey: while at 49ºS fish fed preferably on isopods valvifers (IRI=1416.54), fish from MW preferred the isopod *Serolis* sp. (IRI=11990.11). In relationship with this two isopods were found that the IRI value decreased from the north to the south in isopod valvifers and increased in serolids, although frequency of occurrence did not change lighly between MN and MW area for valvifers, and 49º and MN for serolids.

Gasteropoda were found more important in areas 46ºS and MN. Worm forms occurred in more than 25% in most of the areas (Table 14).

Patagonotothen ramsayi as prey of other fishes

Target fish species from the South West Atlantic (Common hake, Hoki,Toothfish, Kingclip, Red cod, and Southern blue whiting) were studied in the way to know the trophic ecology of fish in this area (Bislop et *al*., unpublish) (Table 15).

Southern blue whiting only fed on fish in 4% of FO, while the rest of species were fed on fish widely. In Common hake and Hoki FO were 26% and 25% respectively, but the percentage of weight found was high (46% in Hake and 88% in Hoki).

Patagonotothen species were widely consumed by Common hake (45%FO, 44%W), Toothfish (57%FO, 61%W), Kingclip (59%FO, 55%W), and Red cod (32%FO, 90%W). Hoki had 22% in FO, but the importance of notothenids in %W were 43%. None notothenids were found in Southern blue whiting.

Results about *Patagonotothen ramsayi* as prey of these piscivorous fishes showed that it was important in their diet (Table 15). This specie was found with a low frequency overall prey (<15%), %W were hight in some species: Toothfish fed on Rock cod in 27%W, and Red cod in 66%. Otherwise, in both species *P.ramsayi* were found as the mainly specie of notothenid in weight (57% and 90% respectively). In Toothfish were not *Patagonotothen ramsayi*.

Stomachs of 42 *Micromesistius australis australis* were analised but none notothens were found.

Discussion

Patagonotothen genus was considered a subantarctic subendemic (Stakovic *et al*. 2002) benthic notothenid (Eastman 1993). However, Eastman considered *P.ramsayi* as a bentho pelagic fish due to in the absence of competition were able to fill diffents niches (Eastman 2000).

Different studies were carried on south east of Falklands, whereabout diet of *Patagonotothen ramsayi* showed an opportunistic feed behaviour. This species fed mainly on plankton species, and benthic species as a secondary item (Koen Alonso *et al*. 2002, Laptikhovsky 2004). In the Patagonian shelf, Mianzan *et al*. (1996) found a high occurrence of Ctenophores and Hydromedusae in stomachs of rockcods catched in two coastal areas: 34ºS-39ºS and 41ºS-48ºS. Laptikhovsky and Arkhipkin (2003) found high occurrence of medusaes from February to July . Although other authors found gelatinous plankton (>10%; Mianzan *et al*. 1996, Laptikhovsky 2004, Laptikhovsky and Arkhipkin 2003) we did not found any in the west of Falkland Islands (MW) and High Seas.

Our results confirm that this species is an opportunistic specie feeding on different zooplanktonic and benthonic organisms (Laptikhovsky 2004, Laptikhovsky & Arkhipkin 2003). The importance of benthos found in Rock cod diet may be the samples were collected from May to September (austral winter), somehow that Laptikhovsky & Arkhipkin (2003) observed in this specie in winter.

Differences in diet between rock cods in MW and High Seas (49ºS), and south east Falkland Islands (SM) were found. In the SM they fed mainly amphipods (22.9%FO) with *T.gaudichuadii* <10%FO and followed by fishery discard (22.8%FO) (Laptikhovsky 2004). Laptikhovsky and Arkhipkin (2003) found ophiurids (>30%FO) as a main prey. But the most important prey in MW and High Seas was *T.gaudichaudii* (>30%FO, >2000 IRI), and isopods (>55%FO, 76 IRI) as a secondary item. Ophiurids were also an important prey (19.38%FO, 156.78 IRI), as well as isopods valvifers (19.38%FO, 181.01 IRI), worm forms (41.25%FO, 9702 IRI), and fish (15%FO, 2820 IRI) (Table 11).

However, Laptikhovsky and Arkhipkin (2003) found Ophiuroids as main prey of their diet during austral winter, and almost exclusively gelatinous plankton during austral summer.

Isopods valvifers are found important in the diet of rock cod in the area of study. This difference from other studies may be the area of the study due to is affected by the Subantartic Current and the Antarctic Polar Front.

Polychaetes occurred in high percentage (>25%FO), but either Laptikhovsky & Arkhipkin (2003) and Laptikhovsky (2004) found this item scarce in the diet of *P.ramsayi*. Moreover, fish items were found important (15%FO) and in other studies the frequency of occurrence is lower (<10%FO).

P.ramsayi occurred in the diet of different target fishery species: *Merluccius hubbsi* (Marini, 1933), *Macruronus magellanicus* (Lönnberg, 1907), *Salilota australis* (Günther, 1878), *Genypterus blacodes* (Schneider, 1801), *Dissostichus eleginoides* (Smitt, 1898), and *Micromesistius australis australis* (Norman, 1937).

M.hubbsi (Common hake) is an opportunistic piscivorous predator being notothenids one of its prey (FAO 1990, Laptikhovsjy & Fetisov 1999, Cousseau & Perrotta 2000). Also, data analised of 992 common hake in the NM and High Seas showed a 45% OF of *Patagonotothen* species in its diet. Adult *M.magellanicus* (Hoki) were found feeding on notothenids (Cousseau & Perrota 2000) and our unpublish result showed 22%FO of fish were *Patagonotothen* species. Cousseau & Perrotta (2000) and Neygaard *et al*. (2004) found notothenids as a predominant fish prey (40-60%FO, Nyegaard *et al*. 2004) of *G.blacodes* (Kingclip) and we found similar results: 59%FO of fish prey was *Patagonotothen* species where 11%FO was *P.ramsayi*. Toothfish (*D.eleginoides*) showed a predominant diet on *Patagonotothen* species (57%FO of fish prey) and Arkhipkin *et al*. (2003), Cousseau & Perrota (2000) and García dela Rosa *et al*. (1997) found similar results. However, Koen Alonso *et al*. (2001) found *P.ramsayi* (35.80%FO) predominant following to *M.hubbsi* (40.86%FO) in latitudes above 47º at Argentine coast. *Patagonotothen* species where found in *S.australis* stomachs by Arkhipkin *et al*. (2001) with differences between sizes (higher frequency of occurrence in large fishes- >50%FO). Our results showed high frequency of occurrence whereabout all *Patagonotothen* species found were rock cod.

M.a.australis (Southern blue whiting) fed mainly on crustaceans (Laptkihovsky & Fetisov 1999, Cousseau & Perrota 2000, Subsecretaría de Pesca 2004) and the occurrence of fish is low without notothens as a component of its diet. Non references of notothens as prey were found in our analysis (8%FO in fish).

Looking throught different studies in other fish species we found *P.ramsayi* and other *Patagonotothen* species as prey of different fish species. Brickle *et al*. (2003) found that rajids fed on rock cod when they are larger than 40cm and with high percentage of occurrence in some species (>50%FO *Bathyraja brachyurops*). Koen Alonso et *al*. (2002) and Laptikhovsky *et al*.(2001) found *P.ramsayi* in the diet of the spiny dogfish (*Squalus acanthias*). In latitudes above 46ºS (Koen Alonso *et al*. 2002) rock cod was preyed on by spiny dogfish being the second fish item and the fourth important item in its diet. Laptikhovsky et *al*. (2001) and Jackson et *al*. (2000) showed the rock cod as an opportunistic prey item for the narrowmouth catshark (*Schroederichthys bivius*) and the southern opah (*Lampris immaculatus*) on the Patagonian shelf.

Other vertebrates feed on *Patagonotothen ramsayi* as gento penguins (*Pygoscelis papua*) (Clausen & Pütz 2003, Pütz *et al*. 2001), magellanic penguin (*Spheniscus magellanicus*), and rockhopper penguin (*Eudyptes chrysocome*) (Pütz *et* al, 2001). On gento penguins rock cod constituted more than 25% of reconstituted mass of their diet (Clausen & Pütz 2003).

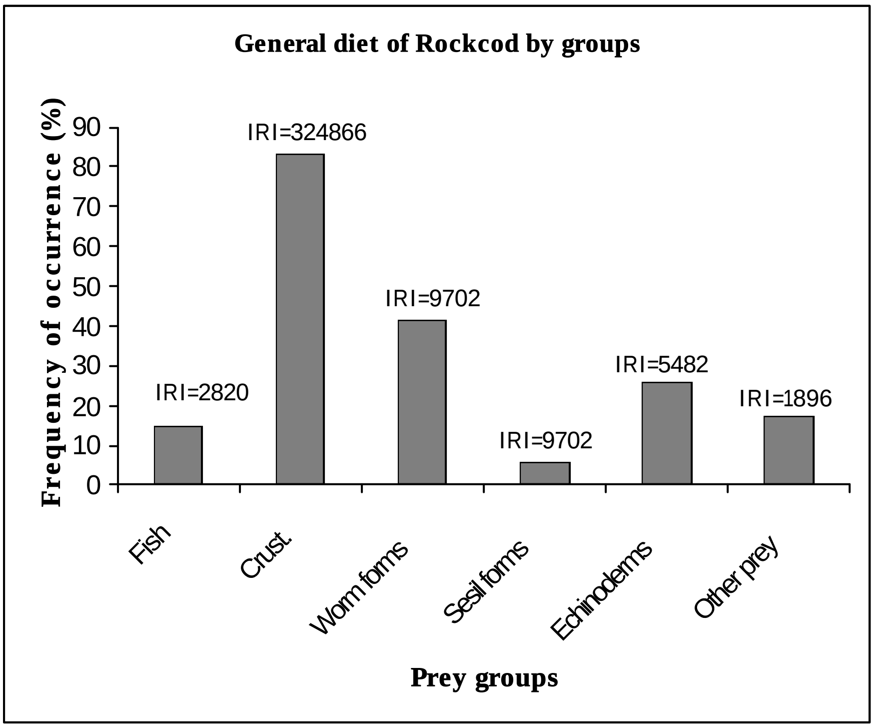

Figure 50. Frequency of occurrence, by group, of prey items in *Patagontothen ramsayi* stomach contents

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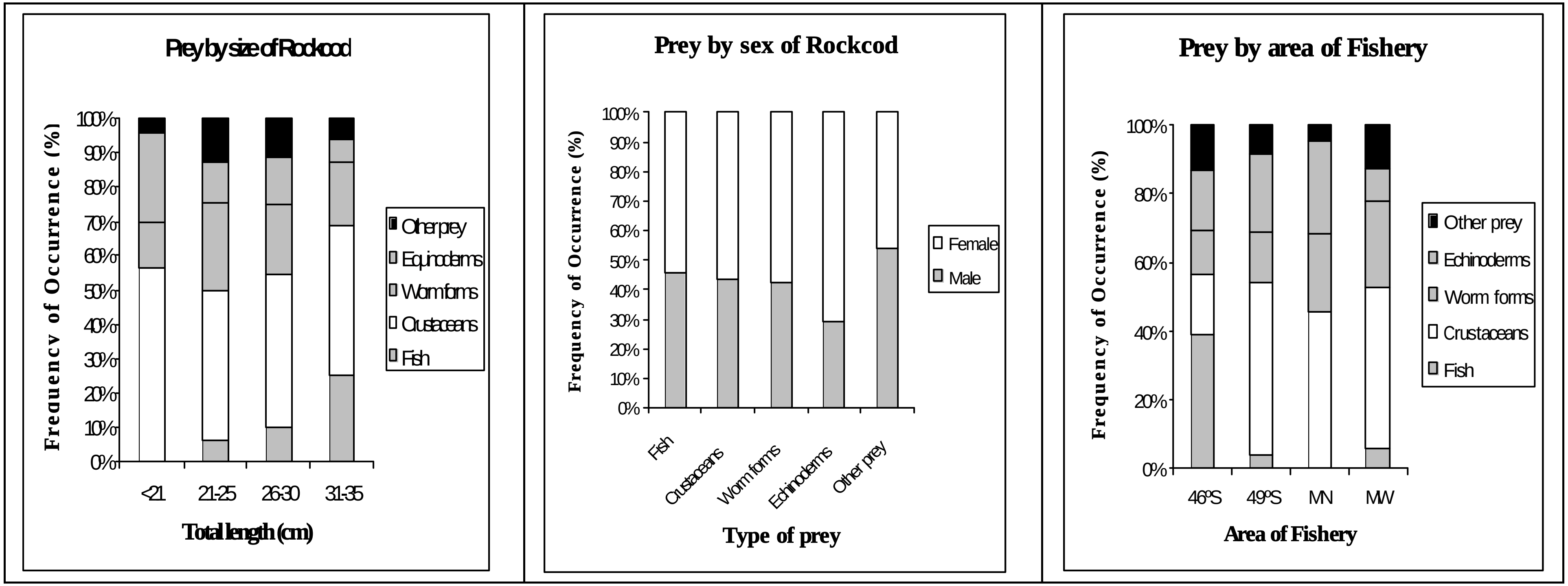

Figure 51. Frequency of occurrence by size, sex, and area of *Patagontothen ramsayi*.

Prey taxon	**FO%**	**W%**	**N%**	**Q**	**IRI**
Seaweed	0.63	0.03	0.04	0.0012	0.0441
Sponge	0.63	0.31	0.04	0.0124	0.2205
Anemones	1.25	0.79	0.08	0.0632	1.0875
Coral	3.75	0.31	0.23	0.0713	2.0250
Worm forms	5.00	0.67	0.31	0.2077	4.9000
Incrustant Annelids	4.38	0.21	0.43	0.0903	2.8032
Polychaeta:					
Burrow-dwelling Polychaetes	26.88	6.37	1.86	11.8482	221.2224
Capellids	0.63	0.03	0.08	0.0024	0.0693
Errant Polychaetes	13.13	1.04	1.59	1.6536	34.5319
Nereids	3.75	0.21	0.35	0.0735	2.1000
Gasteropods	3.75	3.63	0.31	1.1253	14.7750
Squids	1.88	2.07	0.12	0.2484	4.1172
Loligo gahi	1.25	0.06	0.12	0.0072	0.2250
Unidentified Crustaceans	16.25	2.47	2.01	4.9647	72.8000
Naupli	5.63	0.27	2.94	0.7938	18.0723
Unidentified Isopods	9.38	1.83	3.36	6.1488	48.6822
Valvifers	19.38	3.96	5.38	21.3048	181.0092
Cirolanids	11.88	3.48	1.01	3.5148	53.3412
Serolis spp.	40.00	13.26	9.20	121.992	898.4000
S. bonarensis	0.63	0.03	0.04	0.0012	0.0441
Unidentified Amphipods	20.00	1.10	3.33	3.6630	88.6000
Gammarids	8.75	0.52	1.59	0.8268	18.4625
Eusiridae	0.63	0.03	0.04	0.0012	0.0441
Eusirella elegans	0.63	0.18	0.16	0.0288	0.2142
Lysianasidae	8.75	0.27	2.44	0.6588	23.7125
Paracalliop.	0.63	0.03	0.04	0.0012	0.0441
Halice secunda	0.63	0.03	0.04	0.0012	0.0441
Orchomenella spp.	11.25	0.55	4.87	2.6785	60.9750
O.distintus	1.25	0.79	0.08	0.0632	1.0875
Ensirus spp.	0.63	0.03	0.12	0.0036	0.0945

Table 11. General variation in diet of *Patagonotothen ramsayi* from South West Atlantic.

Prey taxon	**FO%**	**W%**	**N%**	**Q**	**IRI**
Hyperiids					
Themisto gaudichaudii	30.00	15.50	45.70	708.35	1836.0000
Unidentified Euphausiids	7.50	0.40	1.32	0.5280	12.9000
Euphausia spp.	2.50	0.15	2.51	0.3765	6.6500
Nematoscelis spp.	0.63	0.03	0.04	0.0012	0.0441
Thysanopoda spp.	1.25	0.06	0.08	0.0048	0.1750
Unidentified Mysids	0.63	0.03	0.04	0.0012	0.0441
Conchostracods	0.63	0.03	0.04	0.0012	0.0441
Ostracods	1.88	0.09	0.12	0.0108	0.3948
Copepods	1.25	0.06	0.35	0.0210	0.5125
Munida spp.	4.38	0.67	0.62	0.4154	5.6502
M.gregaria	2.50	2.01	0.85	1.7085	7.1500
Hermit crab	0.63	0.06	0.04	0.0024	0.0630
Sea urchin	6.88	2.44	0.43	1.0492	19.7456
Ophiuroids	19.38	4.18	3.91	16.3438	156.7842
Bryozoa	0.63	0.03	0.04	0.0012	0.0441
Salps	1.25	0.06	0.12	0.0072	0.2250
Unidentified fish	6.88	12.9	0.50	6.4500	92.1920
Fish eggs	2.50	1.10	0.16	0.1760	3.1500
Patagonotothen spp.	2.50	2.74	0.16	0.4384	7.2500
P.ramsayi	3.13	2.41	0.19	0.4579	8.1380
Merluccius spp.	0.63	8.45	0.04	0.3380	5.3487
Unidentified (miscellaneous)	6.25	1.68	0.43	0.7224	13.1875
Sediment	6.88	0.34	0.43	0.1462	5.2976
Net feeding	1.24	3.99	0.12	0.4788	5.0964
Discard feeding	3.73	15.26	0.23	3.5098	57.7777
Total	111	328	2125		

Table 11 (continued). General variation in diet of *Patagonotothen ramsayi* from the South West Atlantic.

	< 21cm (TL)				21-25 cm (TL)				26-30 cm (TL)				31-35 cm (TL)			
	FO%	**W%**	**N%**	**IRI**	**FO%**	**W%**	**N%**	**IRI**	**FO%**	**W%**	**N%**	**IRI**	**FO%**	**W%**	**N%**	**IRI**
Sessile forms	0	0	0	0	7.23	3.29	0.75	29.21	6.38	2.09	0.23	14.80	0	0	0	0
Worm forms	0	0	0	0	6.02	1.51	0.47	11.92	6.38	0.96	0.23	7.59	0	0	0	0
Incrustant Ann.	0	0	0	0	4.82	0.38	0.56	4.53	6.38	0.48	0.38	5.49	0	0	0	0
Burrow-dwelling P.	6.67	1.32	0.66	13.21	30.12	9.03	2.72	353.91	31.92	16.85	1.44	583.82	25.00	1.07	3.57	116.00
Errant P.	13.33	2.63	1.32	52.65	22.89	2.92	3.75	152.68	10.64	1.12	0.53	17.56	12.50	0.13	1.79	24.00
Gasteropods	0	0	0	0	2.41	1.19	0.19	3.33	6.38	8.19	0.61	56.14	12.50	8.81	1.79	132.50
Squids	0	0	0	0	4.82	6.49	0.47	33.55	2.13	0.16	0.08	0.51	0	0	0	0
Crustaceans	26.67	13.16	9.21	596.61	25.30	4.33	3.75	204.04	12.77	2.41	0.83	41.38	25.00	2.54	3.57	152.75
Naupli	0	0	0	0	7.23	0.56	5.06	40.63	6.38	0.48	1.67	13.72	0	0	0	0
Isopods	0	0	0	0	13.25	3.76	5.90	128.00	8.51	3.21	1.82	42.81	0	0	0	0
Valvifers	53.33	21.05	31.58	2806.8	18.07	2.82	3.75	118.72	17.02	13.48	3.87	295.30	0	0	0	0
Cirolanids	0	0	0	0	13.25	7.24	1.69	118.32	12.77	5.46	0.53	76.49	25.00	0.40	3.57	99.25
***Serolis* spp.**	33.33	14.47	6.58	701.60	48.19	23.24	15.56	1869.77	34.04	17.98	3.26	723.01	37.50	8.81	37.50	1736.63
Amphipods	26.67	5.26	11.84	456.06	21.69	1.69	3.09	101.92	19.15	2.09	2.58	89.43	12.50	0.13	1.79	24
Gammarids	40	7.90	20.40	1132.0	27.71	2.63	9.56	337.79	23.40	6.74	7.20	326.20	25.00	0.53	33.93	861.50
T.gaudichaudii	20	6.58	3.29	197.40	25.30	15.15	28.30	1099.29	51.06	55.06	66.34	6198.68	0	0	0	0
Euphausiids	13.33	2.63	3.29	78.91	10.84	2.35	7.69	108.83	10.64	0.80	0.99	19.05	25.00	0.27	3.57	96.00
***Munida* spp.**	6.67	15.79	6.58	149.21	6.02	0.75	0.47	7.34	10.64	10.92	1.74	134.70	0	0	0	0
Sea urchin	0	0	0	0	6.02	0.47	0.47	5.66	10.64	11.88	0.38	130.45	12.50	0.13	1.79	24.00
Ophiuroids	40.00	7.90	4.61	500.40	18.07	4.89	3.28	147.63	21.28	12.68	4.47	364.95	0	0	0	0
Fish	0	0	0	0	3.62	4.05	0.47	16.36	10.64	12.68	0.38	138.96	50.00	77.17	7.14	4215.50
Fish eggs	0	0	0	0	0	0	0	0	8.51	5.78	0.30	51.74	0	0	0	0
***Patagonotothen* spp.**	0	0	0	0	9.64	13.64	0.75	138.72	2.13	3.85	0.08	8.37	0	0	0	0
Miscellaneous	6.67	1.32	0.66	13.21	18.07	1.60	1.59	57.64	12.77	8.03	0.53	109.31	0	0	0	0
Net feeding	0	0	0	0	1.17	6.16	0.19	7.43	1.89	6.95	0.08	13.29	0	0	0	0
Discard feeding	0	0	0	0	1.17	5.33	0.09	6.34	9.43	43.88	0.38	417.37	0	0	0	0
Total	15	7.6	152		83	106.3	1067		47	62.3	1319		8	74.9	56	
(no net/discard f.)					(85)	(120.1)	(1070)		(53)	(126.7)	(1325)					

Table 12. Variation by length in diet of *Patagonotothen ramsayi* from South West Atlantic.

	Male				Female			
	FO%	**W%**	**N%**	**IRI**	**FO%**	**W%**	**N%**	**IRI**
Sessile forms	8.57	3.71	0.87	39.25	3.33	1.18	0.18	4.53
Worm forms	5.71	1.37	0.43	10.28	4.44	0.67	0.24	4.04
Incrustant Ann.	0	0	0	0	7.78	0.39	0.66	8.17
Burrow-dwelling P.	27.14	9.62	2.50	328.94	26.67	7.85	1.62	252.57
Errant polychaetes	14.29	2.06	1.63	52.73	18.89	1.46	2.10	67.25
Gasteropods	4.29	7.01	0.33	31.49	3.33	3.81	0.48	14.29
Squids	4.29	9.34	0.43	41.93	2.22	0.11	0.12	0.51
Crustaceans	20.00	3.85	4.12	159.40	21.11	3.48	1.74	110.19
Naupli	2.86	0.28	1.84	6.06	7.78	0.39	3.55	30.65
Isopods	14.29	6.04	6.40	177.77	5.56	0.90	1.68	14.35
Valvifers	18.57	14.15	9.22	433.99	20.00	1.51	3.25	95.20
Cirolanids	12.86	11.81	1.74	174.25	11.11	1.57	0.60	24.11
***Serolis* spp.**	34.29	22.53	10.41	1129.51	44.44	15.26	8.59	1059.89
Amphipods	18.57	1.79	3.36	95.64	21.11	1.29	3.31	97.11
Gammarids	27.14	3.98	10.52	393.53	25.56	2.86	8.71	295.73
T.gaudichaudii	28.57	19.09	32.54	1475.07	31.11	20.75	53.01	2294.67
Euphausiids	10.00	3.02	7.59	106.10	12.22	0.67	1.92	31.65
***Munida* spp.**	8.57	3.43	1.74	44.31	5.56	3.53	1.32	26.97
Sea urchin	4.29	0.41	0.33	3.18	8.89	4.32	0.48	42.67
Ophiuroids	12.86	5.63	1.84	96.06	24.44	5.38	5.05	254.91
Fish	7.14	7.97	0.54	60.76	7.78	36.01	0.54	284.36
Fish eggs	2.86	3.43	0.22	10.44	2.22	0.62	0.12	1.64
***Patagonotothen* spp.**	5.71	11.40	0.43	67.55	5.56	4.82	0.30	28.47
Miscelaneous	15.71	1.51	1.41	45.87	12.22	3.20	0.72	47.90
Net feeding	1.41	7.88	0.11	11.27	1.11	3.40	0.12	3.91
Discard feeding	4.23	26.95	0.32	115.35	3.33	14.66	0.18	49.42
Total	70	72.8	926		90	178.3	1664	
(no net/discard)	(71)	(111.7)	(922)			(217.6)	(1669)	

Table 13. Variation by sex in diet of *Patagonotothen ramsayi* from South West Atlantic.

	46ºS				49ºS				MN				MW			
	FO%	**W%**	**N%**	**IRI**	**FO%**	**W%**	**N%**	**IRI**	**FO%**	**W%**	**N%**	**IRI**	**FO%**	**W%**	**N%**	**IRI**
Sessile forms	0	0	0	0	11.54	16.80	0.92	204.41	0	0	0	0	5.41	1.04	0.38	7.68
Worm forms	9.09	0.57	2.13	24.54	0	0	0	0	0	0	0	0	6.31	0.77	0.33	6.94
Incrustant Ann.	0	0	0	0	0	0	0	0	0	0	0	0	6.31	0.27	0.52	4.99
Burrow-dwelling P.	27.27	6.00	6.38	337.60	11.54	4.00	1.23	60.35	25.00	17.71	3.19	522.50	30.63	6.44	1.88	254.84
Errant P.	0	0	0	0	15.39	3.0	1.85	77.72	25.00	3.13	3.19	158.00	18.02	1.31	1.93	58.39
Gasteropods	9.09	14.00	2.13	146.62	0	0	0	0	0	0	0	0	4.51	2.66	0.47	14.12
Squids	0	0	0	0	0	0	0	0	0	0	0	0	4.51	2.70	0.28	13.44
Crustaceans	9.09	0.29	4.26	41.36	15.39	4.80	4.31	140.20	33.33	19.79	4.26	801.59	21.62	2.31	2.21	97.72
Naupli	0	0	0	0	0	0	0	0	0	0	0	0	8.11	0.35	3.58	31.87
Isopods		0	0	0	3.85	0.80	0.31	4.27	8.33	1.04	2.13	26.41	11.71	2.24	3.95	72.49
Valvifers	9.09	0.29	2.13	22.00	42.31	14.40	19.08	1416.54	16.67	2.08	5.32	123.36	15.32	3.97	3.34	111.99
Cirolanids	9.09	14	14.90	262.70	11.54	0.80	0.92	19.85	33.33	10.42	4.26	489.28	9.91	1.12	0.57	16.75
***Serolis* spp.**	9.09	0.29	2.13	22.00	30.77	4.80	4.00	270.78	33.33	9.38	8.51	596.27	45.95	15.70	10.20	1190.11
Amphipods	9.09	0.29	2.13	22.00	34.62	4.80	7.69	432.40	16.67	2.08	2.13	70.18	18.02	0.93	2.73	65.95
Gammarids	0	0	0	0	26.92	6.40	10.77	462.22	8.33	1.04	3.19	35.24	30.63	2.74	9.60	377.97
T.gaudichaudii	9.09	0.29	0.26	5.00	38.46	22.40	37.85	2317.22	16.67	2.08	3.19	87.85	31.53	16.12	49.60	2072.15
Euphausiids	0	0	0	0	11.54	1.60	1.85	39.81	8.33	1.04	2.13	26.41	12.61	1.16	4.42	70.36
***Munida* spp.**	0	0	0	0	7.69	0	3.39	26.07	0	0	0	0	8.11	2.82	1.27	33.17
Sea urchin	0	0	0	0	0	0	0	0	0	0	0	0	9.91	3.09	0.52	35.78
Ophiuroids	36.36	8.29	31.92	1462.04	42.31	11.20	4.92	682.04	50.00	29.17	55.32	4224.5	9.01	2.51	0.85	30.27
Fish	18.18	11.43	4.26	285.24	7.69	3.20	0.62	29.38	0	0	2.13	0	7.21	25.30	0.50	186.02
Fish eggs	0	0	0	0	0	0	0	0	0	0	0	0	3.60	1.39	0.19	5.69
***Patagonotothen* spp.**	72.73	43.43	17.02	4396.53	0	0	0	0	0	0	0	0	0.90	0.66	0.05	0.64
Miscelaneous	27.27	0.86	6.38	197.44	3.85	0.80	0.31	4.27	8.33	1.04	1.06	17.49	15.32	2.43	1.22	55.92
Net feeding	909	17.45	4.08	195.71	0	0	0	0	0	0	0	0	0.90	3.11	0.05	2.84
Discard feeding	0	0	0	0	11.11	78.92	0.92	887.02	0	0	0	0	2.70	5.37	0.14	14.88
Total	11	35	47		26	12.50	325		12	9.6	94		111	259.3	2125	
		(42.4)	(49)		(27)	(59.3)	(328)							(283.3)	(2129)	

Table 14. Variation by fishery areas in diet of *Patagonotothen ramsayi* from South West Atlantic.

	FO% fish	FO% Pat-fish	FO% P.r.-Pat	FO% P.r.-fish	FO% P.r.-total
Common Hake (n=992)	25.71	44.71	38.60	17.25	4.44
Hoki (n=91)	25.28	21.74	0	0	5.50 (Pat/fish)
Toothfish (n=71)	42.25	56.67	47.06	26.67	11.27
Kingclip (n=264)	53.03	59.29	36.15	21.43	11.36
Red cod (n=80)	42.05	0	32.36	0	13.75
	W% fish	**W% Pat-fish**	**WO% P.r.-Pat**	**W% P.r.-fish**	**W% P.r.-total**
Common Hake (w=20976.5)	46.02	44.43	24.78	16.61	7.64
Hoki (w=642.7)	88.16	42.66	0	0	37.61 (Pat/fish)
Toothfish (w=5259.8)	79.42	60.87	56.52	34.39	27.31
Kingclip (w=5110.73)	90.06	55.15	28.06	15.47	13.93
Red cod (w=1344.4)	77.48	0	89.79	0	65.57

Table 15. FO% and W% of *Patagonotothen ramsayi* by other fish species.

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Task 2.4

GIS

Task 2.4. GIS (Analysis of the spatial and temporal distribution of the resource. Leader UA).

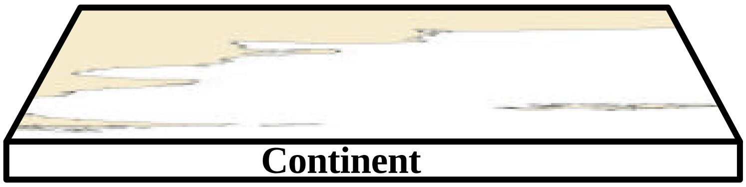
Deliverable # 18 Analysis of the spatial and temporal distribution of the resource

GIS (IEO, 1st progress report)

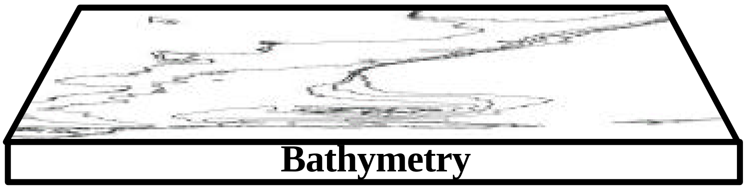
The Fisheries GIS is based on an integrated database from which data is retrieved and used to present the monthly and seasonal geographical change in the distribution of CPUE, SST and densities calculated from CPUE corresponding to historical data of *Patagonotothen* spp. The first task in the development of the GIS was the definition of database tables necessary for the system. After defining the structure of our database and methodology for necessary calculations, next step was the integration of our data into the GIS platform.

Layers of the GIS developed at the IEO were:

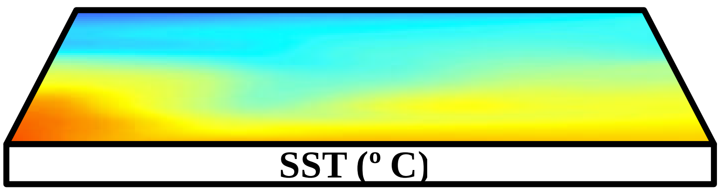
1. <u>Continent Layer</u>



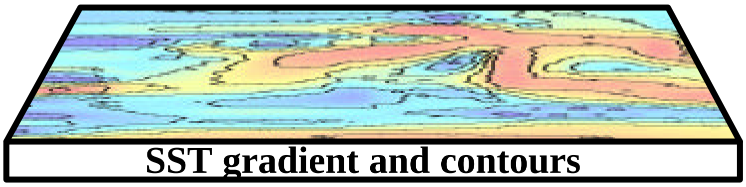
2. <u>Bathymetry of the Patagonian Shelf</u> obtained from GEBCO software. This bathymetry was entered into the GIS in order to obtain the bathymetric lines. Contour lines considered were 0 m, 200 m, 500 m and 1000 m.



3. <u>Monthly mean SST</u> with spatial resolution of 1º latitude by 1º longitude. These data were integrated in the ACCESS database as tables, and in the GIS as grids. SST layer was estimated by using the KRIGING method. This interpolation method assumes that the distance or direction between points reflects a spatial correlation that can be used to explain variations in the surface. Kriging fits a mathematical function to a specific number of points, or all points within a specified radius, to determine the output value for each location.



4. Thermal gradient obtained using the ArcGis Slope function. This function identifies the slope, in this case, the maximum rate of change in sea surface temperature from each cell to its neighbours. From the SST gradient layer the temperature contours were also calculated where each line represents all contiguous locations with the same value.



5. Rockcod monthly densities. For this task, historical catch and effort data (from 1989 to 2002) collected by FIFD and IEO observers were used. From these data monthly average Catch Per Unit Effort (CPUE) was estimated and used to obtain monthly densities of the species. Density is a spatial analyst function that distributes the quantity or magnitude of point/line observations over a unit area to create a continuous raster. Densities were calculated by using the POINTDENSITY function included into the ArcGis software. POINTDENSITY is a good tool to show higher abundances of the species by using CPUE values . Densities were made by using simple calculations. Using this tool, density is calculated using the number of points that fall within the neighbourhood of each output grid cell, divided by the area of the neighbourhood. After the density calculation *Patagonotothen* spp. data were categorized by the ArcMap function of manual breaks to display CPUE density by seven groupings. By this function we have grouped ranges of values into classes that allows to spot patterns in the data more easily. The definition of a class range determines which features fall into that class and which affects the appearance of the map. Each class range is depicted in a different colour on the resulting map. Manual assignment of classes is an useful technique for isolating and highlighting ranges of data.

It is important to mention that Patagonotothen genus contains 14 species in the waters off southern South America being the most abundant Patagonotothen Ramsayi. This genus is a by-catch fishery and nowadays the discard percentage is 100%.

From the start of the project the observers have encountered 5 species of *Patagonotothen* within the study area: *ramsayi*, *tesellata*, *guntheri*, *squamiceps* and *elegans*. IEO observers have had difficulties with the identification of the species, being that the reason why the GIS does not make differentiation between species and is only considering the genus.

The GIS provides the means to integrate remotely sensed SST data and fisheries data over very broad temporal and spatial scales.The results serve to demonstrate the potential of GIS as a tool for the investigation of habitat associations for *Patagonotothen* spp. in Falkland region (figures 1 and 2).

The time series satellite-derived SST observations obtained from the Advanced Very High Resolution Radiometer (AVHRR) clearly depicted the Oceanic Front produced by the mixing of the two main currents affecting the study area (Falkland and Brazil current). In the Confluence region both currents separate from the continental slope and flow offshore creating an area of strong contrasts and complex dynamics. The Confluence Zone is located approximately at 38º S migrating northward during the Southern Hemisphere winter and southwards in summer. This is a wide area characterized by intense horizontal and vertical mixing. It is placed at the approximate latitude of 39 degrees south but is displaced to the north during winter. Due to this mixing the Patagonian Shelf is considered one of the highest productive ecosystems.

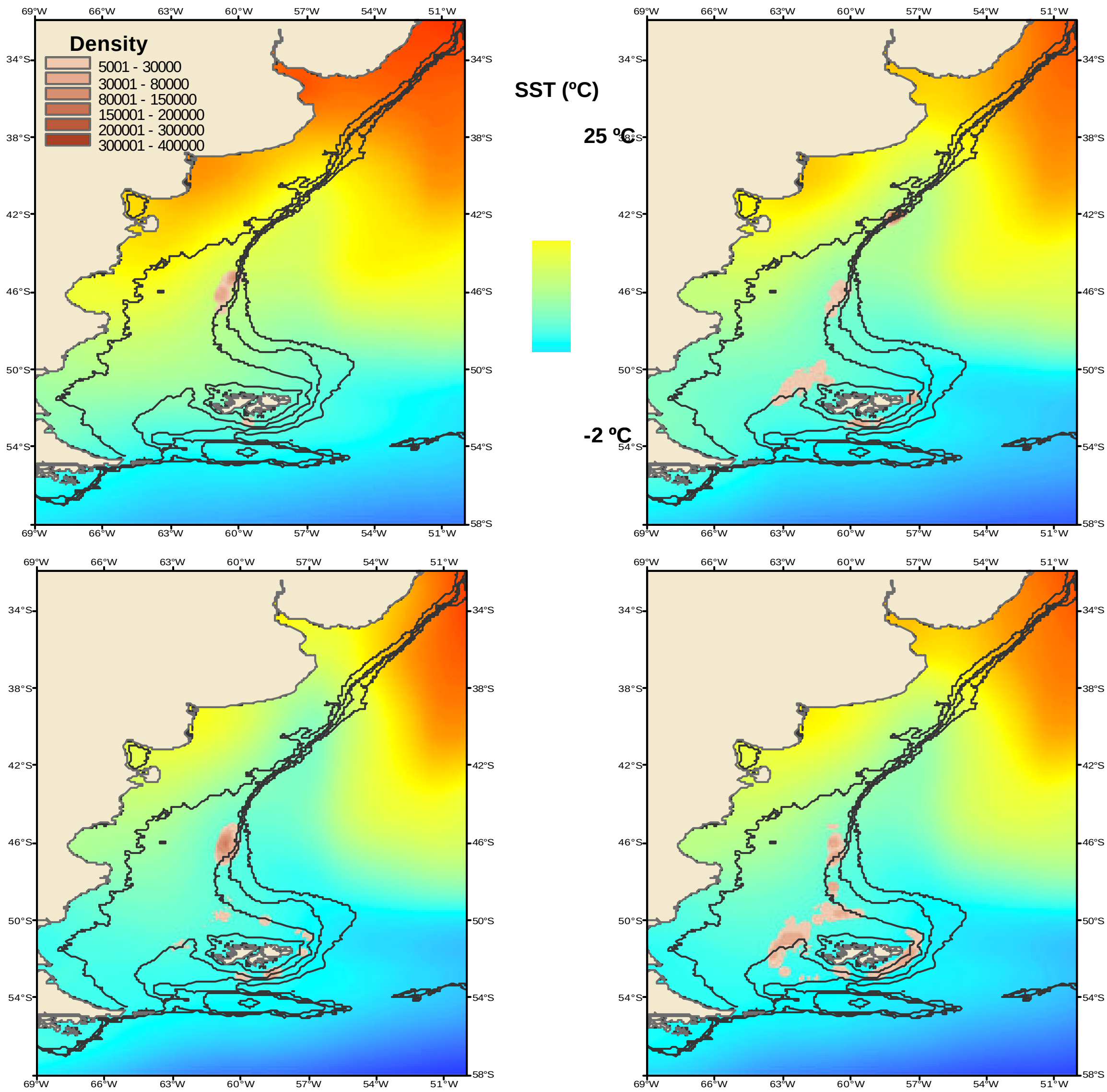


Figure 1: The four maps represent *Patagonotothen* spp. density estimated from CPUE (kg/hour) data (collected from 1989 to 2002) and seasonal averages for SST corresponding to January (top left), May (top right), August (bottom left) and October (bottom right)

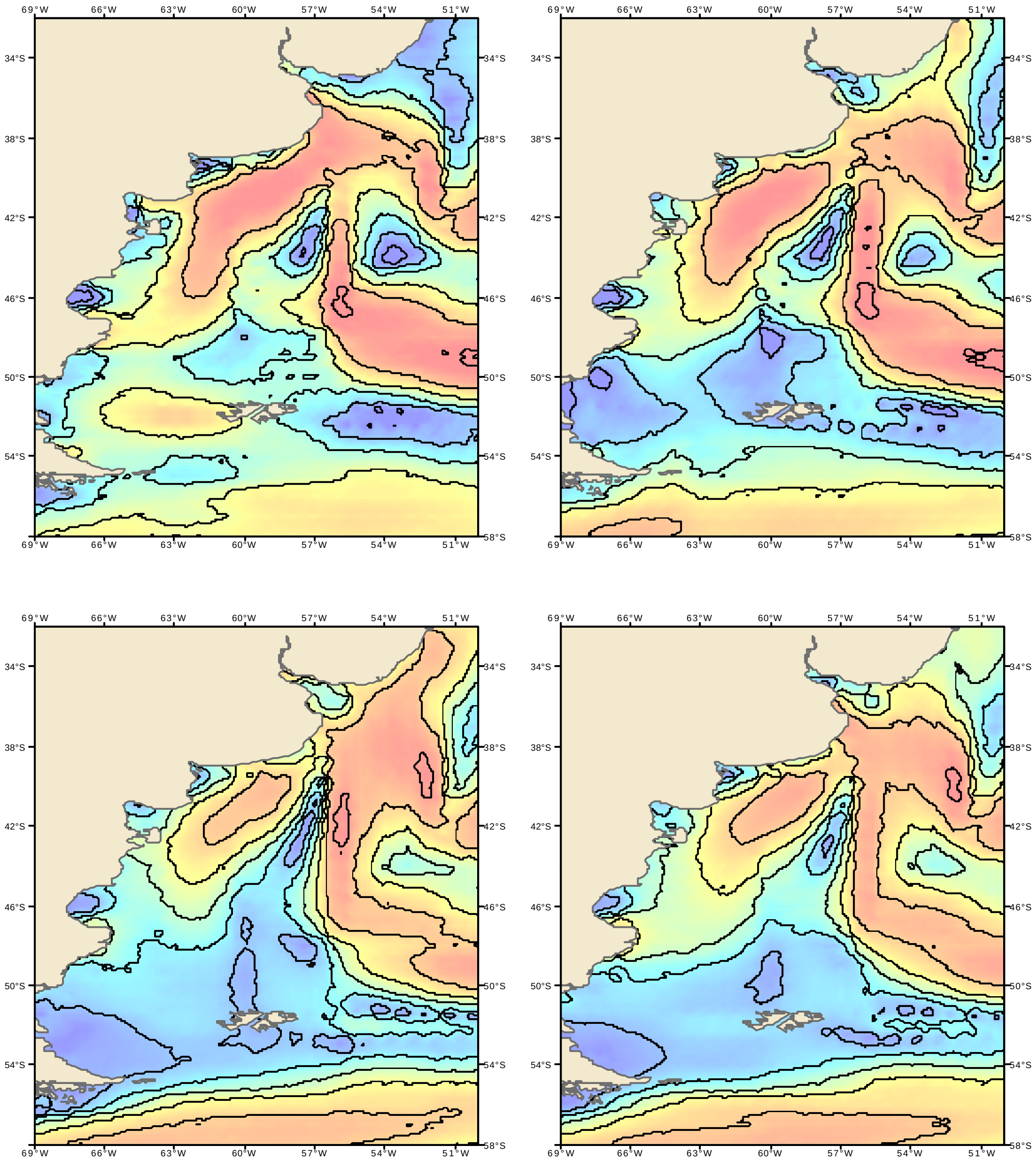


Figure 2: Thermal gradients calculated using the slope function from SST data January (top left), May (top right), August (bottom left) and October (bottom right).

GIS (IEO, 2nd progress report)

Data sources: fishery data

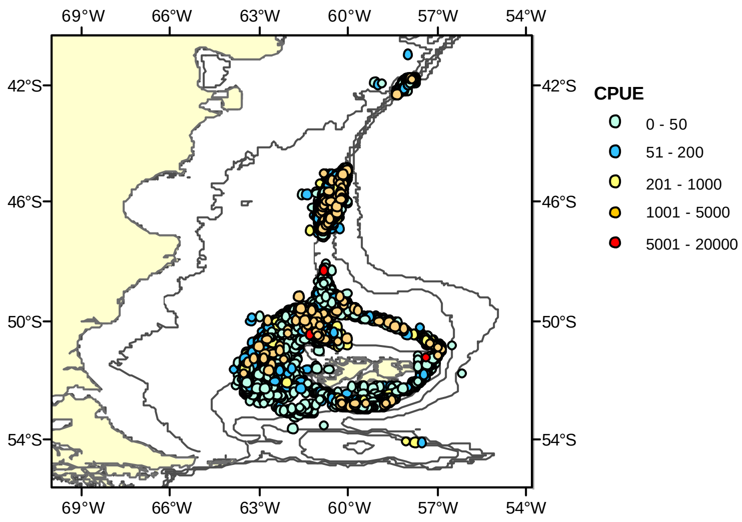


Figure 3. Haul locations positive for *Patagonotothen* spp. from 1988-2003.

Spatially referenced commercial fishery data, as well as bathymetric data were examined using Geographic Information System (GIS) techniques in order to map and represent information about the distribution and the abundance of catches of *Patagonotothen* spp. recorded by scientific observers in the Falkland Islands and in the High Seas from 1988 to 2003 (figure 3). The use of data from the observer programs provides considerably wider spatial and temporal coverage than is normally the case with scientific survey data. However the inference of distribution patterns from commercial data requires some caution due to the fact that location of commercial trawls is influenced by a variety of considerations such as license conditions, vessel capabilities, commercial priorities and the knowledge and experience of the crew.

Bathymetry contours of the Patagonian shelf were extracted from the GEBCO (General Bathymetric Chart of the Oceans) Digital Atlas. Bathymetric contours represented here are 0 m, 200 m, 500 m and 1000 m.

Daily fishery data for the present study were collected by observers working for the IEO (Instituto Español de Oceanografía, Vigo, Spain) and FIGFD (Falkland Islands Government Fisheries Department, Stanley) on board commercial vessels for the 17-year period 1988 - 2003. All fishery and environmental data were integrated into a database (MS Access) and GIS (ArcGIS version 8.2) for use in analysis and modelling.

CPUE (catches per unit effort, kg/hr) was used as an index of abundance in the fishery (Waluda *et al*., 1999). This index reflects abundance and accounts for changes in fleet activity over the 17-year period. Observers collected also supplementary data, i.e. main characteristics of every haul, environmental and physical data. This comprised fishing location, depth, tow time, SST, SBT, sea state, lunar cycle, sky pattern, etc.

Although the catching power of individual boats is variable, this is not easily quantifiable and it was considered to be impractical to attempt to apply correction factors. Therefore hours fishing is used as the index of effort. Although this will introduce additional noise into the data it should not be a source of bias.

Maps were visually analysed in order to find variations in the spatial distribution of CPUE of *Patagonotothen* spp. on a monthly basis.

Grid maps

Patagonotothen spp. raster data sets were created with the GIS in a monthly basis. Each cell in the map, is a square that represents a specific portion of an area with a spatial resolution of 0.5 degree longitude and 0.5 degree latitude square. The size of the cell was selected in order to accomplish a detailed analysis of the temporal evolution of the features represented in the maps (CPUE , ratio of catches to the total catches and modal length).

Density surface

Patagonotothen spp. density surfaces were created in the GIS as monthly raster layers. Each cell in every layer gets a density value based on the number of features (hauls with CPUE > 0 kg/h) within a radius cell of 0.125 degrees. To create a density surface we have used the Kernel method that uses a mathematical function to give more importance to features closer to the center of the cell. With this method, maps with patterns that are easier to interpret were obtained. The GIS defines a neighbourhood (based on the search radius specified, in this case 1.5 degrees) around each cell centre. It then totals the number of features that fall within that neighbourhood and divides that number by the area of the neighbourhood. That value is assigned to the cell. The GIS moves on to the next cell and repeats the same procedure, resulting in the creation of a smoothed surface. Mapping density shows where the highest concentration of *Patagonotothen* spp. is found on a monthly basis.

Yearly distribution of Patagonotothen spp. CPUE and averaged CPUE maps

Figures 4 and 5 illustrates the annual distribution of observed CPUE (kg/hr) from 1988 to 2003 for *Patagonotothen* spp. Rockcod catches in 14 years does not describe a clear spatio-temporal pattern. In general terms we conclude that higher concentrations of high annual values of CPUE were seen between 1996 and 1999. From 1989 to 1995, the CPUE values fluctuate from low to high being the CPUE lowest values in 1989 and the highest in 1997.

Monthly distribution of Patagonotothen spp. CPUE and averaged CPUE maps

Figures 6 and 7 show the monthly distribution of rockcod CPUE. Fish abundance was higher in the austral summer than in the winter. February, March and April were the months that registered higher concentration of high CPUE values. From February to May there is an expansion in the distribution catches from the western area towards the eastern area. Catches of *Patagonotothen* spp. were recorded all around the Islands from August to October and restricted to the western area in June, July and November.

Patagonotothen spp. density maps

Density surface maps (Figure 8) show the abundance distribution of this species through the year. Density maps show a similar temporal pattern than figures 4 and 5. Maximum density values were recorded within March, July and August. These values are located in all cases in division 46. April was characterized by the presence of high density values in division 46 and 49. From August to December there is a clear fall in density values, reaching the minimum in December.

Patagonotothen spp. CPUE distribution per strata

The distribution of *Patagonotothen* spp. per strata (Figure 9) give us an idea about the habitat of the species. Maximum concentration of *Patagonotothen* spp. CPUE were recorded in 100-200 m and 200-300 strata. Few catches were recorded in 0-100, 300-400, 400-500 and higher than 500 m strata. Catches in the 0-100 m strata were mainly located in the division 46, 49 and MS. In the 300-400 m strata catches were located mainly in division 42, 46 and MS. Strata 400-500 m and higher than 500 m show few catches at division 42 and MS. Catches located between 100-200 m were found all around the Islands and also in International Waters.

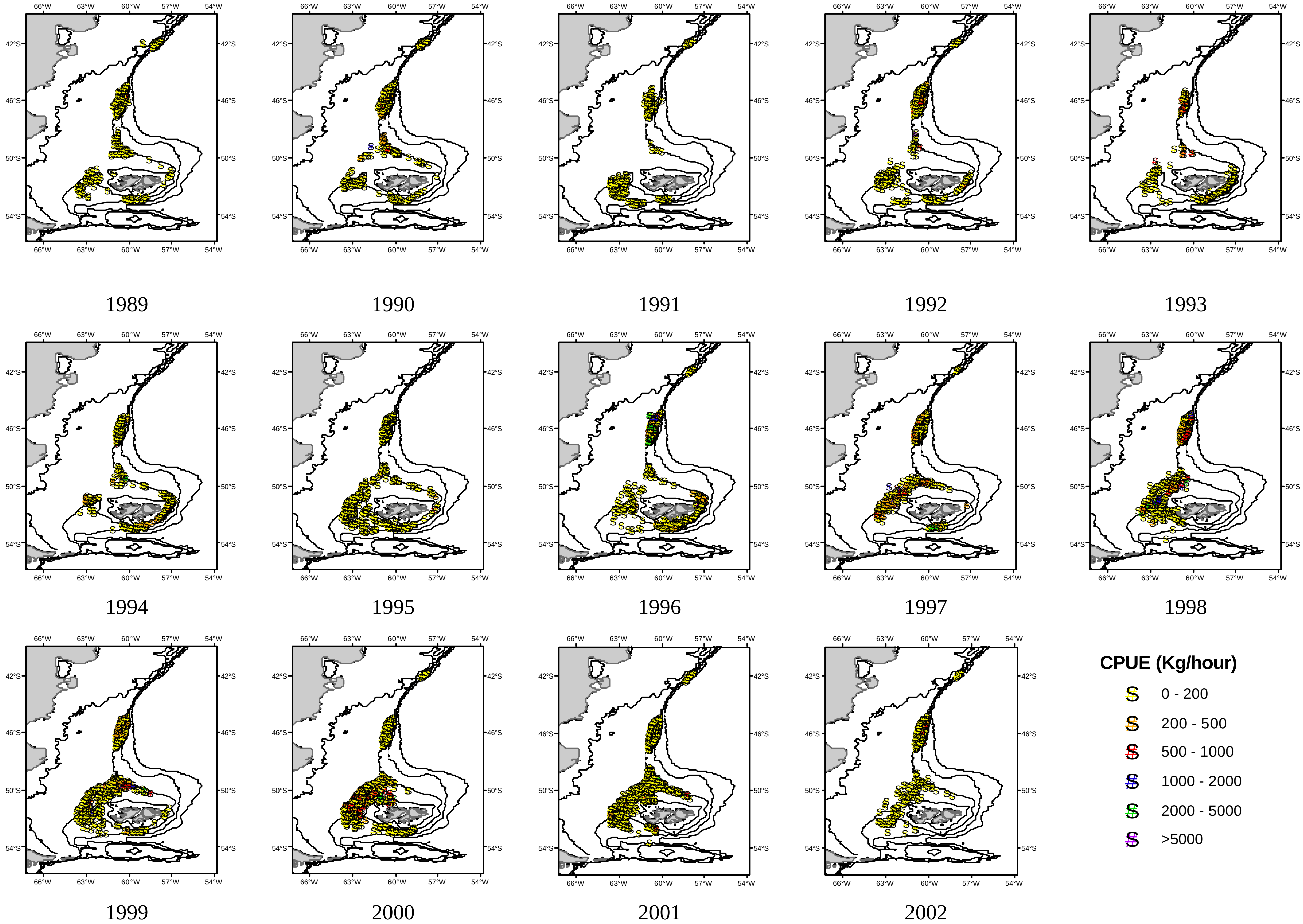


Figure 4. Yearly distribution of *Patagonotothen* spp. CPUE (Kg/hr)

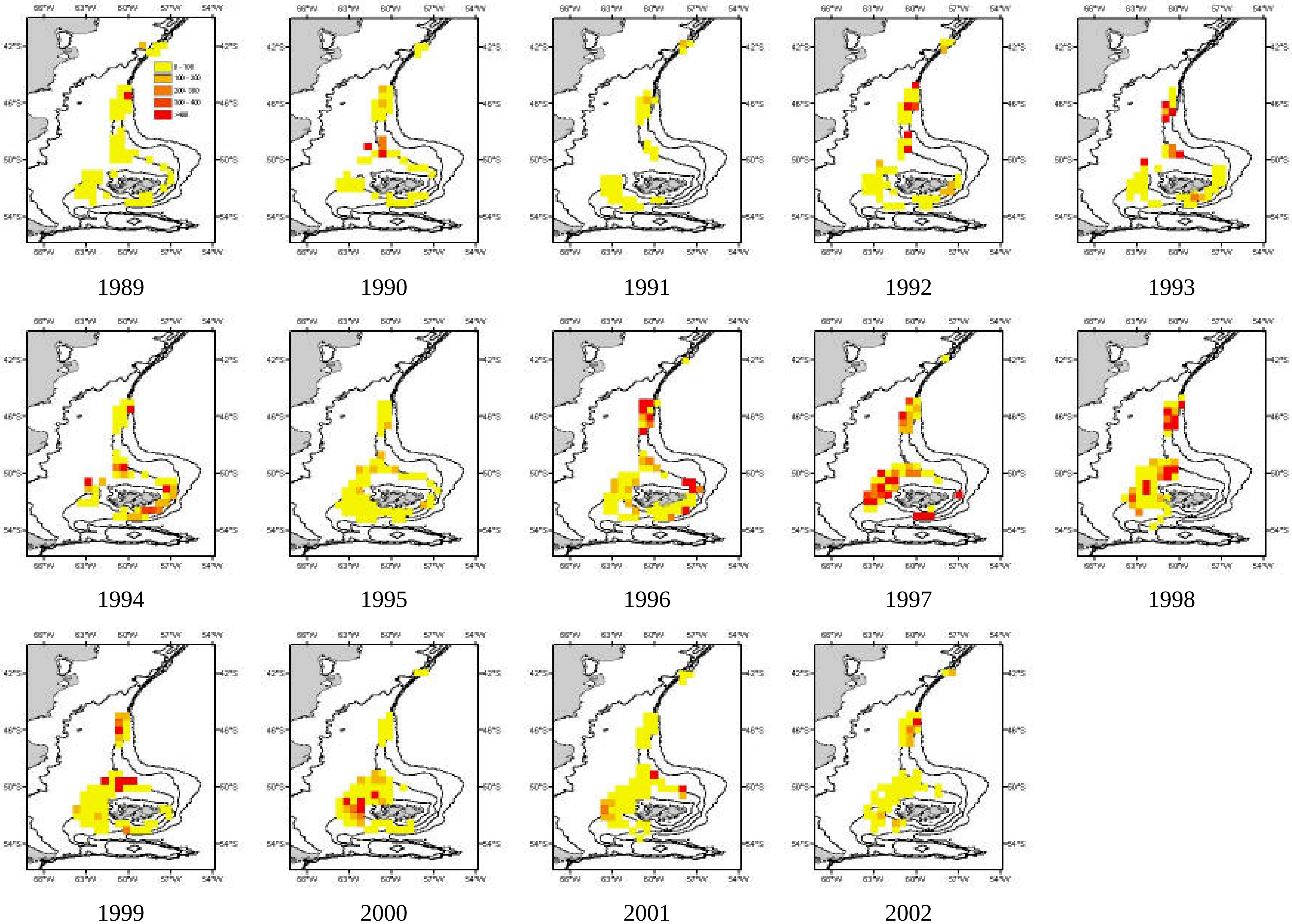


Figure 5. *Patagonotothe*n spp. CPUE (by 0.5 x 0.5 degrees rectangles)

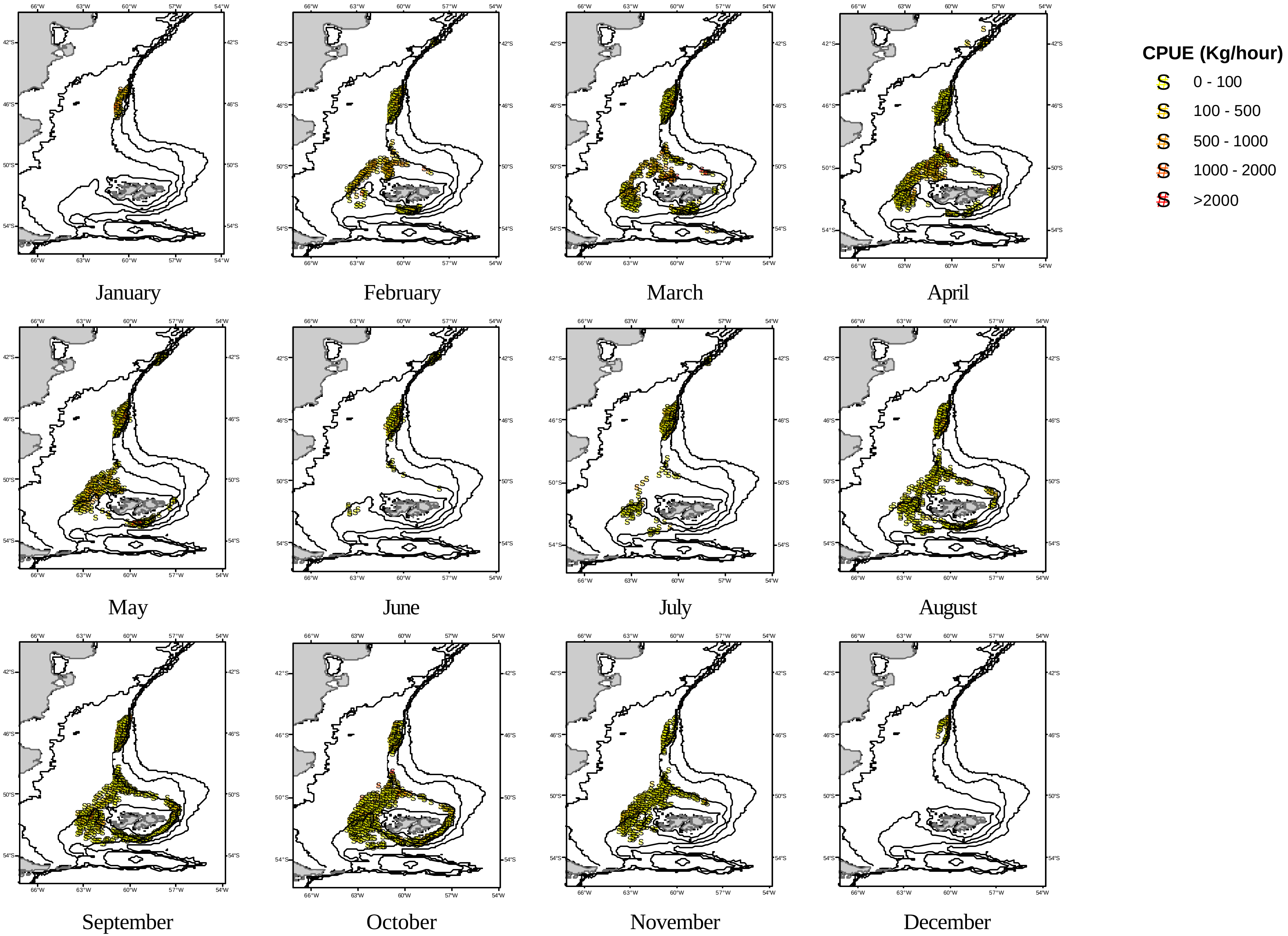


Figure 6. Monthly distribution of *Patagonotothen* spp. CPUE (Kg/h)

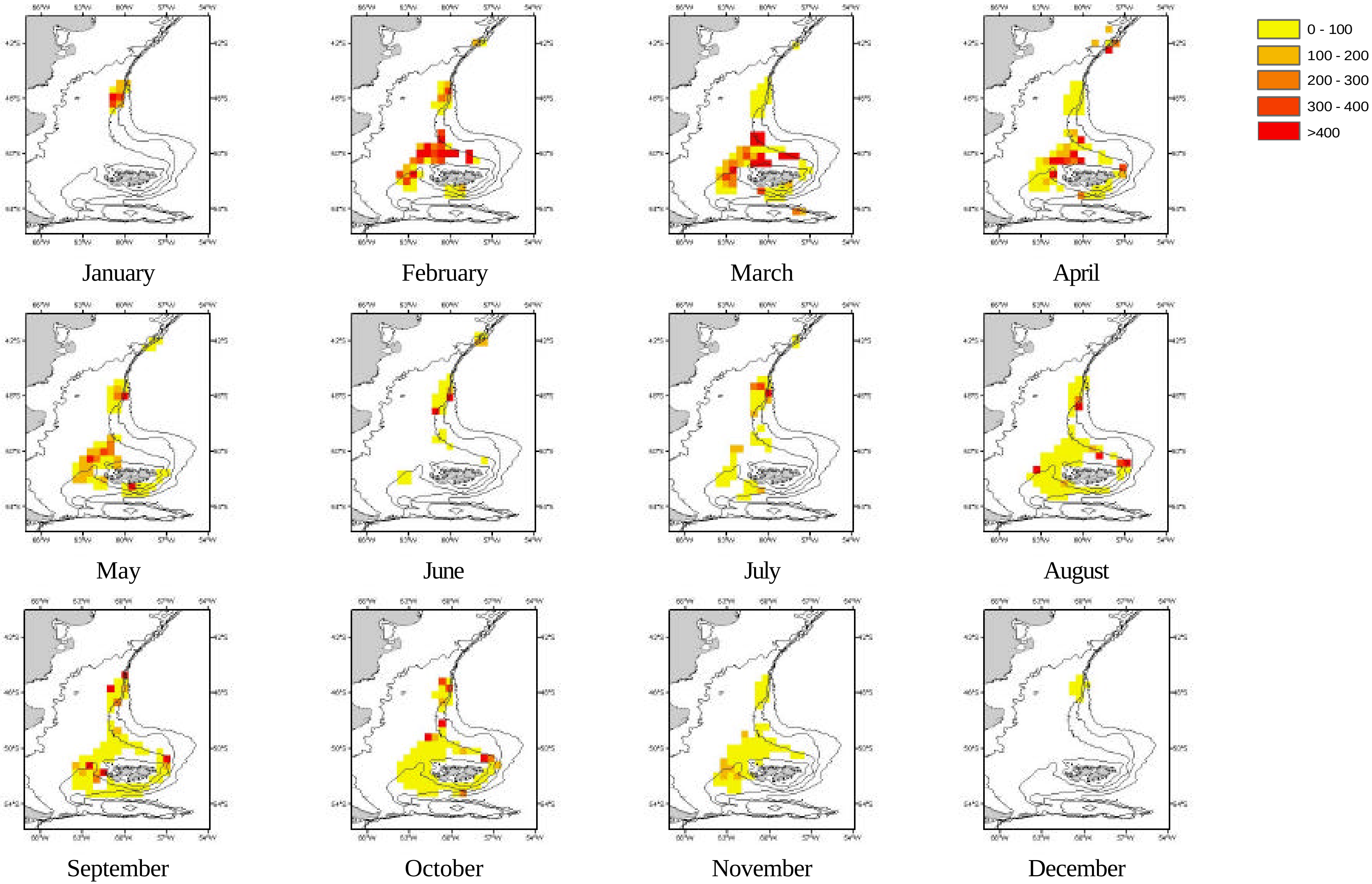


Figure 7. *Patagonotothen* spp. monthly CPUE (kg/hour) (by 0.5 x 0.5 degrees rectangles)

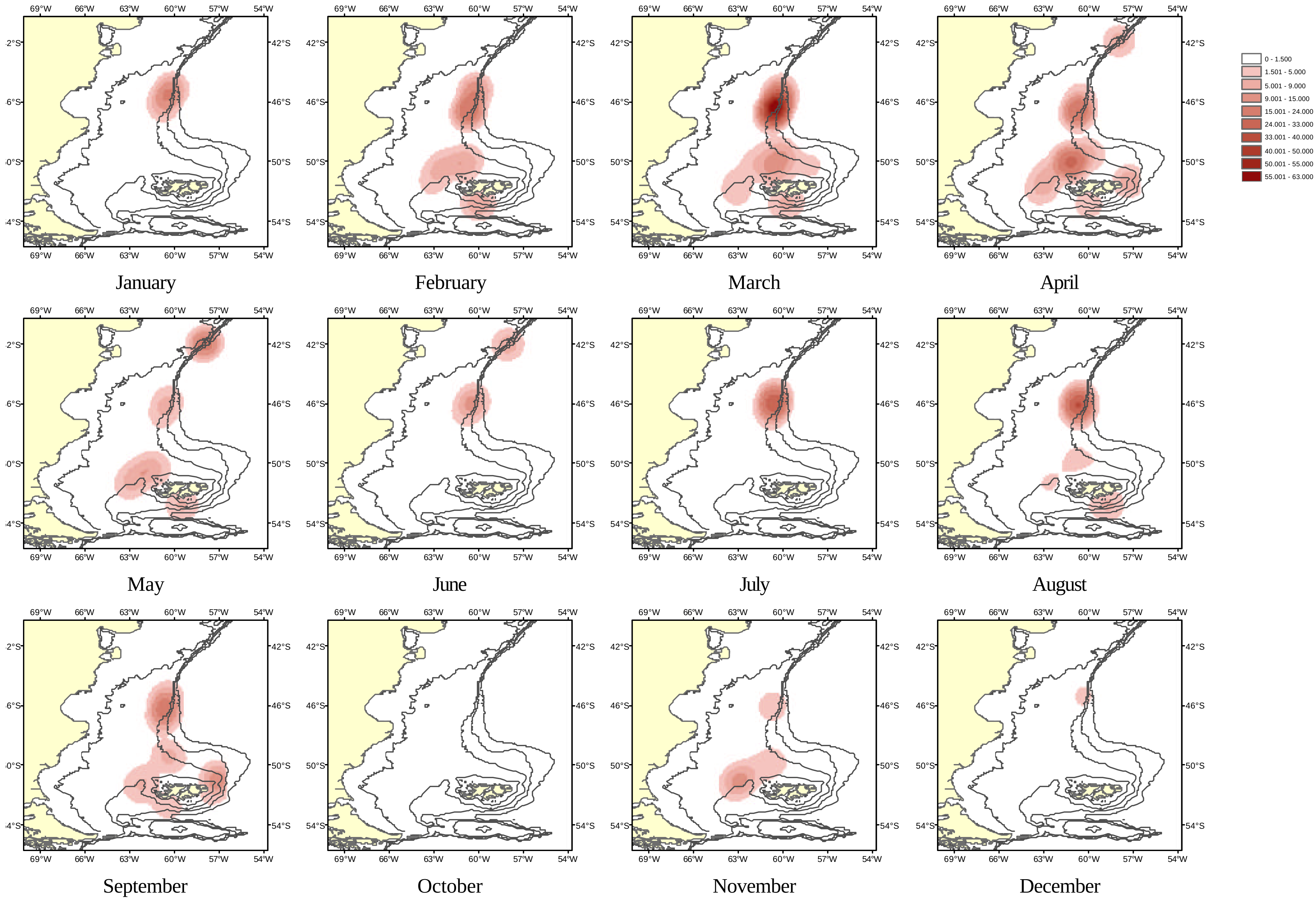
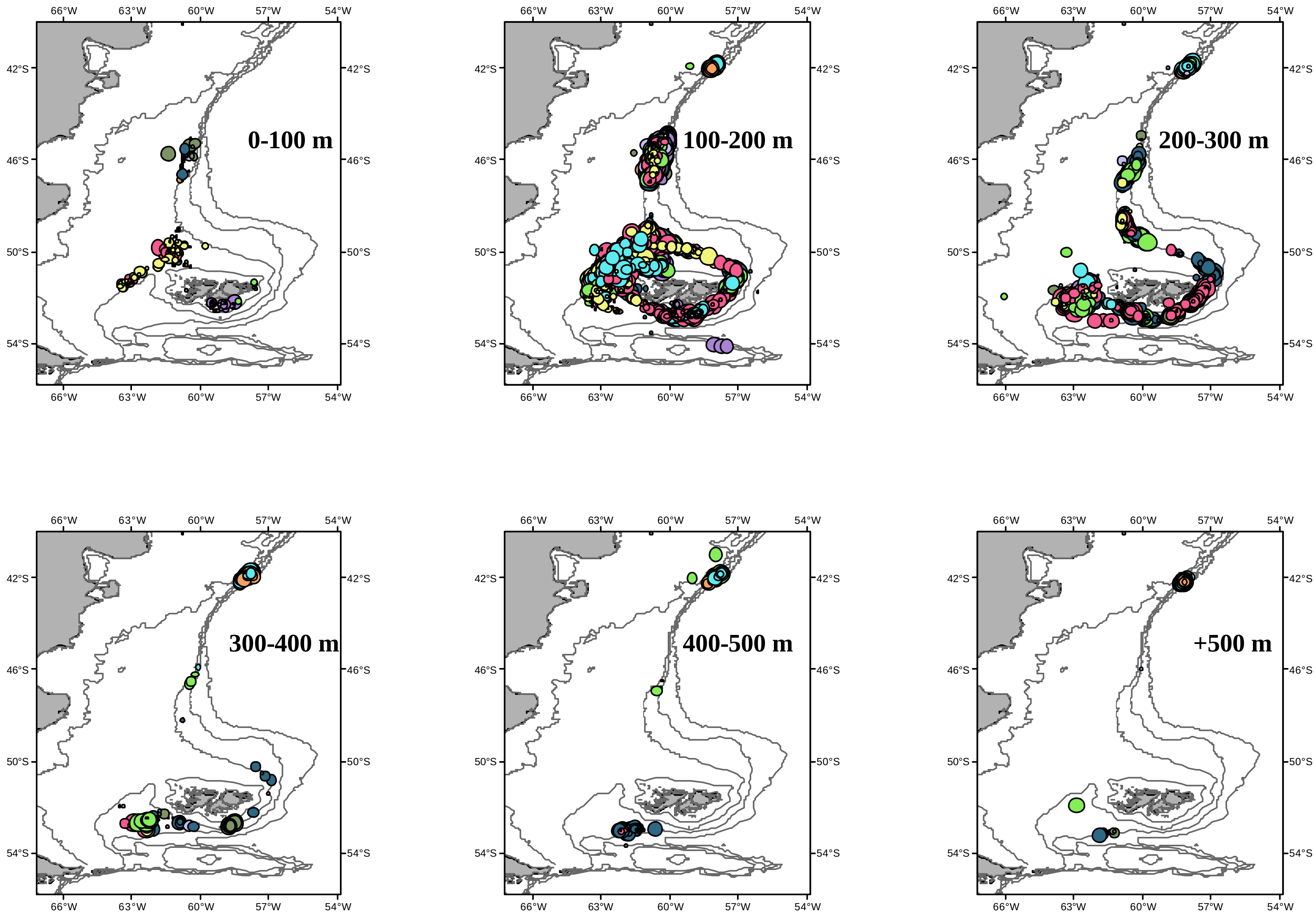


Figure 8. *Patagonotothen* spp. density maps (0.125 x 0.125 degrees resolution)



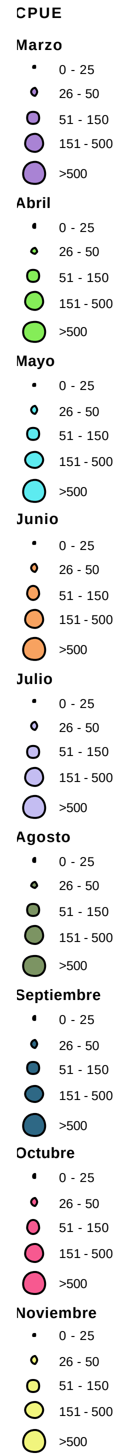


Figure 9. *Patagonotothen* spp. CPUE (kg/hour) per strata

Sub Task 2.4.1 Fishery Forecasting

(UNIABDN, 1st progress report, 2003)

1. Data assembly, processing and integration

Fishery data

FIFD data

The data available comprised a total of 5749 hauls records from 1988 to 2001. Only 61 hauls include records of *Patagonotothen* spp. (code 1010) catches. Only two recorded catches were more than 100 kg (500 kg and 200 kg). The minimum recorded catch was 0.04 kg. All catches were discarded. Therefore FIFD data are not used in the present analysis.

Spanish data

The data were provided by IEO (Vigo) and refer to all hauls monitored by observers (i.e. a sample of total fishing effort) during 1989 to 2002. Observer effort varied from year to year. During this period, there were 10203 recorded hauls with *Patagonotothen* spp catches. The species was thus recorded in 55% of the total recorded 18559 hauls. Spanish fishery data from 1989 to 2002 were integrated into a MS Access database and used in analysis and modelling. The data are recorded haul by haul, and include catches and discards by species, start and end time, start and end position, gear type, and environmental data (as mentioned below).

Environmental data

Sea surface temperature data

Weekly averaged multi-channel sea-surface temperature data derived from the NOAA Advanced Very High Resolution Radiometer (AVHRR) from both the ascending pass (daytime) and descending pass (night-time) are available from the Physical Oceanography Distributed Active Archive Center, Jet Propulsion laboratory, USA. The data are obtained at the equal angle grid with spatial resolution of 2048/360 degree per pixel, i.e., the size of a pixel at the equator is 19.55 km. Data from January 1982 to December 2000 were downloaded from the Physical Oceanography Distributed Active Archive Center, Jet Propulsion laboratory, USA. Considering the diurnal warming effects, which affect the estimated SST from AVHRR data (Cornillon and Stramma, 1985; Stramma, *et al*., 1986), only night-time data were downloaded. The data were processed and converted into GIS as grids. The data will be used for analyzing the relationships between fish abundance and oceanic circulation.

Reynolds global monthly mean SST with 1 x 1 degree resolution data from 1982 to 2002 were downloaded from the web site of the National Center for Atmospheric Researches (NCAR). The data are the output of a model using input of marine surface observations, the NOAA Advanced Very High Resolution Radiometer (AVHRR) data and the presence of sea ice (Reynolds and Marsico, 1993). The data covering the study area were extracted from global data sets and integrated into a MS Access database.

Bathymetric data

Gridded bathymetric data with 1' by 1' resolution were extracted from GEBCO (General Bathymetric Chart of the Oceans) 2003 CD ROM, replacing 5' by 5' data which had previously been used. This is the best bathymetric data available and is recommended for use by all partners. The data covering the project area have been integrated into GIS as grids.

Bathymetry contour lines (vector structure) and coastline were extracted from the GEBCO 2003 CD ROM. The contour line interval is 10 metres. The data were imported into the GIS as a shapefile and coverage.

2. **Fish abundance, discards and other indices**

Indices were defined as follows:

Fish abundance indices

1. *Single haul CPUE (catches per unit effort, kg/h): the ratio of the catches of Patagonotothen spp. to the fishing hours for a single haul.*
2. *Monthly mean CPUE (kg/h) by 0.5 degrees rectangle*: the sum of total *Patagonotothen* spp. catches divided by the sum of total effort for all hauls within a 0.5^o rectangle and a month.
3. *Long term monthly mean CPUE (kg/h) by 0.5 degrees rectangle*: is defined as the sum of total *Patagonotothen* spp. catches divided by the sum of total effort for all hauls within a 0.5^o rectangle from 1989 to 2002.

Fish discard indices

1. *Single haul DPUE (discards per unit effort, kg/h)*: the ratio of the discards of *Patagonotothen* spp. to the fishing hours for a single haul.
2. *Monthly mean DPUE (kg/h) by 0.5 degrees rectangle*: the sum of total *Patagonotothen* spp. discards divided by the sum of total effort for all hauls within a 0.5^o rectangle and a month.
3. *Long term monthly mean DPUE (kg/h) by 0.5 degrees rectangle*: the sum of total *Patagonotothen* spp. discards divided by the sum of total effort for all hauls within a 0.5^o rectangle from 1989 to 2002.

Single haul ratio indices

1. *The ratio of single haul Patagonotothen spp. catches to the catches of all species (SCAC)*: the ratio of *Patagonotothen* spp. catches to the summed catches of all species for a single haul.

2. *The ratio of single haul Patagonotothen spp. discard to the catches of Patagonotothen spp. (SDSC)*: the ratio of *Patagonotothen* spp. discards to the *Patagonotothen* spp. catches for a single haul
3. *The ratio of single haul Patagonotothen spp. discards to the discards of all species (SDAD)*: the ratio of *Patagonotothen* spp. discards to the discards of all species for a single haul.
4. *The ratio of single haul Patagonotothen spp. discards to the catches of all species (SDAC)*: the ratio of *Patagonotothen* spp. discards to the catches of all species for a single haul.

Single year monthly mean ratio indices

a. *Single year monthly mean SDAC by 0.5 degrees rectangle*: the ratio of the sum of *Patagonotothen* spp. discards to the sum of the catches of all species within a 0.5^{o} rectangle and a month.
b. *Single year monthly mean SDSC by 0.5 degrees rectangle*: the ratio of the sum of *Patagonotothen* spp. discards to the sum of the catches *Patagonotothen* spp. within a 0.5^{o} rectangle and a month.
c. *Single year monthly mean SDAD by 0.5 degrees rectangle*: the ratio of the sum of *Patagonotothen* spp. discards to the sum of the discards of all species within a 0.5^{o} rectangle and a month.
d. *Single year monthly mean SDAC by 0.5 degrees rectangle*: the ratio of the sum of *Patagonotothen* spp. discards to the sum of the catches of all species within a 0.5^{o} rectangle and a month.

Long-term mean ratio indices

1. *Long-term monthly mean SDAC by 0.5 degrees rectangle*: the ratio of the sum of *Patagonotothen* spp. discards to the sum of the catches of all species within a 0.5^{o} rectangle and a month.
2. *Long-term monthly mean SDSC by 0.5 degrees rectangle*: the ratio of the sum of *Patagonotothen* spp. discards to the sum of the catches *Patagonotothen* spp. within a 0.5^{o} rectangle and a month.
3. *Long-term monthly mean SDAD by 0.5 degrees rectangle*: the ratio of the sum of *Patagonotothen* spp. discards to the sum of the discards of all species within a 0.5^{o} rectangle and a month.
4. *Long-term monthly mean SDAC by 0.5 degrees rectangle*: the ratio of the sum of *Patagonotothen* spp. discards to the sum of the catches of all species within a 0.5^{o} rectangle and a month.

3. Data análisis

Data analysis was carried out in three phases:

a. Exploratory analysis based on the database, to determine the structure and distribution of the data and the calculated indices.
b. Correlation analysis of relationships between fish abundance and environmental variables. Future analysis will include application of GAMs and regression trees.

c. Visualization and visual analysis based on GIS. The Spanish fishery data and the calculated indices, and environmental data, were input into GIS from the Access database and converted into point shapefiles. The point shapefiles were converted into grids. Because remote sensed SST data cover the whole study area, the time-series maps were then made to display the spatial distribution of monthly mean Patagonotothen spp. CPUE by 0.5o rectangle with contour line SST background for each single month from 1989 to 2002. Time-series maps of long term monthly index means from 1989 to 2002, and single year monthly index means (CPUE, DPUE, SDSC, SDAC, SDAD, SCAC) by 0.5o rectangle, were also made.

3.1. *Patagonotothen* spp. catches and abundance

3.1.1. The status of *Patagonotothen* spp. catches by the Spanish fleet

Table 1 lists the total fishing hauls recorded in each single month from 1989 to 2002, and the hauls with *Patagonotothen* spp. catches. During the period from 1989 to 2002, there were 10203 hauls with *Patagonotothen* spp catches, i.e. 55% of the total recorded 18559 hauls.

On average, more than 50% of recorded hauls included *Patagonotothen* spp. catches in 10 years out of the total recorded 14 years, and only in September and October was *Patagonotothen* spp. recorded in fewer than 50% of hauls. The lowest ratio of the hauls with *Patagonotothen* spp. catches to the total recorded hauls, 0.319, appeared in 1989, and the highest, 0.922, in 2000. However, there is no simple temporal pattern describing the temporal change in relative importance of *Patagonotothen* spp. in catches.

Table 2 and Figures 10 and 11 show the ratio of *Patagonotothen* spp. catches to the total catches (all species) (SCAC). The catches of *Patagonotothen* spp. comprised from 0 to 35% of catches by weight, annual mean values varying from 0 to about 17%. There were two peaks in SCAC annually: one in January and the other in October and November. From 1989 to 1995, the SCAC fluctuated bi-annually, with alternating “high” and “low” years. High annual values of SCAC were seen between 1996 and 1999.

3.1.2. Temporal distribution of fish abundance

Table 3 and Figures 12 - 14 show the annual and monthly mean CPUE. Fish abundance varies seasonally. Fish abundance was higher in the austral summer than in the winter. Within the recorded 14 years, CPUE was lowest in 1989 (CPUE = 16.2 kg/h) and highest in 1997 (186.4 kg/h). There were two high abundance peaks annually: one in February and March, the other in October. From 1989 to 1995, abundance fluctuated bi-annually, with alternating “high” and “low” years. High annual values were seen between 1996 and 1999. Thus CPUE and SCAC follow similar patterns, implying that the proportion of *Patagonotothen* spp. in catches is mainly a function of fluctuations in its abundance rather than variation in abundance of other species (Figures 11 and 14).

3.1.3. Spatial distribution of fish abundance

The display of long-term monthly mean CPUE (Figure 15) shows that, the catches of *Patagonotothen* spp. occurred only in the middle area in December and January, while catches in the north area were recorded from February to June. In the south area, the distribution of *Patagonotothen* spp. expanded from the western area towards the eastern area from February to May, and shrank back to the western area in June and July. Catches were recorded all around the Falkland islands from August to October, but were restricted to the western area again in November. The spatial distribution of the long-term monthly mean ratio of *Patagonotothen* spp. catches to the catches of all species (SCAC) follows a similar temporal pattern (Figure 16).

3.2. *Patagonotothen* spp. discards

3.2.1. The status of discarding by the Spanish fleet

Figures 17 and 18 are the pair plots of single haul *Patagonotothen* spp. discard rates and catch rates (DPUE and CPUE, respectively). These figures, together with Figure 11, show that for almost all hauls, from 1989 to 2002, all catches of *Patagonotothen* spp. were discarded.

3.2.2. Temporal pattern of discarding

Table 4 lists monthly mean *Patagonotothen* spp. DPUE. Table 5 lists the monthly mean ratio of discards to catches of *Patagonotothen* spp. (SDSC). Figures 19 and 20 show the annual mean CPUE and DPUE, and monthly mean ratio of *Patagonotothen* spp. discards to the total catches of *Patagonotothen* spp. (SDSC), respectively. Because almost all catches were discarded, the temporal patterns of fish discards and DPUE are almost as the same as the temporal pattern of CPUE. There were only few months with lower DPUE than CPUE. Few months have SDSC <1. October 1991 has the lowest SDSC (=0.338), although all catches were discarded in other months of that year.

Table 6 and Figure 21 show the ratio of the discards of *Patagonotothen* spp. to the catches of all species (SDAC). Annually mean and monthly mean SDAC show similar patterns to the CPUE (see Table 4, Figures 11 and 19).

Table 7 and Figures 22–23 show the ratio of the discards of *Patagonotothen* spp. to the discards of all species (SDAD). Discards of *Patagonotothen* spp. represent around 45% of all discards over the period from 1989 to 2002, with highest SDAD (0.786) in 1998 and lowest SDAD (0.133) in 1989.

3.2.3. Spatial distribution of discarding

Because most of the *Patagonotothen* catches were discarded, as shown in Figures 24 and 25, the general spatial distributions of DPUE and SCAC are similar to the general spatial distribution of CPUE and SDAC. Figures 26 and 27 show the distribution of long-term monthly mean SDSC and SDAD, respectively. Only a few rectangles have low SDSC (Figure 25). However, Figure 27 shows significant spatial differences in SDAD in each month.

3.3. Fish abundance in relation to environmental variables

Preliminary analysis has so far only considered correlations between fish abundance and environmental variables, which were calculated based on single haul data (with CPUE > 0), and recorded SST and depth in the middle area and south area. Tables 8 and 9 show the results. Although, within areas of occurrence, there are significant correlations between fish abundance and SST and depth in some months, there is no clear overall correlation pattern reflecting the relationships between fish abundance and SST and depth.

Table 1: Total hauls and the hauls with *Patagonotothen* spp. catches (Spanish data)

Year	Hauls	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum	%
1989	Total	-	76	303	507	673	447	181	310	375	146	-	-	3018	0.319
	With catches	-	-	31	145	253	251	86	61	100	35	-	-	962	
1990	Total	-	90	236	255	316	157	100	82	152	23	-	-	1411	0.580
	With catches	-	43	181	221	186	85	68	-	17	18	-	-	819	
1991	Total	-	19	167	163	90	130	177	287	167	62	-	-	1262	0.351
	With catches	-	10	130	84	39	63	63	54	-	-	-	-	443	
1992	Total	-	114	163	137	81	53	164	331	229	117	-	-	1389	0.562
	With catches	-	78	106	89	65	46	153	105	74	65	-	-	781	
1993	Total	67	180	163	174	8	-	147	161	186	178	3	-	1267	0.225
	With catches	-	-	-	-	-	-	52	30	85	116	2	-	285	
1994	Total	-	96	195	176	114	-	53	197	161	124	-	-	1116	0.475
	With catches	-	44	19	16	8	-	53	129	142	119	-	-	530	
1995	Total	-	138	144	126	90	-	55	186	169	160	36	-	1104	0.459
	With catches	-	56	75	54	24	-	10	75	75	102	36	-	507	
1996	Total	-	125	190	213	171	-	67	211	206	136	-	-	1319	0.642
	With catches	-	96	166	152	47	-	65	60	158	103	-	-	847	
1997	Total	85	150	150	94	98	-	103	159	182	101	-	-	1122	0.869
	With catches	85	140	134	93	31	-	100	152	145	95	-	-	975	
1998	Total	86	78	173	153	71	-	76	145	156	124	29	-	1091	0.844
	With catches	85	54	95	151	71	-	69	128	141	104	23	-	921	
1999	Total	57	80	256	171	101	41	52	171	92	65	73	41	1159	0.557
	With catches	56	69	75	81	8	17	47	117	49	57	70	40	646	
2000	Total	8	84	147	181	178	28	-	62	62	96	82	-	928	0.922
	With catches	6	82	145	175	169	26	-	58	36	81	78	-	856	
2001	Total	-	120	145	164	136	33	12	179	201	242	248	14	1480	0.693
	With catches	-	113	113	117	70	-	12	132	78	173	217	3	1025	
2002	Total	-	45	62	98	174	77	73	103	71	81	54	-	838	0.672
	With catches	-	45	44	84	131	47	39	20	42	57	54	-	563	
Sum	Total	303	1395	2494	2612	2301	966	1260	2584	2409	1655	525	55	18559	
	With catches	232	830	1314	1462	1102	535	817	1121	1142	1125	480	43	10203	0.550
	%	0.766	0.595	0.527	0.560	0.479	0.554	0.648	0.434	0.474	0.680	0.914	0.782	0.550	

Table 2: The ratio of single haul *Patagonotothen spp*. catches to the catches of all species (SCAC): average monthly mean SCAC (Spanish data, 1989-2002)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1989			0.003	0.008	0.024	0.021	0.049	0.010	0.011	0.007			0.015
1990		0.020	0.049	0.066	0.045	0.047	0.090		0.004	0.214			0.059
1991		0.035	0.023	0.021	0.014	0.024	0.013	0.003					0.015
1992		0.032	0.038	0.035	0.052	0.100	0.166	0.050	0.010	0.106			0.065
1993							0.041	0.026	0.050	0.066	0.016		0.020
1994		0.167	0.003	0.012	0.002		0.021	0.027	0.095	0.213			0.067
1995		0.014	0.027	0.011	0.014		0.011	0.009	0.016	0.034	0.040		0.020
1996		0.046	0.035	0.052	0.003		0.153	0.048	0.268	0.268			0.109
1997	0.150	0.111	0.204	0.065	0.114		0.186	0.313	0.156	0.201			0.167
1998	0.133	0.107	0.153	0.164	0.150		0.038	0.124	0.116	0.197	0.356		0.154
1999	0.206	0.191	0.088	0.170	0.004	0.040	0.275	0.082	0.094	0.168	0.184	0.166	0.139
2000	0.024	0.127	0.096	0.109	0.131	0.025		0.086	0.029	0.125	0.190		0.094
2001		0.151	0.059	0.093	0.033		0.030	0.017	0.005	0.031	0.047	0.006	0.043
2002		0.078	0.016	0.111	0.103	0.198	0.034	0.027	0.016	0.023	0.040		0.065
Mean	0.103	0.077	0.057	0.065	0.049	0.057	0.085	0.059	0.062	0.118	0.125	0.086	

Table 3: Monthly mean CPUE (kg/h, Spanish data, 1989-2002)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1989			5.4	21.1	33.7	27.5	34.9	7.5	10.2	5.5			16.2
1990		100.4	101.4	77.5	66.8	55.3	88.4		4.1	147.4			71.3
1991		32.9	44.2	33.3	20.1	14.0	7.0	2.6					17.1
1992		83.2	69.4	46.2	42.4	92.6	181.3	63.6	11.4	115.7			78.4
1993							43.2	37.6	39.1	51.0	11.9		18.3
1994		127.4	2.0	20.2	2.5		23.0	26.5	116.6	194.8			64.1
1995		30.2	82.3	32.7	32.4		16.7	13.1	36.8	43.0	28.5		35.1
1996		69.4	67.3	119.9	8.3		169.1	52.2	230.8	193.3			113.8
1997	193.8	114.9	400.7	90.3	76.4		144.1	259.1	150.2	247.8			186.4
1998	185.0	92.1	260.3	217.0	168.3		18.4	91.7	98.9	206.0	301.8		163.9
1999	364.1	431.7	125.9	255.0	3.0	23.6	107.1	64.4	81.1	151.2	123.6	134.1	155.4
2000	27.3	288.5	267.1	154.8	116.1	10.4		51.1	36.2	119.5	291.8		136.3
2001		174.2	82.5	91.4	57.8		17.7	11.4	8.8	41.2	39.7	3.1	48.0
2002		77.2	14.2	78.2	63.2	164.6	35.7	23.9	22.9	19.0	44.8		54.4
Mean	154.0	115.9	108.8	88.4	49.5	48.5	68.2	50.3	60.5	109.7	120.3	68.6	

Table 4: Average monthly mean DPUE (Spanish data, 1989-2002)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1989			5.4	21.1	33.7	27.5	34.9	7.5	10.2	5.5			16.20
1990		100.4	101.4	77.5	66.8	33.4	44.2		4.1	147.4			63.92
1991		32.9	44.2	33.3	20.1	14.0	7.0	2.6					17.12
1992		83.2	69.4	46.2	42.4	92.6	181.3	63.6	11.4	39.1			69.92
1993							43.2	37.6	39.1	50.7	11.9		18.27
1994		127.4	2.0	20.2	2.5		23.0	26.5	116.5	194.8			64.10
1995		30.2	82.3	32.7	32.4		16.7	13.0	36.8	43.0	28.5		35.06
1996		69.4	67.3	119.9	8.3		169.1	52.2	230.8	193.3			113.78
1997	193.8	114.9	400.7	90.3	76.4		135.0	259.1	150.2	247.8			185.37
1998	184.3	92.1	260.3	217.0	168.3		18.4	91.7	98.9	206.0	301.8		163.87
1999	364.1	431.7	125.9	255.0	3.0	23.6	107.1	64.4	81.1	151.2	123.6	134.1	155.39
2000	27.1	288.5	267.1	154.8	116.1	10.4		51.1	36.2	119.5	291.8		136.25
2001		169.7	82.4	91.3	57.8		17.7	11.1	8.1	26.6	22.9	3.1	44.61
2002		74.5	14.2	76.9	63.2	164.6	35.7	23.8	22.8	14.3	40.1		
Mean	153.9	115.3	108.8	88.3	49.4	45.8	64.1	50.3	60.4	102.8	117.2	68.6	

Table 5: Average monthly mean SDSC (Spanish data, 1989-2002)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989			1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		
1990		1.000	1.000	1.000	1.000	0.604	0.501		1.000	1.000		
1991		1.000	1.000	1.000	1.000	1.000	1.000	0.995				
1992		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.338		
1993							1.000	1.000	1.000	0.994	1.000	
1994		1.000	1.000	1.000	1.000		1.000	1.000	0.999	1.000		
1995		1.000	1.000	1.000	1.000		1.000	0.994	1.000	1.000	1.000	
1996		1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000		
1997	1.000	1.000	1.000	1.000	1.000		0.937	1.000	1.000	1.000		
1998	0.996	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	
1999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2000	0.995	1.000	1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000	
2001		0.974	0.998	0.999	1.000		1.000	0.969	0.921	0.646	0.576	1.000
2002		0.966	1.000	0.984	1.000	1.000	1.000	0.997	0.995	0.755	0.895	

Table 6: Average monthly mean SDAC (Spanish data, 1989-2002)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1989			0.003	0.008	0.024	0.021	0.049	0.010	0.011	0.007			0.015
1990		0.020	0.049	0.066	0.045	0.029	0.045		0.004	0.214			0.052
1991		0.035	0.023	0.021	0.014	0.024	0.013	0.003					0.015
1992		0.032	0.038	0.035	0.052	0.100	0.166	0.050	0.010	0.036			0.058
1993							0.041	0.026	0.050	0.066	0.016		0.020
1994		0.167	0.003	0.012	0.002		0.021	0.027	0.095	0.213			0.067
1995		0.014	0.027	0.011	0.014		0.011	0.009	0.016	0.034	0.040		0.020
1996		0.046	0.035	0.052	0.003		0.153	0.048	0.268	0.268			0.109
1997	0.150	0.111	0.204	0.065	0.114		0.175	0.313	0.156	0.201			0.165
1998	0.133	0.107	0.153	0.164	0.150		0.038	0.124	0.116	0.197	0.356		0.154
1999	0.206	0.191	0.088	0.170	0.004	0.040	0.275	0.082	0.094	0.168	0.184	0.166	0.139
2000	0.024	0.127	0.096	0.109	0.131	0.025		0.086	0.029	0.125	0.190		0.094
2001		0.147	0.059	0.093	0.033		0.030	0.016	0.005	0.020	0.027	0.006	0.040
2002		0.076	0.016	0.110	0.103	0.198	0.034	0.027	0.015	0.018	0.036		0.063
Mean	0.103	0.077	0.057	0.065	0.049	0.054	0.081	0.059	0.062	0.112	0.121	0.086	

Table 7: Average monthly mean SDAD (Spanish data, 1989-2002)

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1989			0.169	0.100	0.275	0.206	0.214	0.140	0.053	0.039			0.133
1990		0.162	0.505	0.389	0.295	0.180	0.590		0.073	0.982			0.353
1991		0.282	0.171	0.416	0.364	0.436	0.059	0.013					0.193
1992		0.232	0.413	0.280	0.599	0.731	0.904	0.849	0.142	0.413			0.507
1993							0.810	0.845	0.828	0.610	0.223		0.368
1994		0.528	0.292	0.525	0.082		0.637	0.438	0.611	0.756			0.484
1995		0.119	0.109	0.051	0.070		0.213	0.390	0.374	0.152	0.295		0.197
1996		0.691	0.196	0.363	0.033		0.213	0.152	0.557	0.442			0.331
1997	0.864	0.722	0.922	0.560	0.885		0.800	0.881	0.382	0.549			0.730
1998	0.958	0.854	0.966	0.887	0.937		0.839	0.521	0.365	0.650	0.880		0.786
1999	0.849	0.864	0.730	0.862	0.789	1.000	0.932	0.409	0.770	0.542	0.740	0.499	0.749
2000	0.646	0.564	0.480	0.527	0.684	0.488		0.708	0.300	0.940	0.886		0.622
2001		0.873	0.538	0.664	0.203		0.602	0.160	0.036	0.294	0.175	0.025	0.325
2002		0.905	0.857	0.557	0.639	0.979	0.636	0.282	0.108	0.190	0.393	2002	0.554
	0.664	0.523	0.453	0.441	0.418	0.503	0.573	0.413	0.329	0.469	0.513	0.262	

Table 8: Spearman correlations between *Patagonotothen* spp. CPUE and SST (hauls with catches > 0)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Middle	ρ	**0.192**	**0.119**	**0.127**	**0.296**	0.089	-0.101	**-0.152**	**-0.078**	0.001	-0.084	0.173	-0.055
	p-value	0.003	0.005	0.001	0	0.122	0.089	0	0.041	0.983	0.275	0.089	0.72
	n	232	548	687	571	301	285	711	682	317	172	97	43
South	ρ	-	**0.189**	**0.251**	0.056	**0.119**	-0.076	**0.545**	**0.278**	0.016	**-0.116**	**-0.256**	-
	p-value	-	0.002	0	0.128	0.031	0.777	0	0	0.655	0	0	-
	n	-	273	616	732	331	14	86	438	825	953	383	-

Table 9: Spearman correlation between *Patagonotothen* spp. CPUE and depth (hauls with catches > 0)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Middle	ρ	0.066	0.066	**0.077**	**0.082**	**0.19**	0.013	0.054	**0.238**	0.098	0.013	0.042	**-0.468**
	p-value	0.319	0.121	0.043	0.05	0.001	0.825	0.153	0	0.081	0.864	0.682	0.003
	n	232	548	687	571	301	285	711	682	317	172	97	42
South	ρ	-	-0.106	-0.022	**-0.182**	**0.203**	0.085	-0.206	**0.172**	**0.159**	**-0.065**	0.092	-
	p-value	-	0.079	0.581	0	0	0.775	0.058	0	0	0.046	0.071	-
	n	-	273	616	730	331	13	86	438	825	953	382	-

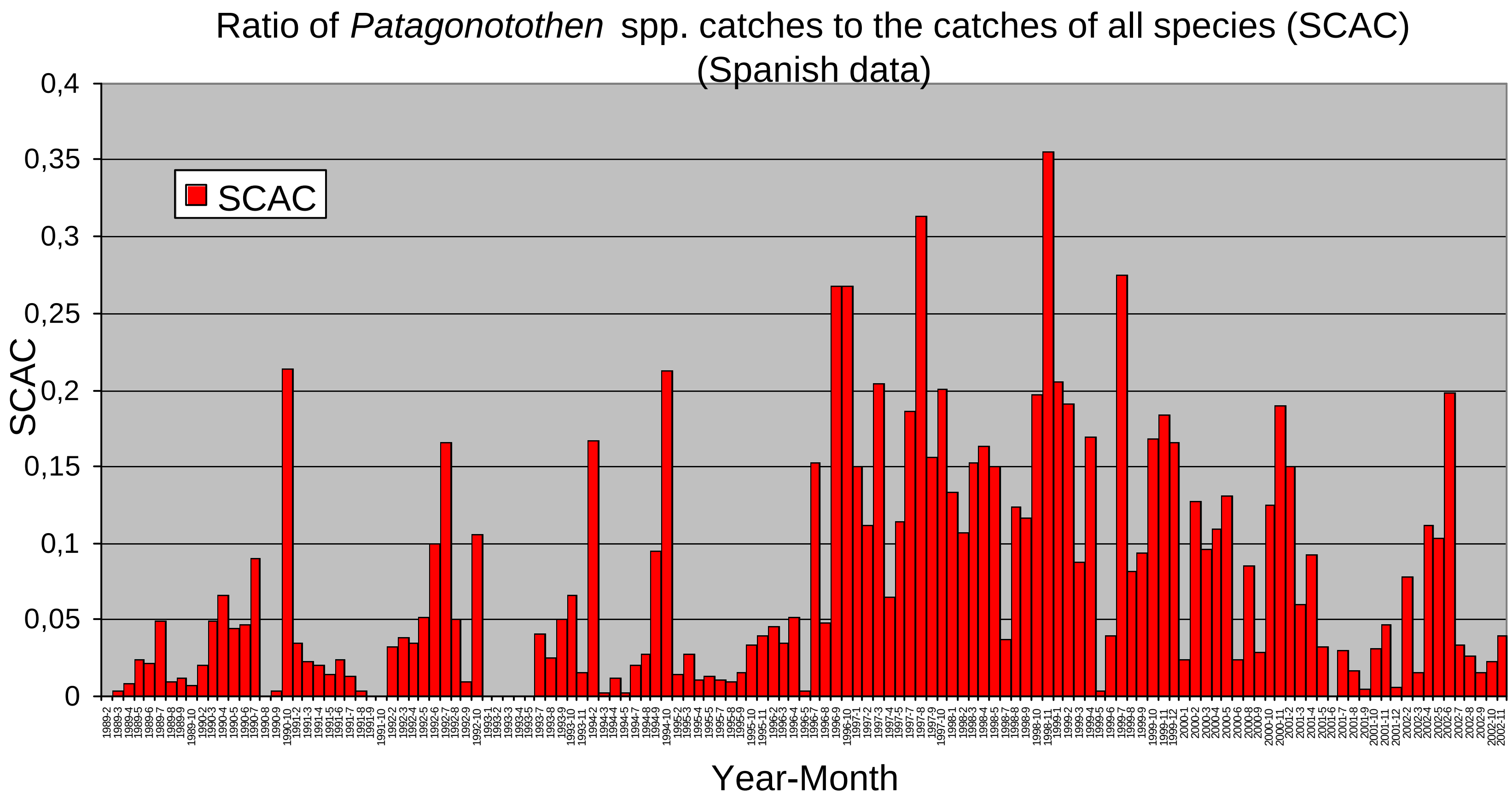


Figure 10: Ratio of *Patagonotothen* spp. catches to the catches of all species (SCAC)

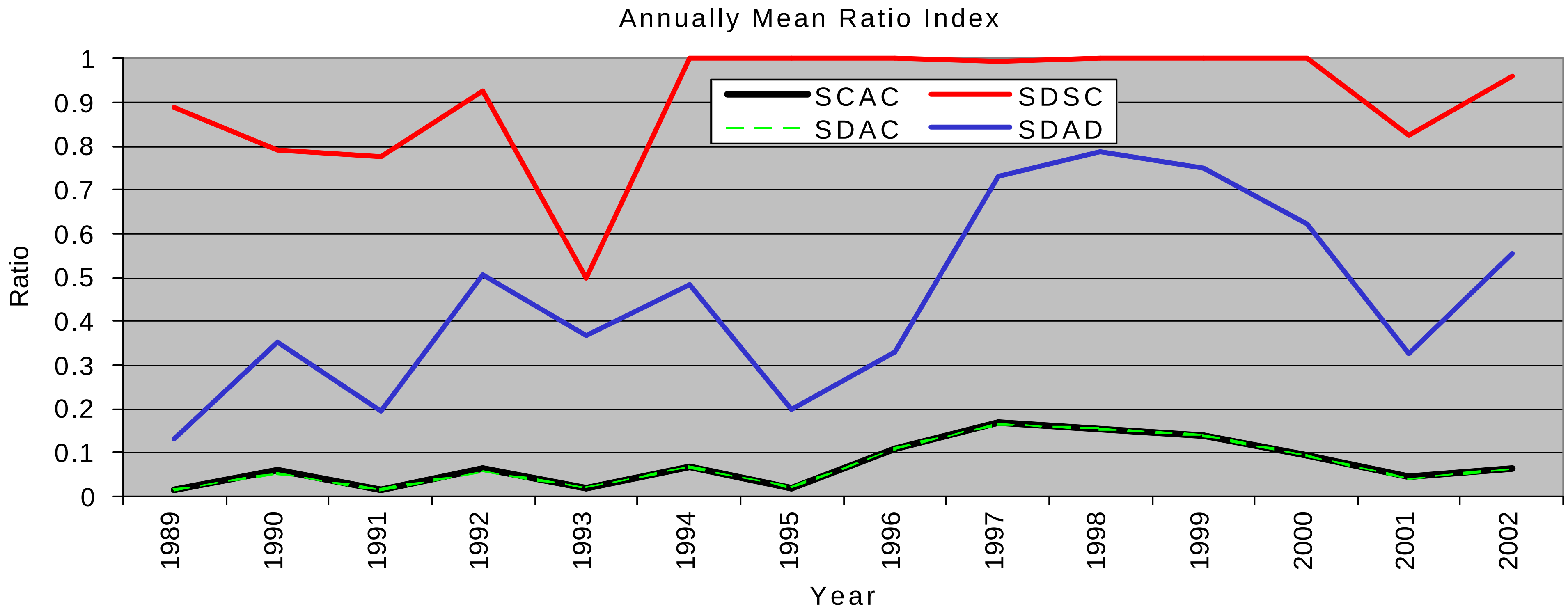


Figure 11: Annually Mean Ratio Index

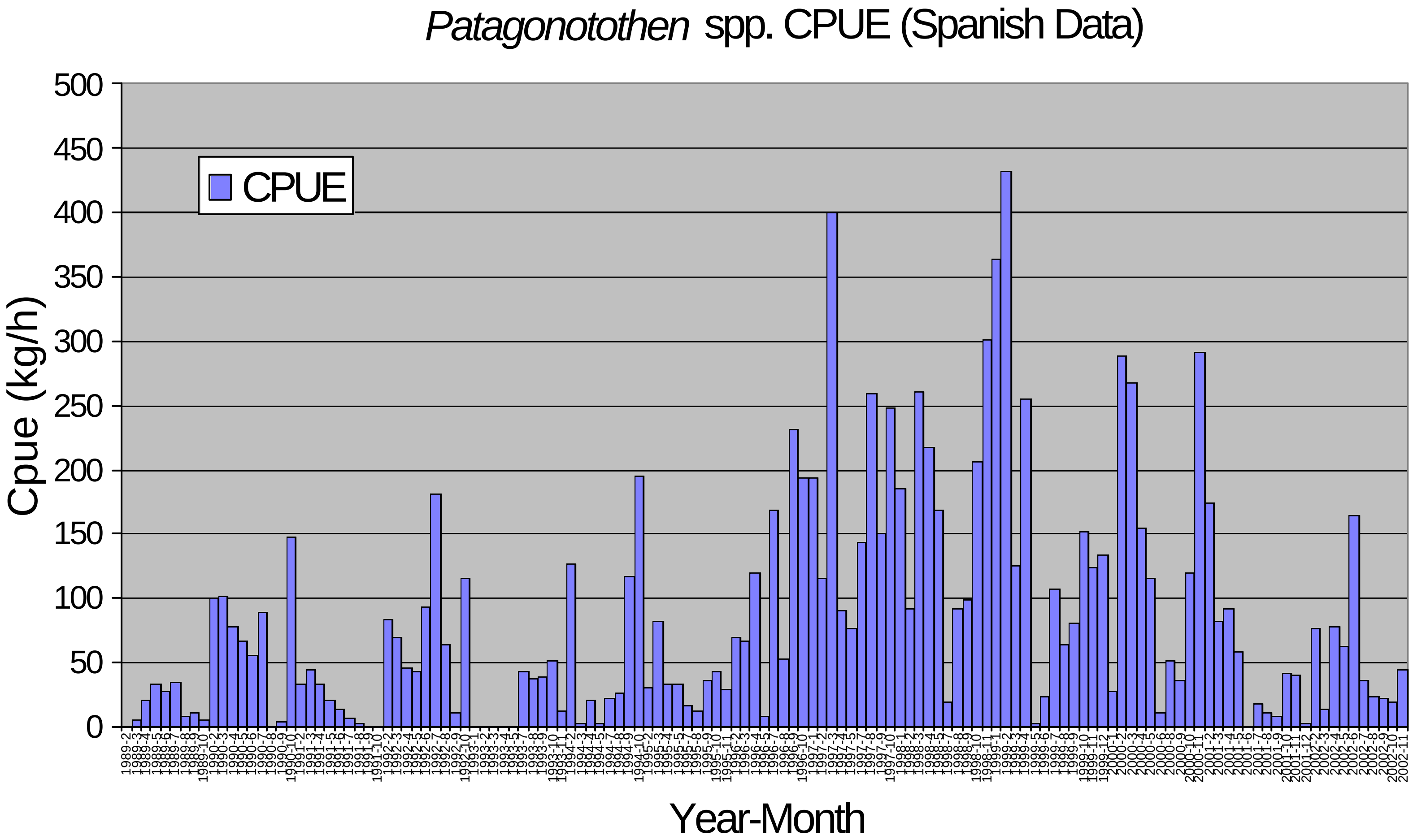


Figure 12: *Patagonotothen* spp. CPUE

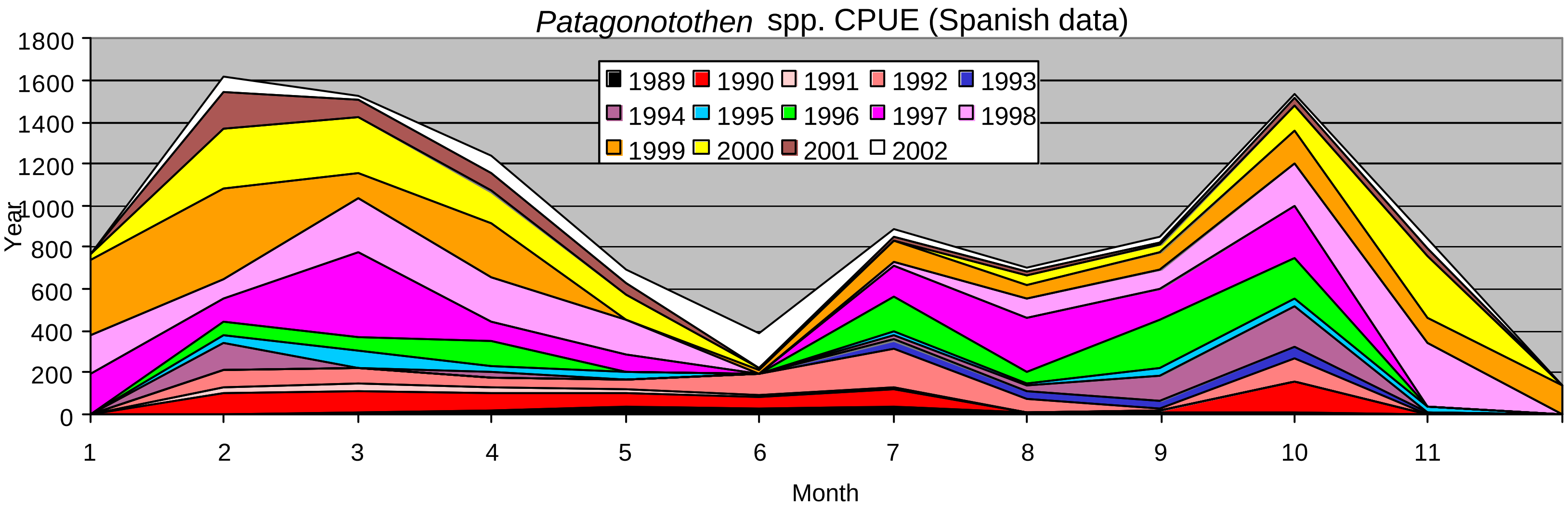


Figure 13: *Patagonotothen* spp. CPUE

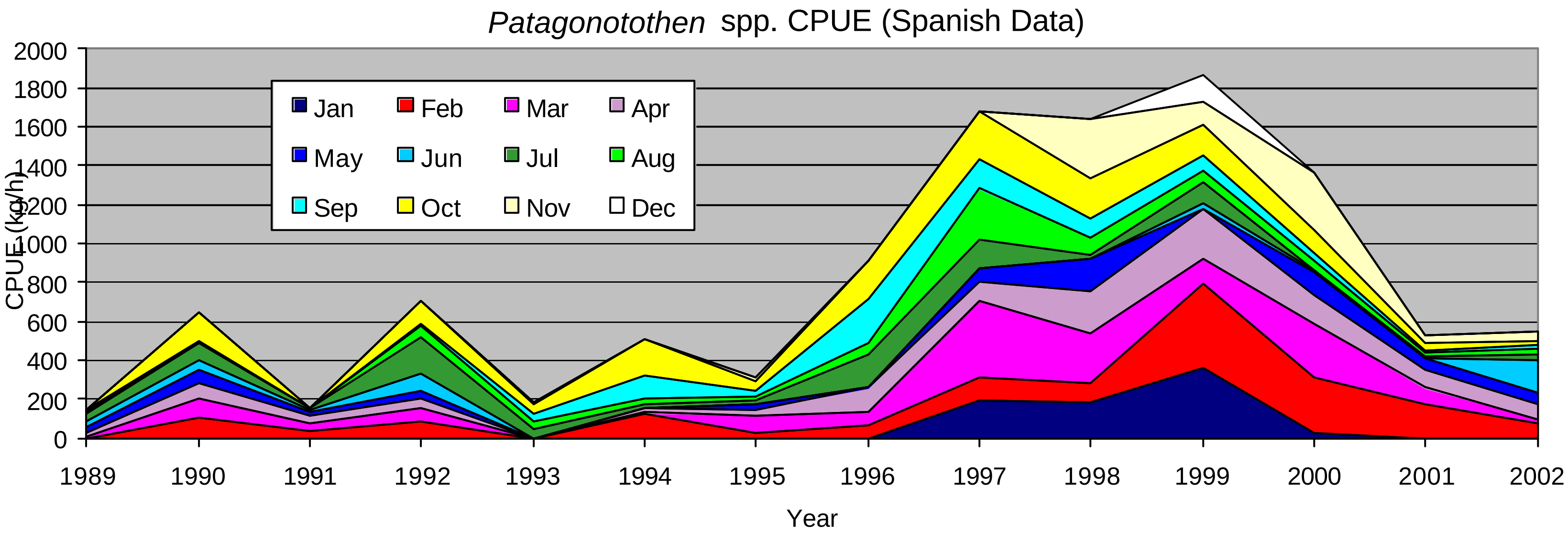


Figure 14: *Patagonotothen* spp. CPUE

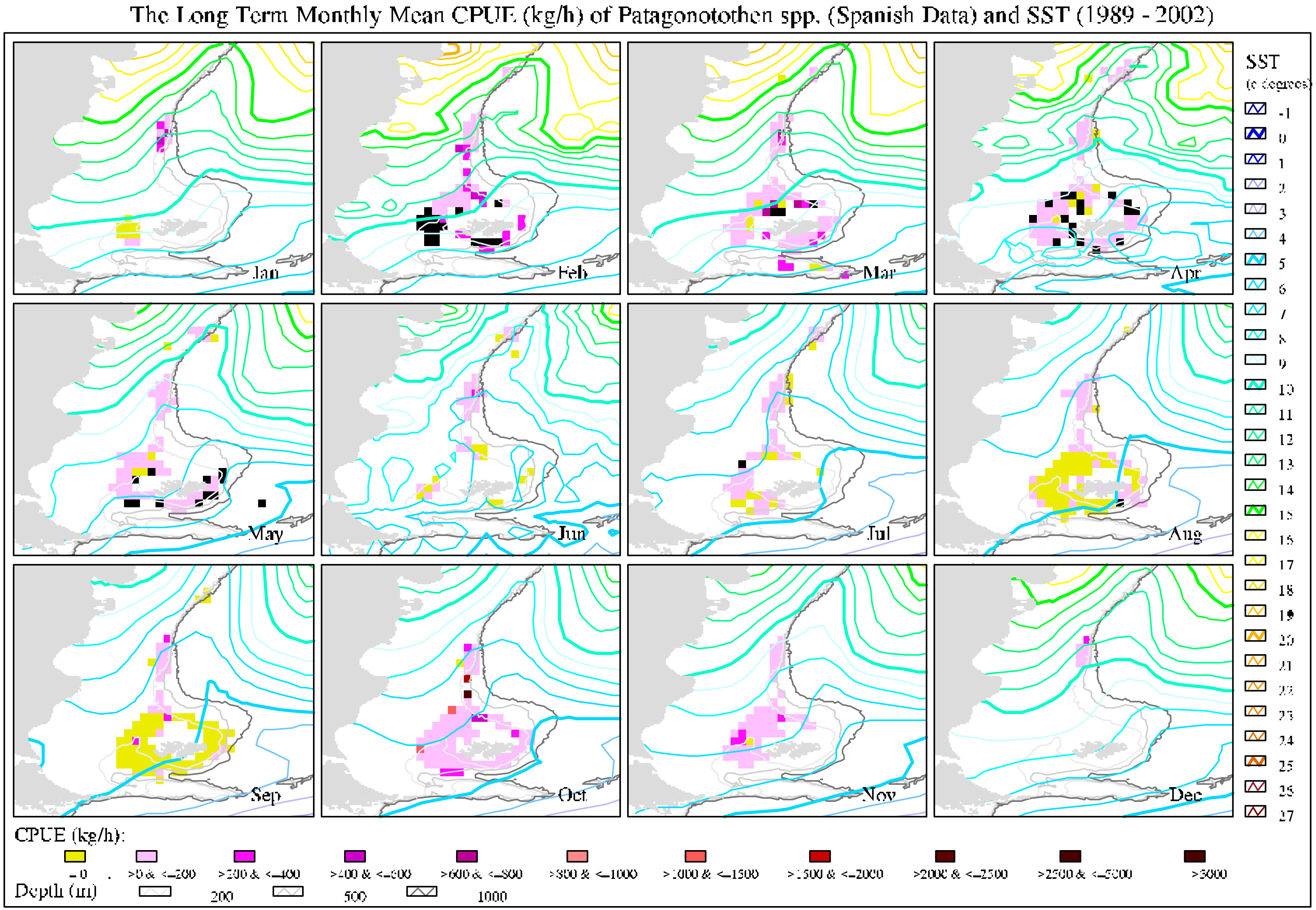


Figure 15: Long-term monthly mean CPUE of *Patagonotothen* spp. and SST (1989-2002)

The long-term mean ratio of catches of patagonotothen spp. to catches of all species (Spanish data, 1989 - 2002)

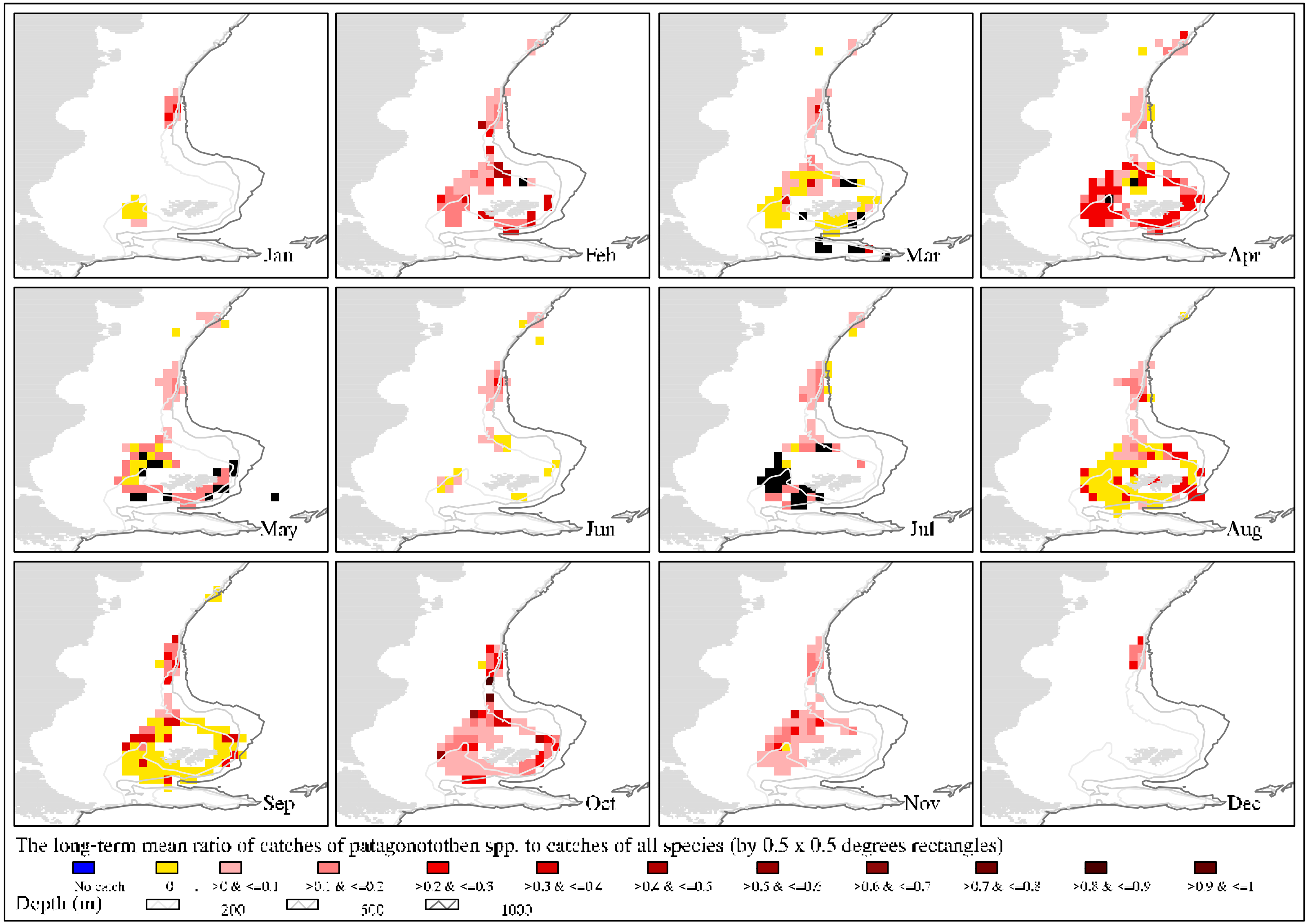


Figure 16: Long-term monthly mean ratio of *Patagonotothen* spp. catches to the catches of all species (SCAC)

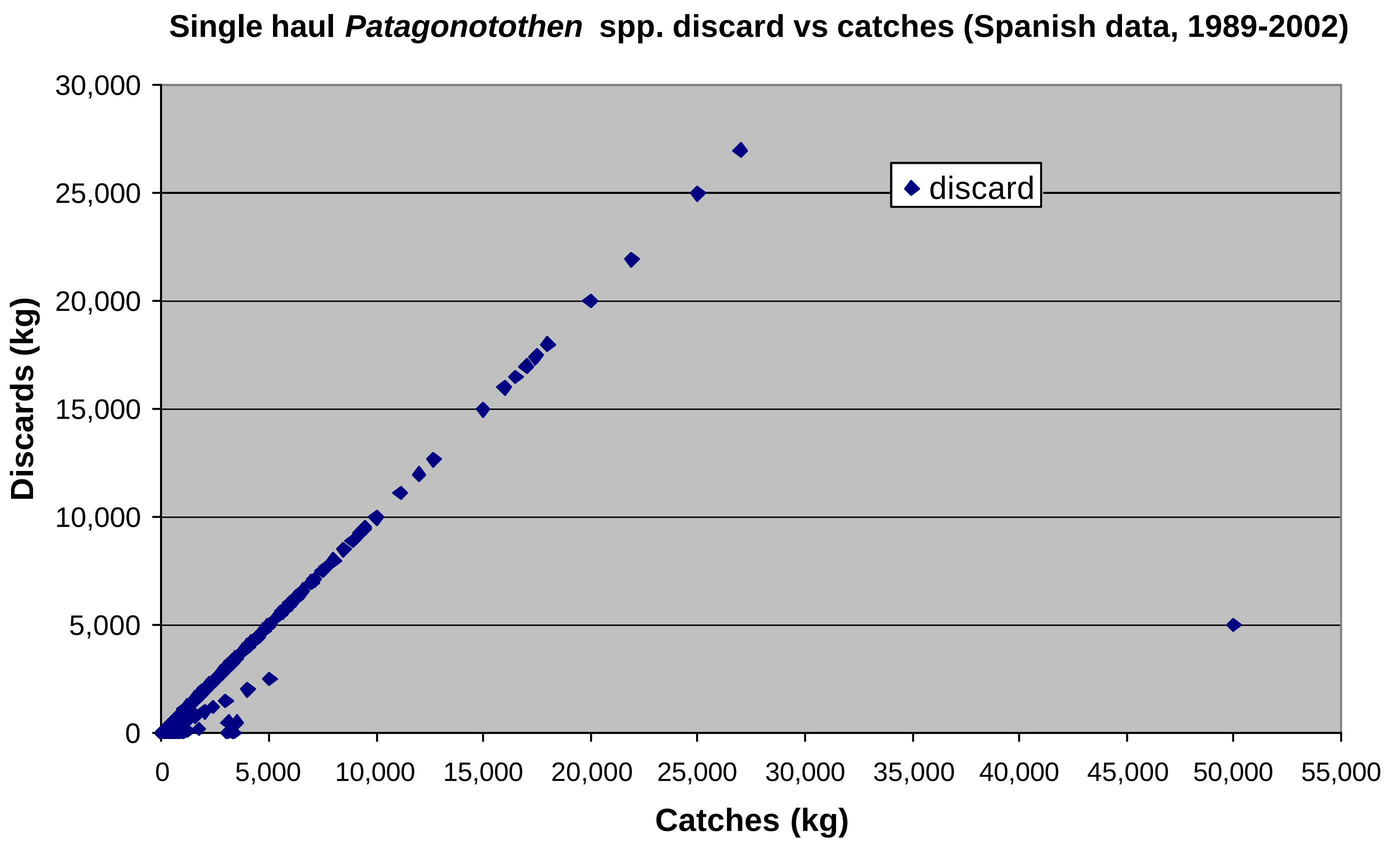


Figure 17: Single haul *Patagonotothen* spp. discard vs catches

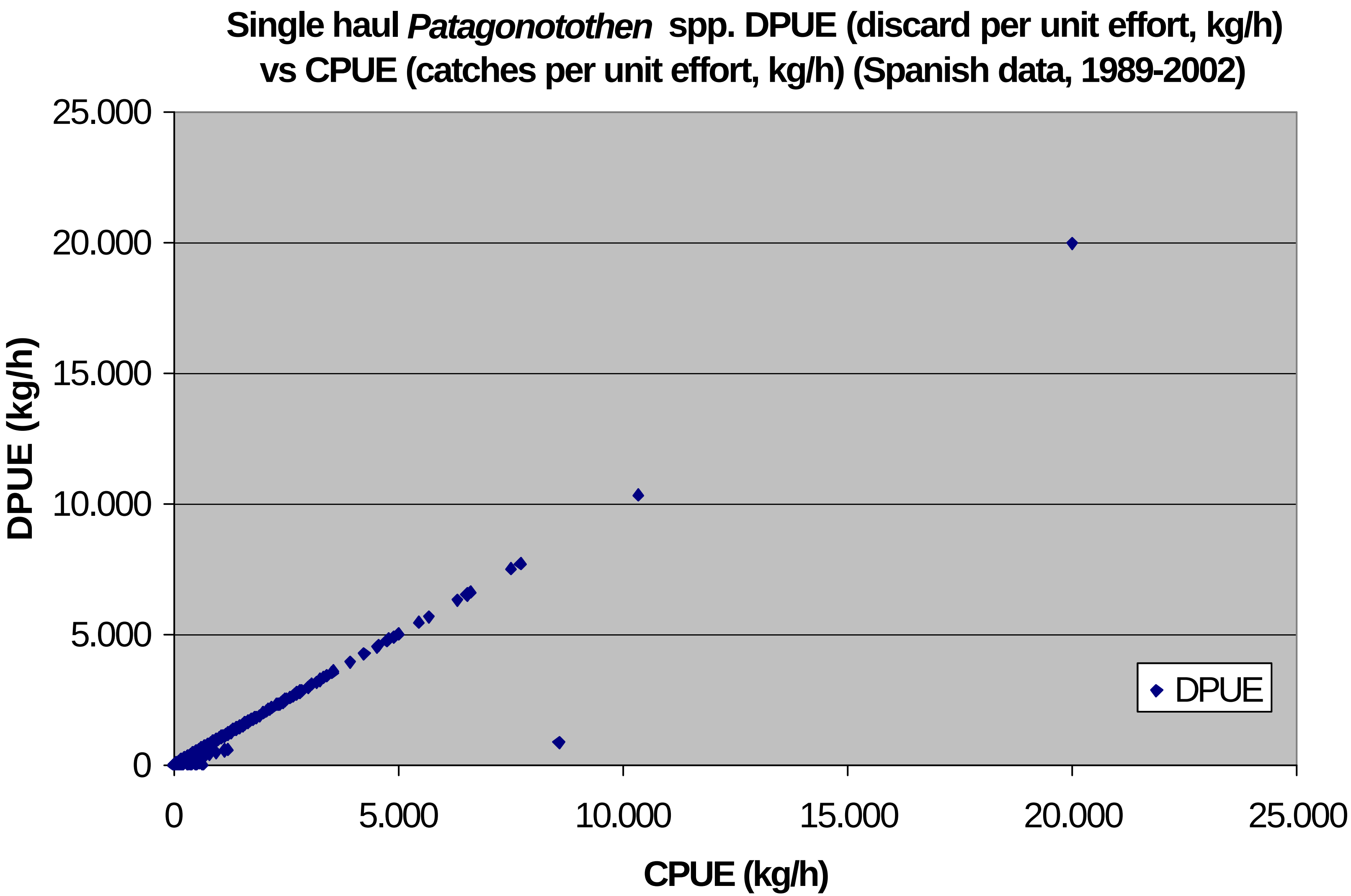


Figure 18: Single haul *Patagonotothen* spp. DPUE vs CPUE

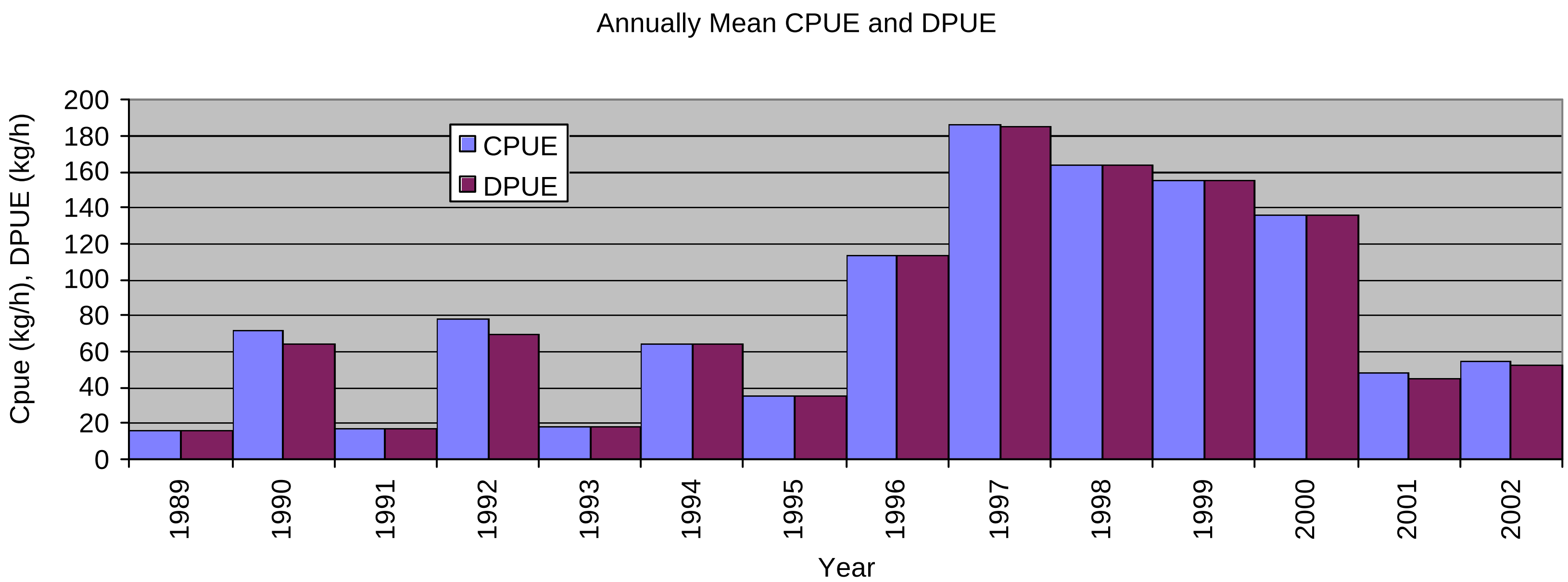


Figure 19: Annually Mean CPUE and DPUE

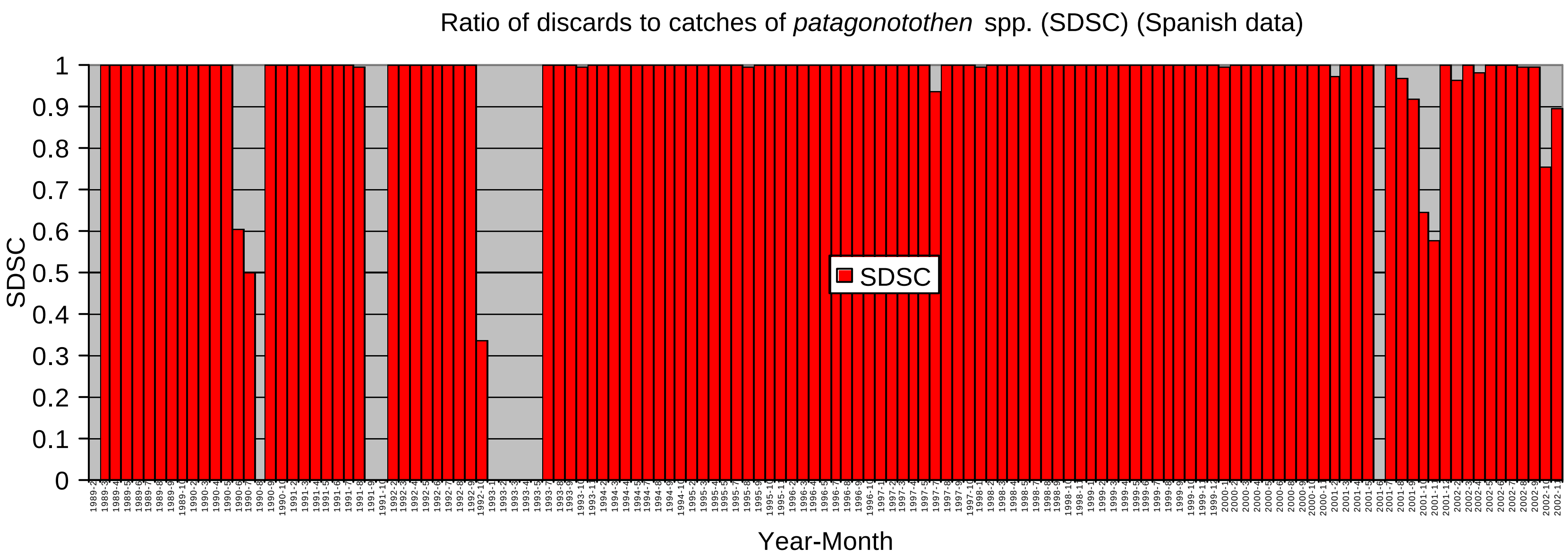


Figure 20: Ratio of discards to catches of *Patagonotothen* spp. (SDSC)

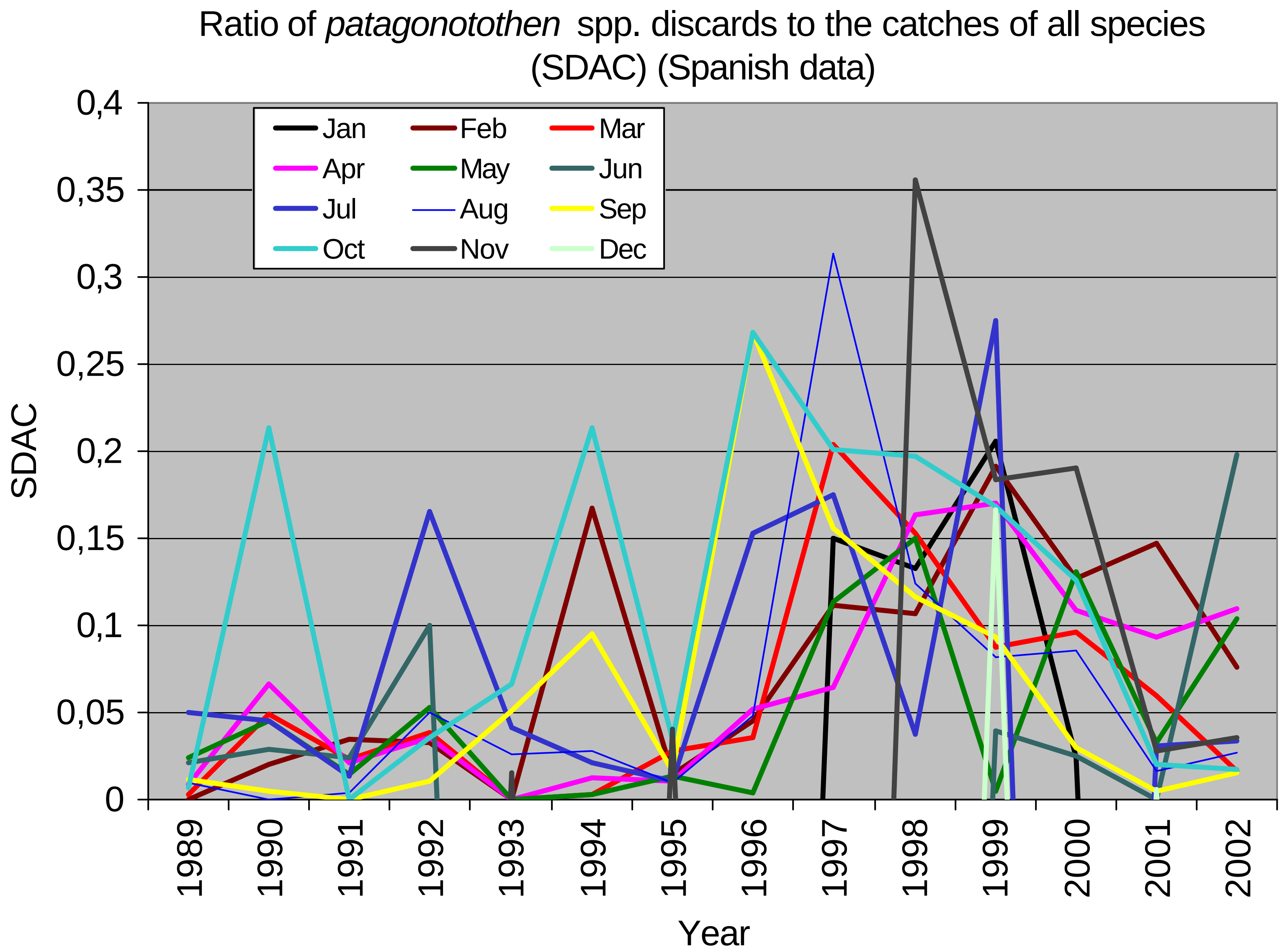


Figure 21: Ratio of *Patagonotothen* spp. discards to the catches of all species (SDAC)

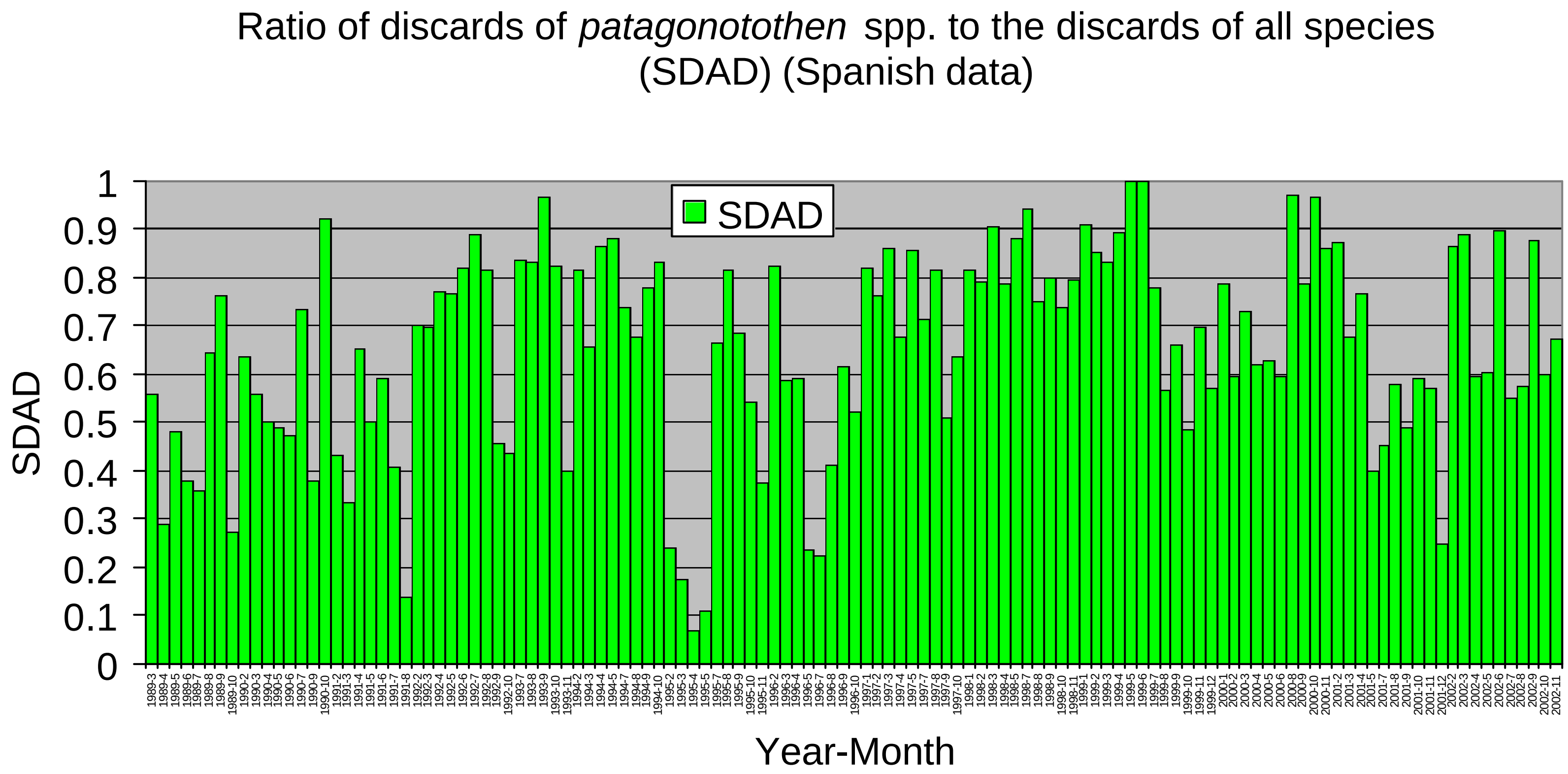


Figure 22: Ratio of discards of *Patagonotothen* spp. to the discards of all species (SDAD)

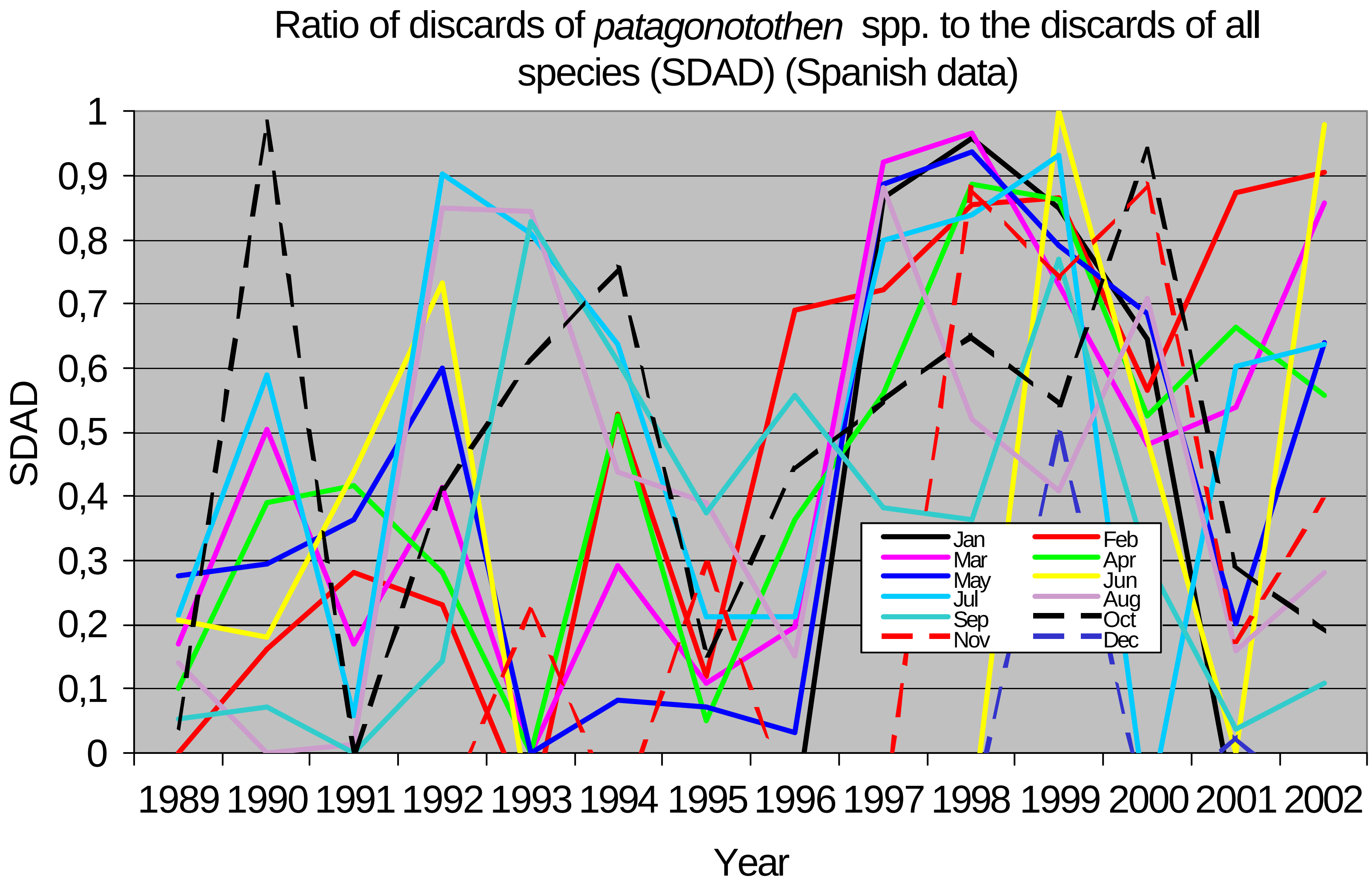


Figure 23: Ratio of discards of *Patagonotothen* spp. to the discards of all species (SDAD)

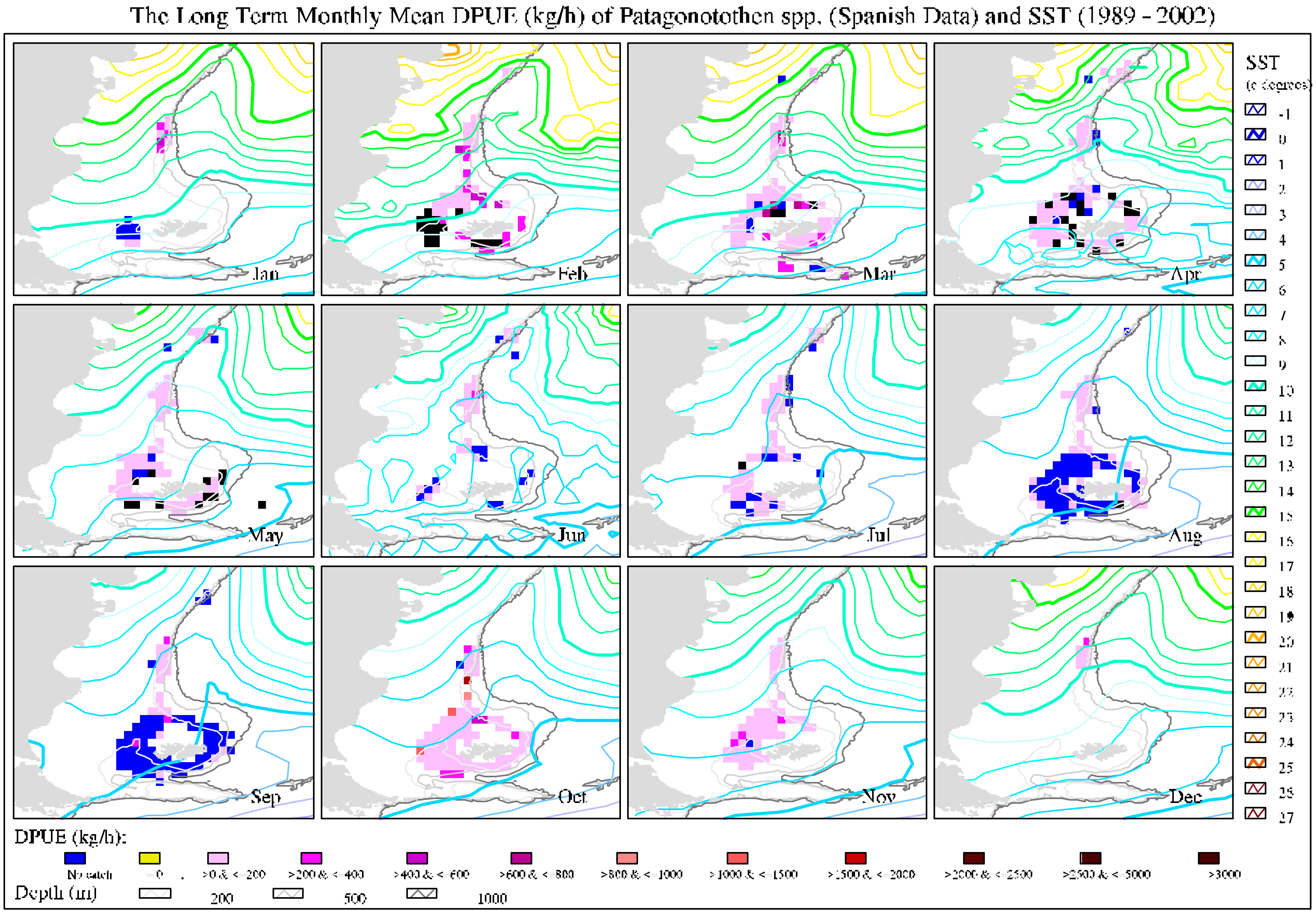


Figure 24: Long-term mean discards of *Patagonotothen* spp. per unit effort (kh/h) month by month.

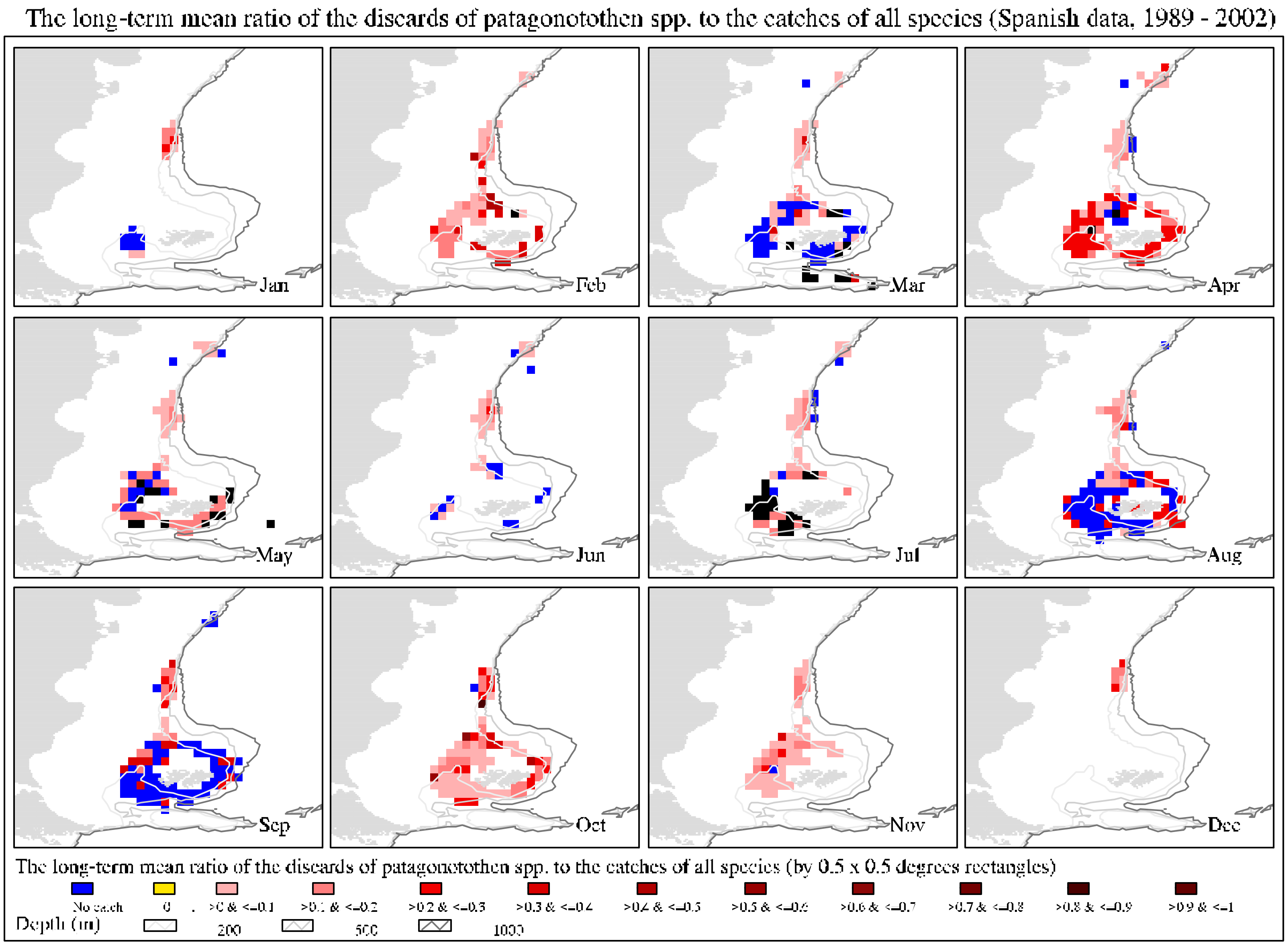


Figure 25: Long-term mean ratio of the discards of *Patagonotothen* spp.to the catches of all species month by month.

The long-term mean ratio of the discards to the catches of patagonotothen spp. (Spanish data, 1989 - 2002)

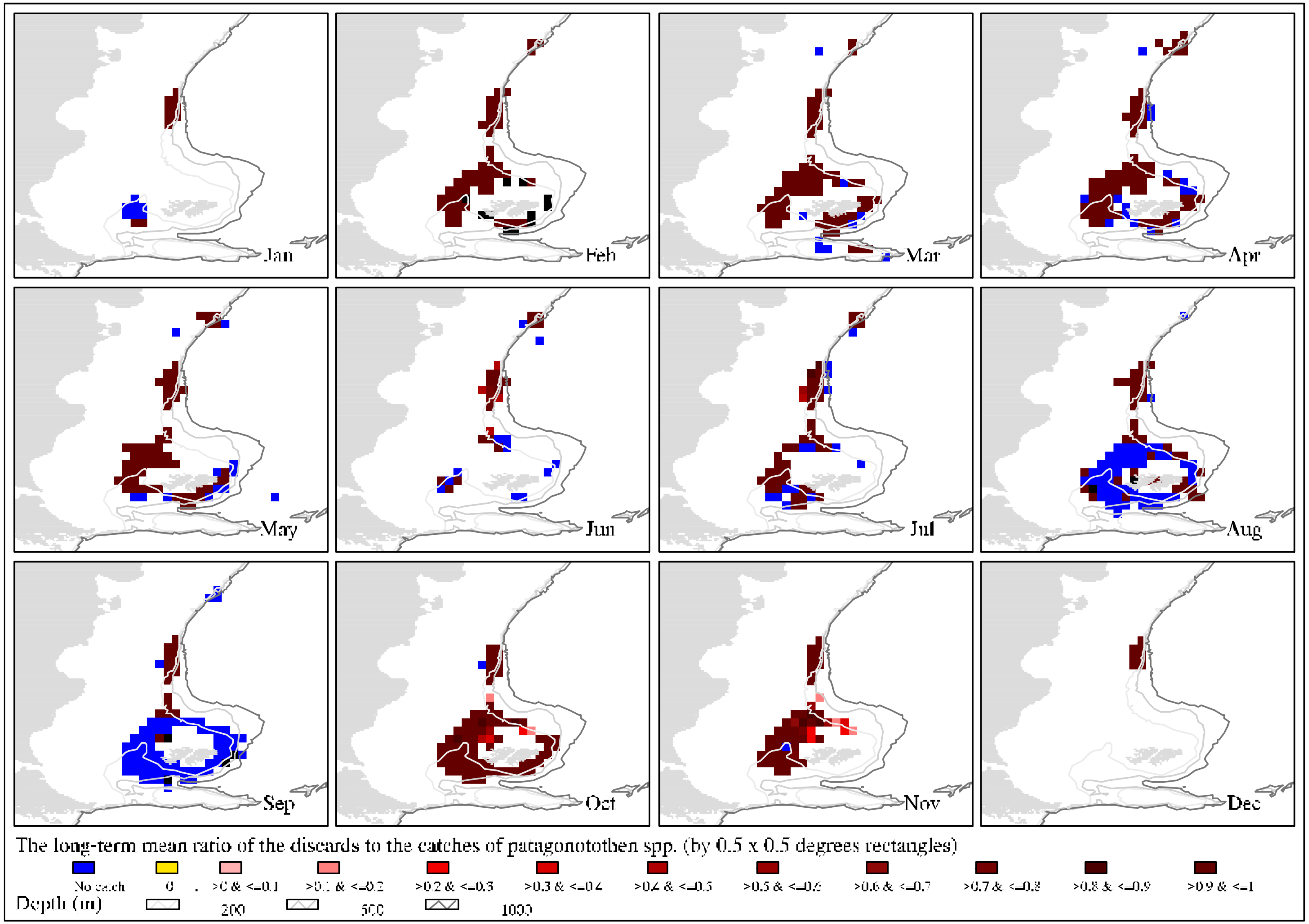


Figure 26: Long-term mean ratio of the discards to the catches of *Patagonotothen* spp. month by month

The long-term mean ratio of the discards of patagonotothen spp. to the discards of all species (Spanish data, 1989 - 2002)

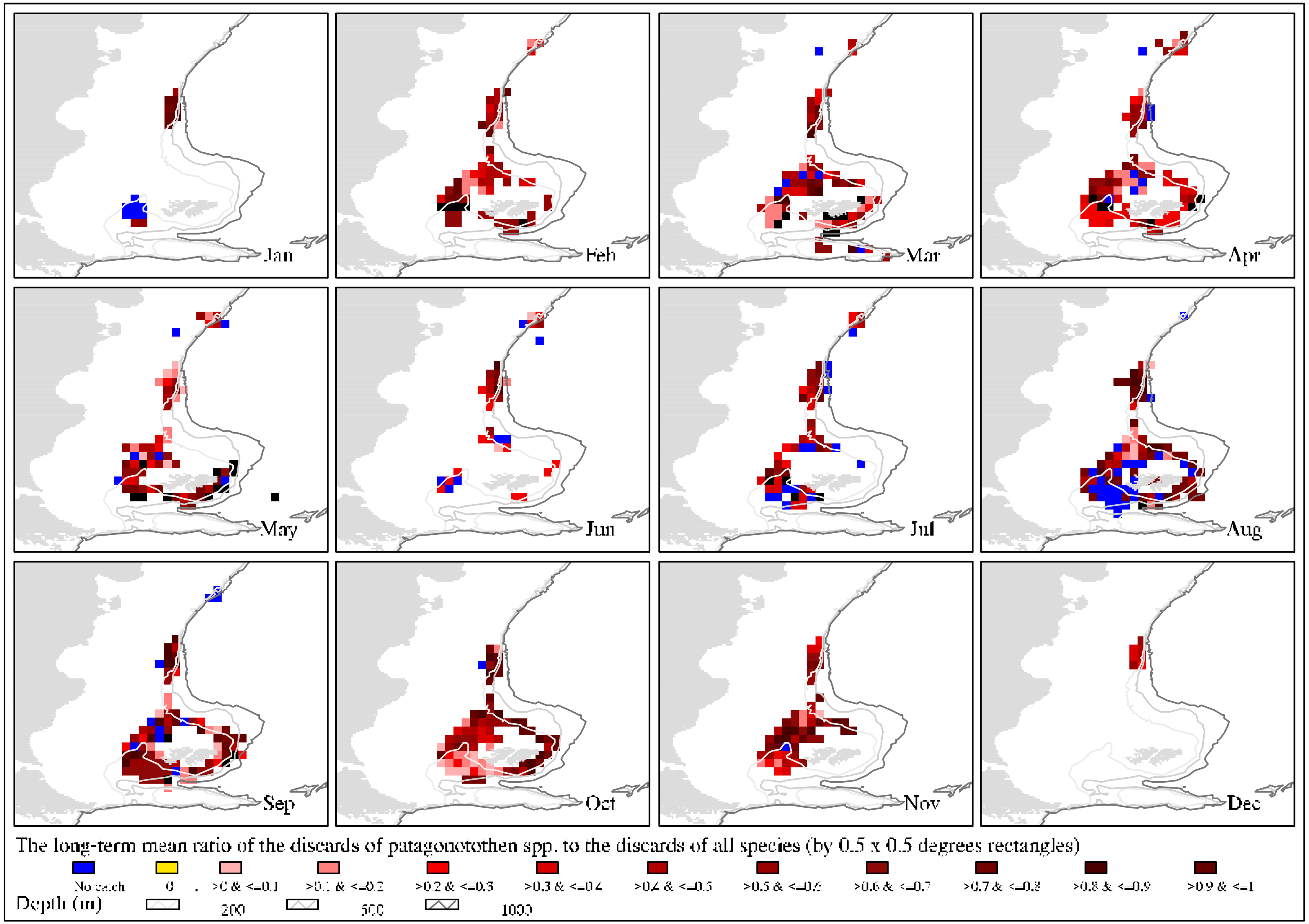


Figure 27: Long-term mean ratio of the discards of *Patagonotothen* spp. to the discards of all species month by month

Deliverable # 17: Fishery forecasting (2nd progress report, 2003)

Spanish fishery data

Original data were recorded by day, month, year, and longitude and latitude (including minutes). There are 11051 original haul records of *Patagonotothen* spp. in the Vigo (Malvinas) data.

Data scanning was firstly carried out to check the reliability of data to be used. CPUE (kg/h) was firstly calculated. The hauls with Nil CPUE and extremely high CPUE (>500) were not used in modelling. There are 614 hauls with *Patagonotothen* spp. CPUE >500, 120 hauls with CPUE = 0. Total 734 hauls, 6.64% of all hauls, were not considered at the first stage. However, Some hauls have not complete record of environmental variables. Further scanning the data also found that the zero values of SST and SBT recorded in some hauls may be wrong, as shown in Figures 28 and 30. Therefore, The hauls used for modelling are these hauls have SST and SBT greater than zero, and have depth value. There are only 890 hauls in the middle area, and 1725 hauls in the south area, were used in modelling. Figures 29 and 31 is the matrix plot of CPUE, location, and environmental variables of these hauls.

FIFD fishery data

FIFD data have only 1019 the records with catches of Patagonotothen spp. and 208 records have SST and SBT values over 17 years. Thus FIFD data are not used in the development of the model.

Statistical modelling

Since the relationships between CPUE and predictors may not be always linear in different situations, Generalised Additive Models (GAMs) were used to model the spatial and temporal distributions of CPUE. GAMs extend the concept of GLMs (generalised linear models) by fitting non-parametric functions to estimate the relationships between response and predictors. The non-parametric functions are estimated from the data using smoothing operations. The general form of a GAM is :

$$g(x) = \alpha + \sum f_i(x_i)$$

where g(x) is additive predictor, α is a constant intercept term, f_i are non-parametric functions of predictors or terms and x_i are predictors. g(x) can be used in all the situations where the linear predictors were used for generalised linear model. E.g. it can be a single term ($f(x) + \alpha$), a semi-parametric term ($x^t \beta + f(x) + \alpha$, t, β and α are constants) and a fully additive model ($\alpha + \sum f_i(x_i)$) (see Hastie, 1997 for detail). f_i are analogous to the regression coefficients in a linear model and are fitted using scatter plot smoothers, such as the locally weighted regression smoother and the smooth spline smoother.

In this study, the response is CPUE of Patagonotothen spp. A robust method (Venables & Ripley, 1999) within GAM was used to perform a robust version of the GAM fit. It provides a method not greatly affected by outliers and gives a good fit to the bulk of the data.

The models were developed using stepwise GAM method. The initial terms for each predictor consists of lineal, and spline smoother terms with df from 2 to 5. The predictors, the smoothers with different arguments for predictors and the model forms (parametric, non-parametric or semi-parametric) were determined automatically by GAM stepwise model-building algorithms in terms of AIC (Akaike Information Criterion, for detail see Hastie, 1997). The AIC statistic accounts simultaneously for the degrees of freedom used and the goodness of the fit: more parsimonious models have a lower AIC. The stepwise for GAMs allow one to step through arbitrary models along a pre-specified path. Then the stepwise selected the final models with the lowest AIC by dropping predictors or replacing the linear terms with non-parametric functions with predictors.

Deviance estimated in the models, analogous to the residual sums of squares, is a measure of the fit of the models. A pseudo coefficient of determination, R2, is estimated as one minus the ratio of the deviance of the model to the deviance of the null model (1 - deviance/null.deviance, see Swartzman et al, 1992). Thus the pseudo coefficient was used as an index for the model fit. The importance of an individual term to the model fit was illustrated by GAM plots. Dashed lines represent two standard error boundaries around the covariate main effects. Tick marks on the x-axis show locations of data points. The density of points for different covariate values is shown by the rug under the single covariate effect plots. The dished curves are pointwise 2 x standard-error bands.

Two kind of models are developed. The first, defined as monthly-based models, were developed based on single haul records of CPUE, and environmental variables, i.e. longitude, latitude, SST, SBT and depth. The single month models were developed for the middle and south areas separately. As the first type models show high residual deviance, caused by the high diversity of CPUE between the hauls located at same locations and with similar values of environmental variables. Therefore, we tried the second type of model, defined as the overall model, bases on single haul with the ratio of *Patagonotothen* spp. catches in weight to the haul total catches of all species in weight is equal or greater than 0.5. This model was developed using single haul records of CPUE and environmental variables, i.e. year, month longitude, latitude, SST, SBT, and depth, in the middle and south areas.

Results

Monthly-based models for the middle and south areas

Tables 10 and 11 list the model outputs for the middle area. Figures 32 to 48 show the model fit to the predictors in the middle and south areas respectively. Figures 49 to 65 show the comparison between fitted CPUE value and the original CPUE value in the middle and south areas respectively. The pseudo R listed in Tables 10 and 11 indicated that the pseudo R in most of months are high. The model terms are different from month to month. The residual deviance in each month model is high. By comparing the fitted and original CPUE values in Figures 49 to 65, it is found most low original CPUE have over-fitted values, and most high original CPUE have under-fitted values. The reason is that, as mentioned in section 2, within a very small area, and with similar values of environmental variables, some hauls have very high CPUE, but some have very low CPUE.

The overall model

The overall model was developed using the haul records with the ratio of *Patagonotothen* spp. catches in weight to the haul total catches of all species in weight is equal or greater than 0.5. As the number of hauls used in the model is very limited, the model developed cover whole year and the middle and south areas. The model output is: Formula = cpue ~ s(depth, 2) + lat + s(month, 4). The residual deviance is: 212473.7 on 23.02684 degrees of freedom. The pseudoR = 0.50. Figure 66 shows the matrix plot of CPUE, location and environmental variables used in the overall model (hauls with the ratio of *Patagonotothen* spp to the catches of species >=0.5). Figure 67 shows the model fit for CPUE to the predictor terms. Figure 68 show the comparison between fitted CPUE value and the original CPUE value in the middle and south areas respectively

Discussion

The fishery forecasts developed by Aberdeen University and IEO could not be tested by the observers at the end of the second fishing season as originally planned in the work programme, due to the fact that the fleet had already stopped their operations. This happened due to an earlier than expected closure of the fishery around the Falkland Islands. For validation of the forecasts, a model was developed making predictions with historical data and comparing them to the most recent years data, with acceptable results.

Although the models developed using step GAM method, which give the optimum outputs, the model results show that the residual deviance is high. In general, the low CPUE values have over-fitted values, and the high CPUE values have under-fitted values. This is caused by the high diversity of CPUE values from the hauls located in the same area and with the similar environmental condition.

The monthly-based models show clear difference from month to month. This may indicate the complex of environment influence on fish distribution and abundance. However, the overall model has only depth, lat, and month predictors, indicating that, on the large area scale, sea temperature is not importance environmental factor, lat (=latitude) may reflects fish migration, and depth is important for fish abundance. As depth is high related to longitude, the model does not select longitude as a predictor.

Although the models have high residual deviance, they give average fitted values compared with the original CPUE values. This may indicate that the models are feasible for predicting average fish abundance levels.

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Hastie, T. J., (1997). Generalised Additive Models, In Statistical Models in S. Chapman & Hall, London.

Venables, W. N., and Ripley, B. D. (1999). Modern Applied Statistics with S-PLUS, 3rd ed. Springer-Verlag, New York.

Swartzman, Huang, Q. C., and Kaluzny, S. (1992). Spatial Analysis of Bering Sea Groundfish Survey Data Using Generalised Additive Models. Canadian Journal of Fisheries and Aquatic Science, 49: 1366-1378.

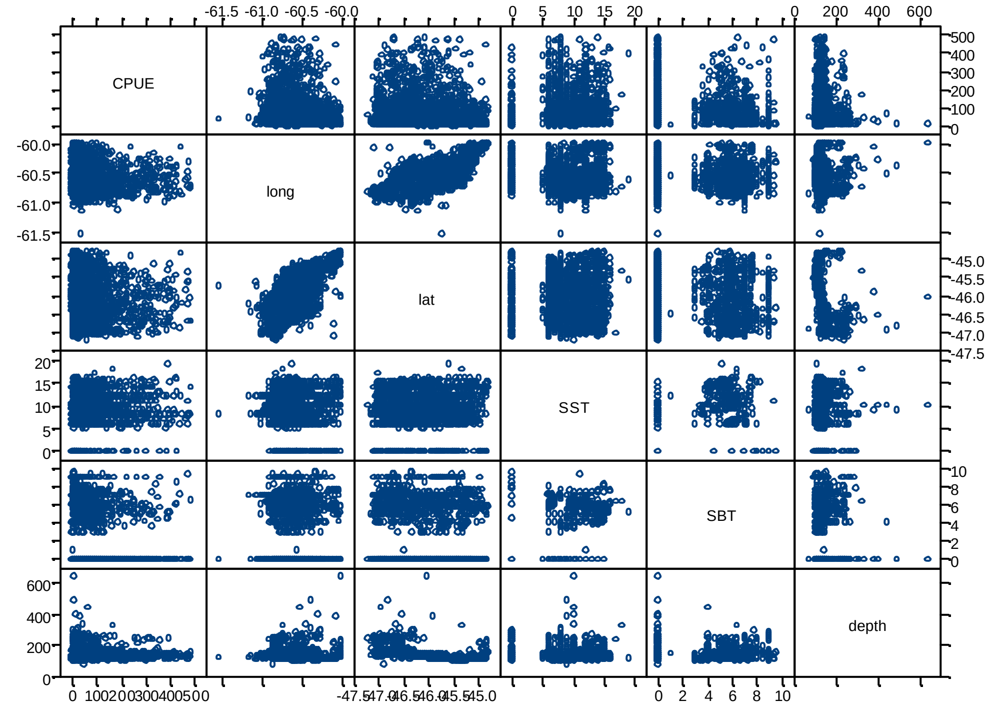


Figure 28. Matrix plot of haul records of CPUE and predictors with 0 value of SST and SBT. The figure shows that hauls with SST = 0 or SBT=0 are not suitable to be used in modelling (middle area).

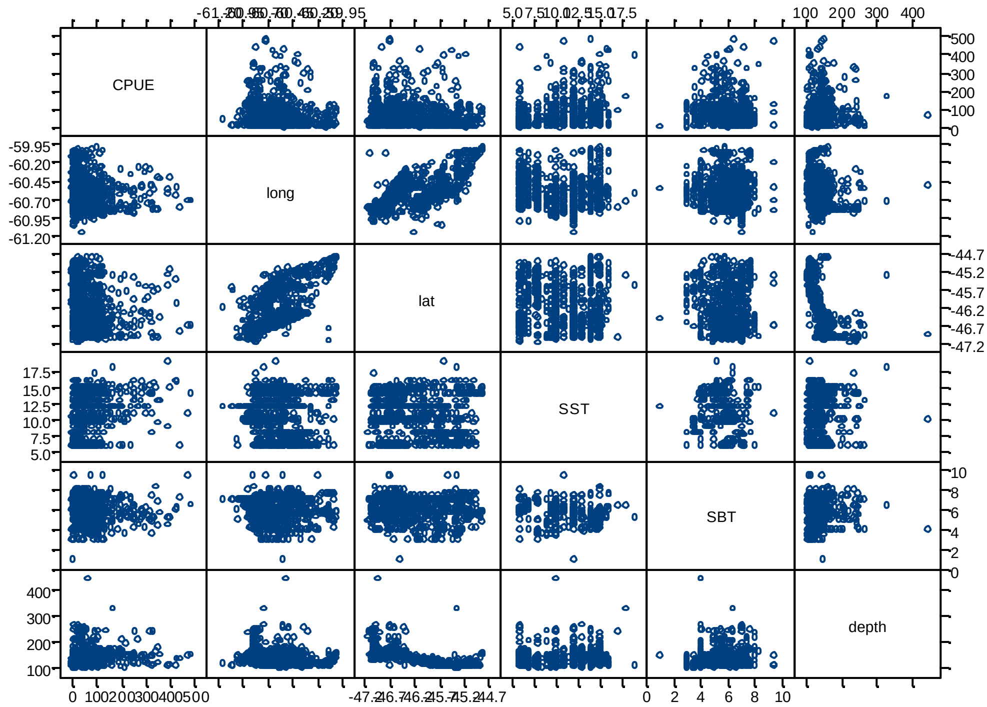


Figure 29. Matrix plot of CPUE and predictors, after deleting the hauls with SST=0 or SBT=0 (middle area).

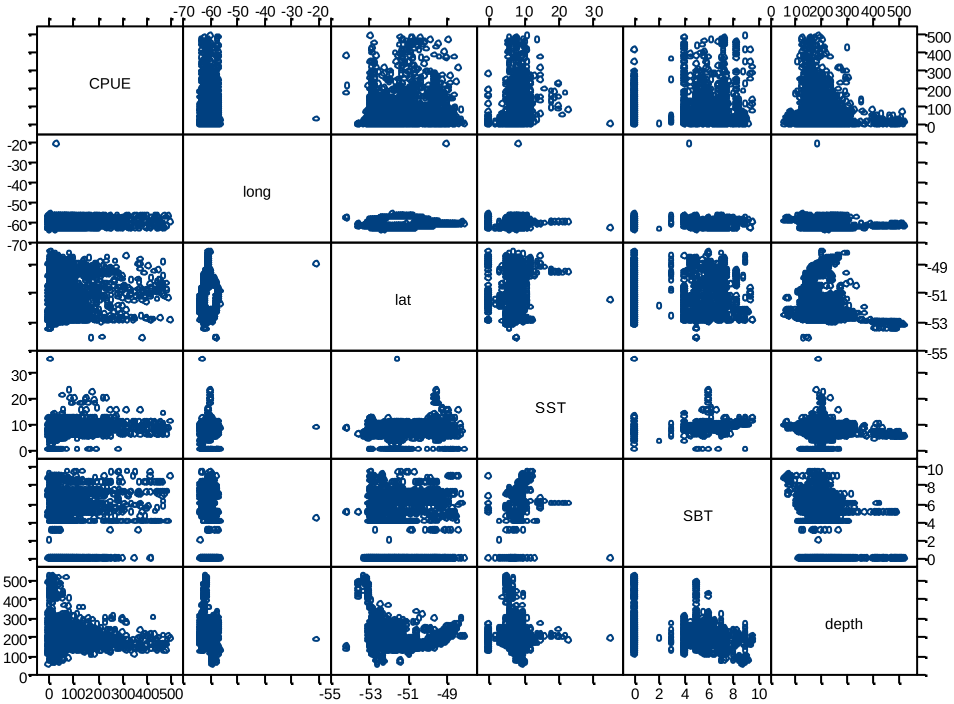


Figure 30. Matrix plot of haul records of CPUE and predictors with 0 value of SST and SBT. The figure shows that hauls with SST = 0 or SBT=0 are not suitable to be used in modelling (south area).

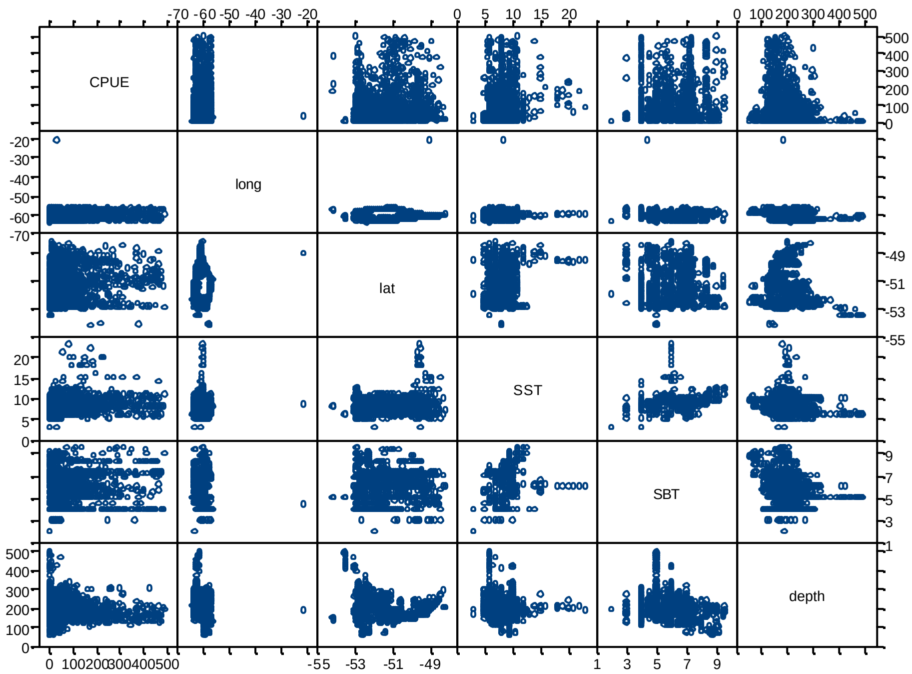


Figure 31. Matrix plot of CPUE and predictors, after deleting the hauls with SST=0 or SBT=0 (south area).

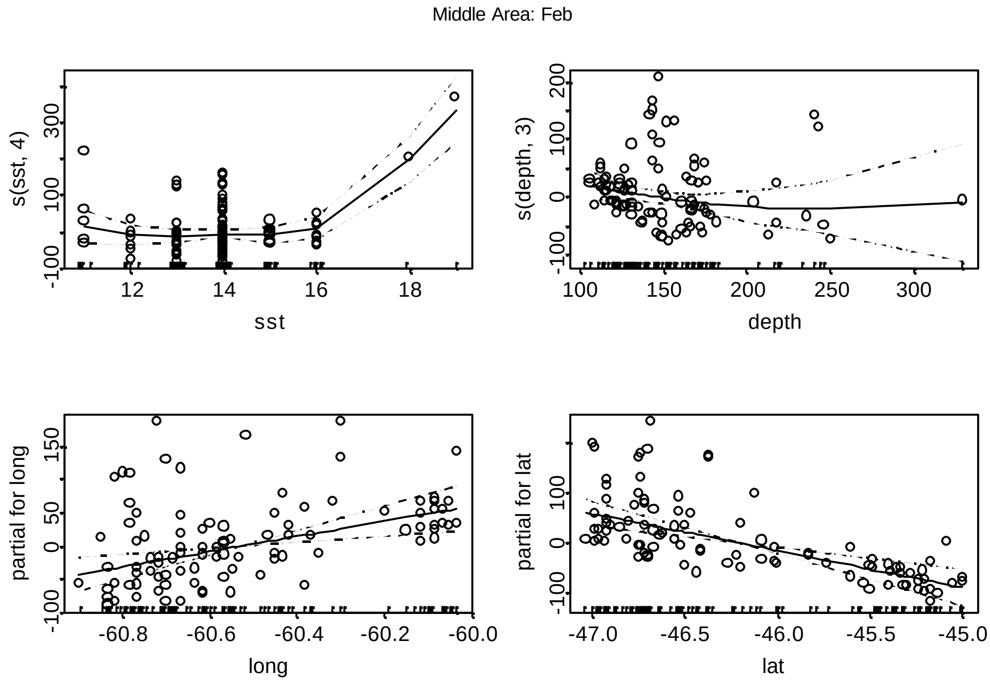


Figure 32. Middle area in February: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

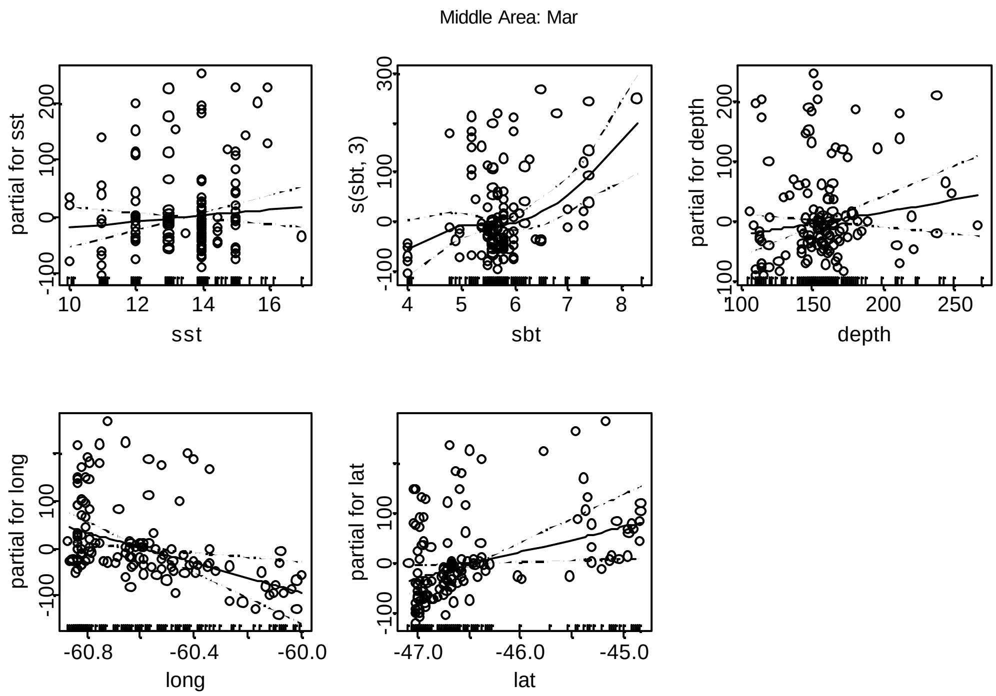


Figure 33. Middle area in March: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

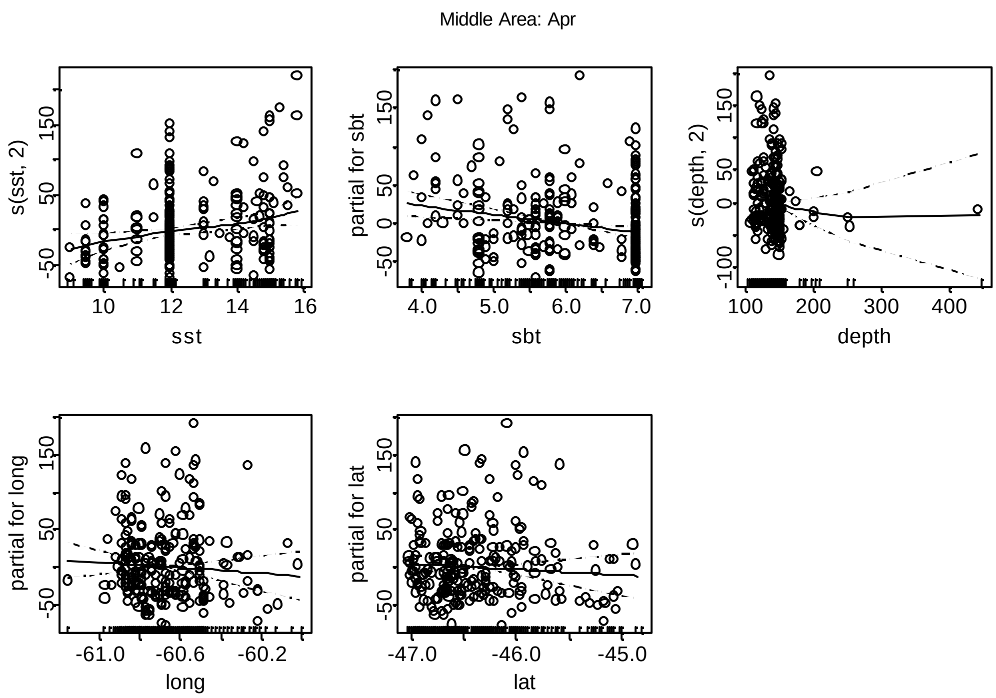


Figure 34. Middle area in April: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

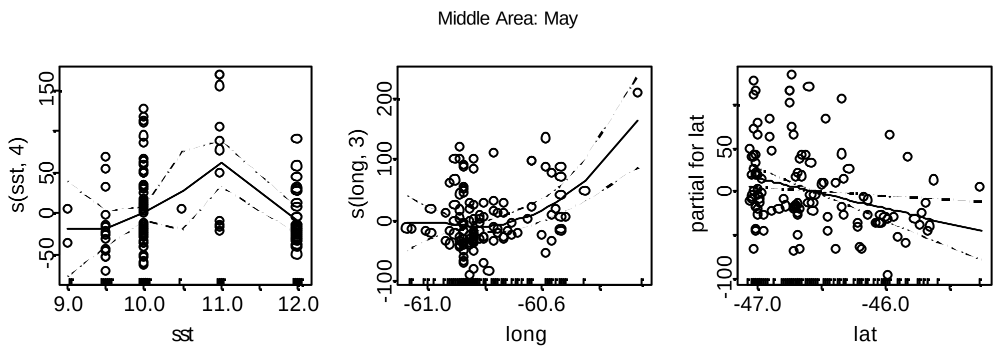


Figure 35. Middle area in May: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands)

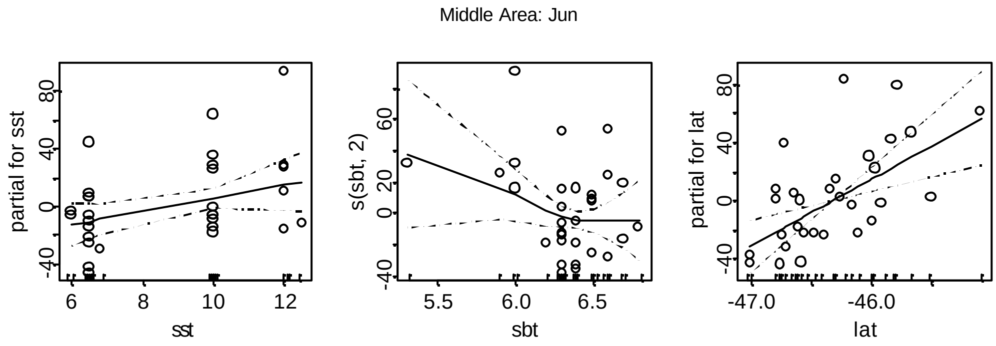


Figure 36. Middle area in June: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

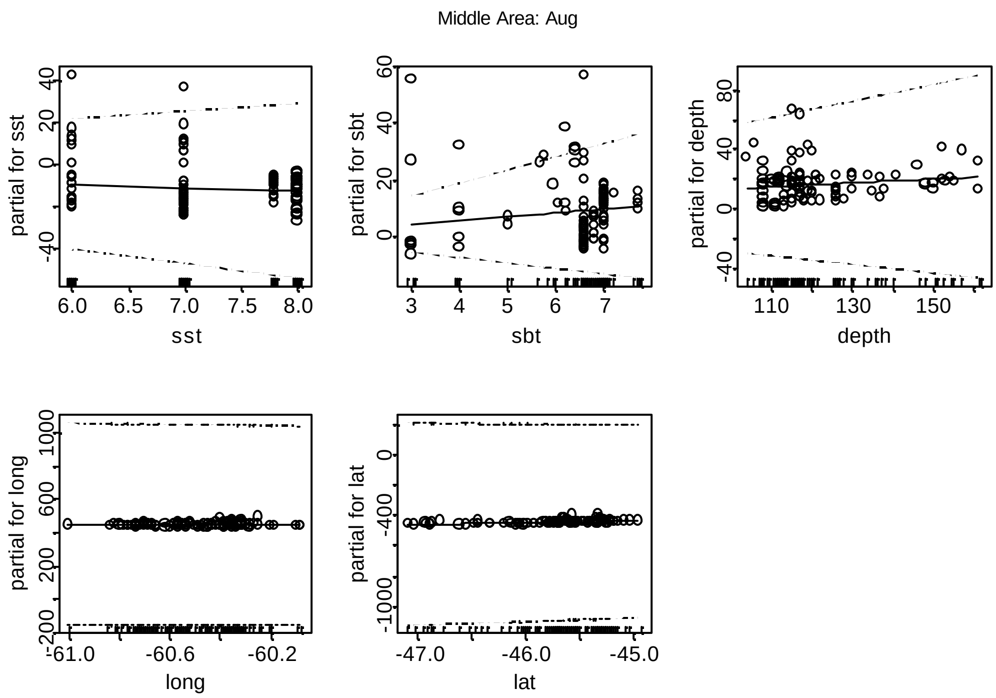


Figure 37. Middle area in August: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

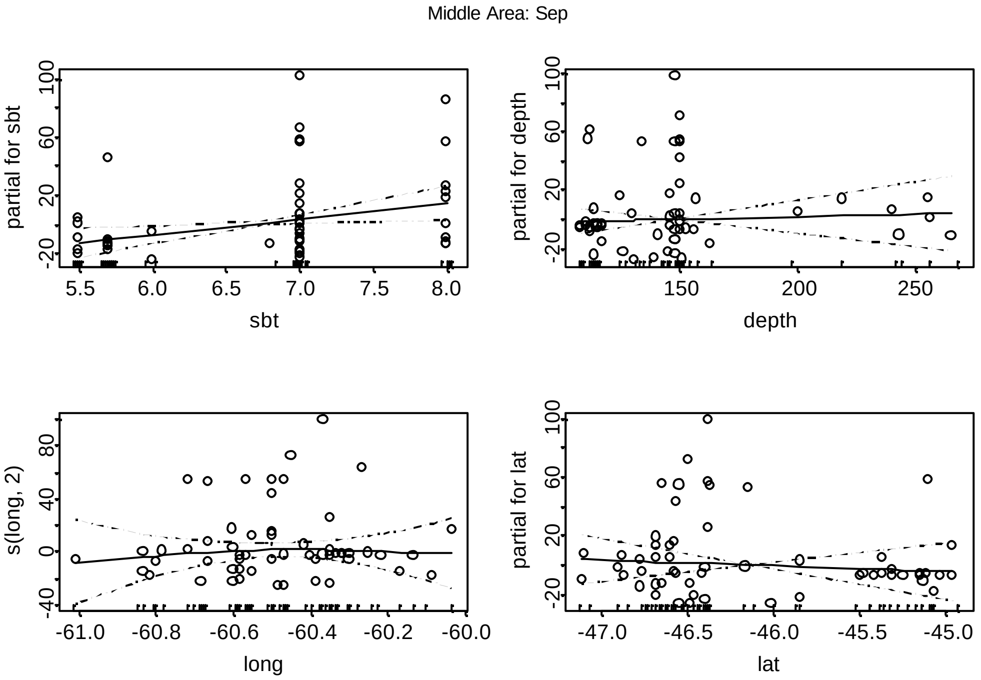


Figure 38. Middle area in September: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

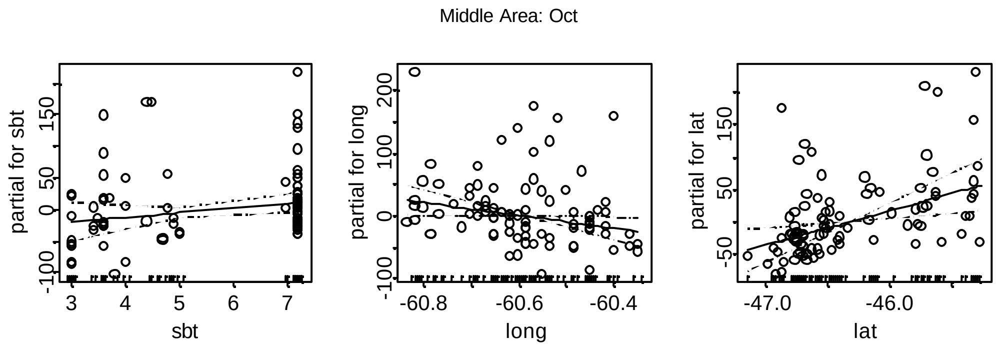


Figure 39. Middle area in October: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

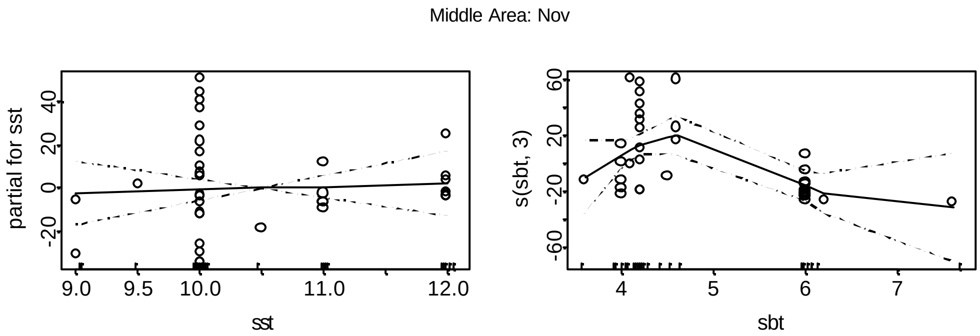


Figure 40. Middle area in November: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

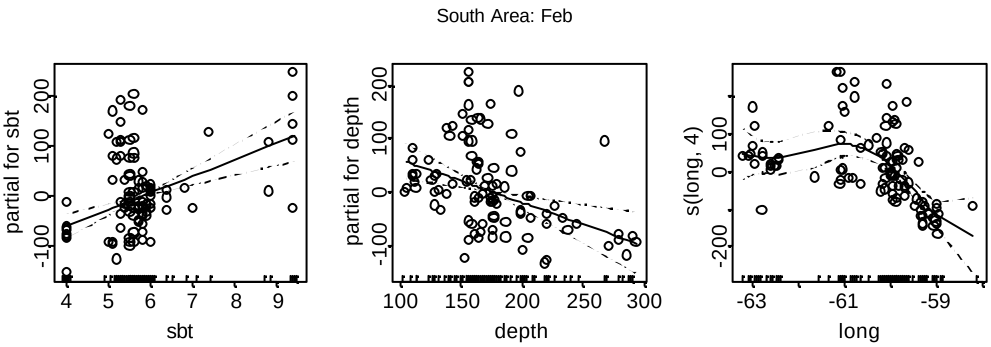


Figure 41. South area in February: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

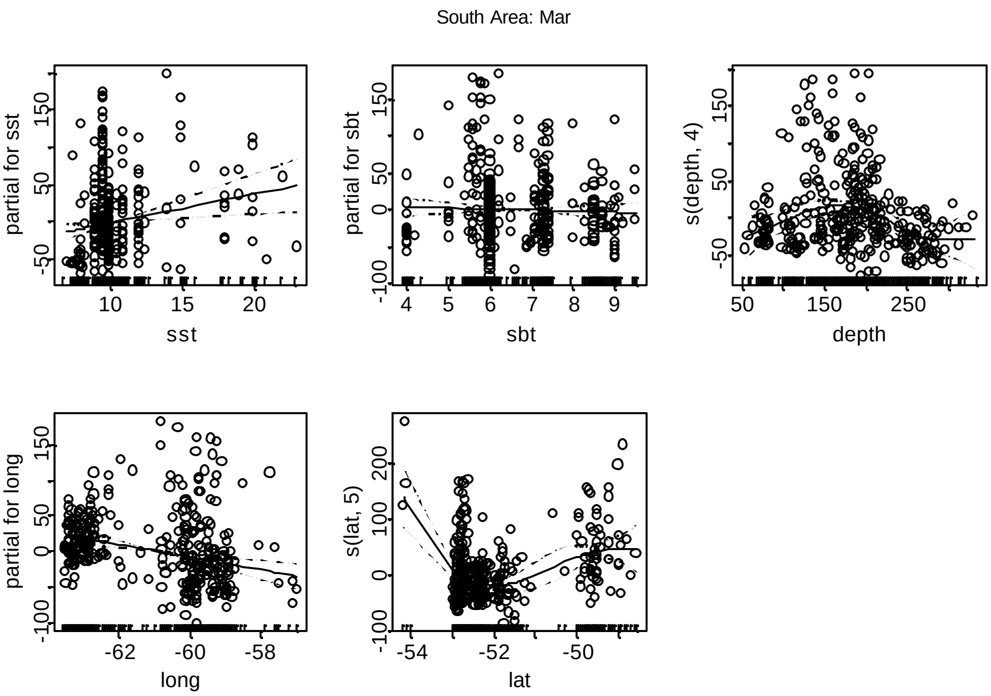


Figure 42. South area March: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

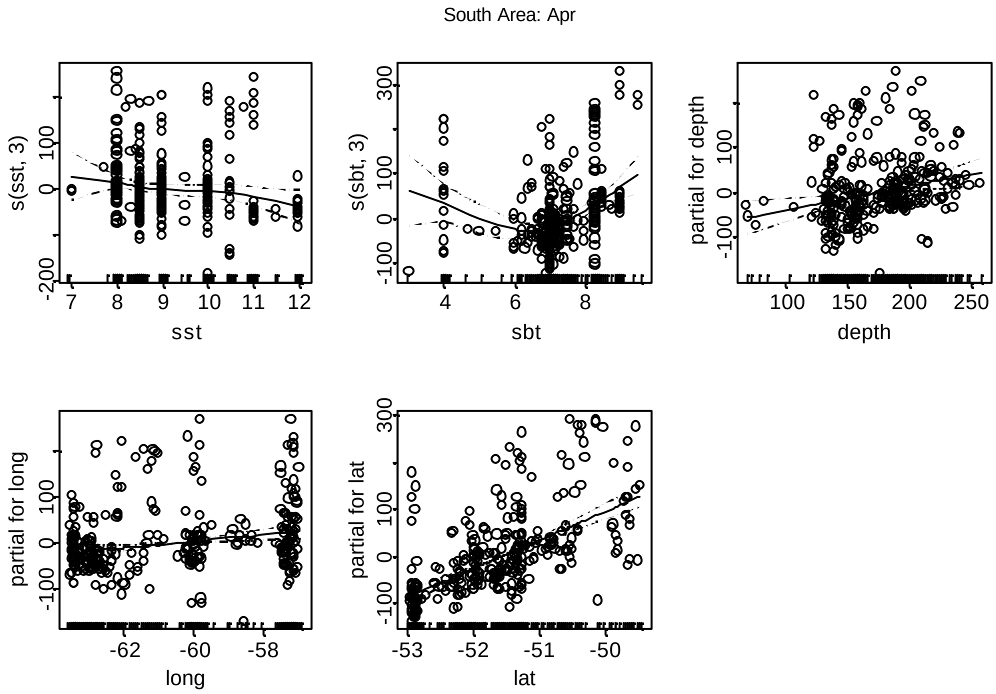


Figure 43. South area April: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

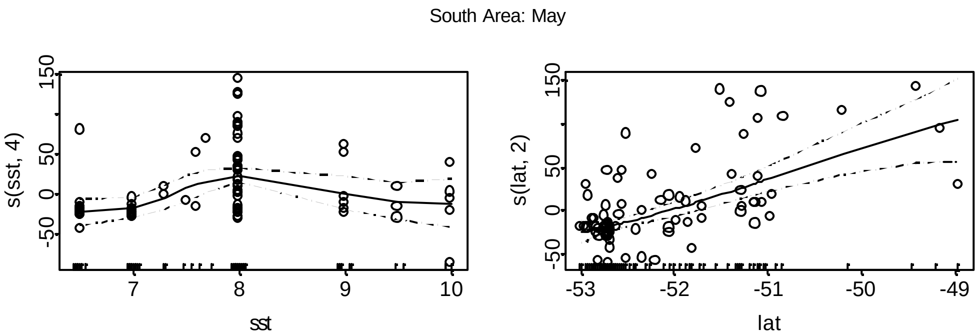


Figure 44. South area May: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

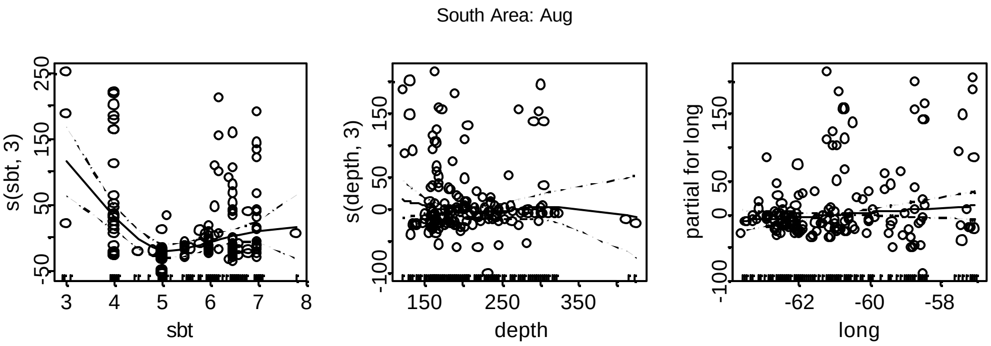


Figure 45. South area August: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

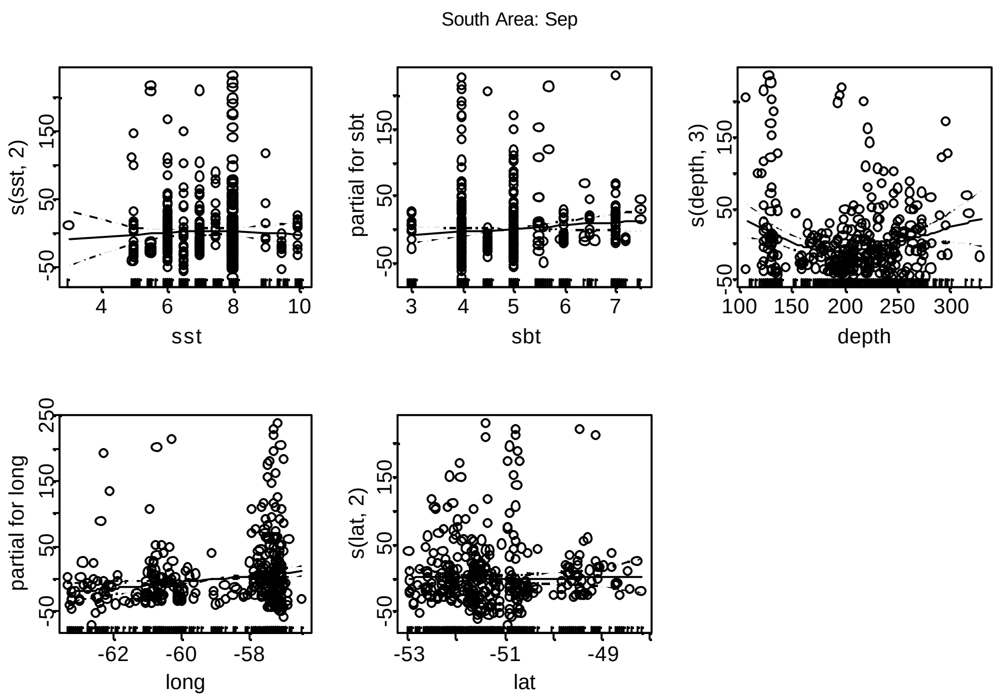


Figure 46. South area September: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

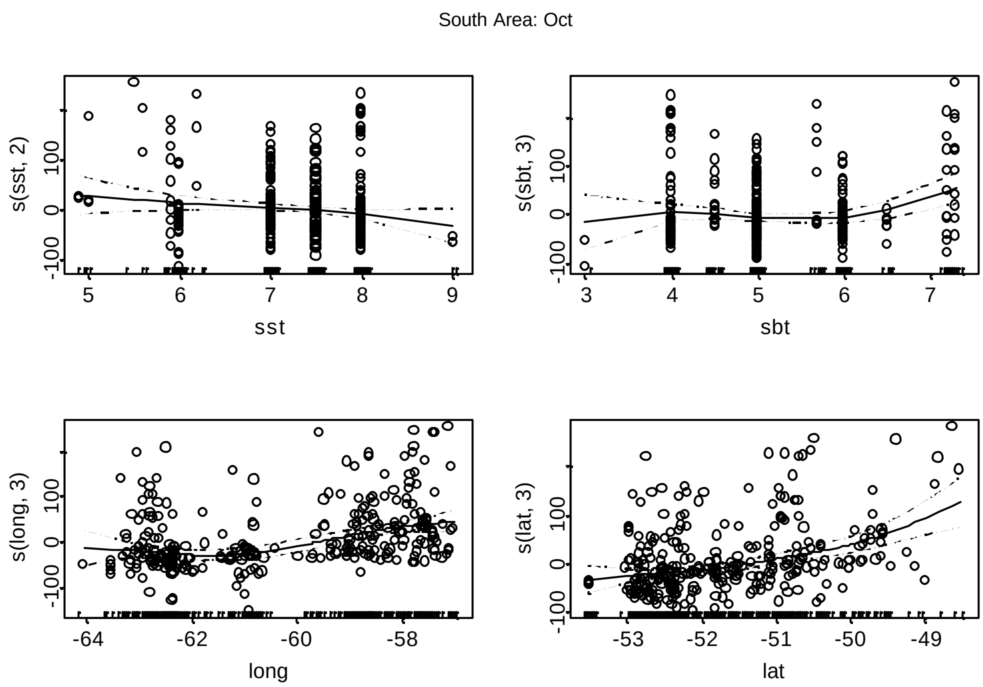


Figure 47. South area October: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

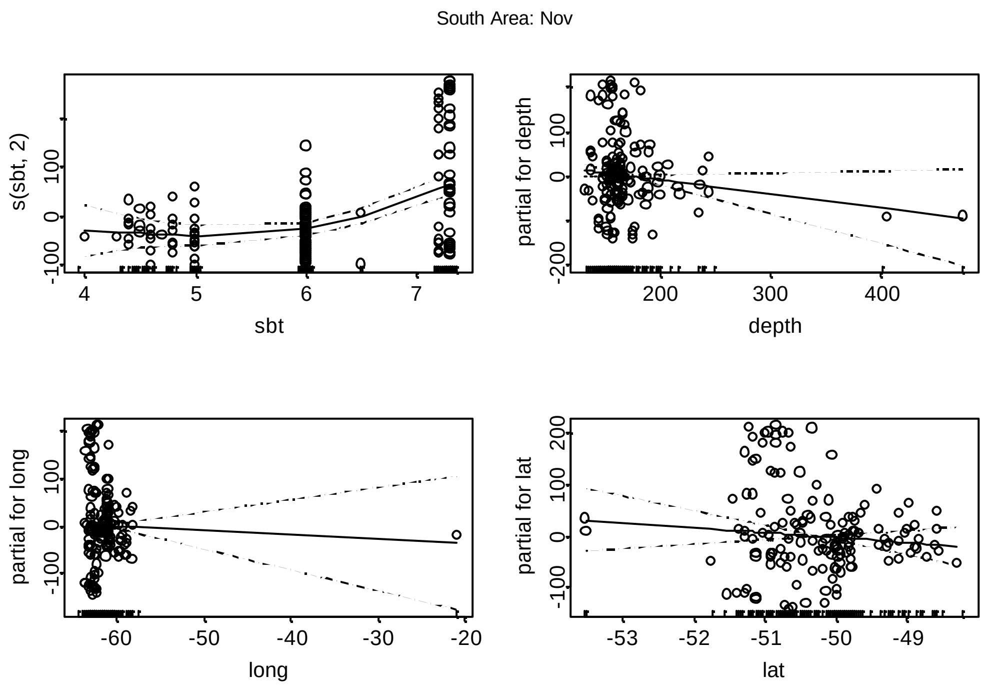


Figure 48. South area November: Optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands).

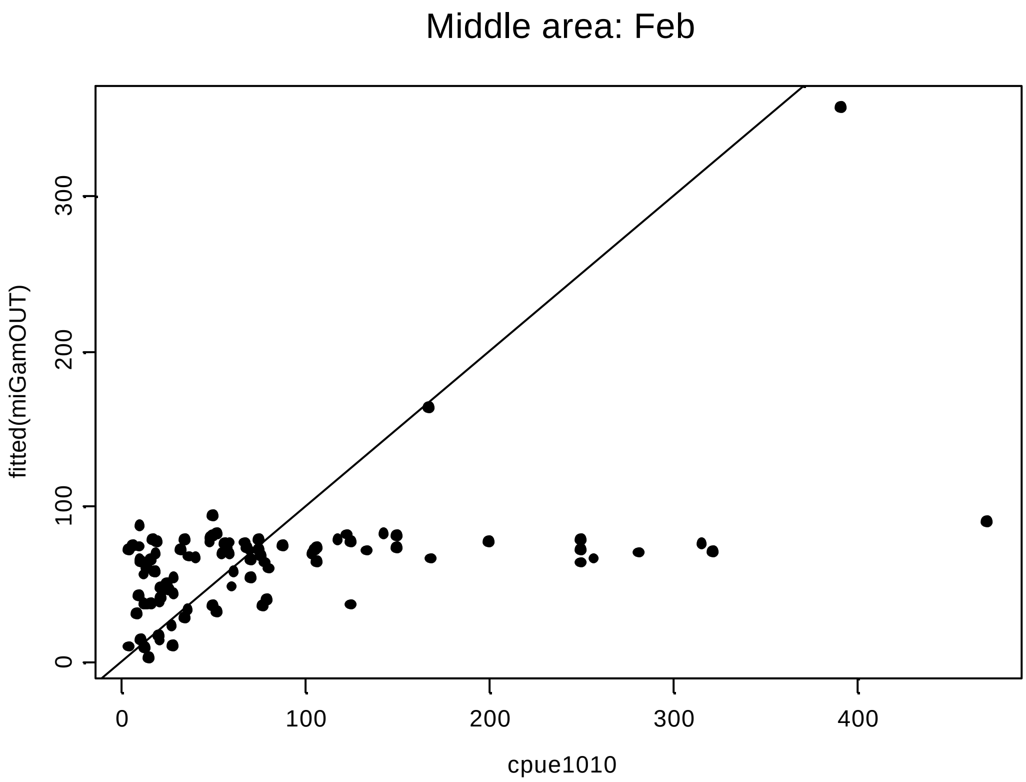


Figure 49. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in February in the middle area.

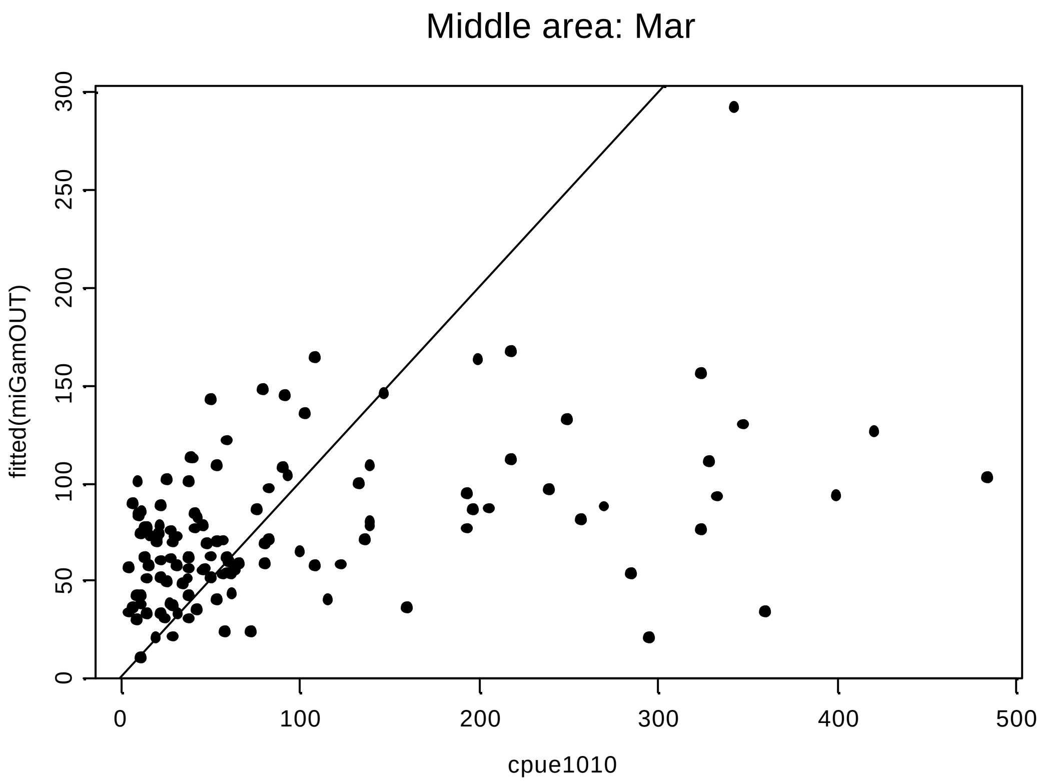


Figure 50. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in March in the middle area.

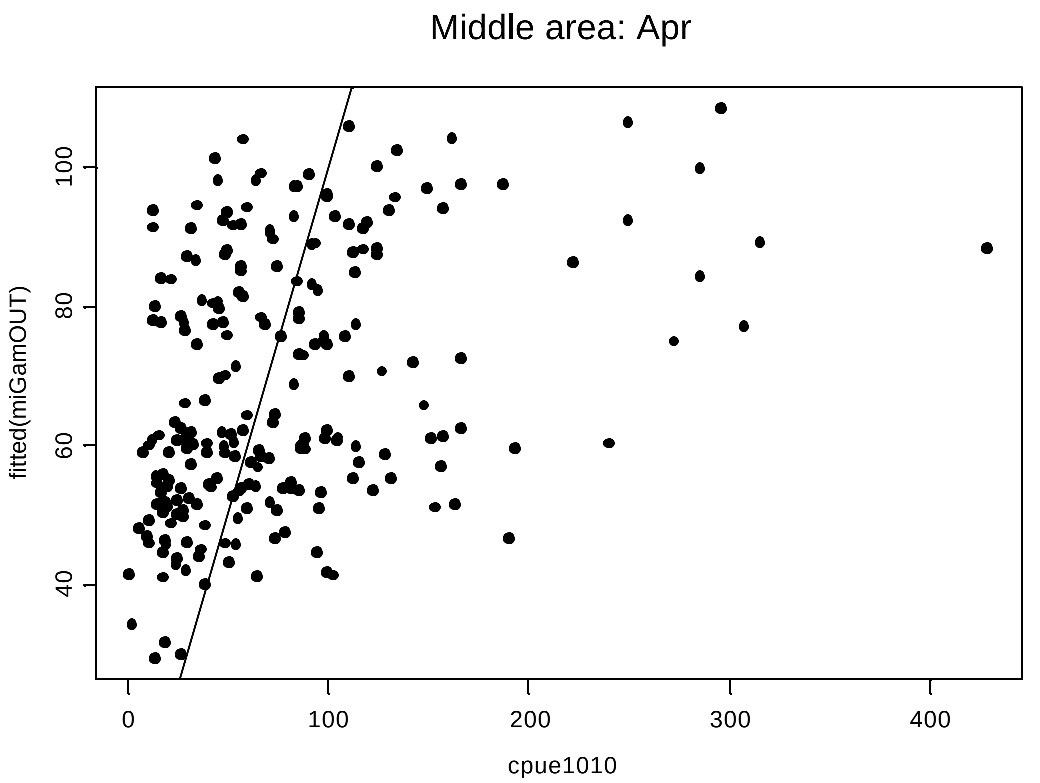


Figure 51. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in April in the middle area.

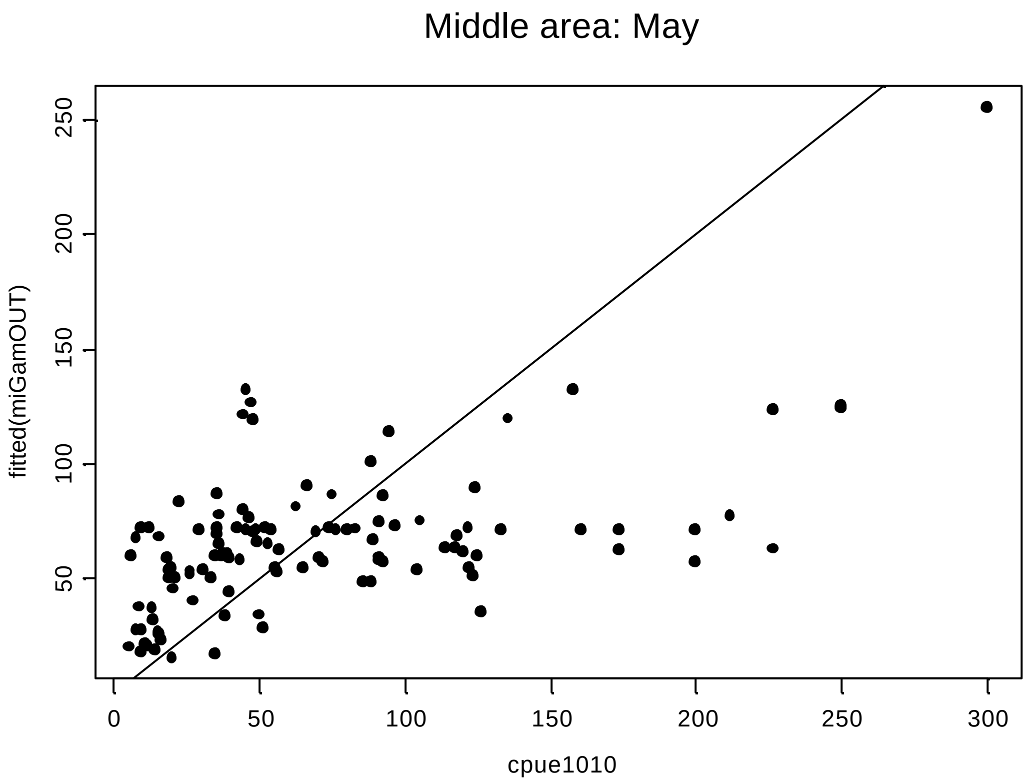


Figure 52. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in May in the middle area.

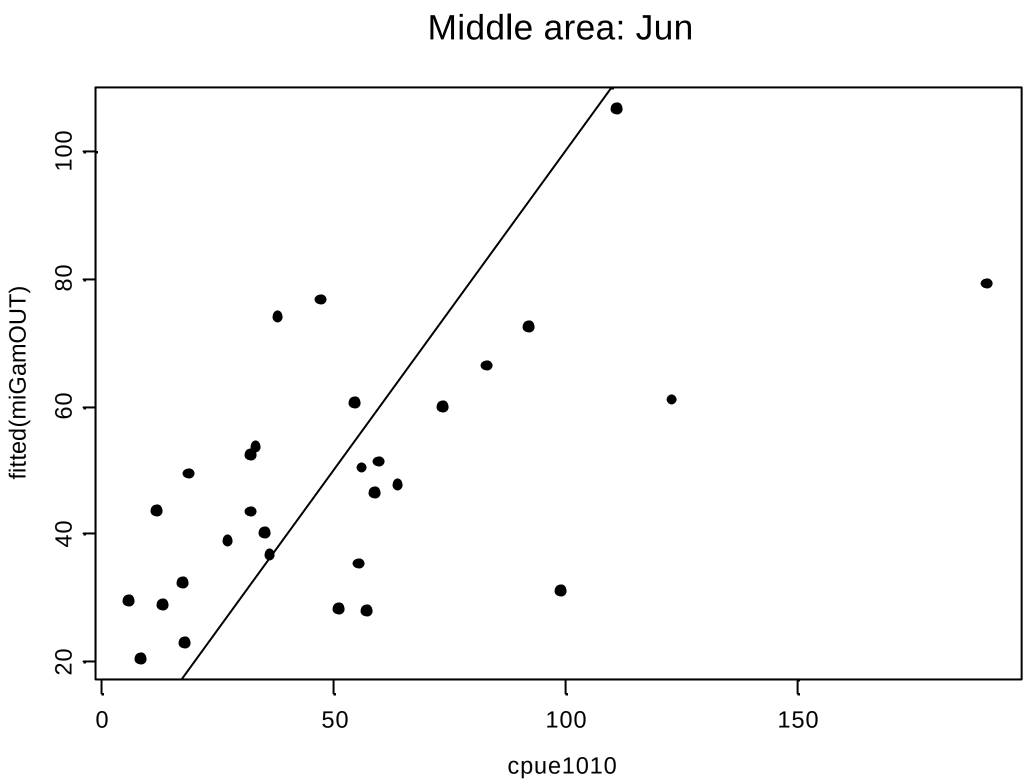


Figure 53. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in June in the middle area.

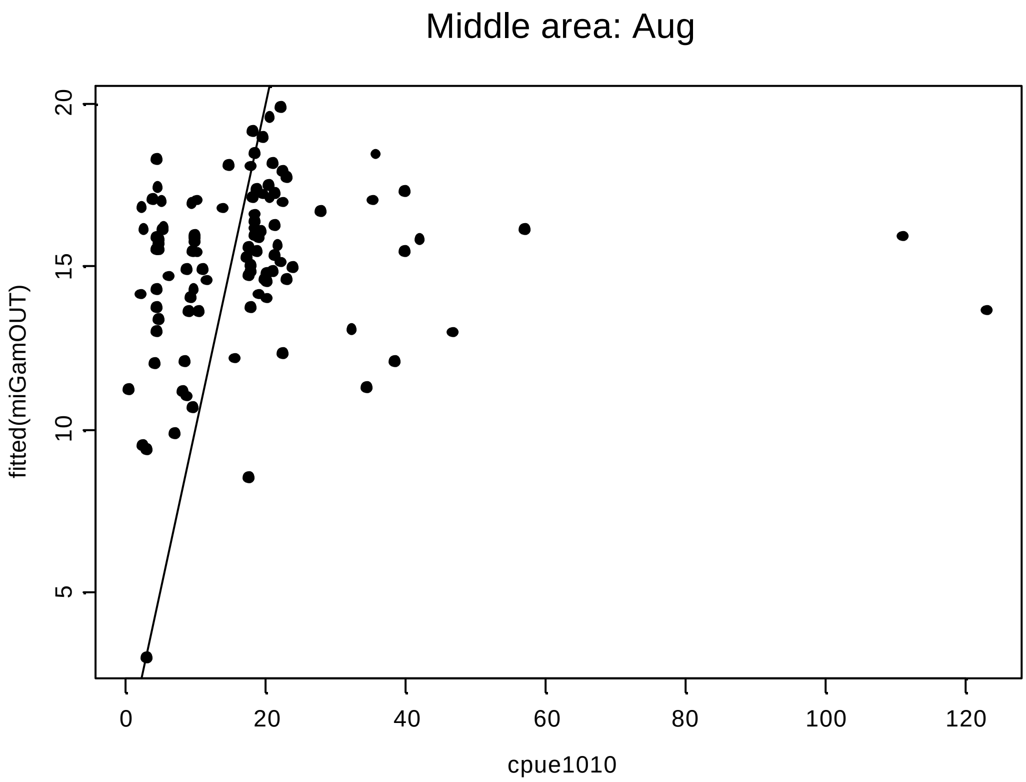


Figure 54. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in August in the middle area.

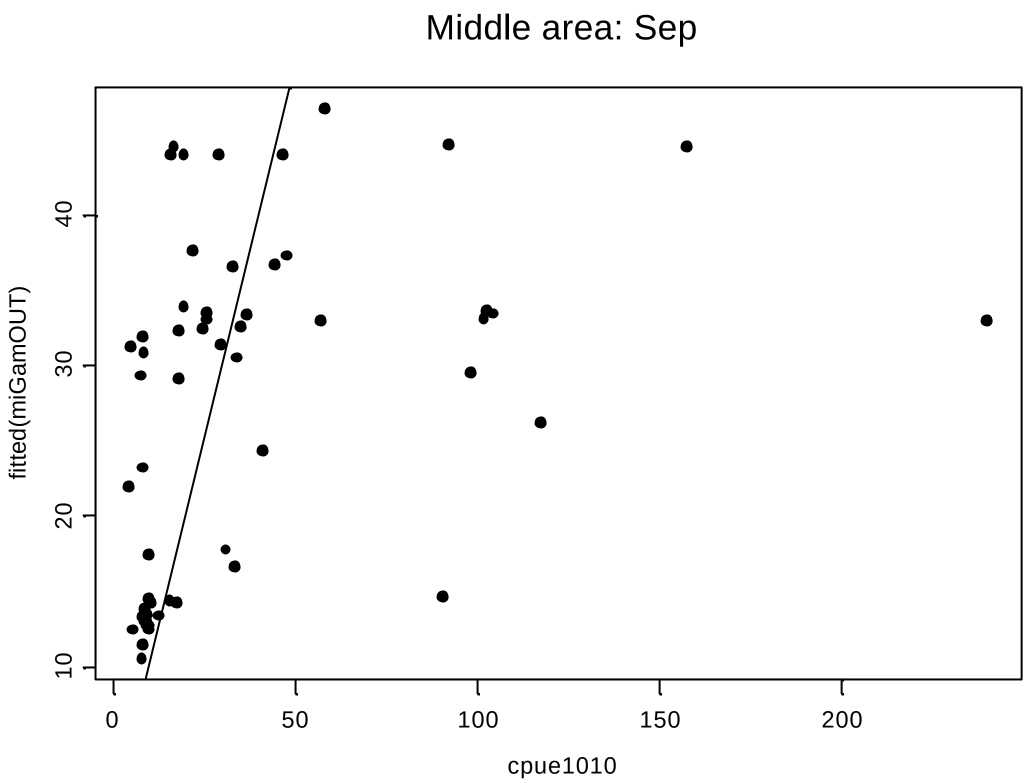


Figure 55. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in September in the middle area.

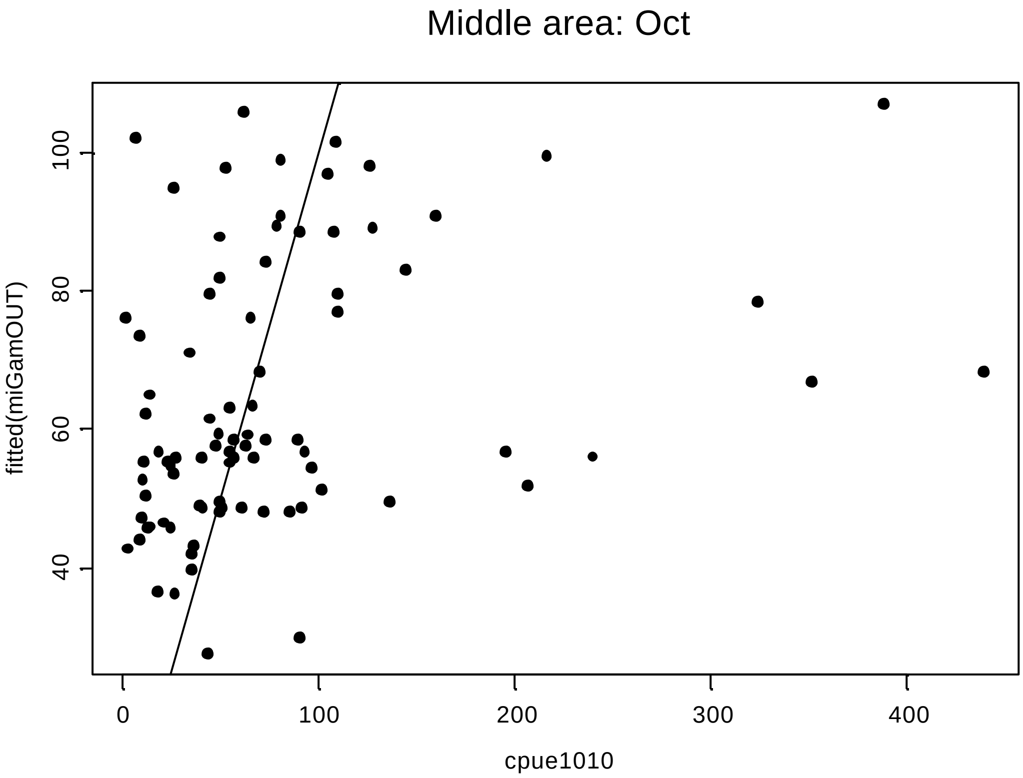


Figure 56. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in October in the middle area.

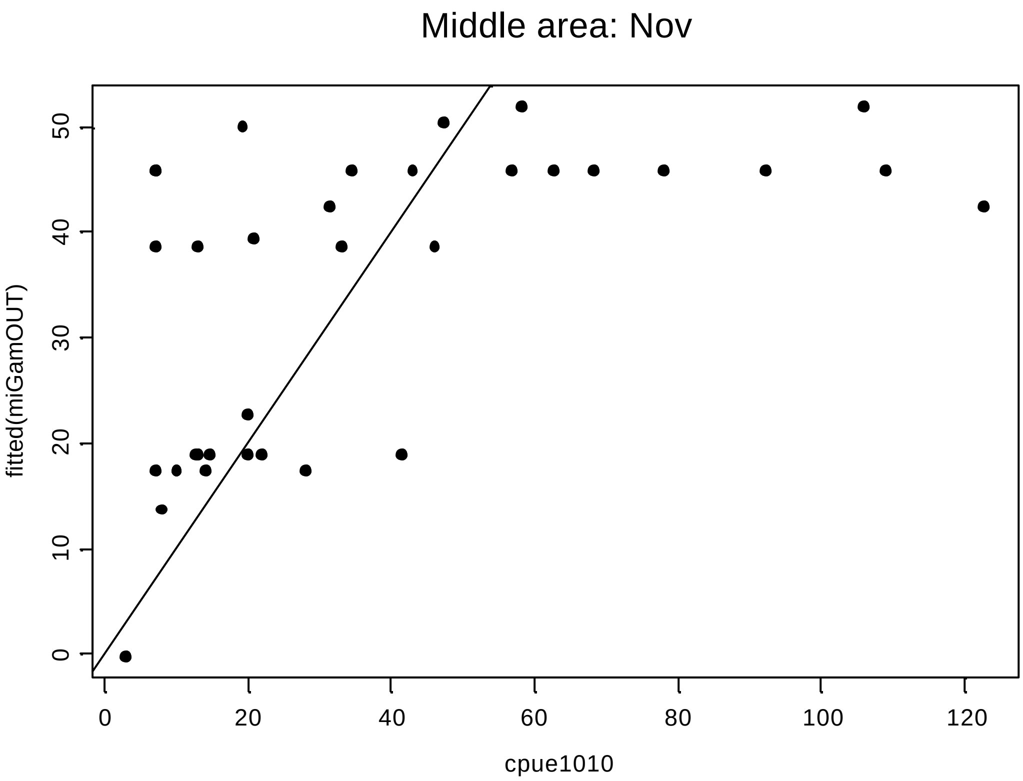


Figure 57. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in November in the middle area.

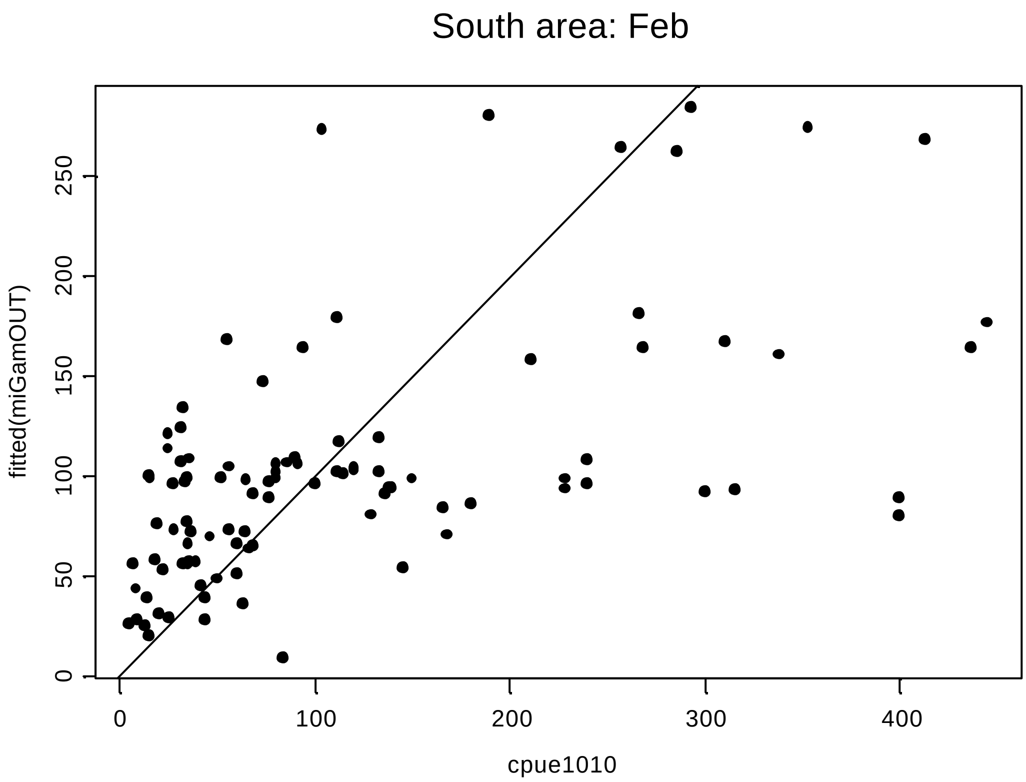


Figure 58. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in February in the south area.

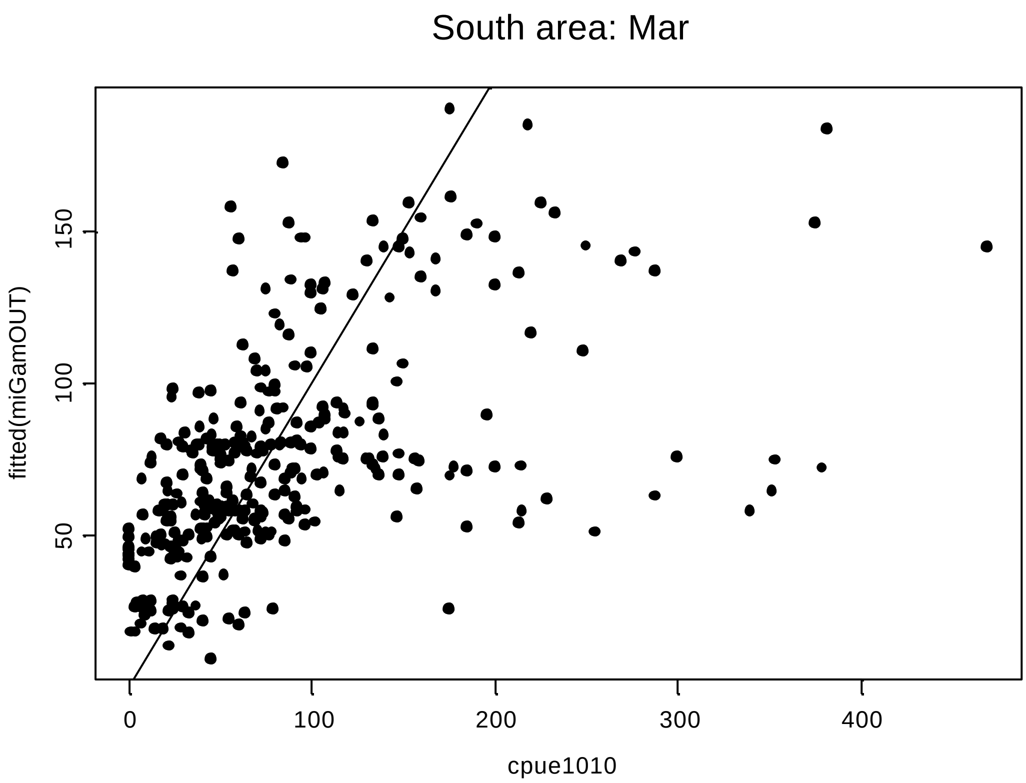


Figure 59. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in March in the south area.

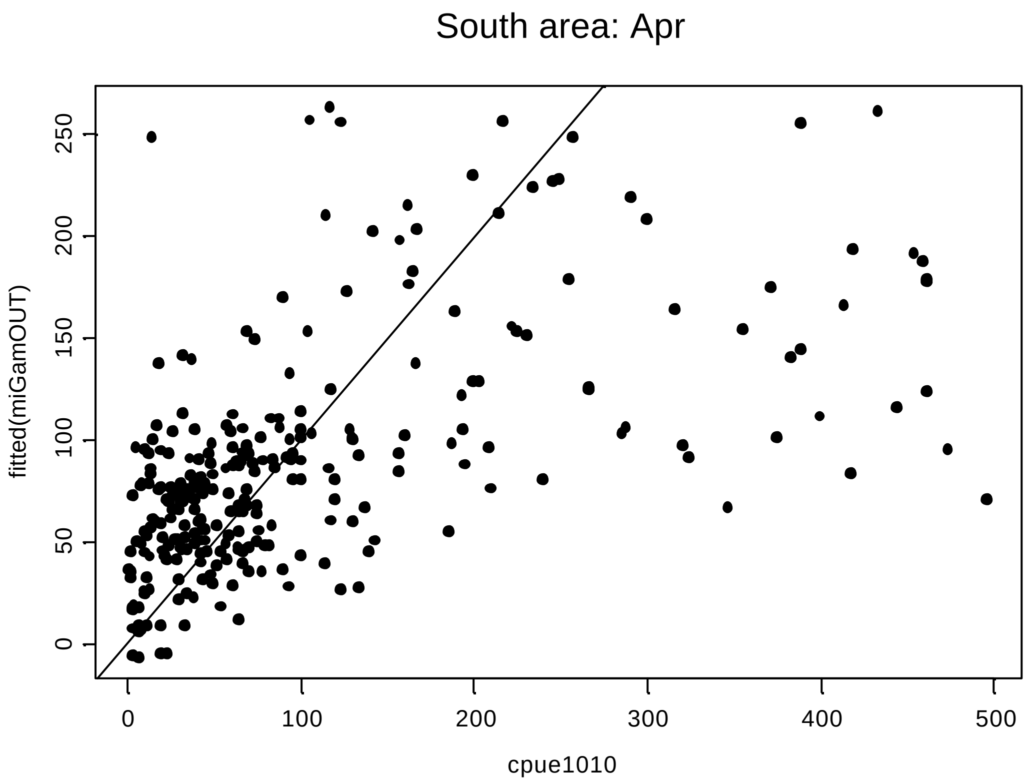


Figure 60. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in April in the south area.

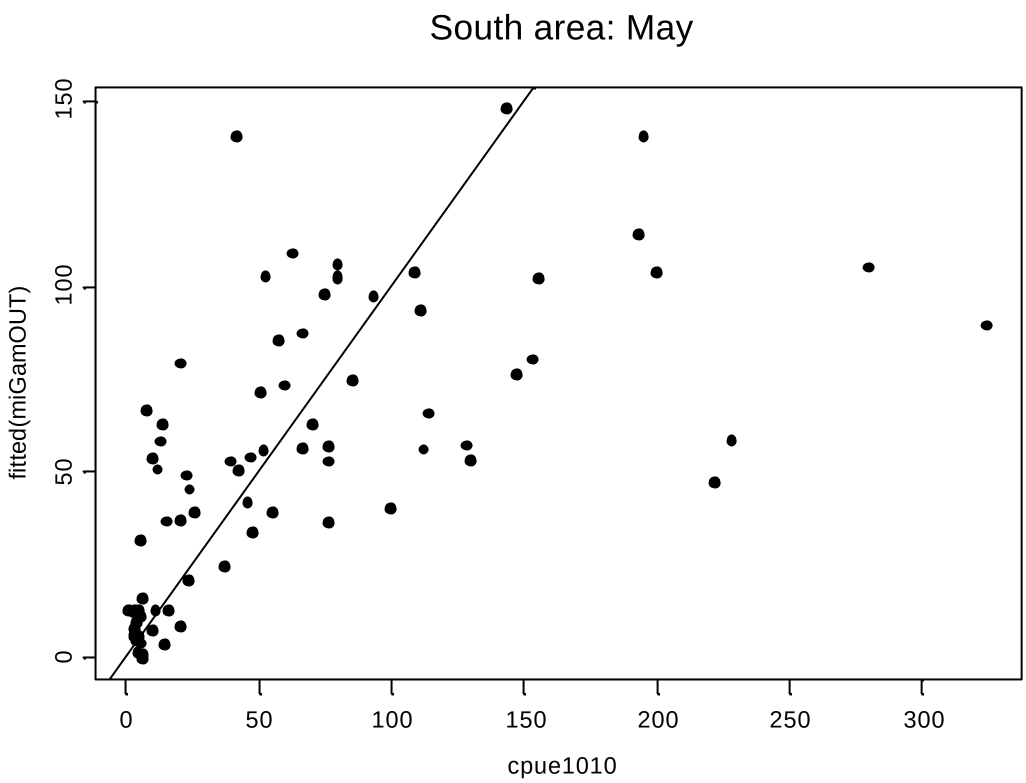


Figure 61. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in May in the south area.

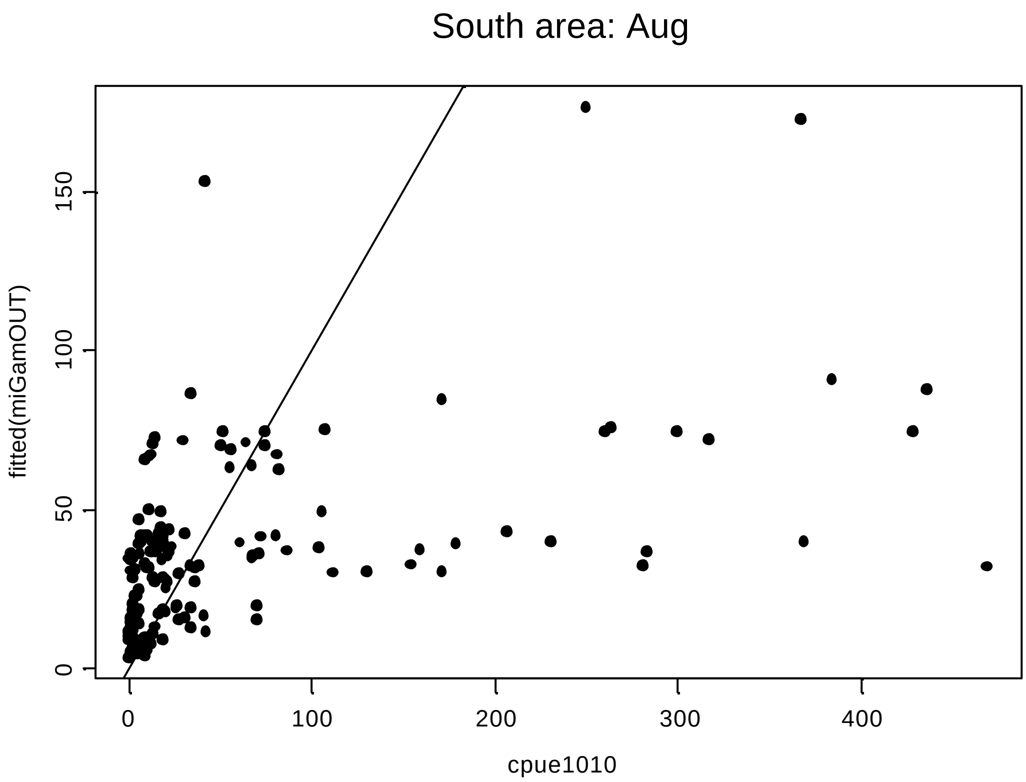


Figure 62. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in August in the south area.

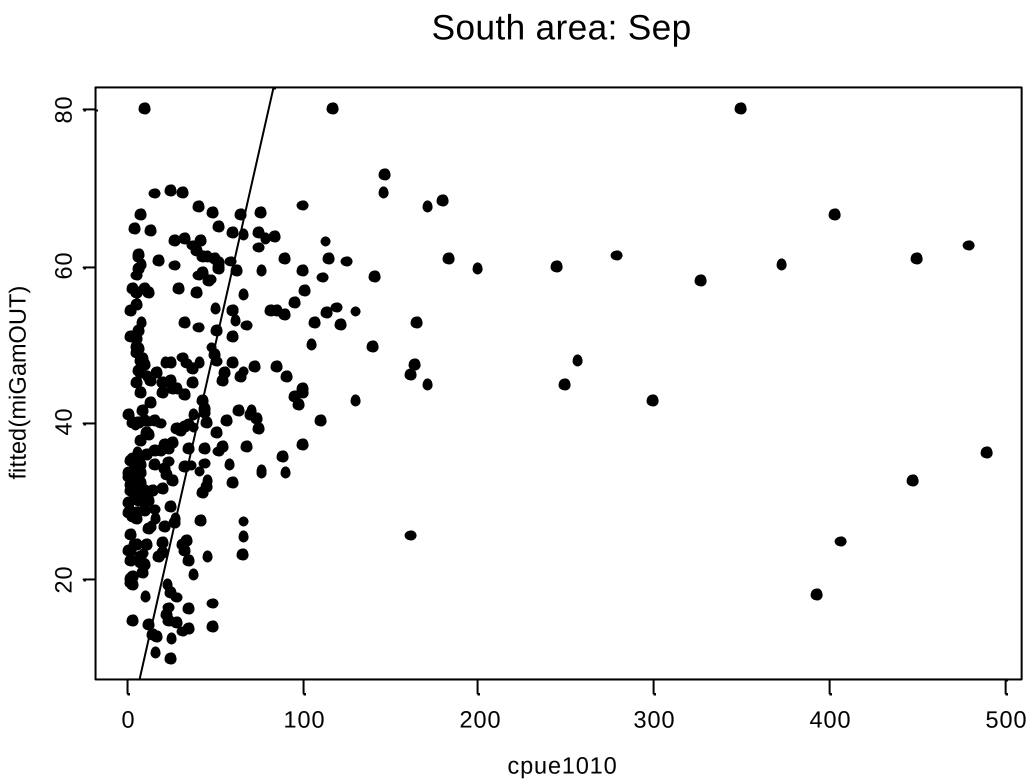


Figure 63. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in September in the south area.

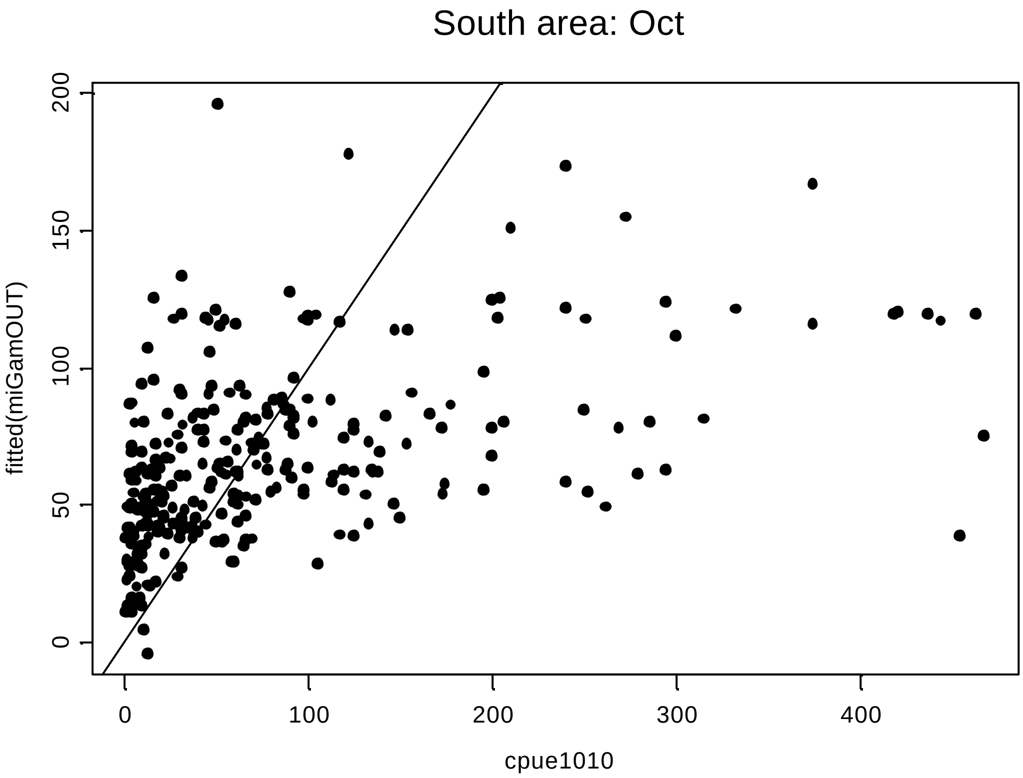


Figure 64. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in October in the south area.

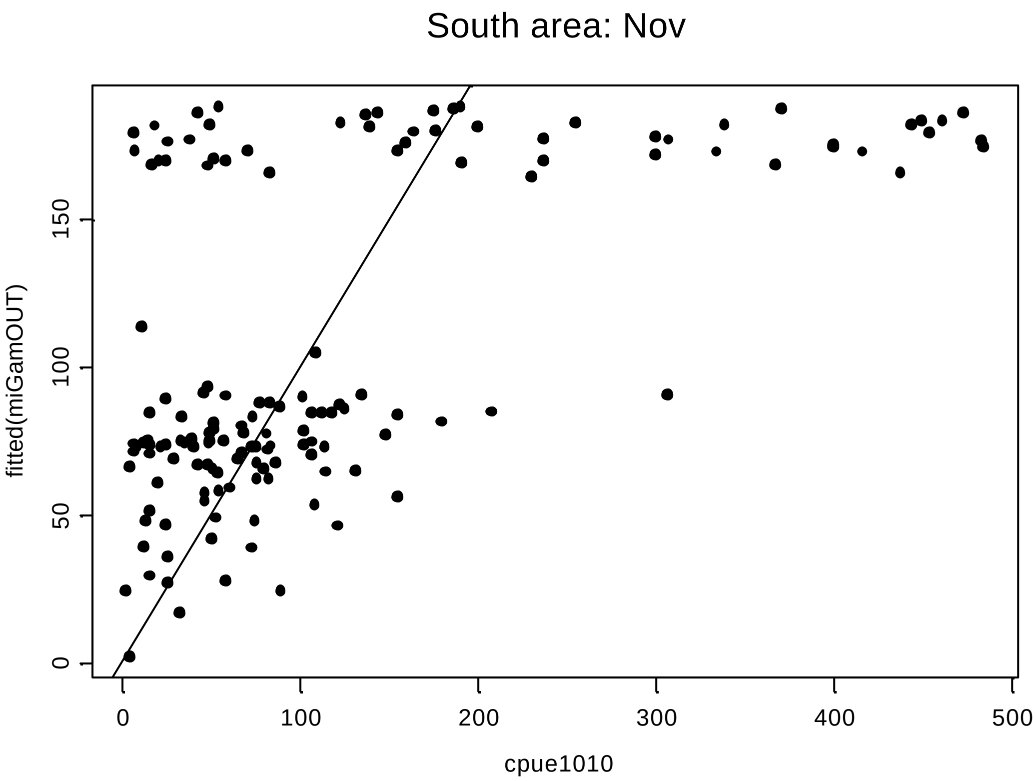


Figure 65. Monthly-based model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values in November in the south area.

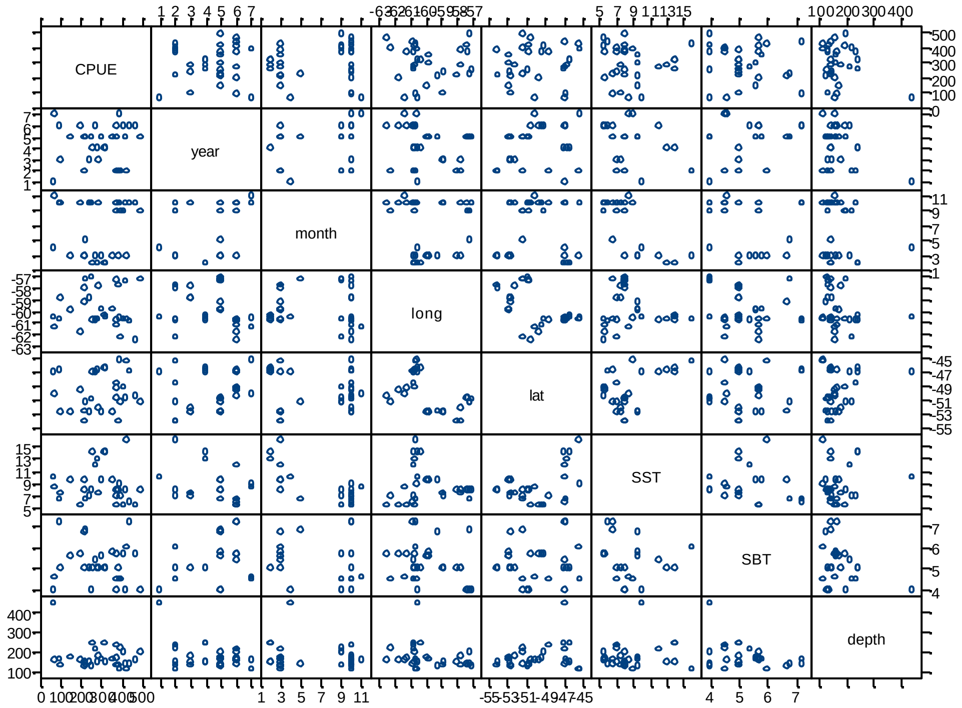


Figure 66. The matrix plot of CPUE, location and environmental variables used in the overall model (hauls with the ratio of *Patagonotothen* spp to the catches of species >=0.5)

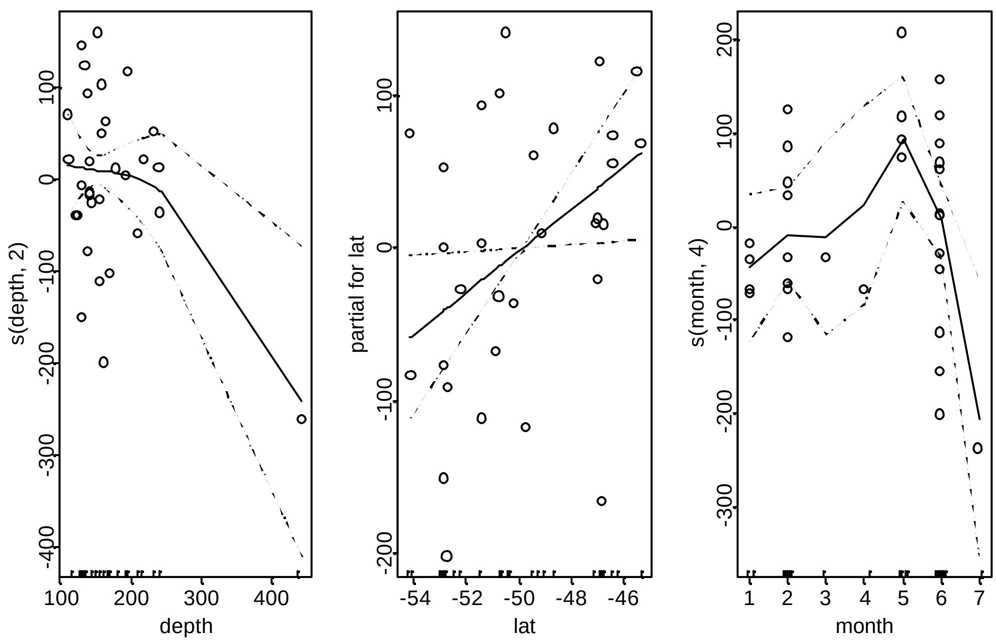


Figure 67. Overall model: the optimal GAM model fit for CPUE to the predictors (the dashed curves are pointwise 2 x standard-error bands, hauls with the ratio of *Patagonotothen* spp to the catches of species >= 0.5).

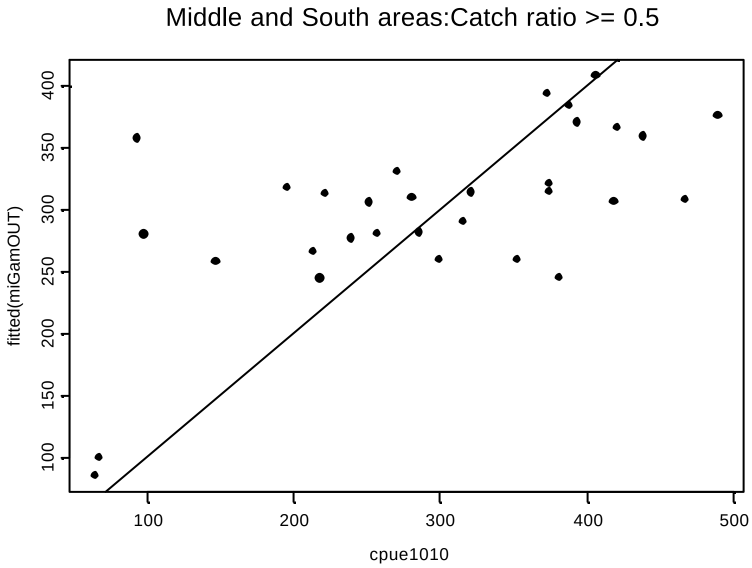


Figure 68. Overall model: the plot of model fitted CPUE values (y-axis) vs the original CPUE values (hauls with the ratio of *Patagonotothen* spp to the catches of species >=0.5).

Table 10: The middle area single month model results

Month	Model terms (CPUE ~)					Degrees of Freedom	Residual Deviance	Pseudo R
	SST	SBT	Longitude	Latitude	Depth			
Feb	s(sst, 4)	-	long	lat	s(depth,3)	95 total; 85.10747 Residual	322124	0.57
Mar	sst	s(sbt,3)	long	lat	depth	127 total; 119.078 Residual	776611.5	0.44
Apr	s(sst, 2)	sbt	long	lat	s(depth,2)	232 total; 224.048 Residual	570127	0.40
May	s(sst, 4)	-	s(long,3)	lat	-	113 total; 104.038 Residual	244346.6	0.41
Jun	sst	s(sbt, 2)		lat	-	30 total; 25.02617 Residual	22211.4	0.52
Aug	sst	sbt	long	lat	depth	103 total; 98 Residual	14205.39	0.78
Sep	-	sbt	s(long, 2)	lat	depth	56 total; 50.03738 Residual	42682.3	0.60
Oct	-	sbt	long	lat	-	88 total; 84 Residual	283316.8	0.51
Nov	sst	s(sbt, 3)	-	-	-	35 total; 30.06872 Residual	15469.11	0.57

Table 11: South Area single month model results

Month	Model terms (CPUE ~)					Degrees of Freedom	Residual Deviance	Pseudo R
	SST	SBT	Longitude	Latitude	Depth			
Feb	-	sbt	s(long, 4)		depth	100 total; 93.07711 Residual	564932.7	0.54
Mar	sst	sbt	long	s(lat, 5)	s(depth, 4)	322 total; 309.1698 Residual	802478.6	0.56
Apr	s(sst, 3)	s(sbt, 3)	long	lat	depth	283 total; 273.2076 Residual	1596681	0.55
May	s(sst, 4)	-	-	s(lat, 2)	-	86 total; 79.06293 Residual	118162.3	0.70
Aug	-	s(sbt, 3)	long	-	s(depth, 3)	164 total; 156.1029 Residual	529261	0.64
Sep	s(sst, 2)	sbt		s(lat, 2)	s(depth, 3)	316 total; 306.0956 Residual	913706.9	0.56
Oct	s(sst, 2)	s(sbt, 3)	s(long, 3)	s(lat, 3)		293 total; 281.2372 Residual	1309437	0.49
Nov	-	s(sbt, 2)	long	lat	depth	148 total; 142.0222 Residual	1013758	0.54

Residual Deviance
564932.7
802478.6
1596681
118162.3
529261
913706.9
1309437
1013758

Fishery forecasting (IEO)

Before applying GAMs techniques, scatter plots were made in order to determine the relationship between the variables and *Patagonotothen* spp. abundance.

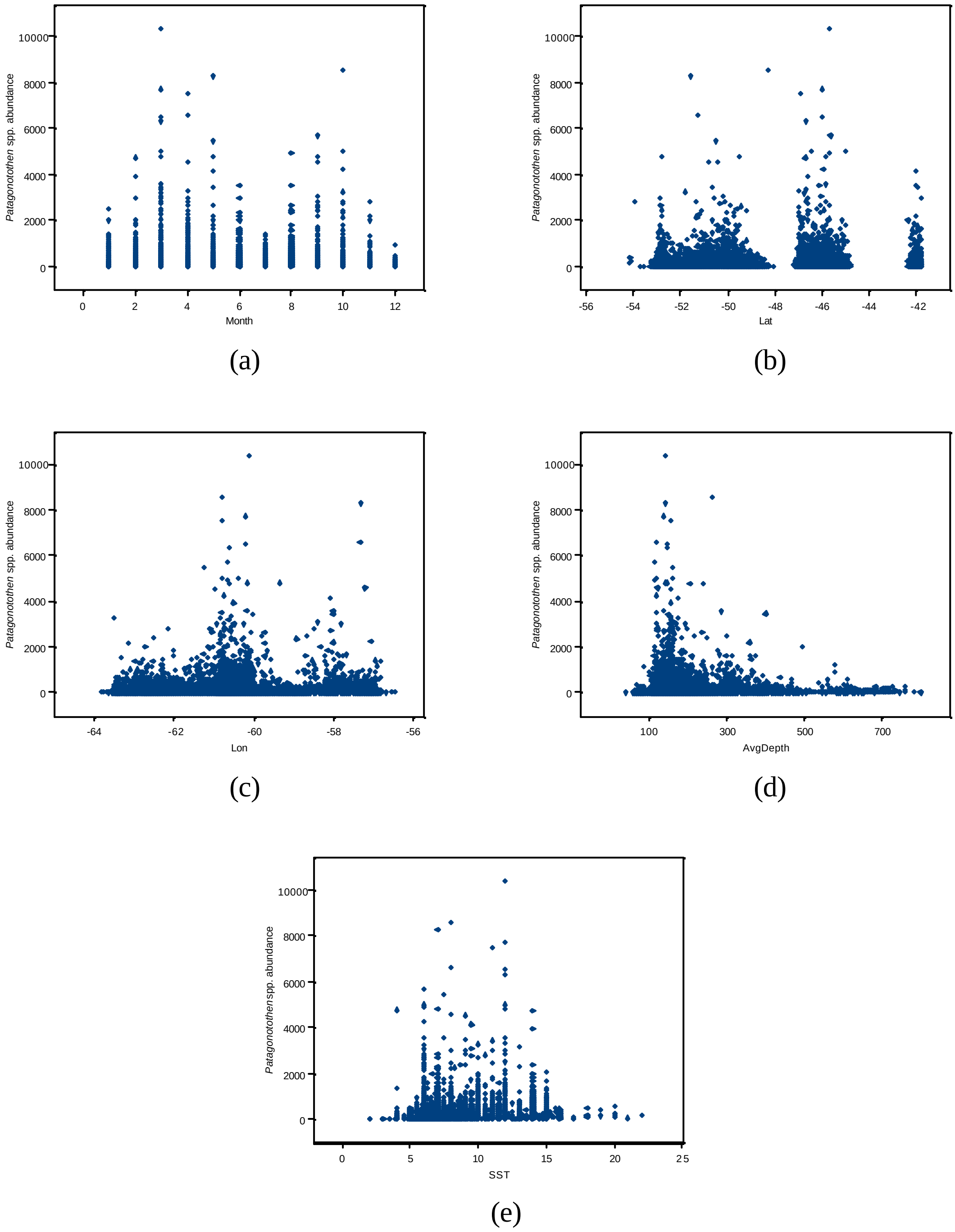


Figure 69. Scatter plots showing the relationship between *Patagonotothen* spp. abundance (CPUE as kg/h) and month (January to December), latitude (decimal degrees), longitude (decimal degrees), average depth (m) and SST (ºC)

Scatter plots (Fig. 69) confirm the non-linearity of the relationships between CPUE and environmental variables. They suggest the following relationships:

1. *Patagonotothen* spp. abundance shows two peaks located in March and October. Minimum values of CPUE were found during January, July and December.
2. The relationship of abundance (in terms of CPUE) with the geographic position (latitude and longitude) is basically indicating the location where the vessels are fishing. *Patagonotothen* spp. was fished all around the Falkland Islands and also within High Seas, being the maximum abundance found at latitude 46º S and longitude 59º W. However, this doesn't quite explain the lower CPUE values at the edges of the main fishing areas – we may suggest that the fishing is focused in the high abundance areas
3. *Patagonotothen* spp. abundance seems to be positively related to 100-200 m depth range.
4. Highest *Patagonotothen* spp. CPUE values were associated with SST between 6.3º C and 12º C

Presence/Absence model

This model predicts the level of probability of success of catching the species. SST, latitude and month were the best explanatory variables (see Table 12) and these were used as the basis for model building.

Table 12. Values of the AIC, p-values, deviance explained and adjusted R-squared values for each explanatory variable for first step in the forward selection procedure for model of presence/absence. Initial models were constructed using those variables which explained the highest proportion of variation in the response variable.

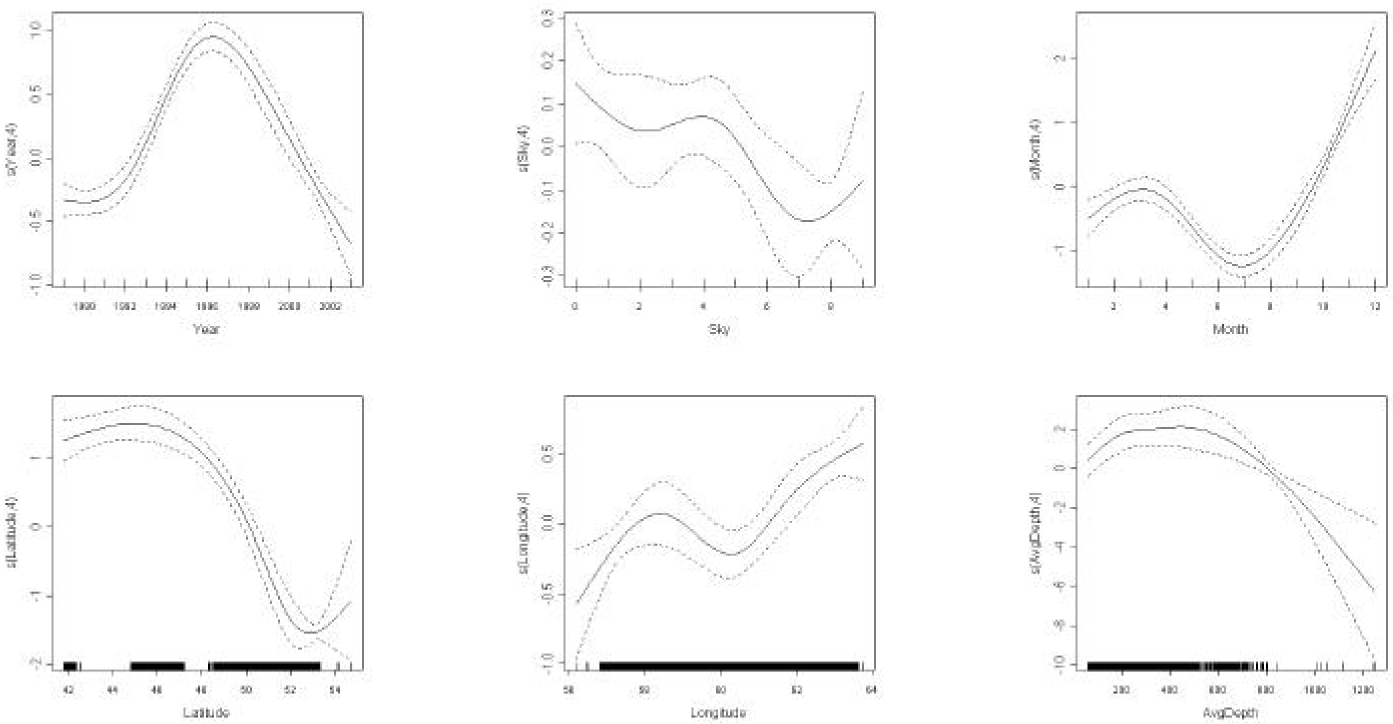
Single explanatory variable	AIC	p-value	Dev. Explained	R-sqr (adj)
Year	1.36	$<2.22e^{-16}$	2.18%	0.0297
Sea	1.37	$<2.22e^{-16}$	0.983%	0.0131
Moon	1.39	0.068	0.0531%	0.00042
Sky	1.38	$<2.22e^{-16}$	0.614%	0.00808
Week	1.39	0.24	0.0314%	0.000125
Month	**1.34**	$\mathbf{<2.22e^{-16}}$	**3.21%**	**0.0411**
Latitude	**1.24**	$\mathbf{<2.22e^{-16}}$	**10.2%**	**0.137**
Longitude	1.37	$<2.22e^{-16}$	1.39%	0.0189
AvgDepth	1.38	$2.6e^{-13}$	0.495%	0.00651
SST	**1.35**	$\mathbf{<2.22e^{-16}}$	**2.52%**	**0.0337**

Table 13. Addition of each term to the presence/absence model

	R-sq (adj)	Dev.explained	AIC
Model [1]	0.195	14.5%	1.19
Model [2]	0.197	14.7%	1.18
Model [3]	0.185	13.6%	1.20
Model [4]	0.224	17%	1.15
Model [5]	0.231	18%	1.14
Model [6]	0.231	18.1%	1.14
Model [7]	0.232	18.3%	1.14
Model [8]	0.231	18.2%	1.14
Model [9]	**0.242**	**19.1%**	**1.13**
Model [10]	0.241	19%	1.13

[1] PA~ s(Month)+s(Lat)
[2] PA~ s(Month)+s(Lat)+s(SST)
[3] PA~ s(Month)+s(SST)+Lat
[4] PA~ s(Month)+s(Lat)+s(SST)+s(Year)
[5] PA~ s(Month)+s(Lat)+s(SST)+s(Year)+s(Lon)
[6] PA~ s(Month)+s(Lat)+s(SST)+s(Year)+s(Lon)+s(Sea)
[7] PA~ s(Month)+s(Lat)+s(SST)+s(Year)+s(Lon)+s(Sea)+s(Sky)
[8] PA~ s(Month)+s(Lat)+s(SST)+s(Year)+s(Sea)+s(Sky)+Lon
[9] PA~ s(Month)+s(Lat)+s(SST)+s(Year)+s(Sea)+s(Sky)+s(Lon)+s(AvgDepth)
[10] PA~ s(Month)+s(Lat)+s(SST)+s(Year)+s(Sky)+s(Lon)+s(AvgDepth)

The results indicate that the best model (with the smaller AIC value) was model 9. This included effects of SST, latitude, month, average depth, year, sea, sky and longitude and is presented in figure 70:



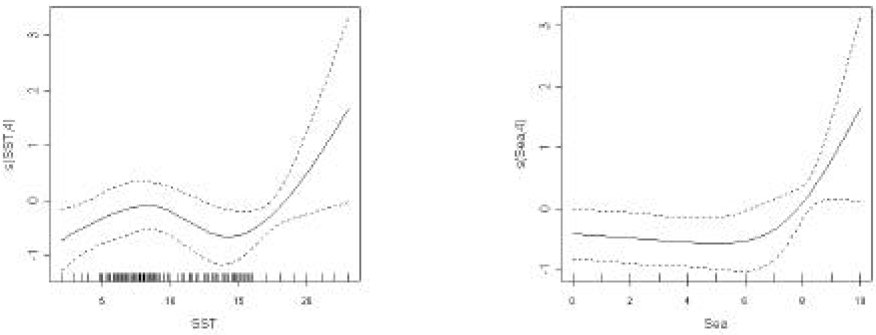


Figure 70. PA~s(Month)+s(Lat)+s(SST)+s(Year)+s(Sea)+s(Sky)+s(Lon)+s(AvgDepth)

The probability of catching rockcod generally increased at higher SST values. Confidence limits tend to be wider for SST values above 17º C due to the fact that the scarcity of data. Regarding latitude there is a clear decreasing trend in the probability of catching rockcod from 42º S to 52º S.

The presence/absence model also suggests a maximum in catches located in 1996 followed by a rapid decrease. The GAM plot shows that there is a clear seasonal effect on the probability of catching rockcod with a minimum value located during July and then, the curve undergoes an increase. In terms of longitude there is a peak of probability of catches located between 59 and 58º W. In terms of average depth, the probability of success of catching rockcod is highest in depths around 600 metres and then the curve undergoes a decrease. Regarding to sky and sea, GAM plots show how the probability of success of catching rockcod decreases with the cloud coverage and keeps quite a lot constant during the six first stages of the Beaufort scale. From state seven curve undergoes an increase that should not be taken into account because confidence limits are very wide.

Abundance (CPUE) model

This model predicts how abundant the species should be when present.

Table 14. Values of the AIC, p-values, deviance explained and adjusted R-squared values for each explanatory variable for first step in the forward selection procedure for model of abundance. Initial models were constructed using those variables which explained the highest proportion of variation in the response variable.

Single explanatory variable	AIC	p-value	Dev. Explained	R-sqr (adj)
Year	**305.3**	**8.98e^{-10}**	**8.83%**	**0.0488**
Moon	326.7	0.0125	2.12%	0.00783
Sky	330.5	0.1257	1.33%	0.00283
Week	329.5	0.0886	1.29%	0.00357
Month	332.3	0.3586	0.87%	0.00120
Latitude	**323.3**	**0.0015**	**3.52%**	**0.01450**
Longitude	327.6	0.0280	2.18%	0.00739
AvgDepth	330.8	0.2072	1.28%	0.00172
SST	331.2	0.2221	1.14%	0.00148

The final model included effects of SST, latitude, month, average depth, Moon and year.

Table 15. Addition of each term to the abundance model

	R-sq (adj)	Dev.explained	AIC
Model [1]	0.0564	11.4%	300.86
Model [2]	0.0795	14.7%	292.67
Model [3]	0.087	16%	291.91
Model [4]	0.0995	18.1%	287.42
Model [5]	0.0948	17.1%	287.70
Model [6]	0.0958	18.4%	287.38
Model [7]	0.103	18.7%	288.40
Model [8]	0.106	19.1%	287.47
Model [9]	0.0953	19%	288.17
Model [10]	0.12	22.5%	284.20
Model [11]	**0.103**	**19.6%**	**285.80**
Model [12]	0.0775	17.7%	293.28

[1] CPUE~ s(Year)+s(Lat)
[2] CPUE~ s(Year)+s(Lat)+s(Moon)
[3] CPUE~ s(Year)+s(Lat)+s(Moon)+s(Lon)
[4] CPUE~ s(Year)+s(Lat)+s(Moon)+s(Lon)+s(AvgDepth)
[5] CPUE~ s(Year)+s(Lat)+s(Moon)+s(AvgDepth)
[6] CPUE~ s(Year)+s(Lat)+s(Moon)+s(AvgDepth)+s(Month)
[7] CPUE~ s(Year)+s(Lat)+s(Moon)+s(Lon)+s(AvgDepth)+s(Week)
[8] CPUE~ s(Year)+s(Lat)+s(Moon)+s(Lon)+s(AvgDepth)+s(SST)
[9] CPUE~ s(Year)+s(Lat)+s(Moon)+s(Lon)+s(AvgDepth)+s(Month)
[10] CPUE~ s(Year)+s(Lat)+s(Moon)+s(Lon)+s(AvgDepth)+s(Month)+s(Week)+s(SST)+s(Sky)
[11] CPUE~ s(Year)+s(Month)+s(Lat)+s(AvgDepth)+s(SST)+s(Moon)
[12] CPUE~ s(Year)+s(Month)+s(Lat)+s(Lon)+s(AvgDepth)+s(SST)

The results indicate that the best model (with the smaller AIC value) was model 11. Note that even though model 10 shows a smaller AIC value, this was not considered the best because some of the variables (such as week, longitude and sky) included in it were not significant. The best model included effects of SST, latitude, month, average depth, Moon and year and is presented in figure 71:

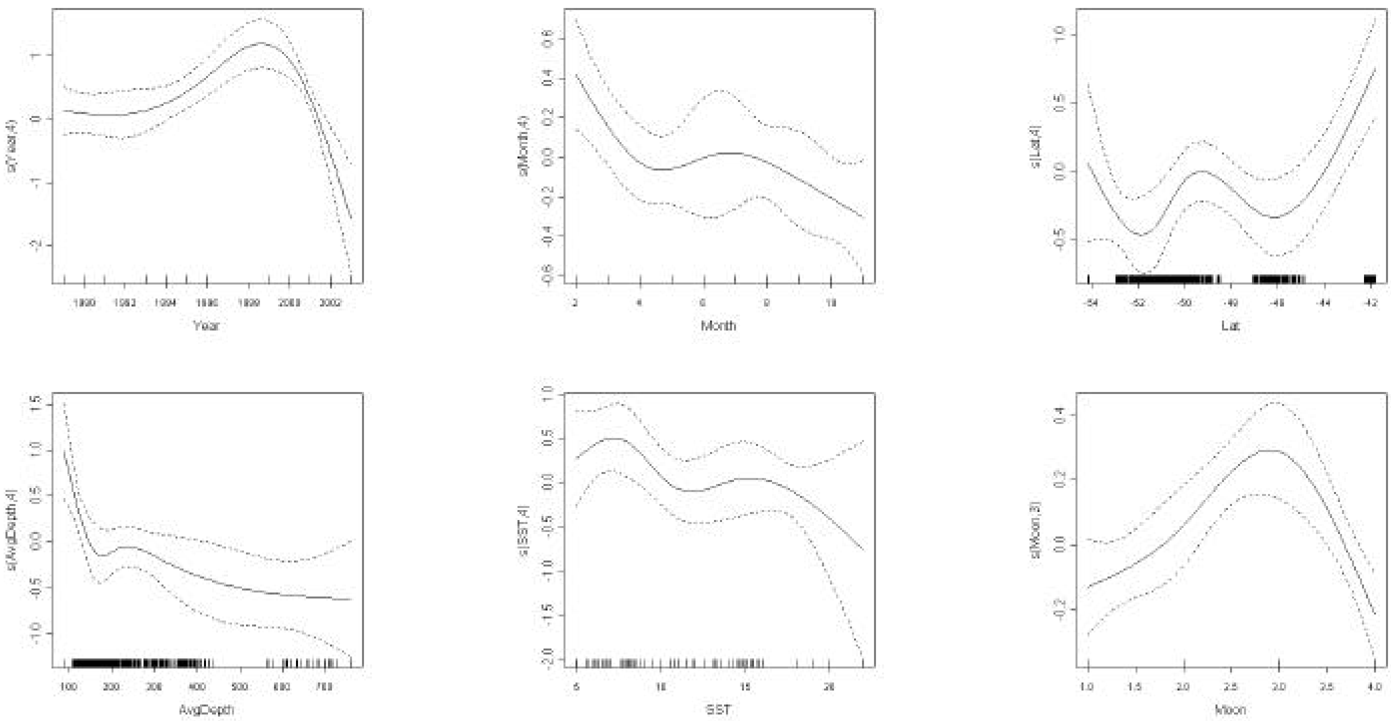


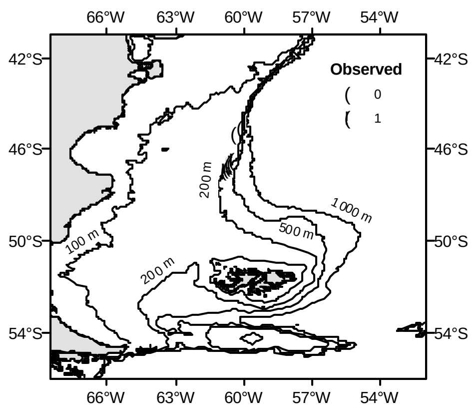
Figure 71. GAM model [11]: CPUE~ s(Year)+s(Month)+s(Lat)+s(AvgDepth)+s(SST)+s(Moon)

There is a clear increase in abundances from 1990 onwards (the maximum abundances occurring between 1998 and 1999 and then a clear decrease). There was also a slight seasonal effect on *Patagonotothen* spp. abundance. There is a general decline in abundance from January to December with a small increase between May and July and then after reaching a peak the decreasing trend continues towards the end of the year. Regarding latitude, a peak in abundances was found around 50º and 48º S followed by an increasing trend. In terms of depth there is a clear decreasing trend with increasing depth. *Patagonotothen* spp. preferentially occurs in areas with SST between 5º and 10º C. Regarding to Moon, GAM plots show that higher abundances were found in stage three.

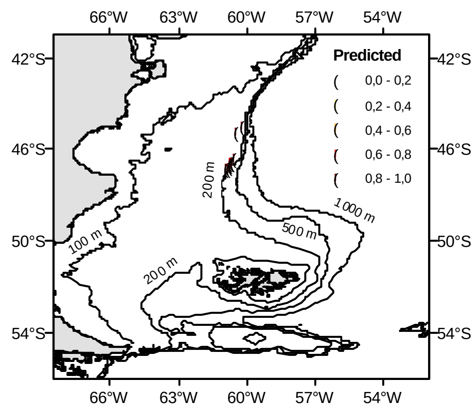
Predicting abundance, presence/absence and making maps

The aim of this study was to show how GAM and GIS can be combined to predict rockcod distribution. The main objective was to determine the ability of these techniques, when integrated, to model and map rockcod distribution in the South West Atlantic area.

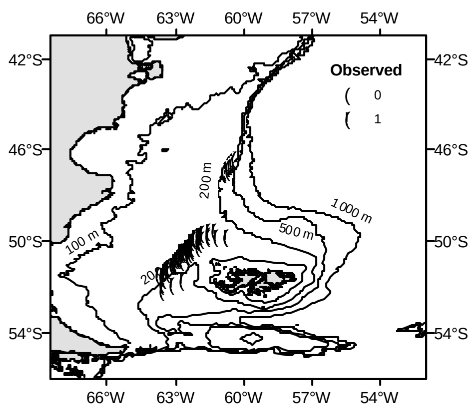
The fitted models were used to predict abundance or presence/absence over a grid of points in the South West Atlantic area. Predicted values were returned to ArcGIS for plotting. Maps of the predicted abundance and predicted presence/absence of rockcod are shown in figures 72 and 73:



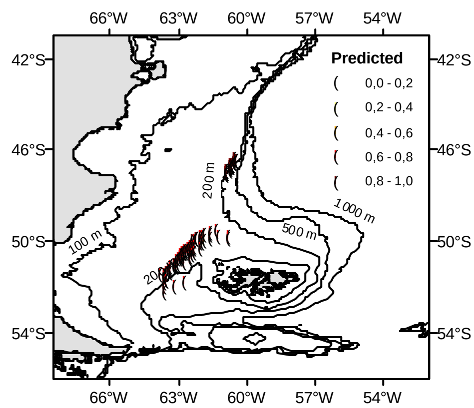
January



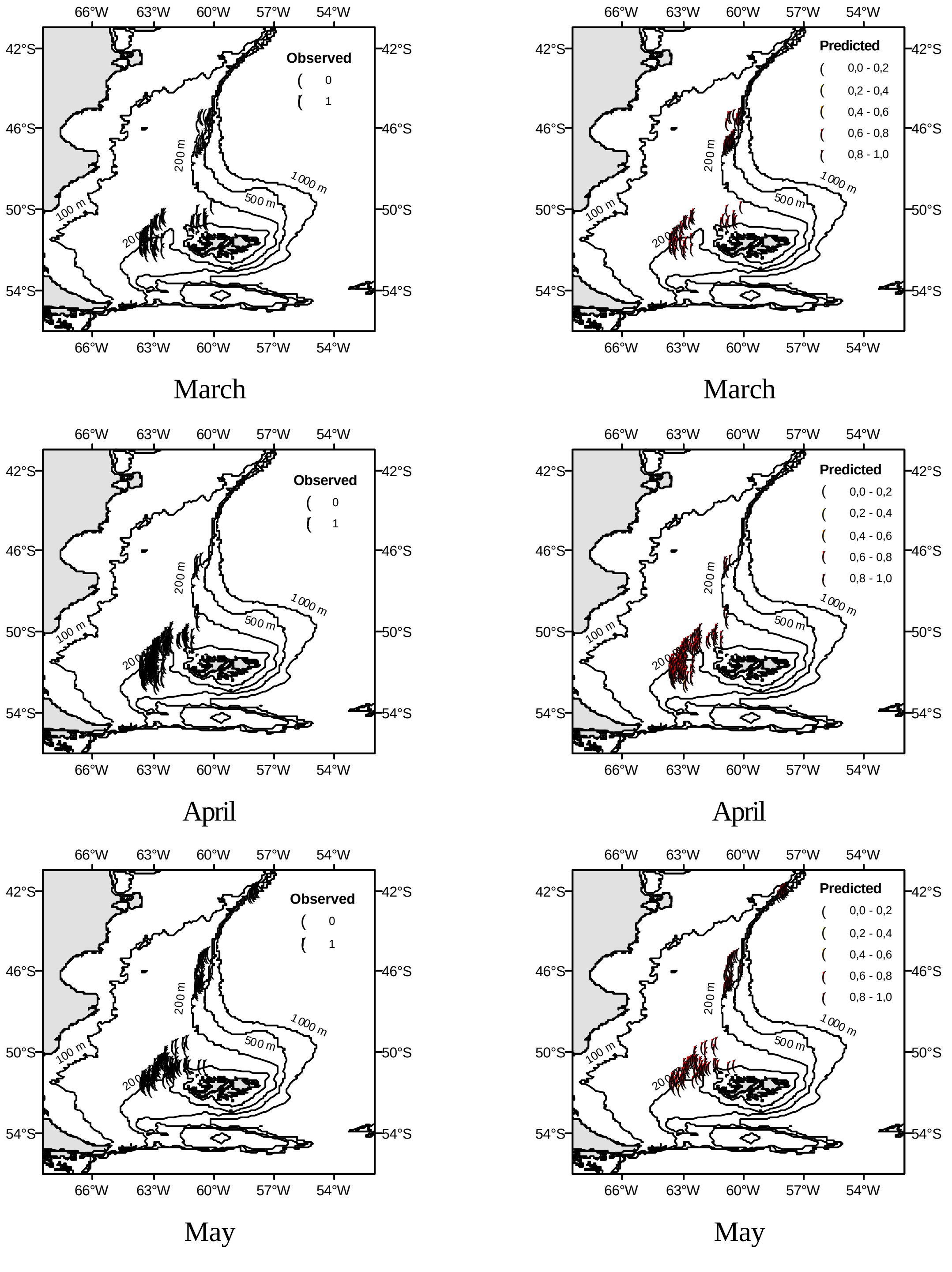
January

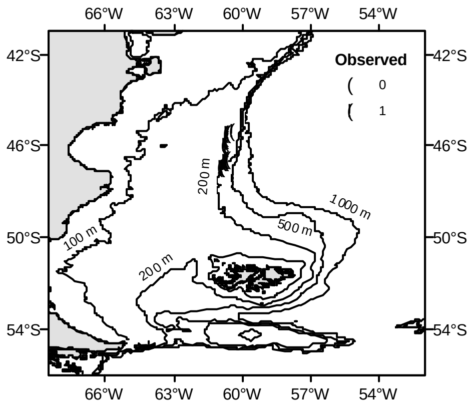


February

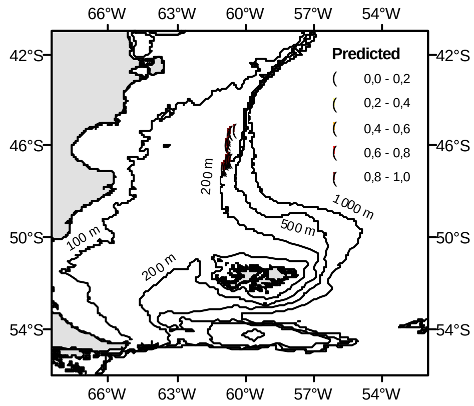


February

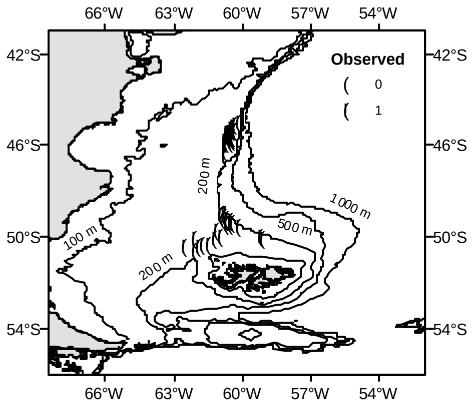

Observed
0
1
Predicted
0,0 - 0,2
0,2 - 0,4
0,4 - 0,6
0,6 - 0,8
0,8 - 1,0
100 m
200 m
500 m
1000 m
66°W
63°W
60°W
57°W
54°W
42°S
46°S
50°S
54°S
March
March
April
April
May
May



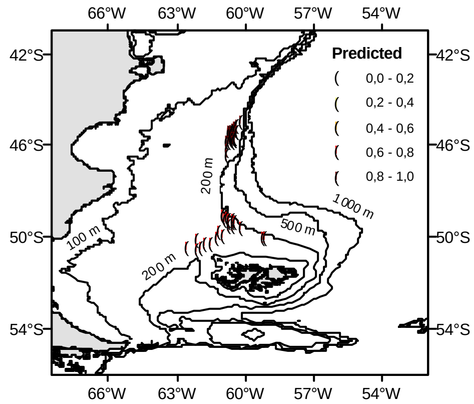
June



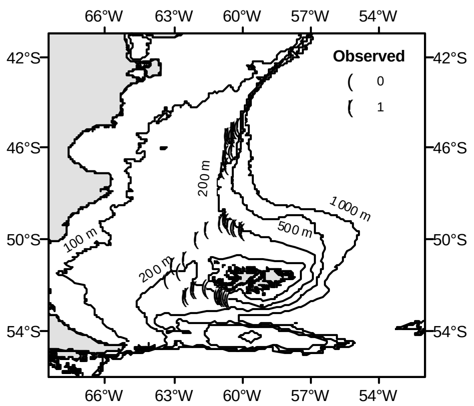
June



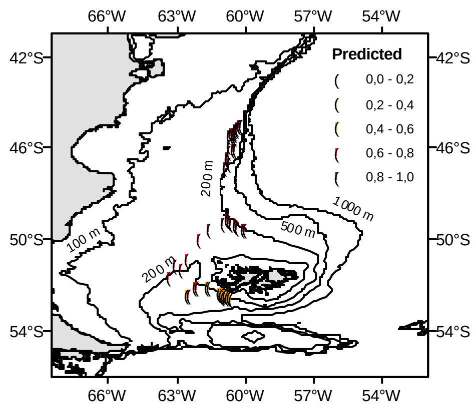
August



August



September



September

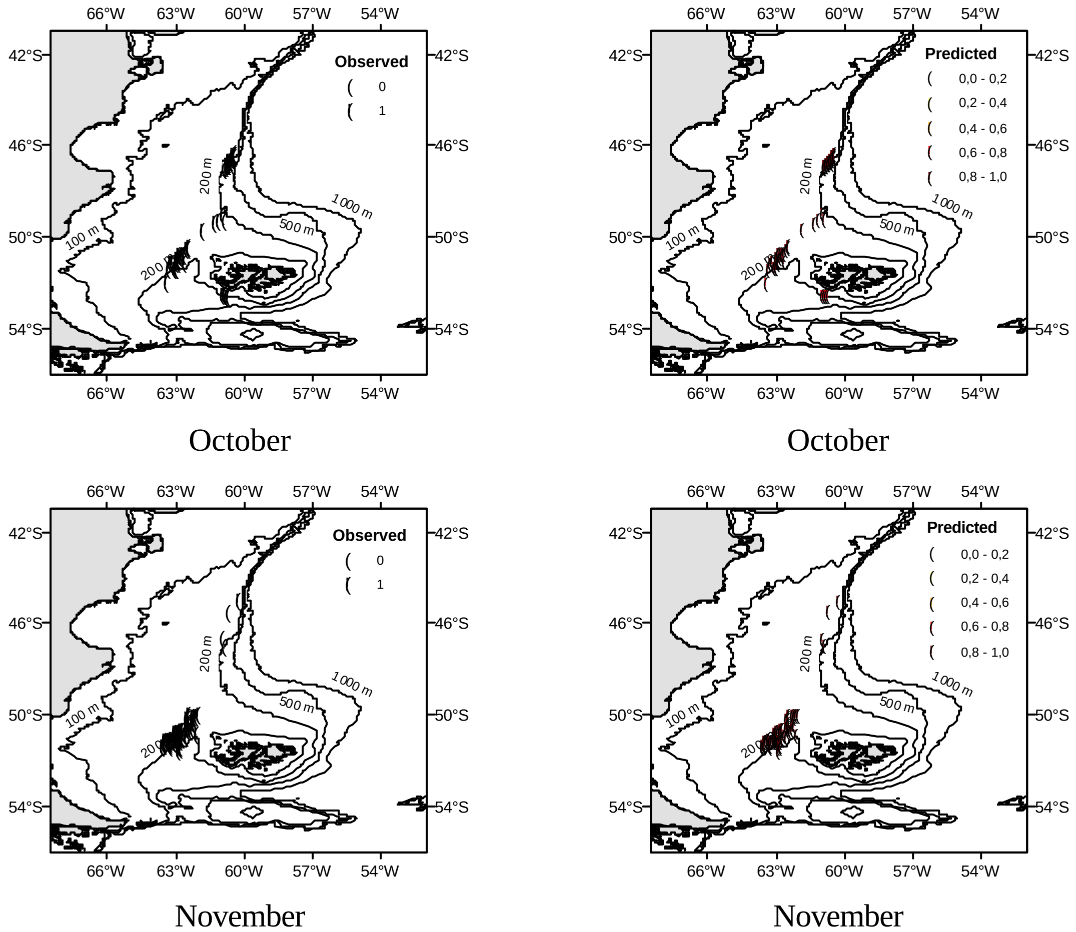
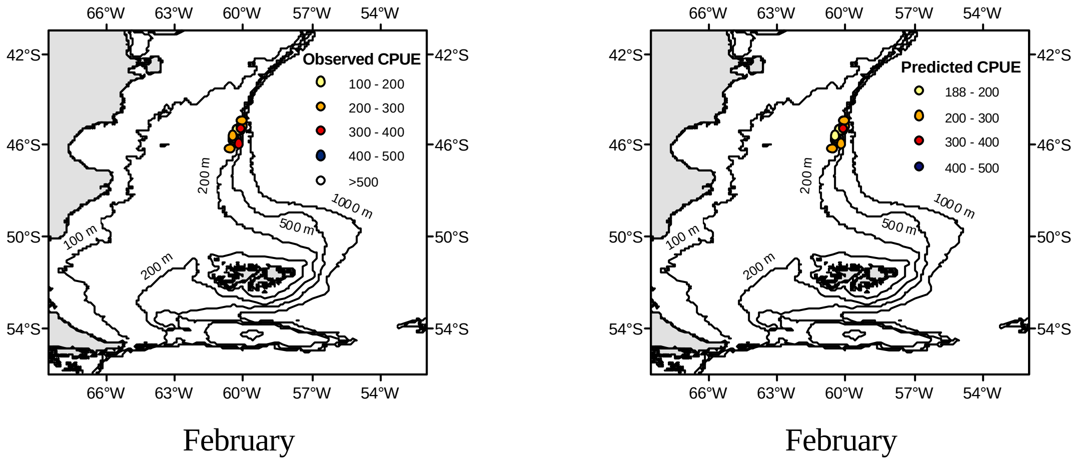
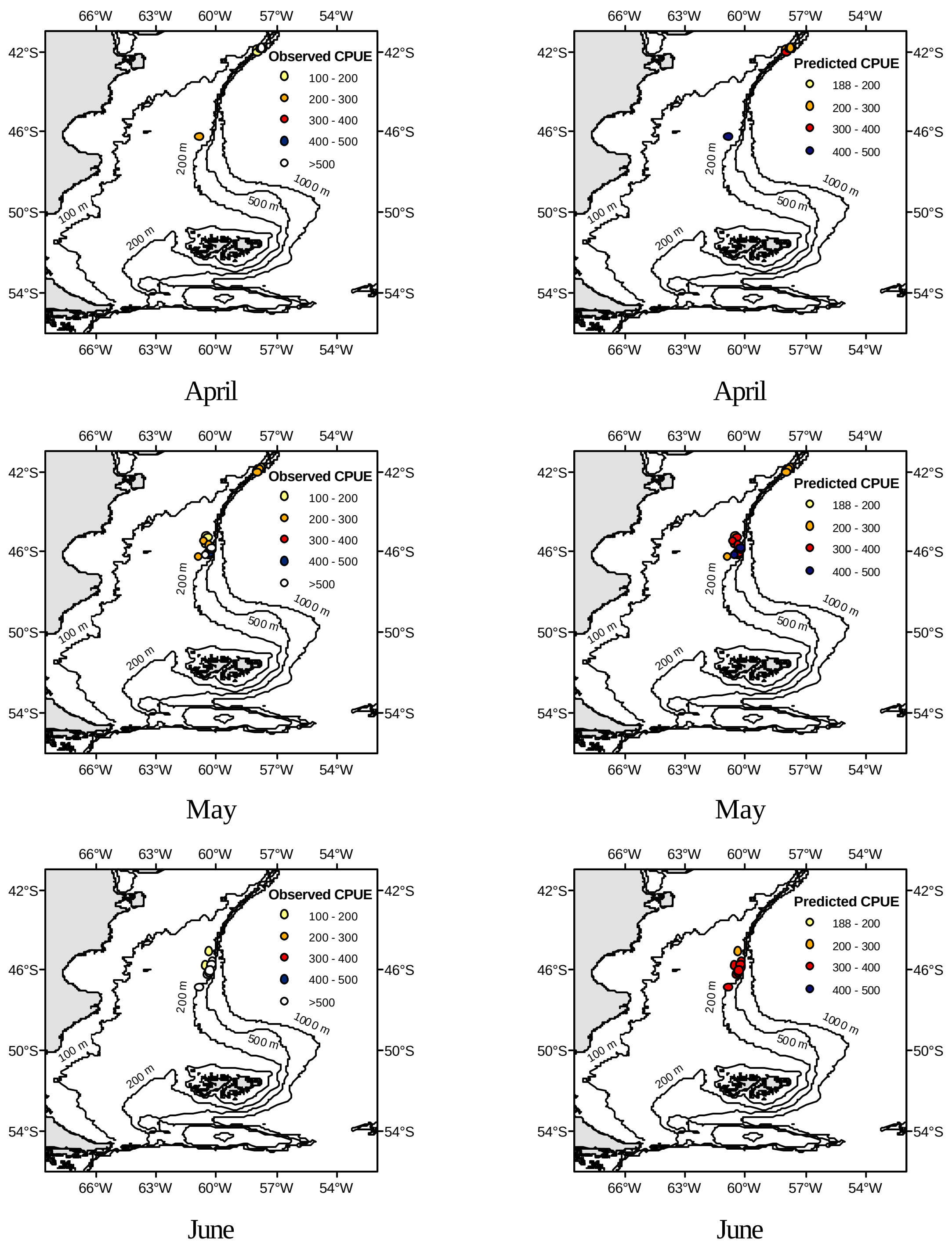
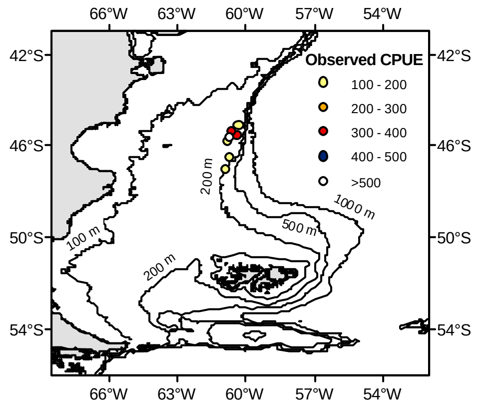
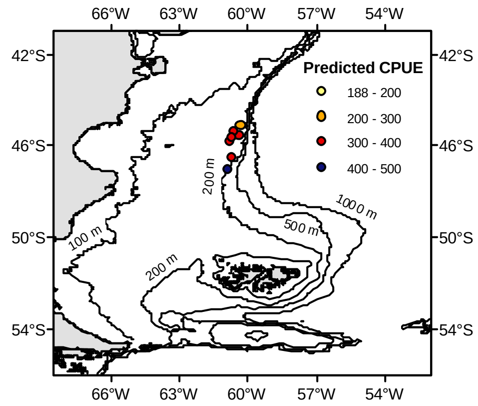


Figure 72. Maps of observed (left) and predicted (right) distribution of presence/absence of rockcod during 2000. Predicted values obtained from GAMs using binomial distribution.



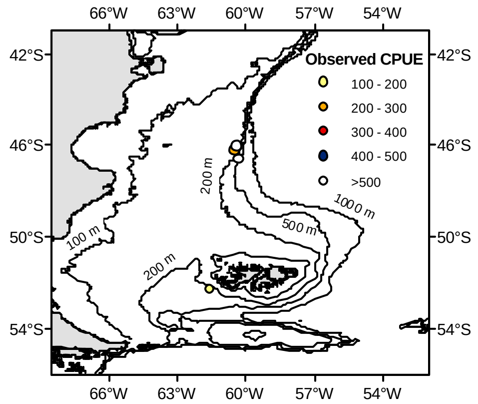

Observed CPUE
100 - 200
200 - 300
300 - 400
400 - 500
>500
Predicted CPUE
188 - 200
200 - 300
300 - 400
400 - 500
100 m
200 m
500 m
1000 m
66°W
63°W
60°W
57°W
54°W
42°S
46°S
50°S
54°S
April
May
June

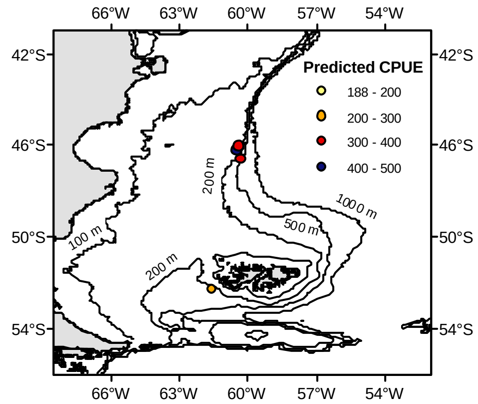




July

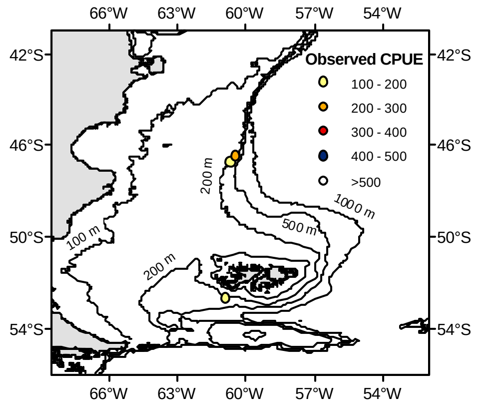
July

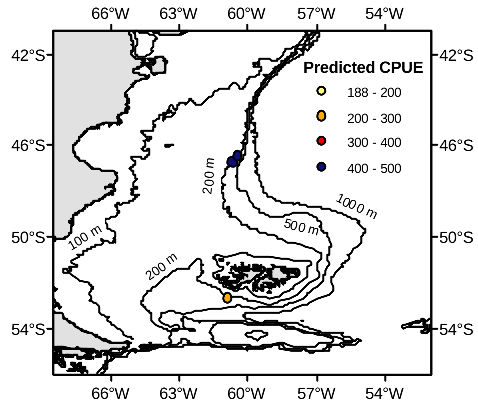




August

September





September

September

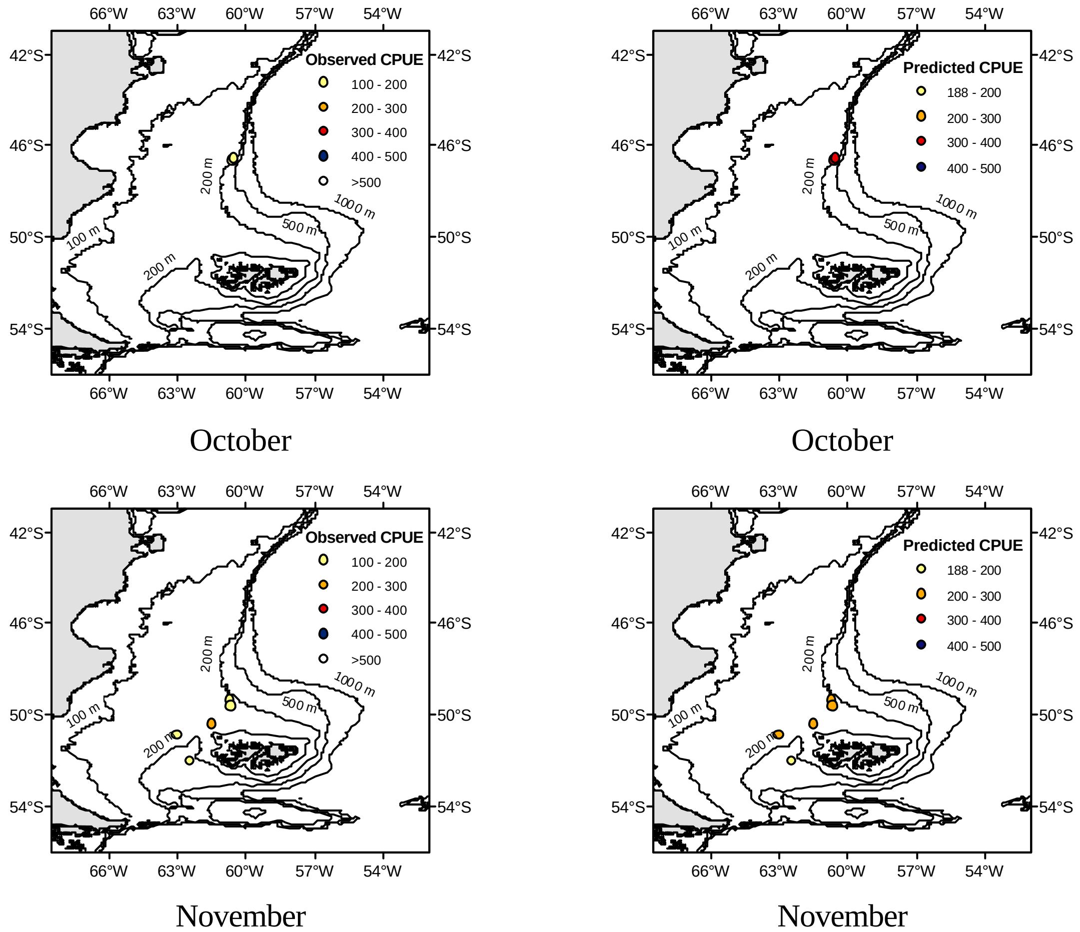


Figure 73. Maps of observed (left) and predicted (right) distribution of abundance of rockcod during 2002. Predicted values obtained from GAMs using quasipoisson distribution.

The GAM analyses indicate that differing fishery and environmental/geographical conditions influence the presence/absence and the abundance (CPUE) data. Both sources of information (presence/absence data and abundance data) indicated the level of probability of catching rockcod and the level of non-zero CPUE respectively. Final models (*i.e.* models resulting from the stepwise procedure) explained a 19.1% (PA model) and 19.6% (abundance model).

The combination of GAMs and GIS allowed us to visualize temporal and spatial variations in the distribution of *Patagonotothen* spp. in Falkland areas. The combination of GIS with statistical analysis methods has become an important and powerful approach for spatio-temporal analysis, understanding, prediction, and visualization of fishery resources in relation to environmental variation in spatial and temporal dimensions.

The discovery of relationships between environmental-geographical variability and fish abundance may form the basis of predicting fisheries abundance, with applications in fisheries forecasting and management. Future research in this field must be focused in the addition of new variables to the model in order to improve the deviance explained. These models allow the evaluation of possible causal mechanisms underlying potential relationships and suggest that successful fishery forecasting is a realistic goal.

References

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Task 2.5

ASSESSMENT

Task 2.5. Assessment. Leader ICON

Stock Assessment of Rockcod, *Patagonotothen* spp. (2nd progress report)

Deliverable # 16 General review of assessment and management practices of the Fisheries

Introduction

The southwest Atlantic is a major world fishing area. The large extent of the relatively shallow Patagonian continental shelf creates the conditions for high ocean productivity and supports large stocks of finfish and squid. The Falkland Islands are situated on the eastern edge of this shelf. Falkland Island territorial waters (the 200-mile EEZ) cover a large part of the shelf, and contain sizable stocks of fish and squid (Agnew, 2002; FIGFD, 2004). The two major fisheries in Falklands waters are squid fisheries for *Illex argentinus* (or Argentine shortfin squid) (Agnew *et al*. 2005) and *Loligo gahi* (Patagonian longfin squid) (Agnew *et al*. 2005). A number of other species of fish are caught in Falkland waters. Small quantities of very high value kingklip (FIGFD 2004) and Patagonian toothfish are taken, the latter by longlines within the FOCZ (Falklands Outer Conservation Zone) (des Clers *et al*. 1996). There is also a fishery for a mixture of skate and ray species that takes place to the north and west of the Islands (Wakeford *et al*. 2004). Hake (*Merluccius hubbsi* and *M. australis*) was once caught in large quantities on the Patagonian shelf, but has now declined in importance both in Falkland Island and Argentine waters (Hill *et al*. 2002; FIGFD 2004). A mixed finfish fishery takes primarily southern blue whiting, hoki (a rat-tail or grenadier) and red cod (Agnew 2002). The largest catches of southern blue whiting are taken by Surimi vessels, which strip the flesh from the fish and re-constitute it as Surimi (crab sticks) (FIGFD 2004). Hake, hoki and southern blue whiting occur over the whole of the Patagonian shelf, so like *Illex* they are stocks, which are common to both Falkland Island and Argentine waters (Agnew 2002).

Illex argentinus (or Argentine shortfin squid) is a large squid, reaching 50cm in length of the mantle (the body without the tentacles). Both species of squid live for only one year. Young *Illex* are thought to hatch and spend their juvenile lives in the far northern waters of Argentina and Uruguay (Arkhipkin, 1993), and start migrating south in the summer to spend the autumn (March to June) in feeding grounds more or less equally split between Argentine and Falkland Island waters. In the early winter, they return to their spawning grounds in the north. Consequently, the fishery within the Islands for *Illex* generally runs from mid-February to mid-June (Basson *et al*. 1996).

Loligo, the Patagonian longfin squid, are smaller than *Illex* reaching 30cm mantle length. In contrast to *Illex*, *Loligo* is a local species, probably spawning around the northern and western coasts of the Falklands. As the juvenile *Loligo* grow they move further offshore until they recruit to the fishery (start being caught) on their adult feeding grounds (Patterson 1988; Hatfield *et al*. 1990). They eventually leave the fishing grounds to spawn. There are two major fishing periods for *Loligo*, in the autumn (February to May inclusive) and the spring (August to October) (Agnew *et al*. 1998; Agnew *et al*. 2005). Over the last several years considerable progress has been made understanding the behaviour of these squid, and the effect of environment on recruitment (Agnew *et al* 2002, Arkhipkin & Middlton 2002, Laptikhovsky & Arkhipkin 2003, Arkhipkin *et al* 2004).

Management and stock assessment for Finfish

Management advice is provided to the Falkland Islands Government on a routine and *ad hoc* basis. The Renewable Resources Assessment Group (RRAG) at Imperial College, London routinely assesses the status of fish and squid stocks around the islands and reports the results to the Falkland Islands Fisheries Department (FIFD). For squid, which require monitoring throughout the season, weekly or daily assessments are performed (Agnew *et al*. 1998; Agnew *et al*. 2005). Finfish assessments are performed on an annual basis once an entire years data becomes available (Agnew *et al*. 1999; Wakeford *et al*. 2004). RRAG provides advice on fee structures, fee levels and the number of vessels that should be licensed in all Falklands fisheries.

Fundamental to the provision of sound management advice is the assessment of the size of fish or squid stocks and the likely effects of fishing on these stocks. The analysis of fisheries and other data using appropriate statistical and mathematical procedures is defined as *stock assessment*. A stock is a managed population unit. Stock assessments generally result in a statement of the likely size of the stock, and the catch levels that can be sustained by the stock without overexploiting it. The squid species around the Falkland Islands live for only one year, which means that the state of one year's stock is largely independent of the previous year. Thus assessments are required throughout the season, on a weekly or daily basis, to establish at what point fishing on the stock should cease so as to allow sufficient animals to breed (Agnew *et al*. 1998; Hill & Agnew 2002). This is referred to as 'real-time' management and underlies much of the Falklands contract work of RRAG. For most fish species, which live for more than one year (toothfish and southern blue whiting live for over 30 years), it is sufficient to assess them annually since most of the animals in the stock this year will still be in the stock next year.

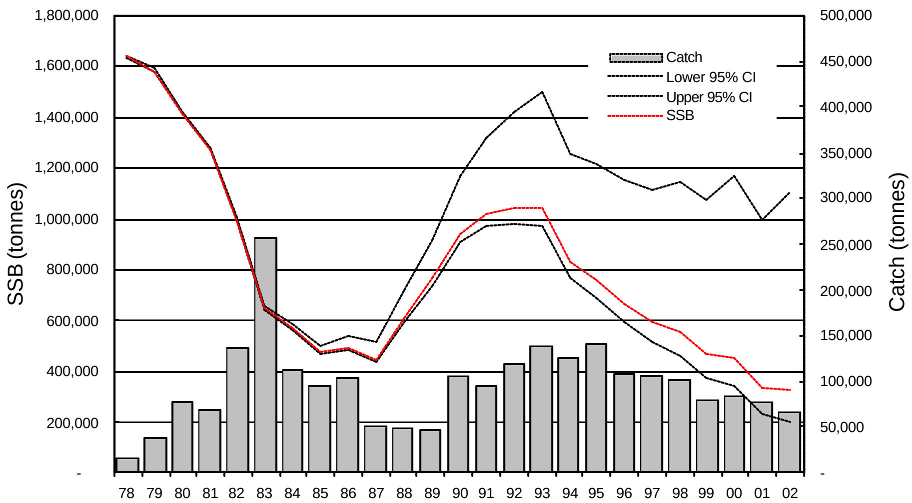


Figure 1. Example of a stock recruitment carried out for southern blue whiting. Estimated spawning stock biomass (SSB) with 95% confidence limits.

Currently only the southern blue whiting (Agnew *et al.* 1999) and ray populations (Wakeford *et al.* 2004) are assessed on an annual basis. The southern blue whiting is assessed using a VPA (Virtual population analysis) model. The model is a cohort analysis that incorporates catch data from 1978 to 2002 from both Argentina and UK fisheries and incorporates Pope's approximation. The data is then tuned to CPUE tuning series from the various fleets operating in both fisheries. The biomass estimate obtained from the VPA (fig.1) then allows the calculation of the allowable effort for the Surimi fishery and other finfish fisheries that also take a large proportion of southern blue whiting.

All fisheries management in the Falkland Islands is by effort rather than catch control. That is, instead of setting an allowable catch in tonnes, an allowable effort is set limiting the number of vessels that may enter a fishery. Following stock assessment, RRAG determines total allowable effort for a given species and a given season based on the current level of the stock from the stock assessment. The fishing power of individual vessels within a fleet is reviewed in order to allocate each vessel with an appropriate vessel unit, based on fishing plan and vessel size, for each fishery.

Rockcod and the Falkland Islands Fisheries

The capture of fish and other resources from the sea is imperfect and in the course of trying to harvest a target species, no matter how specific the gear, fish and other species are also caught that are not in demand or should not be caught due to the policy implemented within that particular fishery. Much of this bycatch is discarded to sea. However, efforts have and are being made across the globe to reduce the capture of these animals in the first place, by using more species-specific gear or to changes in management policy that makes the capture of these animals less likely. Complete eradication of the problem is very difficult in mixed species fisheries, and in these cases it seems sensible to try to utilise any unavoidable bycatch (FAO, 1995).

The benefits gained by the seafood industry are directly related to the profitability of fishing operations, as well as good catches being dependant on fish abundance. Searching for a new fisheries resource is an expensive and time consuming process which can reduce profitability. In this sense to make use of a species currently rejected to sea should increase yield and profitability, particularly in an effort-controlled fishery such as that around the Falkland Islands. Bottom trawls are one of the least selective fishing and often many species caught are discarded with subsequent loss of profitability to fleets, damage to the ecosystems and wasted resources that could be used as a food source.

The "ROCKCOD" project (Q5CR-2002-71709) aimed to develop and research the possibility of adding value to a fishery resource that is currently discarded at sea by the EU fleet fishing in the Southwest Atlantic. "Rockcod", a complex of several species but principally *Patagonotothen ramsayi*, is currently taken as by catch in the trawl fisheries in the Falklands (*Illex*, *Loligo* and finfish) (Clucas, 1997) and is subject to the Falkland Island fisheries management requirement that bycatch species should form no more than 10% of the total catch. If the by catch exceeds this value then vessels must move to other fishing grounds.

The present study was initiated to assess abundance trends and sustainability for exploitation of the resource and to provide advice on the likely impact on long term biological consequences of exploitation and increases in the current level of exploitation. The aim of this investigation was to provide a preliminary analysis of stock status of Rockcod within Falklands Island waters using methods implemented for other finfish stocks in Falkland waters and methods not already employed. The data to be used has been provided by FIFD (from observer database, biological data and survey data) and by IEO, Spain. The data has been utilised within several different assessment methods in order to fully investigate the fishery and any management options associated with it. The majority of the assessments were carried out for *Patagonotothen ramsayi* as this species had the most available data and is also the most common species in Rockcod catches. Other assessments grouped the separate species together.

This study sought to develop an assessment from the available methods that could be used to manage Rockcod stocks in the same way that other stocks are managed within Falklands waters. The methods already utilised for other finfish species were used incorporating data from the Rockcod fishery for *Patagonotothen ramsayi* alone and for all *Patagonotothen* species caught in the *Loligo* and finfish fisheries together (in much the same way as the ray fishery). The research was instigated to provide an estimate of current biomass and sustainable catch rates which could then be used to allocate effort for a rockcod fishery or to inform the effort allocation within other fisheries in which rockcod is caught and so provide a mechanism of control within the fisheries for the rockcod population.

Methods and results

Fisheries and Biological data

Fisheries observers onboard trawlers operating bottom trawls within the finfish and *Loligo gahi* fisheries in Falkland Island waters and in high seas waters adjacent to Falkland Island waters between 1994 and 2004 collected material for this work. Daily reports of total catch, position and effort were analysed for the period 1994 to 2004 to estimate seasonal and spatial variation in activities of both fleets and the catches of *Patagonotothen ramsayi* and *Patagonotothen spp*. Before the start of the Rockcod project all catches of *Patagonotothen* species recorded by observers were placed in the same category and no distinction between the different species was made. As a result it was difficult to estimate the total catches of *Patagonotothen ramsayi*. Additionally, vessels without observers only report the main target species when making fishery reports[11] and all other species, included all rockcod species, are placed in one single category. As a result of this the total catch of all rockcod species is unknown.

[11] Logbooks only require the specific reporting of the following categories of catch: Loligo, Illex, hake, southern blue whiting, hoki, rays, kingklip, red cod and “others”. Rockcod are classified as others.

Year	*Patagonotothen spp*		*Patagonotothen ramsayi*	
	Reported	Estimated	Reported	Estimated
1994	125	137	1	61
1995	425	478	40	460
1996	863	993	55	944
1997	1,311	1,482	91	1,298
1998	1,423	1,903	127	1,899
1999	1,002	1,415	117	1,365
2000	871	1,159	81	1,130
2001	506	555	9	508
2002	367	427	35	396
2003	122	281	118	162
2004	377	1,130	218	1,005

Table 1. Catches in tonnes of *Patagonotothen spp*. and *Patagonotothen ramsayi* recorded by observers onboard vessels fishing within Falkland Island waters (source: FID and IEO observer reports, and FIFD survey)

Total catches of rockcod, and specifically of *P. ramsayi*, were estimated by applying the annual proportion of other species that were rockcod or ramsayi in observer records to the total catch of "others" in logbook reports. The results are shown in Table 1.

Observer catch report data demonstrated that *Loligo* vessels took the majority of the catches with a small proportion taken by finfish vessels (except 2003 where over 50% were taken by the finfish vessels). The catches varied widely between years; with 1994 and 2001 being the lowest year for reported catches of *P. ramsayi*. For all rockcod species 2003 was the year in which the lowest catch was recorded.

Demographic data were calculated from observer records by the Falkland Islands Fisheries Department. These basic parameters were used in all assessment models (Tables 2 & 3).

Parameter	Value
M	0.2
Von Bertalanffy growth	
ℓ_∞ (cm)	33.7672
k (yr^{-1})	0.2516
t_0 (yr)	-1.074
Length-weight relationship	
a	3.70×10^{-3}
b	3.3448

Table 2. Parameter values used in assessments provided by FIFD except for Natural mortality, *M*, which is assumed to be 0.2.

Age	Maturity
1	0.01
2	0.07
3	0.22
4	0.43
5	0.63
6	0.75
7	0.85
8	0.92
9	0.92
10+	0.98

Table 3. Maturity ogive created from data provided by FIFD

Assessments

Several assessments were undertaken. All were essentially tuned to CPUE trend data, but they used different assumptions for recruitment. The methodology was that of an age structured production model (ASPM), following the methodologies of Agnew *et al*. (1999) and Brandão *et al*. (2002).

Catch at age

For the purposes of the ASPM, catch-at-age data were required. These were obtained by using observer records of length frequencies within each year. Dividing the frequency at each length by the total numbers for each year converted these into percentages of the total number of fish. The percentage was then multiplied by the total catch weight (from Table 1) to give the total weight of fish caught at each length. Length weight and von Bertalanffy growth parameters given in Table 2 were used to convert the total weight of fish caught at length to catch numbers at age (an age-length key was not used).

Catch (in numbers) at age data from 1994 to 2004 are shown in figure 3. Catches of 2-year-old fish in the trawl fishery are the highest in the years 1994 to 1996 and 1998 and 1-year-old fish are highest in 1997 and 2000 to 2004. In 1999 the picture is completely different: the fishery seems to have caught much older fish this year.

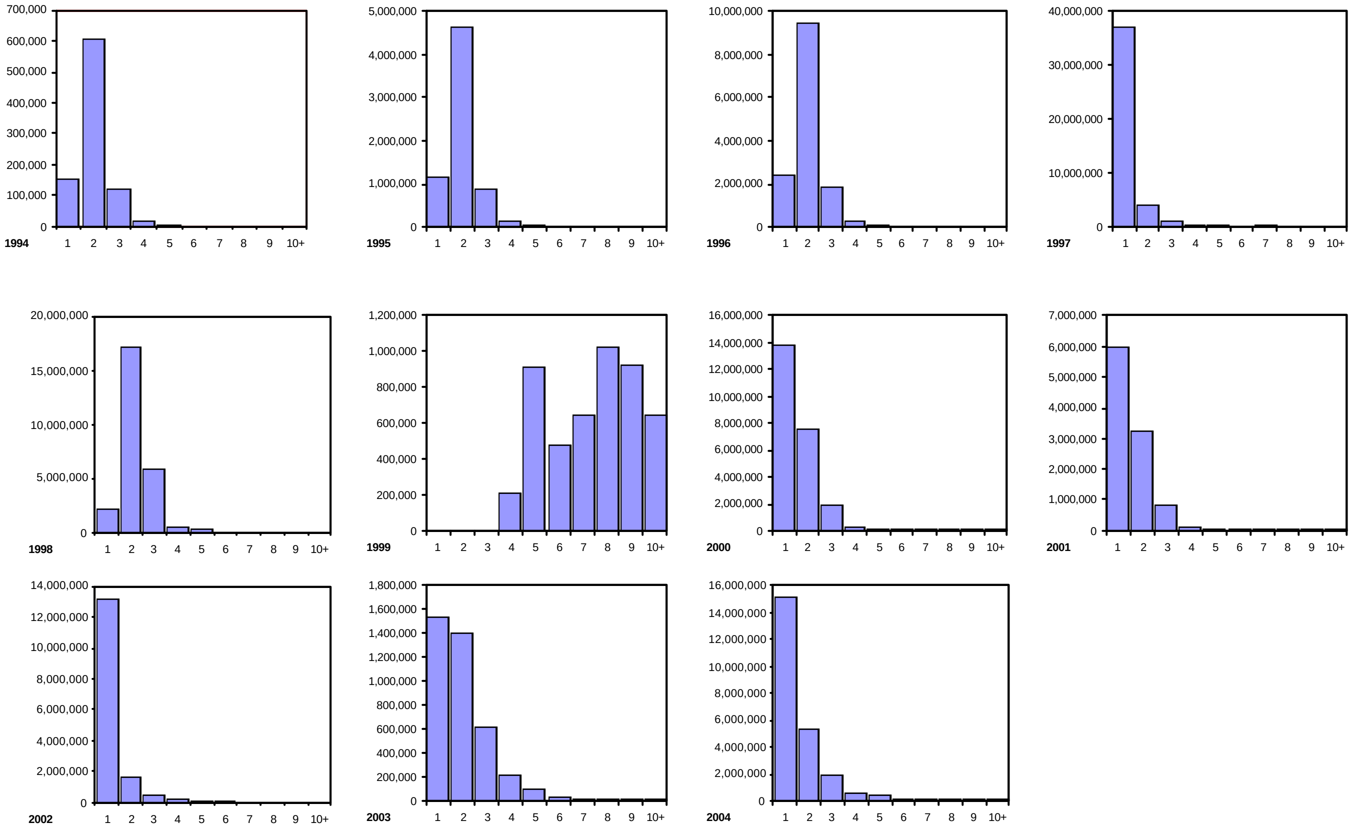


Figure 3. Catch in numbers at age for *Patagonotothen ramsayi*

These data suggest that fish recruit into the trawl fishery at approximately age 1 or 2. However, to capture all possible dynamics, the models were constructed to run from age 0+ onwards.

GLM Standardisation of CPUE data

As previously mentioned, the only assessment types at our disposal were those tuned to CPUE data. The most important assumption of these is that CPUE is proportional to biomass (changes in the CPUE index reflect changes in the underlying population size of the species). A first step in our analysis was construction of a standardised CPUE series. The standardisation of CPUE data was carried out in S-Plus 2000 for MS Windows.

The GLM used for standardisation of trawler CPUE formed a delta - lognormal distribution (as not all hauls or trawls caught Rockcod) with many zeros present within the data. This was modelled as a binomial GLM on the probability of a trawl encountering *P. ramsayi* and a lognormal GLM on abundance for all positive trawls. Following the delta-lognormal model, the estimated CPUE for each year was calculated as a product of the probability of obtaining a positive (non-zero) catch of *P. ramsayi* and the predicted (lognormal) CPUE of *P. ramsayi* in positive hauls.

$$ExpectedCPUE_y = \text{p(+ve catch)}_y.\exp(\ln \text{CPUE}_y) \qquad (1)$$

where p(+ve catch)$_y$ is the probability of catching rockcod in year y and exp(lnCPUEy) is the expected catch of rockcod in positive hauls in year y. The bold parameters in Equation 1 are the predicted values from the binomial and gaussian GLMs which are described in equations 2 and 3.

$$\ln(CPUE) = \mu + a_{year} + ß_{month} + ?_{area} + d_{grtcat} + [? + ?_{lol.perc} + ?_{lol.perc}^{4}] + [p + ?_{depth} + f_{depth}^{3}] + e \qquad (2)$$

where CPUE is the positive *P. ramsayi* catch per unit effort in kg per hour, μ is the intercept, a_{year} is a factor with 11 levels associated with the years 1994-2004, $ß_{month}$ is a factor with 12 levels (January to December), $?_{area}$ is a factor with 4 levels associated with four spatially distinct fishing areas (North east: 52 ºS to 47 ºS latitude and 59 ºW to 52 ºW longitude, North west: 52 ºS to 47 ºS and 59 ºW to 64 ºW, South east: 52 ºS to 57 ºS and 59 ºW to 52 ºW and South west 52 ºS to 57 ºS and 59 ºW to 64 ºW), $[? + ?_{lol.perc} + ?_{lol.perc}^{4}]$ is the percentage of *Loligo gahi* taken in the catch incorporated as a fourth order polynomial and $[p + ?_{depth} + f_{depth}^{3}]$ is the depth at which fish are captured incorporated as a third order polynomial and e is an error term. The binomial model took the form of:

$$p(+ve\ catch) = \mu + a_{year} + ß_{month} + ?_{area} + d_{grtcat} + [? + ?_{lol.perc} + ?_{lol.perc}^{4}] + [p + ?_{depth} + f_{depth}^{3}] + e \qquad (3)$$

where p(+ve catch) is the proportion of fishing events that resulted in a positive catch of *P. ramsayi*.

The standardisation of CPUE for all rockcod species used the same methodology but the GLM used was different:

$$\ln(CPUE) = \mu + a_{year} + ß_{month} + ?_{area} + d_{grtcat} + ?_{lol.perc} + f_{depth} + e \qquad (4)$$

The binomial model took the form of:

$$p(+ve\ catch) = \mu + a_{year} + ß_{month} + ?_{area} + d_{grtcat} + ?_{lol.perc} + f_{depth} + e \qquad (5)$$

where p(+ve catch) is the proportion of fishing events that resulted in a positive catch of all rockcod species. Again the combined estimated CPUE for each year was calculated as a product of the probability of obtaining a positive (non-zero) catch of rockcod and the predicted CPUE of rockcod in positive hauls (equation 3).

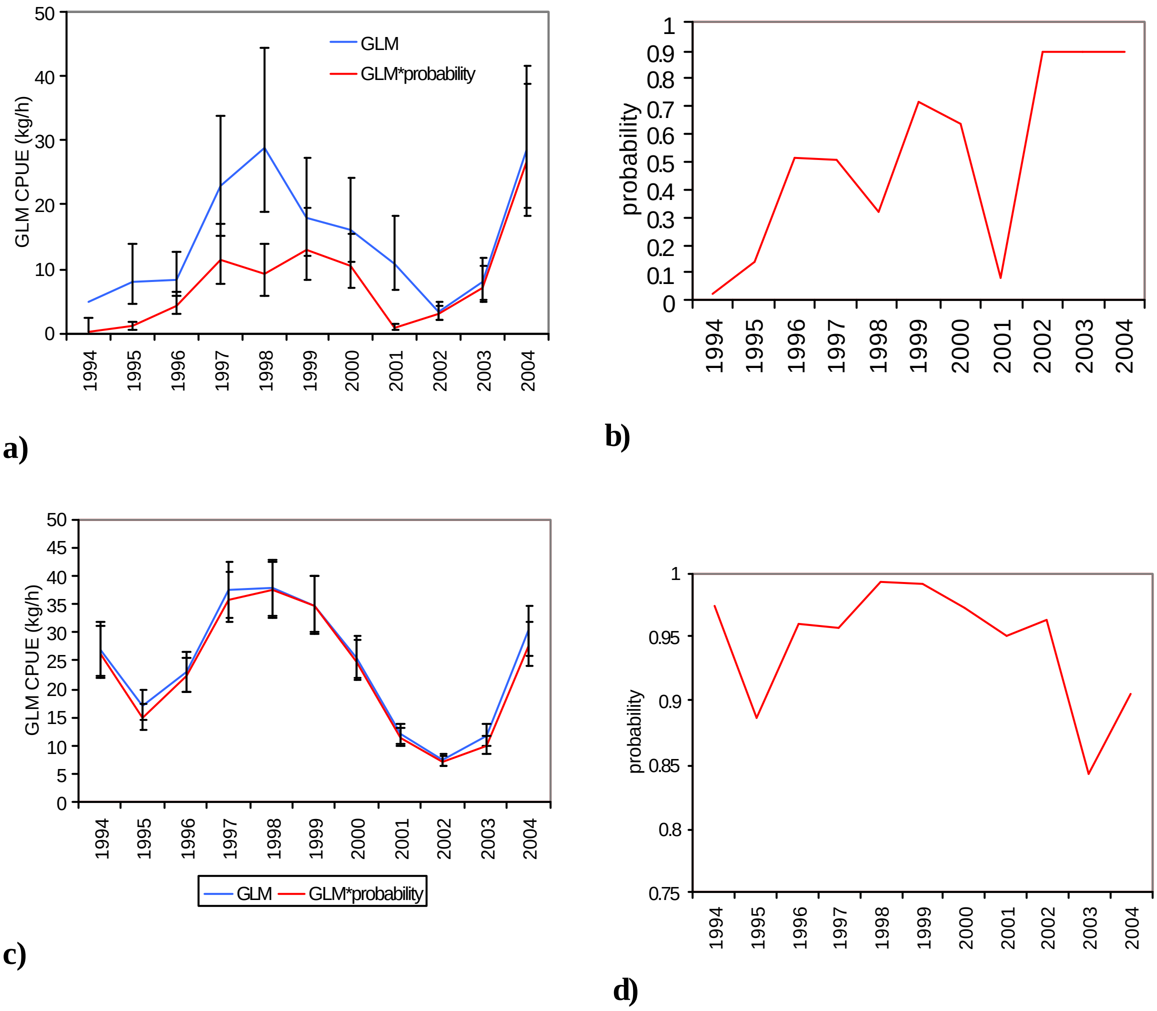


Figure 4. CPUE (a) and probability (b) of catching *P. ramsayi* and CPUE (c) and probability (d) of catching *Patagonotothen spp*. within the trawl fishery. N.B. The C.I. for 1994 is missing from (a) as the upper level is too high to show on the chart. GLM = the predictions of the lognormal GLM on positive catches, GLM*probability is the final result of the delta-lognormal prediction (equation 1) – i.e. the predicted lognormal CPUE adjusted for the probability of achieving a positive haul.

The CPUE for *P. ramsayi* in 1995 starts very low and increases to a peak in 1998 (figure 3a blue line) then decreases rapidly until 2002. However, after 2002 the cpue appears to be increasing again. Interestingly, the probability of encountering Rockcod appears to have been steadily increasing (other than 2001) (figure 3b). In the last few years this was the opposite trend for positive catches of Rockcod where the Rockcod catch rates have been decreasing slowly or have been low. The probability of catching Rockcod adjusted the CPUE so that the decrease began in 1999 rather than 1998. The new decline was more rapid and the lowest point reached in 2001 rather than 2002 (figure 3a red line). The low probability of rockcod being caught in 2001 appears to be an unusual result. The observer effort in this year was similar to all other years and so this does not appear to be as a result of differences in the number of observers or the time spent at sea. However, in this particular year the *Loligo* fishery continued to the end of both seasons and catches of *Loligo* were very high. So the probability of catching rockcod may have been very low due to targeting of Loligo continuing late in the season and the probability of catching *Loligo* being very high (even in October 41% of catches are *Loligo gahi*).

When the data for all rockcod species are examined the picture is quite different. The CPUE series follows a similar but not identical pattern and the probability is very different. The CPUE series for the GLM alone and for the GLM and the binomial model are very similar to each other (figure 3c) and this is due to the probability of catching all rockcod species being above 80% in every year (figure 3d). The probability for all rockcod species is fairly consistent and even in 2001 the probability is above 90%.

This raises the question again as to why there is low probability of catching *P. ramsayi* in this particular year. It is most probably due to an observer-generated effect: it would seem that few rockcod were identified to species level in 2001. The same problem is evident in the early part of the *P. ramsayi* series (Figure 4b, 1994 – 1996), when there was apparently quite a lot of rockcod and very little *P. ramsayi*. This may be due to few of the rockcod being identified to the species level and all being recorded within the *Patagonotothen spp*. group in catch records as a consequence of a good year in the *Loligo gahi* fishery.

Table 4 demonstrates that most of the rockcod recorded by observers in most years was *P. ramsayi*. Given the problem of species separation in the early part of the series and in 2001, we chose to assume that the CPUE series of all rockcod was representative of the CPUE series of ramsayi. In other words, that there was no further information to be gained on changes in ramsayi CPUE by looking at the trends of that species rather than as the trends for rockcod as a whole. Accordingly, on the series GLM*probability in Figure 4c was used in the assessment models.

Year	% *P. ramsayi*
1994	44%
1995	96%
1996	95%
1997	86%
1998	100%
1999	96%
2000	98%
2001	92%
2002	98%
2003	99%
2004	94%
mean	66%

Table 4. Percentage of all identified *Patagonotothen spp*. that are *P. ramsayi*

Estimates of biomass from commercial and research swept-area calculations

Swept-area density measurements were calculated using observer data. An assumed net wingspread (headrope length), the speed of the vessel and the time spent trawling were combined to calculate the distance travelled. Density was then calculated as the catch divided by, *hr* (the length of the headrope in km), *V* (the speed in knots x 1.852) and *t* (the time spent trawling in hours). Since the headrope is not straight when being trawled the value *hr* is larger than the width swept by the trawl. Various estimates have been made of the appropriate conversion factor for swept area, including 0.4 (Shindo 1973) to 0.66 (SCSP 1978). However, Pauly (1980) suggests a value of 0.5. Thus the equation becomes:

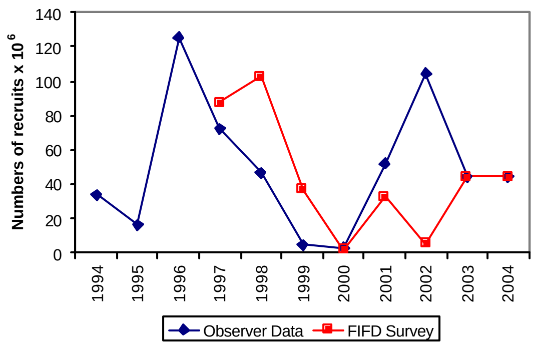
$$\text{Density (kg km}^{-2}\text{)} = \frac{C}{0.5hrVt} \qquad (6)$$

In order to calculate the number of recruits into the fishery the density measurement for each year was then multiplied by the area of the fishery to estimate the biomass of rockcod on the shelf. This was separated into a fraction equal to two year old fish and another equal to fish greater or younger than two years old (recruitment into the fishery was assumed to occur at age 2. Two-year-old fish were used as the length-weight relationship is subject to greater uncertainty in 1-year-old fish and the weight of animals at length was important in the calculation of the numbers of fish). The number of recruits was estimated by dividing biomass of recruits at age 2 by the weight of 2-year-old fish. The number of recruits two years previous (i.e. at age 0+) was then calculated:

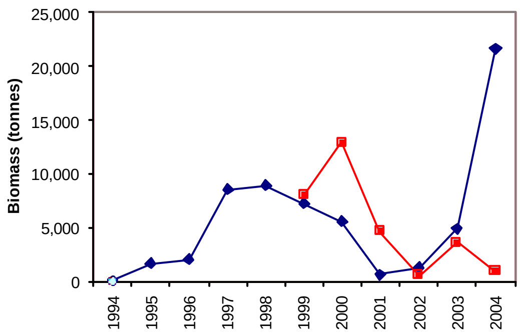
$$r_{y,0} = r_{y+2,2}\left(e^{2M}\right) \qquad (7)$$

where r_y is the number of recruits in year *y* between the years 1994 and 2004. The estimate of 0+ recruits, calculated from observed trawl swept area data is shown in figure 5a. The results indicated a peak in recruitment in 1996 and 2002.

An alternative series of data, from FIFD Surveys, is available. The two data sources show remarkably similar recruitment and biomass trends. It appears that recruitment peaked in 1996 – 1998, and again in 2002, whereas biomass declined from about 10,000 t in 1998 to very low levels in 2002, rising again to about 5000 t in 2003 (the 2004 data are not consistent with the other series nor are they believable).



a)



b)

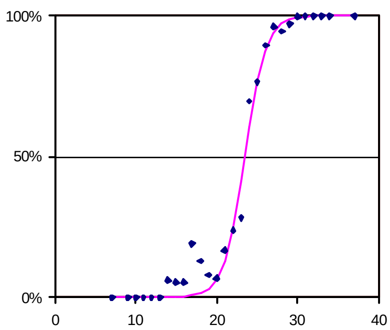
Figure 5. Swept area estimates of (a) the number of recruits to fishery and (b) biomass between 1994 and 2004. N.B. The number of recruits in 2003 and 2004 are based on the mean of the previous years.

Selectivity

A selectivity vector for *Patagonotothen ramsayi* for use within the age structured production model and yield-per-recruit analysis was estimated using a selectivity curve. The number of fish caught in mesh sizes 90 and 95 mm were used to calculate the selectivity vector using the equation below.

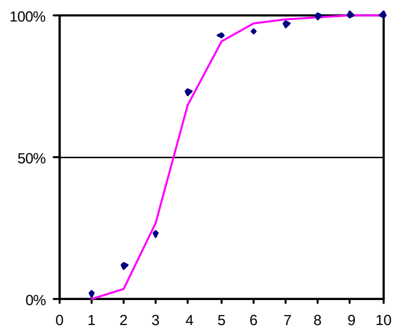
$$P = 1/(1+e^{-r(L-L_c)}) \qquad (8)$$

Where P was the proportion of the catch at length L caught in the larger mesh, r_c was a constant and L_c was the mean length at which 50% of fish are retained in the cod-end. P was calculated as the number of fish of length L in the larger mesh divided by the sum of fish of length L in both mesh sizes. The lengths were then converted to ages using the Von Bertalanffy growth parameters to produced selectivity at age. The vector used in the yield-per-recruit and ASPM models is shown in figure 6. The selectivity suggests that 50% selectivity occurs at age 3.5 and 100% selectivity is reached at age 9.



a)

Age	Selectivity
1	0.00
2	0.03
3	0.27
4	0.68
5	0.91
6	0.97
7	0.99
8	0.99
9	1.00
10+	1.00



b)

Figure 6. Selectivity vector and selectivity at (a) length and (b) age for *Patagonotothen ramsayi*.

ASPM – Age-structured production model

A cohort analysis using data between 1994 and 2003 was constructed in MS Excel using the structure described in Agnew *et al.* (1999). Five formulations of the model were investigated. For the first three recruitment was directly estimated from a swept-area calculations from observer data in commercial operations; 1) using observer monitored swept area density as an estimate of absolute recruitment, 2) using observer monitored swept-area density as an index of recruitment and 3) again using swept area measurements of recruitment but generating it's own catch-at-age using a method similar to that for toothfish utilised by Brandão at al (2002). The other two models (4,5) incorporated a stock recruitment relationship but one (5) generated it's own catch-at-age also. For the indices based on swept area measurements the model required an additional parameter to be established, *q*', relating recruit population size to the index. Recruitment was then either the absolute number of recruits or the number of recruits estimated from the swept area measurements and *q*'. The virgin population was calculated from R_0 and natural mortality. In the interests of simplicity the model estimated R_0 but for the models using a stock-recruitment relationship was estimated from the relationship. The various formulations are shown below.

Model formulation	Recruitment	Catch at age	Estimated parameters
1	Commercial swept area as an absolute estimate of recruitment	As calculated (Figure 3)	B_0
2	Commercial swept area as an index of recruitment	As calculated (Figure 3)	B_0, q'
3	Commercial swept area as an index of recruitment	Estimated from selectivity function	B_0, q', selectivity function
4	Beverton-Holt recruitment function	As calculated (Figure 3)	Beverton Holt parameters
5	Beverton-Holt recruitment function	Estimated from selectivity function	Beverton Holt parameters, selectivity function

Table 5. Methodology applied to each age-structured production model.

The population in each subsequent year was projected forward from the virgin biomass. The rockcod population dynamics are given by the equations:

$$N_{y+1,0} = R(B^{sp}_{y+1}) \tag{9}$$

$$N_{y+1,a+1} = (N_{y,a} - C_{y,a})e^{-M} \tag{10}$$

$$N_{y+1,m} = (N_{y,m} - C_{y,m})e^{-M} + (N_{y,m-1} - C_{y,m-1})e^{-M} \tag{11}$$

where, $N_{y,a}$ was the number of rockcod of age a at the start of year y, $C_{y,a}$ was the catch of rockcod of age a taken by the fishery in year y, M is the natural mortality rate of the fish (assumed to be age independent) and m is the maximum age considered (the plus group of fish aged 10 or older). The catch-at-age in the model that generated its own catch-at-age was given by:

$$C_{y,a} = S_a F_{y,a} N_{y,a} \tag{12}$$

Where $F_{y,a}$ is the proportion of the resource at age a harvested in year y and S_a is the commercial selectivity-at-age given in equation 7 and shown in table 3. This value was then used to calculate the numbers present in the next year at age a+1.

Recruitment into the fishery took different forms depending on whether an index was estimated from the swept area density or the absolute number of recruits was used. Thus, the numbers of fish recruiting into the fishery in the model that used the swept area density as an index of recruitment was given by:

$$N_{y+1,0} = R(B_{y+1}^{sp}) = q' r_{y+1,0} \tag{13}$$

The numbers of fish recruiting into the fishery in the model that used the swept area density as recruitment was given by:

$$N_{y+1,0} = R(B_{y+1}^{sp}) = r_{y+1,0} \tag{14}$$

The weight at age, w_a, was given by the mean weight of individuals from the length-weight relationship at age a. The model estimate of spawning stock biomass (SSB) in year y was given by:

$$B_y^{sp} = w_a f_a N_{y,a} \tag{15}$$

where B_y^{sp} is the spawning stock biomass in year y, and f_a is the proportion mature at age a. In the models that used a stock-recruitment relationship the number of recruits at the start of year y is assumed to relate to the spawning biomass at the start of year y, B_y^{sp}, by a Beverton-Holt stock recruitment relationship (assuming deterministic recruitment):

$$R(B_y^{sp}) = \frac{aB_y^{sp}}{b + B_y^{sp}} \tag{16}$$

The values of the parameters a and *ß* can be calculated given the initial spawning biomass K^{sp} (which the model estimates) and the steepness of the curve h, using the equations in the appendix.

The oldest fish in the population were aggregated into a 'plus group' (all fish of 10 years and above). For all years, the catch numbers at age were rescaled using the sum of products correction to match the actual reported catch. Natural mortality was set at 0.2. The fitting procedure used a log-error model:

$$\text{SSQ} = \sum \left(\ln\left(qCPUE\right) - \ln\left(B_y^{SSB}\right)\right)^2 \tag{17}$$

The first formulation (1) used observer monitored swept area density as absolute recruitment (figure 7). The swept area measurements were taken to be the number of animals recruiting each year and were used to estimate the number of animals in subsequent years. The model population appears to be extremely large and suggest that estimates of the number of recruits are higher than they should be, causing the model to estimate a much larger population than is actually present. The model estimates virgin biomass to be 171,750 tonnes and current biomass (2004) to be 80,400 tonnes, much larger than the predictions of other models. R_0 in this model was estimated as 2.77 x 10^8

and current biomass is 47% of virgin biomass. There is also a rather poor fit of the CPUE trend to the predicted biomass.

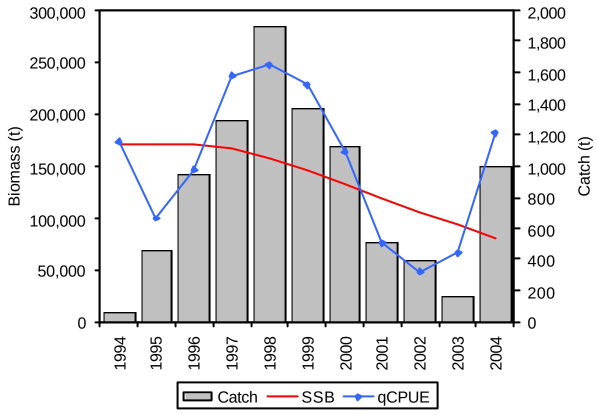


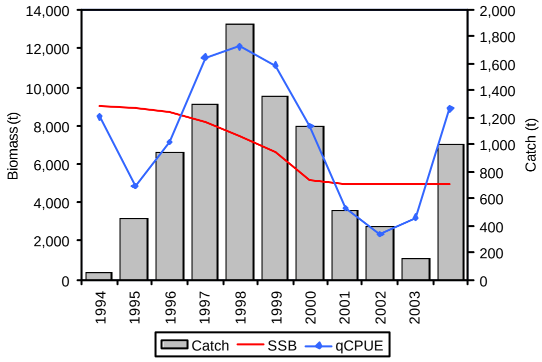
Figure 7. ASPM model estimates of spawning stock biomass (SSB) fitted to qCPUE for model using swept area estimate as the absolute number of recruits model and generating catch-at-age.

The other formulations provide slightly better fits to the data, but none of these are really able to reproduce the quite rapid changes in CPUE seen over the last few years.

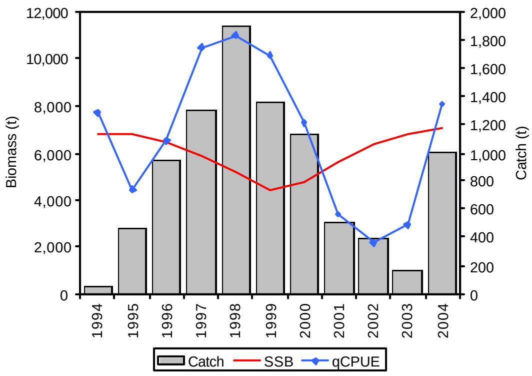
The second formulation (2), which used the observer monitored swept-area density calculation as an index of recruitment and *q*', is shown in figure 9a. The current assessment estimated R_0 to be 1.45 x 10^7 individuals and indicates that the virgin spawning stock biomass was 8,957 tonnes. The spawning stock biomass in 2004 was estimated at 5,015 tonnes (figure 8a) 56% of virgin biomass. The *q*' for this model was 0.515, suggesting that the recruitment estimates used within the models were greater than was required (more than twice as high).

The third formulation (3) , which utilised the index of recruitment but generated its own catch-at-age from the selectivity vector, catches and weight-at-age indicated that R_0 was 1.13 x 10^7 individuals and that the virgin stock biomass was 6,830 tonnes. The model estimated the SSB for 2004 to be 7,082 tonnes (figure 8b), 104% of the virgin biomass. The *q*' for this model was 0.393, which again suggests that the recruitment estimate is too high and the model has reduced the estimate to compensate.

The fourth formulation, that did not use an index of recruitment but included a Beverton-Holt stock recruitment relationship, estimated a higher virgin stock biomass of 13,907 tonnes. The SSB for 2004 was estimated at 6,755 tonnes (figure 8c). R_0 was estimated as 2.25 x 10^7. This model shows a similar decline to the previous models but without stabilisation or a recovery from 2000. The current biomass estimate is 49% of the virgin biomass.



a)



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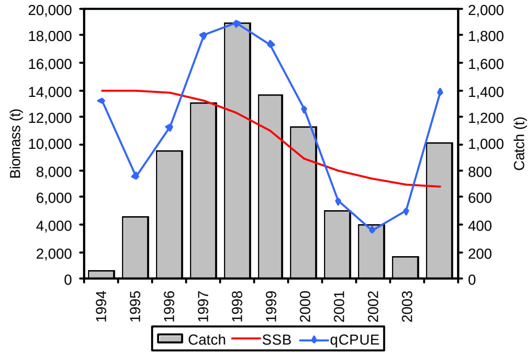
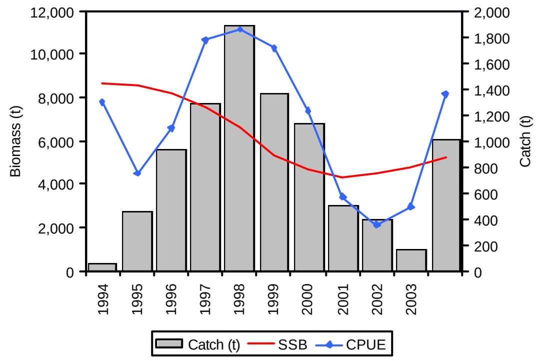


c)



d)

Figure 8. ASPM model estimates of spawning stock biomass (SSB) fitted to qCPUE for (a) formulation 2 using swept area estimate as an index, (b) formulation 3 using recruitment index and model generating catch-at-age, (c) formulation 4 using stock-recruitment relationship and (d) formulation 5 using generated catch-at-age and stock-recruitment relationship.

The fifth formulation, which is effectively either the addition of a stock recruitment relationship to formulation 3 or estimation of catch at age to formulation 4, created a model that was between the second and third formulations, with a recovery beginning in 2000 but not increasing to a point above the virgin biomass. The virgin biomass was estimated as 8,655 tonnes and the biomass in 2004 as 5,239 tonnes, 61% of the virgin biomass (figure 8d). R_0 in this model was estimated as 1.26 x 10^7 individuals.

Which, if any, of these formulations is most likely to be accurate? None of them reproduce the CPUE trajectory satisfactorily. However, the most likely formulations are 2-5, with current SSB being 5000 – 7000 tonnes. This is similar to the biomass being estimated by the research surveys.

Yield-per-recruit

A basic yield-per-recruit model was set up in MS Excel using the same weight-at-age, maturity ogive, selectivity vector and natural mortality utilised in the ASPM. These models can be used to establish management reference points, usually either $F_{0.1}$ management (the point at which the slope of yield per recruit vs F is one tenth of the value near the origin (biological reference point)) or Fmax.

The model assumes that recruitment, fishing mortality and natural mortality are constant from the moment fish become vulnerable to fishing gear. The fundamental yield-per-recruit model gives the yield, *Y* (in biomass) to the fishery as:

$$Y = \sum_{t_c}^{t_{max}} F_t N_t W_t \qquad (18)$$

where t_c and t_{max} are the ages of first capture and maximum ages of cohorts, respectively, F is fishing mortality, N the number of individuals alive and W is their mean weight at time t.

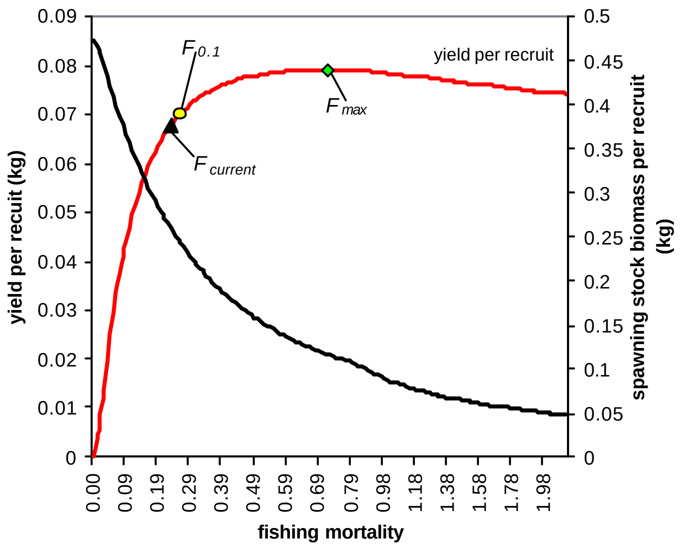


Figure 9. Yield per recruit and spawning stock biomass per recruit.

Current F within the models is 0.23. This level of fishing mortality is slightly below the value for $F_{0.1}$. At $F_{0.1}$, F was 0.26; the yield per recruit 0.07 kg (so that 0.07 kg of fish would be caught for every fish that recruited to the fishery) and the spawning stock biomass per recruit was 0.24 kg (figure 9). The spawning stock biomass ratio (the ratio of SSB per recruit of $F_{0.1}$ to virgin SSB per recruit) was 29%. At $F_{\max}$ (where the yield-per-recruit is maximised) the value of F is 0.72 and the yield per recruit is 0.08 kg and the spawning stock biomass-per-recruit is 0.12 kg. These values for $F_{0.1}$ and F_{max} were then used for the projections detailed in the next section, in order to examine the response of the population to fishing at different fishing mortalities.

Consequences of different management reference points

The most plausible ASPM formulations appear to be 2 and 5. Table 6 presents calculations of sustainable yield at $F_{0.1}$ and F_{max} and $F_{current}$ for these model formulations. In the projections, recruitment was for formulation 2 was assumed to be the same as the recruitment in 2004 and for formulation 5 the stock recruitment relationship was projected forward. Fishing mortality was set as constant throughout the projection period ($F_{0.1}$, F_{max} or $F_{current}$) and using the selectivity vector the fishing mortality for each age group was calculated. This fishing mortality at age was then used to determine the numbers at age in the projections:

$$F_a = S_a F_{0.1} \quad (19)$$

$$N_y = N_{y-1}(e^{-M-F_a}) \quad (20)$$

where F_a is the proportion the resource harvested at age a, Sa is the commercial selectivity at age, $F_{0.1}$ is the fishing mortality at $F_{0.1}$ (this can be F_{max} or $F_{current}$) and the other parameters are as before (equations 10 and 11).

		$F_{0.1}$	F_{max}	$F_{current}$
	F	**0.26**	**0.72**	**0.23**
Formulation 2	Average catch	1,102 tonnes	1,529	1,039
	Maximum catch	1,226	2,233	1,171
	% of virgin SSB in 2020	74%	43%	78%
Formulation 5	Average catch	811	1,030	772
	Maximum catch	1,116	2,672	1,045
	% of virgin SSB in 2020	34 %	14%	37%

Table 6. Results of catch projections at different levels of *F*.

Projections of catch at $F_{0.1}$ for formulation 2 model show that at a fishing mortality of 0.26 the biomass would return to approximately 74% of the virgin biomass level (table 6) and would continue to increase. In formulation 5, the catches at $F_{0.1}$ were slightly lower (table 6) at around 800 tonnes and the population continues to decrease to 38% of the virgin biomass. At F_{max} the average catch was higher in both models. However, for formulation 2 the population decreased to 38% of the virgin biomass whereas formulation 5 has higher maximum catches (table 6) but the population decreases to only 14% of the virgin biomass in 2020. At current F (0.23) formulation 2 has slightly lower catches than at $F_{0.1}$ and the population increases to 78% of the virgin biomass while formulation 5 has average catches of 772 tonnes and a maximum of just over 1,000 tonnes. The population again continues to decrease to only 37%.

Discussion

Our best estimate of current biomass of this stock is around 5000 t SSB, with a possible range from 5000 t – 7000 t. These figures are roughly confirmed by the research surveys. However, it must be said strongly that none of the assessments are satisfactory, in that none of them are able to match the quite large trends in CPUE to similar trends in modelled population biomass.

Why might this be? Part of the answer is almost certainly that these species are not consistently targeted. This not only leads to the data being poor and inconsistent, but probably undermines the basic assumption in our assessment that trends in CPUE reflect trends in population biomass. This is best seen in the very high correlation between CPUE and total catch – CPUE is not following a trend in biomass so much as a trend in catch. If vessels consistently targeted *Patagonotothen ramsayi* and other Rockcod species a more specific trend in catch trends and CPUE might appear.

Although targeting is a problem is it also likely that the changes in rockcod CPUE reflect changes in distribution and density of the species, overlaid with changes in the distribution and density of fishing effort, rather than the abundance of the population as a whole. The latter is most likely because vessels are targeting other species. We have, for instance, mentioned that in 2001 vessels were targeting Loligo for a much extended season, and that therefore this may account for the reduced CPUE and catch in this year. Furthermore, the rate of catch has declined as the probability of encountering *P. ramsayi* has increased. The change in catch and encounter rates appears to indicate that *P. ramsayi* has increased its distribution on the shelf but has become more spread out in space. This would make rockcod more common in catches but less would be caught and the observed pattern of catches would be produced. Conversely, the pattern maybe more as a consequence of more individuals being sampled and identified to species level. Between 1996 and 2002 the average number of length samples for *P. ramsayi* was 334 individuals in a year, however at the end of 2004 that number had risen to an average of 6,399 individuals. In 2003 alone the number of *P. ramsayi* sampled was over 31,000. As a consequence the number of animals and the size of the catch sampled has risen considerably since the beginning of the ROCKCOD project in comparison with the years prior to 2003.

If the variability in CPUE was simply due to changes in targeting and distribution of rockcod, however, one would expect rather more random noise in the signal than is shown in the data. In fact, there seems to a rather smooth trend in the data in Figure 4 and in the catch data, which hints at cyclicity (Figure 7). The period of the apparent cycle is 8 years, roughly the period of general oceanographic cycles in the region. This could be generated through recruitment variability, but this is unlikely given the inability of our models to generate good biomass-CPUE fits even when we explicitly use measured recruitment. It is, in our opinion, much more likely that these trends are created by changes in the distribution and density of rockcod over the shelf. These trends themselves may be created by movements into and out of the Falkland Islands zone (perhaps into Argentine waters), and may be linked to environmental trends.

Projections from the ASPMs, for what they are worth, suggest that average catches of between 700 and 3,000 tonnes annually would be sustainable in the long term. We are unable to reach a more accurate conclusion at this time. Therefore, if any targeted fishery for rockcod were to be contemplated, a precautionary catch limit of between 1,000 and 1,500 t would seem to be appropriate. This level could be revised with the development of more satisfactory assessments using the data from a directed fishery.

It is worth remembering that although this fishery is primarily catching *P. ramsayi*, it is in fact a multispecies fishery. We would strongly recommend that if any directed fishery were contemplated, that specific reporting requirements for rockcod (and *P. ramsayi* in particular) were included. The reliance on opportunistic measurements by observers is not an adequate basis for data collection leading to robust assessments of these stocks.

Deliverable # 19 Estimate of fishery long-term sustainable yield

Activities included in this task were initiated by ICON in February 2004 and finished in December 2004. The work done included analyses of catch at age, GLM standardisation of CPUE data, biomass estimates, ASPM – Age-structured production model, yield-per-recruit and stock-recruitment relationship.

Fundamental to the provision of sound management advice is the assessment of the size of fish or squid stocks and the likely effects of fishing on these stocks. The analysis of fisheries and other data using appropriate statistical and mathematical procedures is defined as *stock assessment*. A stock is a managed population unit. Stock assessments generally result in a statement of the likely size of the stock, and the catch levels that can be sustained by the stock without overexploiting it. For most fish species, which live for more than one year (toothfish and southern blue whiting live for over 30 years), it is sufficient to assess them annually since most of the animals in the stock this year will still be in the stock next year.

The "ROCKCOD" project (CRAF-1999-71709) aimed to develop and research the possibility of adding value to a fishery resource that is currently discarded at sea by the EU fleet fishing in the Southwest Atlantic. "Rockcod", a complex of several species but principally *Patagonotothen ramsayi*, is currently taken as by catch in the trawl fisheries in the Falklands (*Illex*, *Loligo* and finfish). The present study was initiated to assess abundance trends and sustainability for exploitation of the resource and to provide advice on the likely impact on long term biological consequences of exploitation and increases in the current level of exploitation.

The aim of this investigation was to provide a preliminary analysis of stock status of Rockcod within Falklands Island waters using methods implemented for other finfish stocks in Falkland waters and methods not already employed. The data has been utilised within several different assessment methods in order to fully investigate the fishery and any management options associated with it. The majority of the assessments were carried out for *Patagonotothen ramsayi* as this species had the most available data and is also the most common species in Rockcod catches. This study sought to develop an assessment from the available methods that could be used to manage Rockcod stocks in the same way that other stocks are managed within Falklands waters. The research was instigated to provide an estimate of current biomass and sustainable catch rates which could then be used to allocate effort for a rockcod fishery or to inform the effort allocation within other fisheries in which rockcod is caught and so provide a mechanism of control within the fisheries for the rockcod population.

Methods and results

Fisheries and Biological data

Fisheries observers onboard trawlers operating bottom trawls within the finfish and *Loligo gahi* fisheries in Falkland Island waters and in high seas waters adjacent to Falkland Island waters between 1994 and 2004 collected material for this work. Daily reports of total catch, position and effort were analysed for the period 1994 to 2004 to estimate seasonal and spatial variation in activities of both fleets and the catches of *Patagonotothen ramsayi* and *Patagonotothen spp*. Before the start of the Rockcod project all catches of *Patagonotothen* species recorded by observers were placed in the same category and no distinction between the different species was made. As a result it was difficult to estimate the total catches of *Patagonotothen ramsayi*. Additionally, vessels without observers only report the main target species when making fishery reports[12] and all other species, included all rockcod species, are placed in one single category. As a result of this the total catch of all rockcod species is unknown.

Assessments

Several assessments were undertaken. All were essentially tuned to CPUE trend data, but they used different assumptions for recruitment. The methodology was that of an age structured production model (ASPM), following the methodologies of Agnew *et al*. (1999) and Brandão *et al*. (2002).

Catch at age

For the purposes of the ASPM, catch-at-age data were required. These were obtained by using observer records of length frequencies within each year. Length weight and von Bertalanffy growth parameters were used to convert the total weight of fish caught at length to catch numbers at age. These data suggest that fish recruit into the trawl fishery at approximately age 1 or 2.

GLM Standardisation of CPUE data

The only assessment types at our disposal were those tuned to CPUE data. The most important assumption of these is that CPUE is proportional to biomass (changes in the CPUE index reflect changes in the underlying population size of the species). A first step in our analysis was construction of a standardised CPUE series.

The GLM used for standardisation of trawler CPUE formed a delta - lognormal distribution (as not all hauls or trawls caught Rockcod) with many zeros present within the data. This was modelled as a binomial GLM on the probability of a trawl encountering *P. ramsayi* and a lognormal GLM on abundance for all positive trawls.

[12] Logbooks only require the specific reporting of the following categories of catch: Loligo, Illex, hake, southern blue whiting, hoki, rays, kingklip, red cod and “others”. Rockcod are classified as others.

ASPM – Age-structured production model

A cohort analysis using data between 1994 and 2003 was constructed in MS Excel using the structure described in Agnew *et al.* (1999). Five formulations of the model were investigated.

Yield-per-recruit

A basic yield-per-recruit model was set up in MS Excel using the same weight-at-age, maturity ogive, selectivity vector and natural mortality utilised in the ASPM. These models can be used to establish management reference points, usually either $F_{0.1}$ management (the point at which the slope of yield per recruit vs F is one tenth of the value near the origin (biological reference point)) or Fmax.

Discussion

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Projections from the ASPMs, for what they are worth, suggest that average catches of between 700 and 3,000 tonnes annually would be sustainable in the long term. It is worth remembering that although this fishery is primarily catching *P. ramsayi*, it is in fact a multispecies fishery.

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Appendix

Stock-Recruitment Relationship

The spawning biomass in year *y* is given by:

$$B_y^{sp} = \sum_{a=1}^{m} w_a f_a N_{y,a} \tag{A1}$$

where:

f_a is the proportion of fish at age a that are mature

The number of recruits at the start of year y is assumed to relate to the spawning biomass at the start of year y, B_y^{sp}, by a Beverton-Holt stock recruitment relationship (assuming deterministic recruitment):

$$R(B_y^{sp}) = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} \tag{A2}$$

The values of the parameters α and ß can be calculated given the initial spawning biomass K^{sp} and the steepness of the curve *h*, using equations (A2.13)-(A2.17) below. If the initial (and pristine) recruitment is R_0 = $R(K^{sp})$, then steepness is the recruitment (as a fraction of R_0) that results when spawning biomass is 20% of its pristine level, i.e.:

$$hR_0 = R(0.2K^{sp}) \tag{A3}$$

from which it can be shown that:

$$h = \frac{0.2(\beta + K^{sp})}{\beta + 0.2K^{sp}} \tag{A4}$$

Rearranging equation (A2.14) gives:

$$\beta = \frac{0.2K^{sp}(1-h)}{h-0.2} \tag{A5}$$

and solving equation A2 for α gives:

$$\alpha = \frac{0.8hR_0}{h-0.2} \tag{A6}$$

In the absence of exploitation, the population is assumed to be in equilibrium. Therefore R_0 is equal to the loss in numbers due to natural mortality when $B^{sp} = K^{sp}$, and hence:

$$gK^{sp} = R_0 = \frac{aK^{sp}}{b + K^{sp}} \qquad \text{(A7)}$$

where:

$$g = \left\{ \sum_{a=1}^{m-1} w_a f_a e^{-M_a} + \frac{w_m f_m e^{-M_m}}{1 - e^{-M}} \right\}^{-1} \qquad \text{(A8)}$$

WORKPACKAGE 3

CHARACTERISATION OF THE RAW FISH AS FOOD

WORKPACKAGE NUMBER 3: CHARACTERISATION OF THE RAW FISH AS FOOD.

Phase: final report

Start date: 6

Completion date: 16

<u>Current status</u>: finished

Co-ordinated by CSIC-IIM (B1) Person/Month (6).

Other Partners (Person/Months): none

Deliverables Nº: 3,9,11,12.

Milestones Nº: 7.

Objectives (as in the technical annex)

characterisation of the nutritional and sensorial properties together with the biochemical characterisation that will allow the global quality evaluation of rock cod as a new fish product. The microbiological control of the raw fish will assure the possible risk associated to its consumption.

Methodology and study materials (as in the technical annex)

This workpackage is composed by the following tasks:

<u>Task 3.1. Sensorial Evaluation</u>. This task will include the sensorial evaluation of the raw and boiled fish according to the Official EU Methods involving aspects as appearance, colour, flavour and texture. A trained expert panel will perform it.

<u>Task 3.2. Microbiological Evaluation</u>. This task will aim the safety issues related to the consumption of these species. It will attempt the microbiological studies for establishing pathogenic indigenous bacteria of rockcod species and the specific spoilage bacteria inducing chemical changes. The results achieved in this task will be essential since they will be related with the safety and possible toxicological risks associated to rockcod consumption.

<u>Task 3.3. Composition and Nutritional Value</u>. This task will be aimed to determine the nutritional characteristic of the fish species as food. It will include the elemental composition of the raw muscle in terms of water content, fat content, protein and amino acid analysis, and vitamin content. Special stress will be given to the concentration of lysine available, n-3 polyunsaturated fatty acids and cholesterol. These studies will be performed applying different instrumental techniques as absorption and fluorescent spectroscopy, and liquid- and gas- chromatography.

<u>Task 3.4. Biochemical Evaluation</u>. This task will include the determination of compounds derived from the activity of endogenous and microbiological enzymes: Non-Protein-Nitrogen compounds such as the trim ethylamine oxide, free amino acids, nucleotides, and amines (trimethylamine, dimethylamine and biogenic amines). These compounds have an important relationship with the taste of seafood. They have also an important role on the

spoilage of fish during conservation and processing. These compounds will be analysed by official standard methods, and spectrophotometric, fluorimetric and chromatographic techniques.

The proteolic activity, lipase and phospholipase activity in rockcod fresh muscle will be determined by spectroscopic analysis. The research included in this task will be indicative of the degree of higher or lower later processing.

All analyses described in this workpackage will be performed in a representative number of samples according to a statistical design for minimising intra- and inter-specific variations. They will be performed in two different trials distributed during the project:

nº different individuals: 20-30.
Two different trials in 2 years.
All analysis by duplicate
Sensorial analysis: 4 parameters
Microbiological analysis: 3-4 different cultures
Composition and nutritional value: 10 different parameters and methodologies
Biochemical evaluation: 7 different parameters and methodologies

Final report Characterisation

Three species belonging to the general denomination Rockcod were analysed: *Patagonotothen guntheri, Patagonotothen ramsayi and Paranotothenia magellanica.* The study was mainly focused on *P. ramsayi,* the most abundant species. Two different sizes of *P. ramsayi* were considered for some analyses.

A sex differentiation study and a seasonal study was performed focused on *P. ramsayi*.

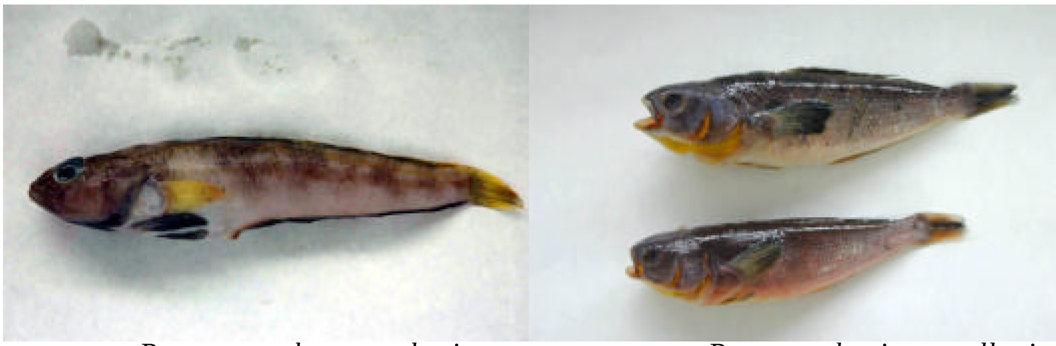
A total of 1934 analyses were carried out: 224 corresponding to the comparison among Rockcod species, 330 employed for sex differentiation and 1380 employed for evaluation of nutritional value and organoleptic characteristics during different months.

All analyses were performed in duplicate or in triplicate.

Task 3.1. Sensorial Evaluation.

Organoleptic evaluation of fresh fish was carried out on board by the observer according to the Official DOCE (1989). The study of *P. ramsayi* demonstrated that all individuals showed a very intense pigmentation and transparent mucus. The external odour was sharply sea weedy and shellfish. Gills were brightly red, without odour and with lamina perfectly separated. Flesh odour was weakly sea weedy and shellfish. In relation with muscle consistency, all individuals showed firm and elastic characteristics.

As regards to frozen samples analysed in IIM during the project, Fig. 1 shows the different species. Table 1 and 2 shows the data corresponding to the first set of samples arrived to IIM in May 2003 (caught April 2003). All individuals analysed showed good sensory quality after frozen storage. However, texture of *P. magellanica* species was rapidly deteriorated at 4ºC, probably due to a high proteolitic activity. *P. guntheri* and *P. ramsayi* showed good muscle properties with high water retention and firm texture.



Patagonotothen. guntheri *Paranotothenia magellanica*

Patagonotothen ramsayi

Fig. 1. *Patagonotothen* spp.

Table 1. Size, weight and sex.

SPECIES	INDIVIDUAL	SIZE (cm)	WEIGHT (g)	SEX
P. guntheri	1	12 .5	21.47	FEMALE
	2	14 .5	26.49	MALE
	3	16 .5	52.46	FEMALE
	4	18	70.02	MALE
P. ramsayi	5	21	113.84	FEMALE
	6	21 .5	118.26	¿?
	7	27 .5	233.07	FEMALE
	8	32	393.01	¿?
	9	34 .5	532.67	FEMALE
P. magellanica	10	21 .5	167.91	¿?
	11	26	276.93	MALE

Table 2. Sensory Analysis.

SPECIES	SKIN	EXTERNAL ODOUR	CONSISTENCY	FLESH ODOUR
P. guntheri	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
P. ramsayi	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
P. magellanica	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish

Task 3.2. Microbiological Evaluation.

Microbiological data corresponding to fresh samples of *P. ramsayi* were negative. Data of coliforms, E.coli and Salmonella were negative. Total microbial content of frozen samples were low: 785 UFC and analyses of coliforme colonies were negative.

Task 3.3. Composition and Nutritional Value.

Task 3.4. Biochemical Evaluation.

a) Comparison among species. Samples caught during April 2003.

For identification purposes, in addition to morphological analysis, the sarcoplasmic protein profiles of fishes were studied. Sarcoplasmic electrophoretic profiles were characteristic of each species (Fig. 2). Profiles of *P. guntheri* and *P. ramsayi* were rather similar. *P. magellanica* sarcoplasmic profile was significantly different. On the basis of these results, a characteristic pattern of sarcoplasmic proteins for each species was determined and used for identifying samples.

Fig.2. Electrophoretic analyses of sarcoplasmic proteins in pH: 3.5-9.5.

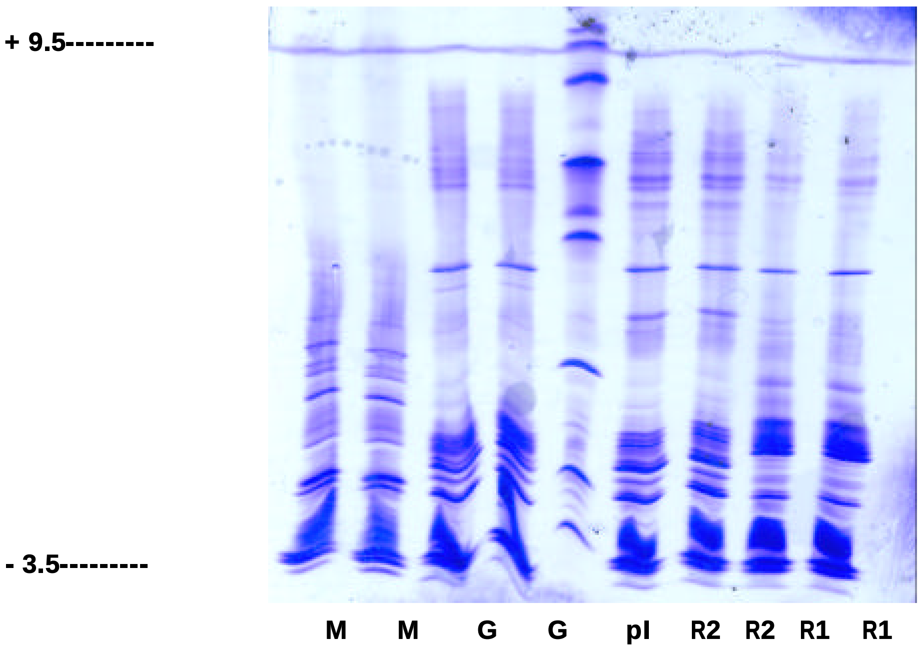


Table 3 shows the muscle composition of the three species. *P. guntheri* and *P. ramsayi* showed similar protein content. *P. magellanica* had less protein content and higher water content. *P. guntheri* showed highest lipid content, and was the fattest species.

As regards to lipid classes, *P.guntheri* showed the highest proportion of triacylglycerols and *P. magellanica* had the highest phospholipid content (Table 4). Fatty acids esterified to triacylglyerols are known to be more saturated than those of phospholipids.

Tables 5 and 6 show the fatty acid composition of the species. The most important feature was the high content of polyunsaturated fatty acids (PUFA) present in the three species.

The most abundant PUFAs were DHA and EPA, both of them n-3 PUFA. EPA (20:5ω3) and DHA (22:6ω3) accounted about 81.37% of total PUFA in *P.guntheri*, 84.11% in *magellanica* and 87.51% in *P. ramsayi*. Therefore, these species are good sources of ω-3 fatty acids. EPA was present at about half the DHA concentration in all species. These high levels of PUFA are in agreement to values found in other species belonging to the same family. Among the n-6 PUFA, arachidonic acid (20:4ω6) was the most abundant for *P. rams*ayi and P: *magellanica* and 18:2ω6 was the most abundant for *guntheri* species. As shown in the Table 5, the n3/n6 ratio in muscle was high for all species and therefore, this is an significant result related to the nutritional and functional properties.

In relation with saturated acids, 16:0 fatty acid was the most abundant in all species. The fatty acid 18:1 ω9 was the most abundant monounsaturated acid. The ratio of PUFA/SFA demonstrated a dominant percentage of PUFA to SFA.

Lipids of *P. guntheri* were more saturated than the others as correspond to their higher content in triacylglycerols and lipid of *P. magellanica* were the most unsaturated according to their high degree of phospholipids.

Table 3. Muscle composition[a] .

SPECIES	WATER	ASH	PROTEIN	FAT
P. guntheri	77.10	1.45	19.76	3.18
P. ramsayi	78.43	1.34	18.06	1.32
P. magellanica	79.97	1.32	16.38	1.44

[e]xpressed on a wet basis weight

Table 4. Lipid and Phospholipid content.

SPECIES	% LIPID [a]	% PL[b].
P. guntheri	3.18 ± 0.42	8.0 ± 0.91
P. ramsayi	1,32 ± 0.37	15.1 ± 1.29
P. magellanica	1,44 ± 0.26	24.5 ± 4.83

[a]% LIPID expressed as a percent in wet weight.
[b] % PL expressed as a percent of total lipids.

Table 5. Fatty acid composition [a]

F. A.	*P. guntheri*	*P. ramsayi*	*P. magellanica*
14:00	4.9	3	2.3
16:00	19.0	19.3	18.4
16:1? 7	7.5	4.9	2.7
18:00	3.3	2.8	4.4
18:1? 9	12.3	9.8	10.0
18:1? 7	2.5	2.7	1.9
18:2? 6	1.2	0.9	1
18:3? 3			1.0
18:4? 3	2.5	1.4	2.5
20:1? 9	6.2	4.3	1.1
20:4? 6	1.4	1.9	2.8
20:4? 3	1.5	0.9	0.7
20:5? 3	11.7	13.9	12.9
22:1? 11	2.6	2.0	0.3
22:5? 3	1.2	1.3	1.4
22:6? 3	22.1	30.8	37.0
n3/n6	15.19	17.49	18.93

[a] expressed as total percent of fatty acids.

Table 6. Saturated, monounsaturated and polyunsaturated content [a].

	%SATURATED	%MONOUNSATURATED	%POLYUNSATURATED	Ratio PUFA/SFA
P. guntheri	27.2	31.3	41.5	1.52
P. ramsayi	25.2	23.6	51.2	2.03
P. magellanica	25	16	59	2.36

[a] expressed as total percent of fatty acids.

Table 7 shows the results of the CNH analysis in dry basis weight which were in agreement with data of the elemental composition.

Table 7. Content of C, H and N.

SPECIES	%N	%C	%H	C/N	H/C
P. GUNTHERI	14.24	47.4	4.12	3.88	1.04
P. RAMSAYI	13.83	48.35	3.83	4.08	0.94
P. MAGELLANIC	13.57	45.48	4.67	3.91	1.22

b) Sex differentiation: males and females.

Samples of *P. ramsayi* caught during summer 2003 and identified as males and females were analysed. We distinguish between medium and big size (samples M: 24-25 cm and samples B: 30-35 cm). Table 8 sumarizes data corresponding to size, weight and sex of those samples and Table 9 shows the sensory analyses. All individuals analysed showed good sensory quality after frozen storage. It didn't notice significant differences between individuals of different size or sex.

The results of CNH analysis and elemental composition were similar in all individuals with a little variability independently of size and sex (Tables 10 and 11). In general, phospholipid content was higher in male than in female (Table 12). This last resutl is in agreement with a higher proportion of reserve lipids as triacylglycerols in females than in males.

Fatty acid anylisis showed similar profiles with a high percent of polyunsaturated acids, specially EPA and DHA (n-3 polyunsaturated fatty acids) (Table 13 and Table 14).

Sarcoplasmic electrophoretic profiles illustrated in Fig. 3, Fig. 4, and Fig. 5 of white muscle proteins were equals independently of the sex.

The sarcoplasmic profiles obtained using different solubilisers and electroforetic approaches were similar (Fig. 3-5).

Table 8. Size, weight and sex.

INDIVIDUAL	SIZE (cm)	WEIGHT (g)	SEX
M1	25	177,4	FEMALE
M2	25,5	168,9	MALE
M3	22	120,2	¿MALE?
M4	24,5	158,7	FEMALE
M5	26,5	207,1	FEMALE
M6	26	161,2	MALE
M7	25,5	184,2	MALE
M8	23,5	145,8	FEMALE
M9	24,5	145,5	MALE
M10	24,5	164,7	FEMALE
M11	23,5	127,3	FEMALE
M12	25	167	FEMALE
B13	30,0	378,28	MALE
B14	36,0	529,20	FEMALE
B15	32,5	445,32	FEMALE

Table 9. Sensory Analysis.

INDIVIDUAL	SKIN	EXTERNAL ODOUR	CONSISTENCY	FLESH ODOUR
M1	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M2	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M3	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M4	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M5	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M6	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M7	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M8	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M9	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish

M10	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M11	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
M12	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
B13	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
B14	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish
B15	Very intense pigmentation	Weakly seaweedy and shellfish	Firm and elastic	Weakly seaweedy and shellfish

Table 10. Content of C, H and N.

INDIVIDUAL	Weight (mg)	%N	%C	C/N
M1	29,74	14,97	46,58	3,6
M2	25,98	14,97	47	3,7
M3	24,84	15,41	47,53	3,6
M4	29,14	15,26	46,33	3,5
M5	36,96	15,82	44,34	3,3
M6	35,51	15,76	45,74	3,4
M7	26,02	14,57	43,39	3,5
M8	19,5	14,45	44,96	3,6
M9	21,52	13,99	43,78	3,6
M10	33,95	14,88	42,68	3,3
M11	27,37	14,63	43,22	3,4
M12	24,53	14,6	43	3,4
B13	11	14,84	47,3	3,7
B14	7,39	14,72	48,08	3,8
B15	15,15	14,85	46,03	3,6

Table 11. Muscle composition

INDIVIDUAL	SEX	WATER	ASH	PROTEIN	FAT
M1	FEMALE	78,30	1.24	19,79	1,74
M2	MALE	79,67	1.16	15,83	1,41
M3	¿MALE?	79,11	1.19	18,42	1,56
M4	FEMALE	79,35	1.18	16,4	1,35
M5	FEMALE	79,24	1.18	18,93	1,32
M6	MALE	79,56	1.17	14,17	2,13
M7	MALE	78,29	1.24	20,26	1,74
M8	FEMALE	78,59	1.22	19,87	1,41
M9	MALE	78,26	1.24	13,62	1,56
M10	FEMALE	78,30	1.24	15,85	1,35
M11	FEMALE	78,32	1.24	19,9	1,32
M12	FEMALE	78,83	1.21	19,04	2,13
B13	MALE	79,51	1.17	16,31	1,11
B14	FEMALE	79,22	1.19	16,82	1,23
B15	FEMALE	79,31	1.18	15,48	0,9

Table 12. Lipid and Phospholipid content.

INDIVIDUAL	SEX	%LIPID	%P
M1	FEMALE	1,74±1,06	12,84±3,80
M2	MALE	1,41±0,38	17,71±6,72
M3	¿MALE?	1,56±0,42	16,762±2,10
M4	FEMALE	1,35±0,04	12,60±1,28
M5	FEMALE	1,32±0,04	15,674±3,70
M6	MALE	2,13±0,00	17,544±1,31
M7	MALE	1,74±0,17	15,94±3,53
M8	FEMALE	1,41±0,04	18,80±0,01
M9	MALE	1,56±0,00	16,16±0,96
M10	FEMALE	1,35±0,13	16,15±0,01
M11	FEMALE	1,32±0,00	9,14±0,93
M12	FEMALE	2,13±0,04	8,02±1,81
B13	MALE	1,11±0,04	21,56±3,57
B14	FEMALE	1,23±0,04	11,39±0,30
B15	FEMALE	0,9±0,08	14,42±2,50

[a]% LIPID expressed as a percent in wet weight.
[b] % PL expressed as a percent of total lipids.

Table 13. Fatty acid composition [a]

FA	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	B13	B14	B15
14:00	4,02	3,98	3,49	3,67	2,07	2,63	4,32	3,50	4,21	3,25	3,37	3,87	2,12	2,23	1,56
16:00	20,34	19,27	18,16	18,51	17,54	19,22	19,05	19,18	19,27	19,85	19,49	14,91	18,07	17,32	16,18
16:1w7	4,97	4,81	4,13	6,18	3,60	4,32	5,97	4,12	5,24	3,66	4,58	5,07	3,71	3,33	2,62
18:00	2,01	2,48	1,93	2,50	1,91	2,91	2,28	2,15	2,18	2,08	2,02	2,12	2,29	2,44	2,97
18:1w9	13,80	11,44	9,61	14,34	6,70	11,20	14,76	11,65	11,60	10,63	12,18	10,11	10,41	10,60	8,64
18:1w7	1,74	1,63	1,81	2,57	6,18	2,53	2,48	1,94	1,90	2,02	1,95	2,66	1,99	2,27	2,80
18:2w6	1,72	1,74	1,14	1,39	1,71	1,29	1,71	1,28	1,31	1,16	1,61	1,27	1,45	1,16	1,07
18:3w3	1,32	1,04	0,93	0,93	4,42	0,75	1,22	1,28	1,02	1,10	1,05	0,66	0,71	0,57	0,38
18:4w3	3,58	2,57	2,43	2,21	1,08	1,67	2,70	3,19	2,72	2,77	2,83	1,45	1,91	1,58	0,69
20:1w9	2,16	2,04	5,93	3,09	1,16	1,60	2,65	2,16	2,00	2,48	1,21	8,28	2,23	4,30	4,90
20:4w6	1,04	1,72	1,24	1,73	2,01	2,07	1,29	1,51	1,57	1,73	1,48	1,55	2,40	2,34	2,55
20:4w3	0,67	0,64	0,98	0,89	1,00	0,63	0,85	0,63	0,84	0,72	0,75	1,12	0,71	0,92	1,05
20:5w3	11,66	11,75	11,86	12,66	5,66	11,74	10,94	11,31	12,38	11,23	11,30	10,89	11,56	12,95	14,41
22:1w11	0,58	0,76	2,32	0,80	10,12	0,34	0,65	0,54	0,63	1,59	0,49	3,13	0,80	1,57	1,08
22:5w3	0,93	0,89	1,08	1,06	0,85	1,10	0,86	0,99	1,42	0,95	1,21	1,80	2,14	1,89	3,99
22:6w3	29,44	33,23	32,96	27,45	39,05	36,00	28,29	34,57	31,72	34,76	34,47	31,13	37,48	34,53	35,11

[a] expressed as total percent .

Table 14. Saturated, monounsaturated and polyunsaturated content. [a]

INDIVIDUAL	SEX	%SATURATED	%MONOUNSATURATED	%POLYUNSATURATED
M1	FEMALE	26,72	23,57	49,70
M2	MALE	25,99	20,91	53,09
M3	¿MALE?	23,80	24,02	52,18
M4	FEMALE	24,92	27,25	47,84
M5	FEMALE	22,48	24,00	53,53
M6	MALE	24,95	20,14	54,91
M7	MALE	25,96	26,83	47,21
M8	FEMALE	25,15	20,67	54,18

M9	MALE	25,93	21,59	52,48
M10	FEMALE	25,47	20,61	53,92
M11	FEMALE	25,15	20,63	54,22
M12	FEMALE	21,03	29,44	49,53
B13	MALE	22,65	19,29	58,07
B14	FEMALE	22,10	22,20	55,70
B15	FEMALE	20.79	20.12	59.09

SEX	%SATURATED	%MONOUNSATURATED	%POLYUNSATURATED
MALE	24,88	22,13	52,99
FEMALE	23,59	23,17	53,08

[a] expressed as total percent .

Fig. 3. Electrophoretic (SDS-PAGE) profiles of white muscle proteins Solubilization in low ionic buffer.

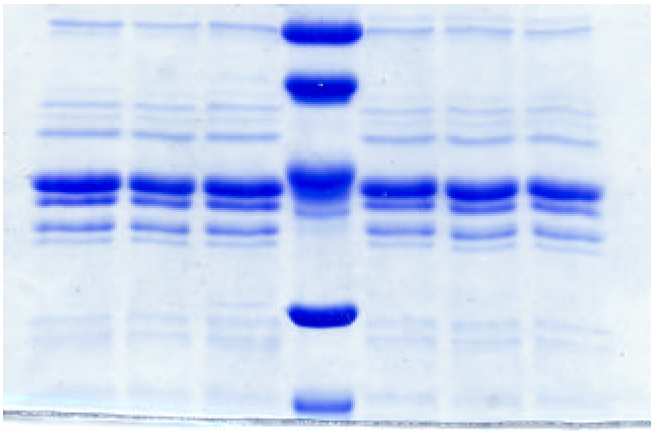


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Fig. 4. Solubilization in SDS buffer

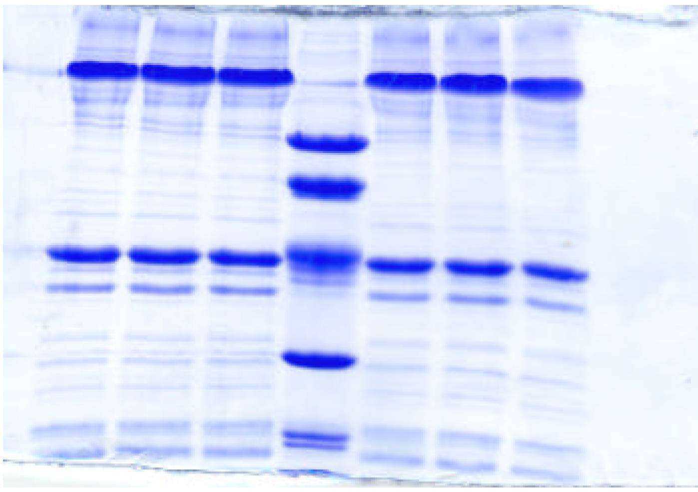

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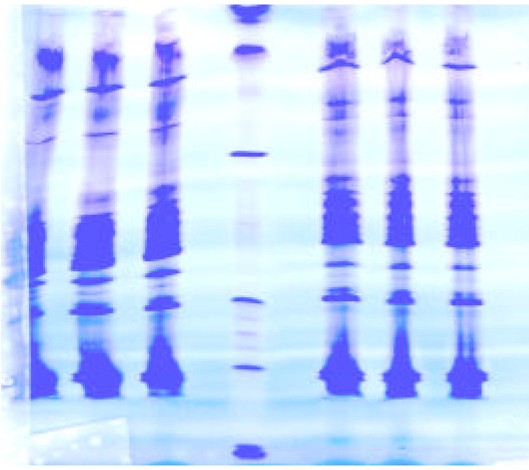
Fig. 5. IEF profiles of white muscle proteins



? Pi ?

c) **Nutritional value of *P. ramsayi.***

Nutritional value of *P. ramsayi* is summarised in Table 15. *P. ramsayi* showed a low fat content and high protein content. This species showed low levels of cholesterol, high levels of vitamin E in comparison to other fish species, and low levels of carbohydrates.

The fatty acids profile showed a high content of PUFA, specially EPA and DHA (Fig. 6).

In relation to mineral content (Table 16), values agreed with those reported for other species and demonstrated that this species is a good source of minerals.

The amino acids content is shown in Table 17. Levels of amino acids were in agreement with data reported in literature for other fish species.

Table 18 shows the variation in muscle composition during different periods of the year. The individuals showed lower fat and protein content at the end of ripening state (austral spring), close to spawning, than during spawning (austral summer). After this period (post-spawning), the fat content decreased and the protein content started to increase. The seasonal variation of the fatty acid composition is showed in Figure 6. The highest amount of DHA was observed during austral winter. The lowest values of DHA was reached during ripening state.

In relation to heavy metals, Hg, Cd, Pb and Cu were analysed. This study also demonstrated that there is not risk associated to the accumulation of toxic metals. All samples showed levels of heavy metals considerably low and under the legislated permitted limits (<50 µg/Kg for Hg and Pb, < 25 µg/Kg for Cd and <195 µg/Kg for Cu in wet weight basis).

Parasites of *Patagonotothen ramsayi* (Nototheniidae) from around Falkland Islands waters (2nd progress report).

Introduction

The parasites of *Patagonotothen* spp. are not well studied and only a handful of studies describing new species from this genus exist in the literature. These include a new species of myxozoan from *P. ramsayi*, *Kudoa ramsayi* (Kalavati et. al., 2000), two new species of myxozoan parasites from *P. sima* (Kalavati et al., 1996) and a new species of sea lice *Caligus nolani* also from *P. sima* (Longshaw, 1997).

Parasites have been widely used as biological tags to provide information for fisheries managers on the movements and population discrimination of their hosts (see MacKenzie, 1983; Lester, 1990; Moser, 1991 Williams *et al.*, 1992; MacKenzie, 2002). There are two main approaches to the use of biological tags (MacKenzie and Abaunza, 1998). The first approach involves the selection of a small number of parasite species according to specific criteria as suggested by Kabata (1963); Sindermann (1983), MacKenzie (1983, 1987, 1998) and Williams *et al.* (1992) and a large number of host species are examined specifically for these parasite species. In the second approach entire parasite assemblages are analysed using sophisticated statistical techniques. Examples include the studies of Lester *et al.* (1986, 1988), George-Nascimento and Arancibia (1992), Speare (1994, 1995), Arthur and Albert (1993) and Baylock *et al.*(2002). According to MacKenzie and Abaunza (1998) this type of approach can be applied to any host species, but is particularly applicable to those which are large and valuable and are not readily available for examination in large numbers. The aim of this study was to provide a baseline for future studies on the possible use of using parasites as biological tags in stock assessment. Also this study was aimed at looking for parasites with public health implications for the food science partners within the project.

Materials and Methods

Samples of *P. ramsayi* were caught during a cruise on the R/V Dorada during January 2004. Figure 1 illustrates the positions of where the samples were collected.

The fish's skin surface was examined by eye under a strong light. Squash preparations were made from any cysts or lesions observed and examined under a compound microscope at magnifications of up to X 400. The total and weight were recorded and the fish was placed back into its tray. The fins were then removed and examined under the dissecting microscope and any lesions or cysts observed were examined more thoroughly. The fish was then washed in its tray of water by hand and then removed. The remaining water and mucus in the tray was then poured through a fine meshed sieve to collect any parasites that were not noted by the visual inspection.

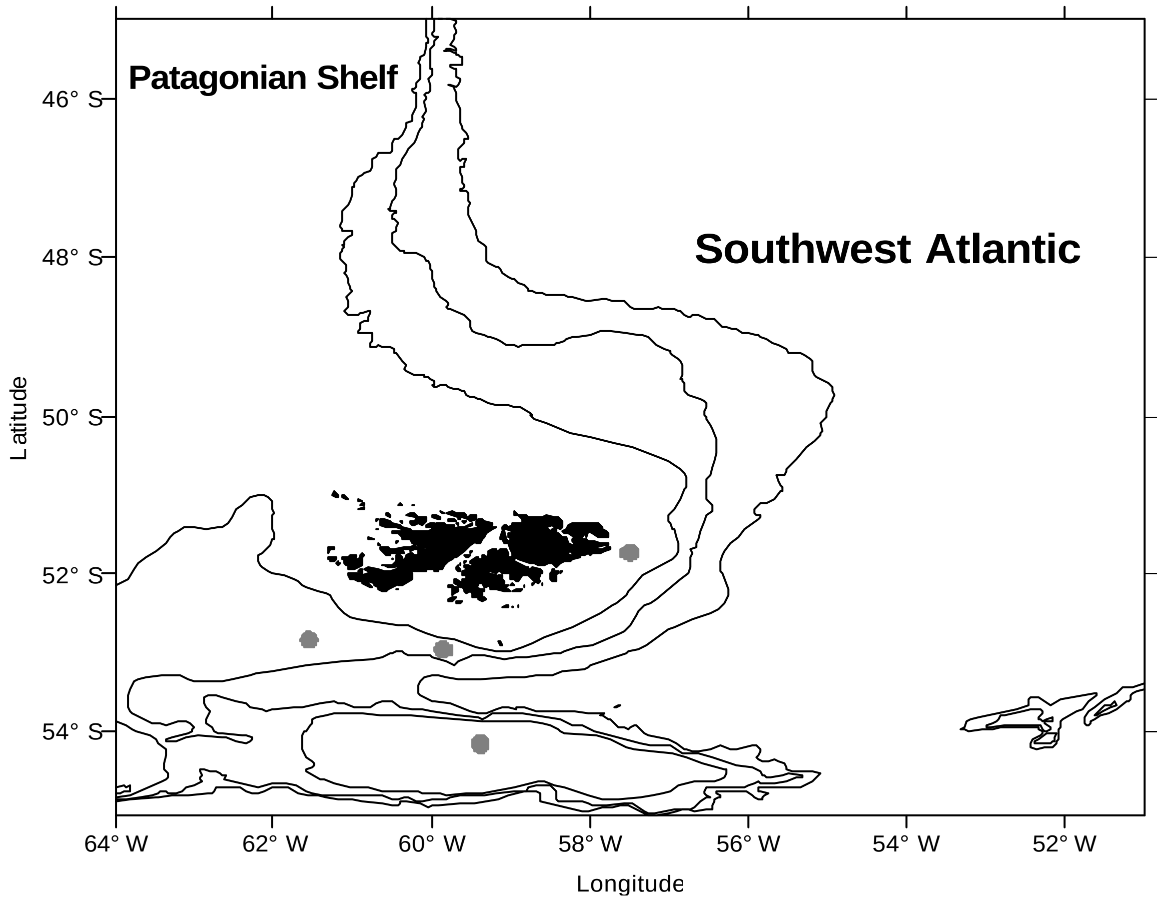


Figure 1: Sample locations for samples of *Patagonotothen ramsayi* collected for parasitological studies

The fish were opened by making an incision from the anus up to the heart so that the viscera could be removed. The internal organs (heart, liver, spleen, gall bladder, gonads, kidney, urinary bladder and digestive tract) were examined for parasites free or encapsulated on the exterior, then separated and individually examined. The stomach, pyloric caeca and intestine were separated and opened longitudinally. In smaller fish the mucosa of the digestive tract was scraped with the back end of a scalpel to remove any parasites. The walls of the stomach, pyloric caeca, and intestine, and the liver, spleen, kidney, and heart were compressed between glass plates and examined for parasites. The body cavity was rinsed and the rinse collected and examined. Squash preparations were made from the liver, spleen, kidney, gonads, intestine, muscle and brain, and scrapings from the urinary and gall bladder were examined for protozoan and myxozoan parasites using a compound microscope at a magnification of X400 under bright field, phase contrast and Nomarski interference contrast illumination. Preparations not found to harbour parasites within 5 minutes were considered to be uninfected. The gills were removed and rinsed, and the arches were examined individually. The buccal cavity was rinsed and the opercula and eyes were rinsed separately. The body musculature was removed from the vertebral column, the skin removed from the fillets and the flaps were thinly sliced and inspected for helminths and myxozoan cysts. All parasites were sorted into major taxonomic groups, cleaned and counted for each organ, noted on an examination sheet and the data subsequently entered onto a database. Representative specimens of all parasite species encountered during this study have been collected and stored in the Falkland Islands Government Fisheries Department (FIFD) reference collection.

Summary statistics for the parasite taxa recovered during this study and studies by other authors include prevalence, mean abundance and mean intensity as recommended by Bush *et. al*. (1997).

Table 1: Prevalence, intensity and abundance of parasites infecting *Patagonotothen ramsayi* from around the Falkland Islands.

Taxa	Stage	Prevalence (%)	Mean Abundance	Mean Intensity	SD	Range of Intensity
***Sphaeromyxa* sp.**		3.33	"	"	"	"
***Ceratomyxa* sp.**		16.67	"	"	"	"
Kudoa ramsayi		46.67	"	"	"	"
Chondracanthus australis	a	3.33	0.03	1.00		1
***Clavella* sp.**	a	10.00	0.10	1.00		1
Elytrophalloides oatesi	a	33.33	0.83	2.50	1.35	1-5
Lepocreadiidae sp.	a	53.33	2.63	4.94	8.30	1-33
Dichelyne (Cucullanellus) fraseri	a	6.67	0.07	1.00		1
***Anisakis* sp.**	l	33.33	0.90	2.70	2.00	1-7
***Hysterothyacium* sp.**	a/l	93.33	18.63	19.96	19.61	2-89
***Contracaecum* sp.**	l	40.00	1.27	3.17	4.57	1-17
Pseudoterranova decipiens	l	46.67	1.07	2.29	2.09	1-7
Nematode sp.	a	13.33	0.40	3.00	2.45	1-6
Grillotia erinaceus	l	23.33	0.80	3.43	4.89	1-14
Tetraphyllidean pleurocercides	l	46.67	2.60	5.57	7.55	1-20
***Corynosoma* sp.**	l	3.33	0.03	1.00		1

a = adlult; l = larvae

Results and Discussion

A total of 901 individual parasites of 16 taxa were collected from 30 P. ramsayi during the course of this study. Table 1 provides summary statistics on the parasites encountered during the present study.

Sphaeromyxa sp. was found to infect the gall bladder of 3.33% of the fish examined and represents a new host record for *P. ramsayi*. Another myxozoan from the gall bladder, *Ceratomyxa* sp., also represents a new host record and was found to infect 16.67% of the fish examined. The myxozoan *Kudoa ramsayi* (Figure 2) found in the musculature was found in 46.67% of the fish examined. The pseudocysts are thin and white and occurred throughout the musculature in heavy infections.

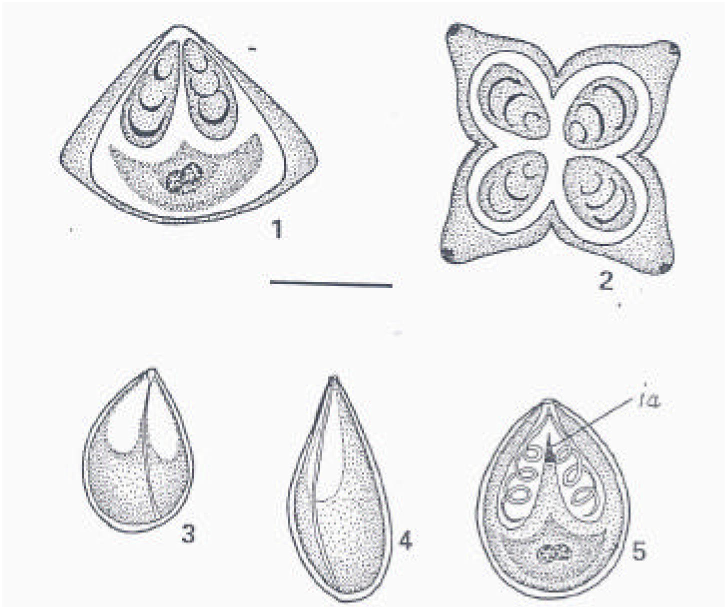


Figure 2: *Kudoa ramsayi* scale bar = 5µm

The copepod *Chondracanthus australis* was only found once during the study and was probably an accidental as the genus is specific to fishes of the family Merluccidae. This also represents a new host record. Another copepod *Clavella* sp. was also only found once unfortunately the animal was too damaged to determine the species.

The digenean *Elytrophalloides oatesi* (Figure 3) was found in 33% of the fish examined. It is a common species in the South Atlantic particularly in nototheniid fish where they normally infect the stomach, oesophagus and during heavy infections the gills.

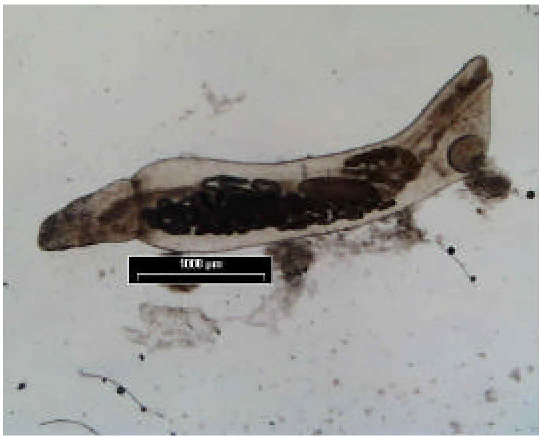


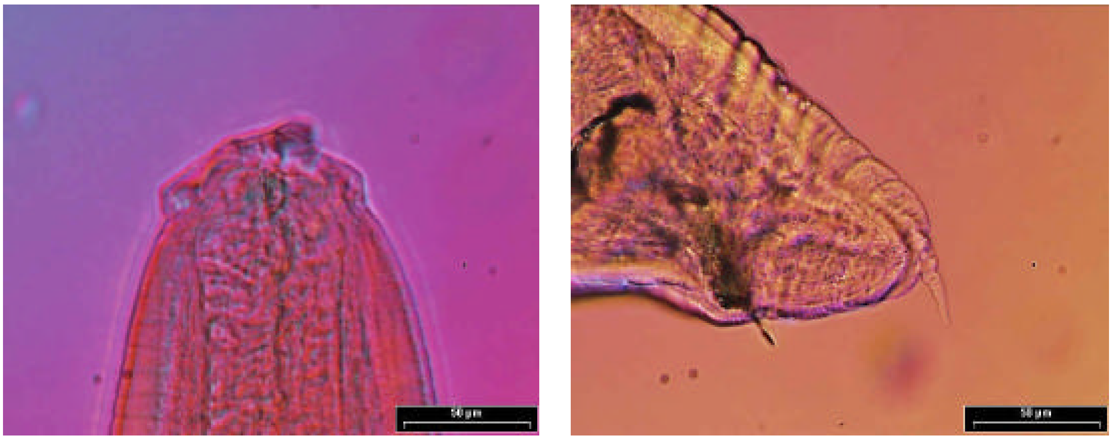
Figure 3: *Elytrophalloides oatesi* adult

An unidentified digenean of the family Lepocreadiidae was found to infect the pyloric caeca of 53% of the fish examined. This species need further examination to identify it.

The nematode *Dichelyne (Cucullanellus) fraseri* (Figure 4) was found to infect the intestine of about 7% of the animals examined. According to Zdzitowiecki and Cielecka, 1996) this species is specific to the notothenioids. This species is found around the SubAntarctic and in the Southwest Atlantic.

Figure 4: *Dichelyne (Cucullanellus) fraseri* adult

Anisakis sp. (whale worm) (Figure 5) is a ubiquitous species and has been reported from 40 different families of fish worldwide (Hays *et al.*, 1998). This is species has public health implications causing anisakiosis. However all the worms found in this study were found within the mesenteries and none were found in the flesh.



a **b**

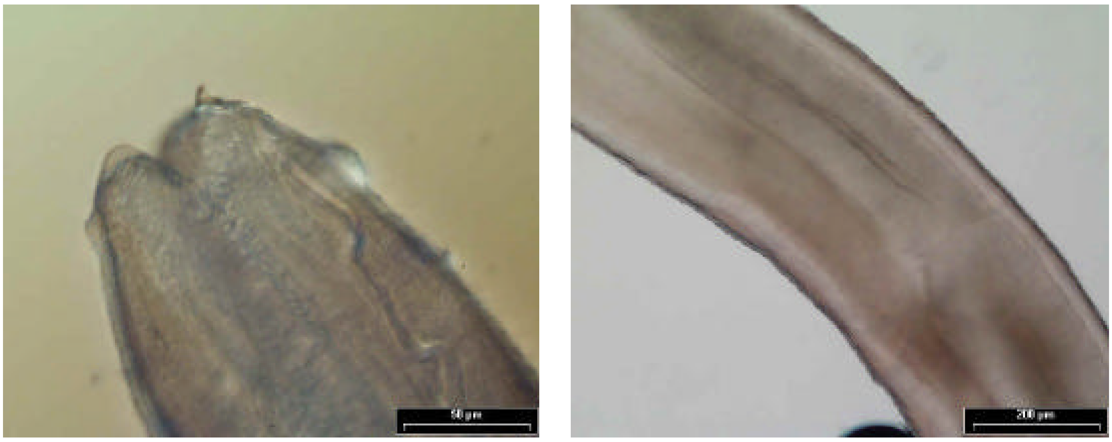
Figure 5: *Anisakis* sp. a) head; b) tail

Hysterothyalcium sp. (Figure 6) is a widespread parasite and occurs in marine teleosts in temperate and cold waters. It has been found in a number of fish from the South Atlantic Navone *et al.* (1998). In the Antarctic and subantarctic this genus (synonym = *Contracaecum (Thannascaris)*) has been reported from a number of nototheniids (Johnston and Mawson, 1945). This parasite has also been recovered from *Eleginops maclovinus* from two out of three sites in the Falkland Islands (MacKenzie and Brickle, unpublished data). Gaevskaya *et al.* (1990) recovered *H. aduncum* and *H. nototheniae* from *D. eleginodes* and Rodriguez and George-Nascimento (1996) recovered *Hysterothyalcium* spp from *D. eleginoides* off central Chile. This species infects the intestines of marine fish.

a **b**

Figure 6: *Hysterothylacium* sp. a) head; b) tail

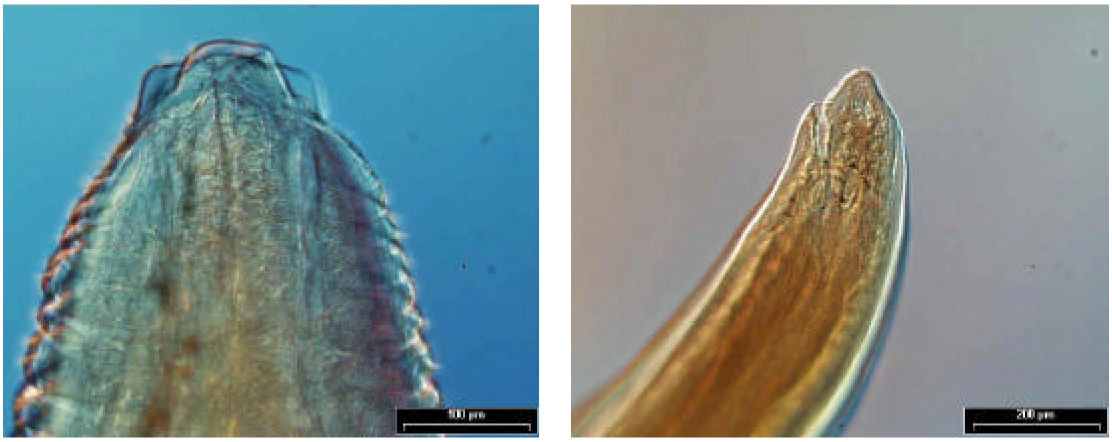
Contracaecum sp. (Figure 7) this species infects seals when adult and is common in the South Atlantic and was found to infect 40% of the *P. ramsayi* examined during this study.



a **b**

Figure 7: *Hysterothylacium* a)head; b) atil

Pseudoterranova decipiens (seal worm) (Figure 8) matures in seals, and the first intermediate hosts are crustaceans such as copepods, amphipods, shrimps, and isopods (Marcogliese, 1996). Only when worms reach the size of about 2 mm are they able to infect fish (McClelland, 1995), which serve as second intermediate hosts (Kerstan, 1991). They attain this size in macroinvertebrates, such as mysids (Jackson *et al*. 1997) which are therefore an essential intermediate host in the life cycle of *P. decipiens* (McClelland, 1995). *Pseudoterranova decipiens* is considered to have a benthic life cycle, as their larvae are unable to swim. This species was found in 47% of the fish examined. This species can also have public health implications and causes a similar condition to *Anisakis*.



a **b**

Figure 8: *Pseudoterranova decipiens* a) head; b) tail

An unidentified nematode was found in 13% of fish examined. This species requires further taxonomic work.

Grillotia ernaceus (Figure 9) is a ubiquitous species and occurs in fish from both the Atlantic and Pacific Oceans (Ruszkowski, 1934, as cited by Rohde, 1984a). Ruszkowski (1934) (as cited by Rohde, 1984) worked out aspects of the life cycle of *G. erinaceus*. The first intermediate hosts are various species of copepods, in which the procercoid larvae develop from the coracidium. Many species of marine fish from both the Pacific and Atlantic Oceans act as second intermediate hosts, and the definitive hosts are elamobranchs. This species was quite common in *P. ramsayi* (23%).

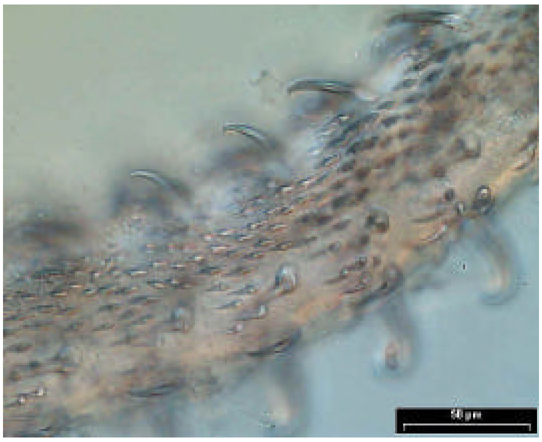


Figure 9: *Grillotia erinaceus* tentacle

Tetraphyllidean cercoides (Figure 10) were also common in *P. ramsayi* (46%). Tetraphyllidean plerocercoids use copepods and euphausiids as intermediate hosts; fish and cephalopods are thought to pick up postlarval stages by feeding on smaller fish, cephalopods and crustaceans and they become adult in elasmobranch fish (Hochberg, 1990). Brickle *et al.* (2001) examined the tetraphyllidean fauna of the South Atlantic squid *Loligo gahi*, which were assumed to be species of the genus Phyllobothrium, and characterised genetically. They found that 12 of the 14 specimens characterised were species of the genus *Clistobothrium*, one of them being *Ceratobothrium*, both parasites of lamnid sharks and the other a trypanorhynch, *Grillotia erinaceus*. They concluded that the technique of using molecular tools to confirm the identities of larval parasites, especially where morphology proves inadequate for distinguishing closely related species or genera, may prove useful in the elucidation of life cycles and oceanic food webs.

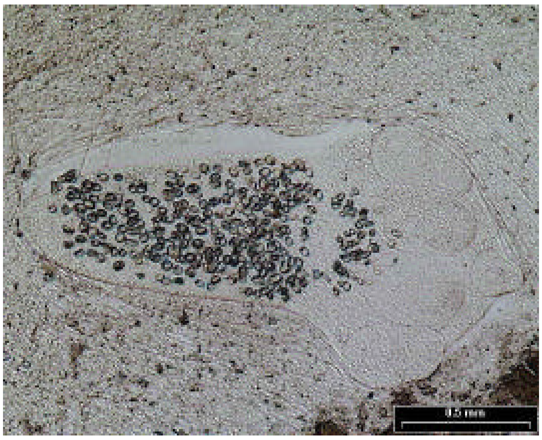


Figure 10: Tetraphyllidean pleuroceroid

Finally the larval acanthocephalan *Corynosoma* sp. was only found once within the mesenteries of an individual *P. ramsayi*. These are parasites of seals and whales. Unfortunately, the parasite was not in a good condition and so could not be identified to species.

From a public health point of view no nematodes (*Anisakis* and *Pseudoterranova*) that are able to infect humans were found in the flesh of *P. ramsayi* although they were found in other organs. However, only a small number of *P. ramsayi* (n = 30) were examined.

This study provides a baseline and reference material for future studies using parasites as biological tags for stock discrimination and host migration.

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Deliverables:

Deliverable # 3: Organoleptic characteristics of Rockcod with special focus in off-flavours

Three *Patagonotothen* species: *P. guntheri, P. ramsayi and P. magellanica* were studied. Frozen Rockcod samples corresponding to different months were sent at IIM during 2003-2004. The study was mainly focused on *P. ramsayi* which is the most abundant species.

In addition to whole fish, we received fillets and tails of fish caught during summer 2003. We have also received organic and aqueous extracts corresponding to the fresh samples of these months at 15th November 2003. However, organic extracts corresponding to fresh samples could not be analysed since they arrived at the IIM in very poor conditions because they were conserved at Falkland islands in erroneous containers (plastic).

Results

Fresh fish: Organoleptic evaluation of fresh fishes was carried out on board by the observers. The study of *P. ramsayi* demonstrated that all individuals showed a very intense pigmentation and transparent mucus. The external odour was sharply sea weedy and shellfish. Gills were brightly red, without odour and with lamina perfectly separated. Flesh odour was weakly sea weedy and shellfish. In relation with muscle consistency, all individuals showed firm and elastic characteristics.

Frozen fish arrived to IIM: Results obtained in all individuals analysed showed good sensorial quality (general appearance, odour and texture) with no off-flavours. It didn't notice significant differences between individuals of different size or sex. Data corresponding to TMA and TVB-N (0.2937 ± 0.004 and 18.33 ± 0.11, respectively) were low in all samples analysed, corresponding to different trials of the year, and there were not important differences among months. Similar results were obtained for TBA and PV values (0.39 ± 0.03 and 1.54 ± 0.01). Considering these results, it could be concluded that the fresh fish showed a good initial quality and the storage and preservation on board were correct .

1- The general appearance of entire samples and pieces was good. However, fish fillets showed a superficial discoloration.

2. Sensorial analysis and quality values regarding to the formation of volatile bases and amines derived from microbial and enzymatic degradation were low. Parameters related to rancidity were also low and did not reveal off-flavours associated to lipid deterioration. Fish fillets were in worse conditions.

3. Texture of *P. guntheri* and *P. ramsayi* was elastic and firm with high water retention. However, texture of *P. magellanica* species was rapidly deteriorated at 4ºC, probably due to a high proteolytic activity.

5. Microbiological analyses did not show significant contamination in all fish and unfrozen samples.

6. The lipid content of the species ranged among 1-3%. *P. guntheri* was the fattest species. The three species showed a high content of polyunsaturated fatty acids, with high contents of EPA and DHA. Lipids of *P. guntheri* were more saturated than the other species.

The seasonal variation was studied in *P. ramsayi.* The lipid content increased along the year and the highest content was detected in samples corresponded to November and December.

Females corresponding to May were in maturation sex stage. Females contained slight higher lipid amount than males. There were richer in triacylglycerols than males, therefore they showed a more saturated fatty acid composition than males.

7. P. guntheri and *P. ramsayi* showed similar protein content. *P. magellanica* had less protein content and higher water content. Sarcoplasmic electrophoretic profiles were characteristic of each species. Profiles of *P. guntheri* and *P. ramsayi* were rather similar. *P. magellanica* sarcoplasmic profile was significantly different.

Deliverable # 9: Safety and possible toxicological risk associated to Rockcod consumption report.

This study was focused on the determination of volatile amines and oxidation products, the microbiological spoilage, the accumulation of toxic metals and the parasites.

No volatile amines and oxidation products were detected in significant amounts in frozen samples arrived to IIM.

No microbiological spoilage was detected in fresh rockcod samples neither in on-board frozen samples.

Total microbial data corresponding to fresh samples of *P. ramsayi* were very low. Data of coliforms, E. coli and Salmonella were negative.

Total microbial content of frozen samples arrived at IIM were low: 785 UFC and analyses of coliforme colonies were negative.

Many organisms are able to regulate the metal concentrations in their tissues. Research has shown that aquatic plants (seaweed) and some molluscs, crustaceans (shrimps/prawns) and fish are not able to successfully regulate metal uptake, and as a result, tend to suffer from metal accumulation. Heavy metals may enter the food chain in several ways. Small amounts are absorbed by organisms directly from the water through their gills and other tissues. However, most of the pollutants found in aquatic organisms arrive there through the food chain. First, bacteria, and other small organisms absorb these materials. In turn, these are eaten by larger animals, eventually being eaten by people. Rockcod species are found in not pollutant waters, therefore they should not show important amounts of contaminants.

The content of Hg, Cd, Pb and Cu in *P. ramsayi* was determined. **The study demonstrated that there was no accumulation of these metals, therefore no risk associated to the consumption due to toxic metals.** All samples showed levels of heavy metals considerably low and under the legislated permitted limits:

- < 50 µg/Kg for Hg and Pb in wet weight basis
- < 25 µg/Kg for Cd in wet weight basis
- < 195 µg/Kg for Cu in wet weight basis

Deliverable # 11: Nutritional characteristics of the fish species as food report.

Three species belonging to the general denomination Rockcod were analysed: *Patagonotothen guntheri, Patagonotothen ramsayi and Paranotothenia magellanica.,* The study was mainly focused *P. ramsayi*. We have also performed a sex differentiation study and a seasonal study.

Table 1 shows the muscle composition of the three species. *P. guntheri* and *P. ramsayi* showed similar protein content. *P. magellanica* had less protein content and higher water content. *P. guntheri* showed highest lipid content, and was the fattest species.

Tables 2 and 3 show the fatty acid composition. The most important feature was the high content of polyunsaturated fatty acids (PUFA) present in the three species.

The most abundant PUFAs were DHA and EPA, both of them n-3 PUFA. EPA (20:5ω3) and DHA (22:6ω3) accounted about 81.37% of total PUFA in *P.guntheri*, 84.11% in *magellanica* and 87.51% in *P. ramsayi*. Therefore, these species are good sources of ω-3 fatty acids. EPA was present at about half the DHA concentration in all species. These high levels of PUFA are in agreement to values found in other species belonging to the same family. Among the n-6 PUFA, arachidonic acid (20:4ω6) was the most abundant for *P. ramsayi* and P: *magellanica* and 18:2ω6 was the most abundant for *guntheri* species. As shown in the Table 2, the n3/n6 ratio in muscle was high for all species and therefore, this is an significant result related to the nutritional and functional properties.

In relation with saturated acids, 16:0 fatty acid was the most abundant in all species. The fatty acid 18:1 ω9 was the most abundant monounsaturated acid. The ratio of PUFA/SFA demonstrated a dominant percentage of PUFA to SFA.

Lipids of *P. guntheri* were more saturated than the others as correspond to their higher content in triacylglycerols and lipid of *P. magellanica* were the most unsaturated according to their high degree of phospholipids.

Table 1 Muscle composition [a] .

SPECIES	WATER	ASH	PROTEIN	FAT
P. guntheri	77.10	1.45	19.76	3.18
P. ramsayi	78.43	1.34	18.06	1.32
P. magellanica	79.97	1.32	16.38	1.44

[a] expressed on a wet basis weight

Table 2. Fatty acid composition [a]

F. A.	*P. guntheri*	*P. ramsayi*	*P. magellanica*
14:00	4.9	3	2.3
16:00	19.0	19.3	18.4
16:1ω7	7.5	4.9	2.7
18:00	3.3	2.8	4.4
18:1ω9	12.3	9.8	10.0
18:1ω7	2.5	2.7	1.9

18:2ω6	1.2	0.9	1
18:3ω3			1.0
18:4ω3	2.5	1.4	2.5
20:1ω9	6.2	4.3	1.1
20:4ω6	1.4	1.9	2.8
20:4ω3	1.5	0.9	0.7
20:5ω3	11.7	13.9	12.9
22:1ω11	2.6	2.0	0.3
22:5ω3	1.2	1.3	1.4
22:6ω3	22.1	30.8	37.0
N3/n6	15.19	17.49	18.93

[a] expressed as total percent of fatty acids.

Table 3. Saturated, monounsaturated and polyunsaturated content [a].

	%SATURATED	%MONOUNSATURATED	%POLYUNSATURATED	Ratio PUFA/SFA
P. guntheri	27.2	31.3	41.5	1.52
P. ramsayi	25.2	23.6	51.2	2.03
P. magellanica	25	16	59	2.36

[a] expressed as total percent of fatty acids.

As a food report, nutritional value of the most abundant Rockcod species, *P. ramsayi*, is shown in Table 4. *P. ramsayi* showed a low fat content and high protein content. This species showed low levels of cholesterol, high levels of vitamin E in comparison to other fish species, and low levels of carbohydrates. The content of minerals agrees with other species reported in bibliography and demonstrated that this species is a good source of minerals (Table 5).

The amino acids content is shown in Table 6. Levels of amino acids were in agreement with data reported in literature for other fish species.

Table 7 shows the variation in muscle composition during different periods of the year. The individuals showed lower fat and protein content at the end of ripening state (austral spring), close to spawning, than during spawning (austral summer). After this period (post-spawning), the fat content decreased and the protein content started to increase. The seasonal variation of the fatty acid composition is showed in Figure 6. The highest amount of DHA was observed during austral winter. The lowest values of DHA was reached during ripening state.

Table 4. Nutritional value of *P. Ramsayi*

	Value
aFat	0.78%-1.34 %
aWater	78.43%-82.08%
aAsh	0.31%-1.70%
aProtein	13.96%-18.06%
Vitamine E	880.74 mg tocopherol/g lipids
aCholesterol	15 mg/100g
aCarbohydrates	0.1%
w **3- Fatty Acids**	≈ 50% of total fatty acids.

[a] expresses as wet weight basis.

Table 5. Mineral content.

mg/Kg muscle on a wet weight basis	
Sodium	650-982
Potasium	2820-3830
Calcium	62.7-110
Magnesium	316-512
Phosphorous	1060-1410
Zinc	3.55-10.1
Manganese	0.239-0.438
Iron	2.23-4.3
Copper	0.101-0.193

Table 6. Essential Amino acid content expresses as g /100 protein

AMINO ACID	g/100g
Histidine	2.66 ± 0.39
Arginine	1.61 ± 0.35
Threonine	2.95 ± 0.52
Tyrosine	2.85 ± 0.41
Methionine	4.03 ± 0.28
Isoleucine	2.86 ± 0.38
Leucine	8.12 ± 1
Phenylalanine	3.77 ± 0.20
Lysine	9.91 ± 1.45

Table 7. Muscle composition in different months[a]

MONTH	% WATER	% FAT	% PROTEIN
MAY	78.43 ± 0.076	1.34 ± 0.03	18.06 ± 3.35
AGOUST	79.73 ± 0.26	0.83 ± 0.16	17.95 ± 1.65
OCTOBER	82.08 ± 1.26	0.78 ± 0.15	13.96 ± 1.4
DECEMBER	80.83 ± 1.17	0.94 ± 0.31	17.92 ± 2.53

[a] Expressed as a wet basis weight

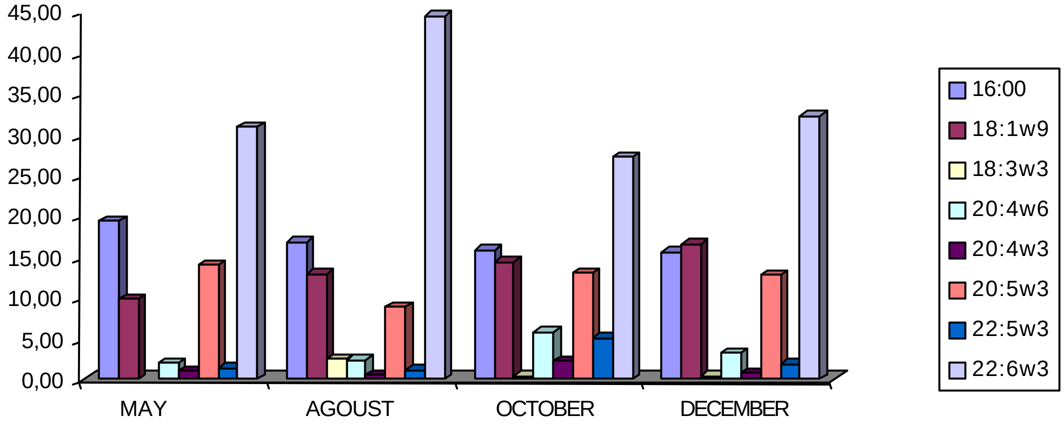


Fig. 6. Variation in fatty acid composition in different months.

WORKPAGE 4

TECHNOLOGICAL SUITABILITY OF ROCKCOD FOR AN INDUSTRIAL PROCESSING LINE

WORKPACKAGE NUMBER 4: TECHNOLOGICAL SUITABILITY OF ROCKCOD FOR AN INDUSTRIAL PROCESSING LINE

Phase: final report

Start date: 5

Completion date: 23

Current status: finished

Co-ordinated by CSIC-IIM (B1) Person/Month (4)

Other Partners (Person/Months): A2 (3), A5(2).

Deliverables Nº: 4,10,15,20,22

Milestones Nº: 5,7.

Objective (as in the technical annex)

to study the suitability of Rock cod for two different industrial processing lines and to produce adequate seafood to supply the European market under different formats.

Methodology and study materials (as in the technical annex)

This workpackage is composed by the following tasks:

Task 4.1. Physical Suitability (Leader IIM)

Deliverable 4: Rockcod suitability for physical processing (fillet, gut, etc).

Yields: The yield is a relevant factor on the technological suitability and value of fish species. It depends on the ratio between edible and inedible parts of the fish. It provides an indication of the ability of fish species for being processing as fillets, minced muscle or entire fish. The average yield of manual processing of Rockcod species was established in our Lab calculating the flesh which can be used after behead, gut, bone and skin the fish. The yields of *P. guntheri* and *P. ramsayi* were 35.6 ±1.7 and 33.5 ± 0.6, respectively. The yield was not very high, but because of the size, *P. ramsayi* can be almost totally used for filleting. However, *P. guntheri* is too small for filleting, and the flesh could be only used for minced muscle.

Crown Seafoods obtained a yield of 57 % transforming Rockcod tunks into mincing fish (meat fish without bone and skin)

Task 4.2 Development of the technical modifications on board commercial vessels. Developed by OPTIMAR

On board two Argos vessels (Argos Pereira and Argos Vigo), Argos personnel and the ANAMER observer carried out several processing runs with the target species:

Fish freezing:

Using the information collected during the Rockcod Exploratory Award, EXAW 1642, Contract nº QLK5-2001-41642, one of two sample batches gathered showed yellowish taints spread all over the fish body, after several months under freezing conditions; so special attention was paid by the observer during his trip to get a good isolation of the gathered samples using plastic film, prior to the freezing process.

Care was also taken in getting a good frozen product in the minimum time. Two different freezing systems were available on board: an Ultrafreezing Tunnel and Contact Trays. The tunnel is the slower system, the product needs 6 hours to get the suitable freezing state. The trays are a quicker method spending 2-3 hours to freeze the product. So the quicker method was used during trials.

Machinery checks:

To process the fish headed, gutted and tailless had no problems. Three commercial size could be envisaged:

24-28 cm. Weight: >150gr.
29-34 cm. Weight: 150-200 gr.
>35 cm. Weight: 200 gr, or higher.

Fillets: The fish has hard scale skin that was easily eliminated by the skin machines. The problem arose with the automatic filleting machine. The two vessels, Argos Pereira and Argos Vigo, have a multi purpose fish processing lay out. Filleting machines in multipurpose lay outs are designed for fish greater in size than *Patagonotothen* spp., so the installation didn't get fillets from the target fish. Rockcod filleted samples were hand made.

The following photo series (Figs. 1 to 12) shows Rockcod processing on board Argos Vigo vessel

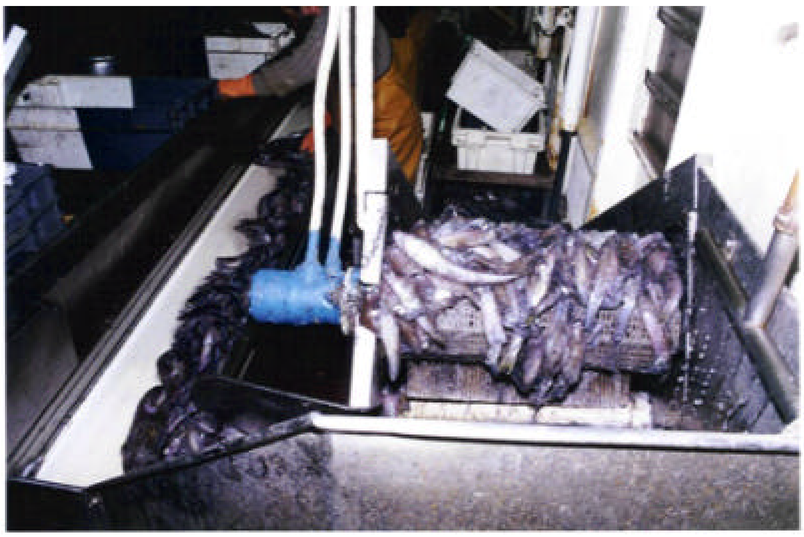


Fig 1. Basin outlet belt. Non selected Species.

Fig 2. Manual species selection at the basin outlet belt.

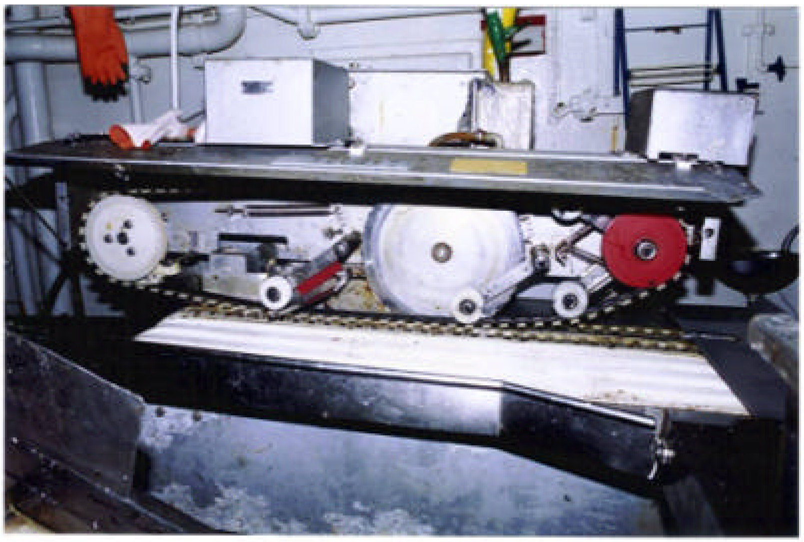


Fig. 3. The BAADER 424 heading machine used for *P. Ramsay* manufacturing.

Fig. 4. BAADER 424 heading machine for trunks manufacturing.

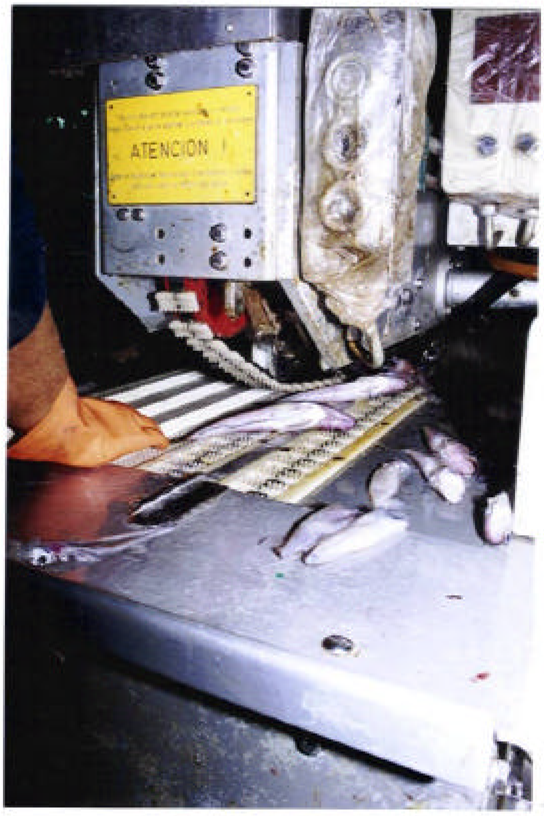


Fig. 5. *P. Ramsayi* heading at the BAADER 424

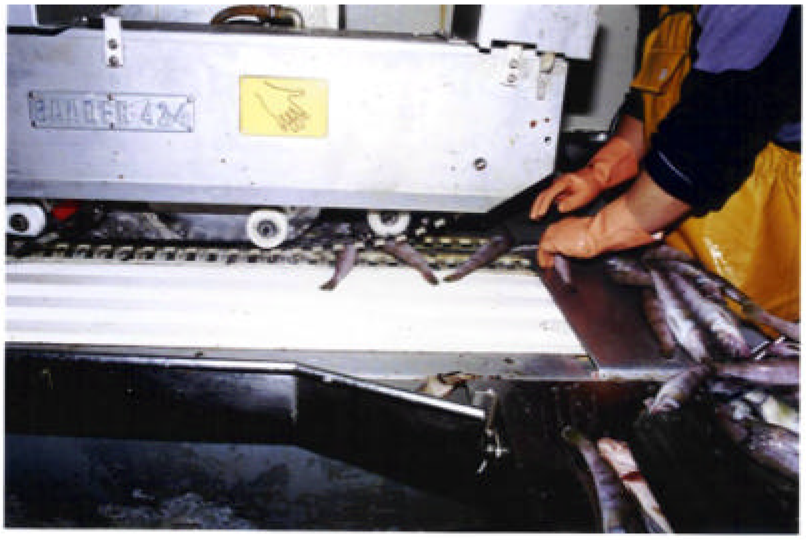
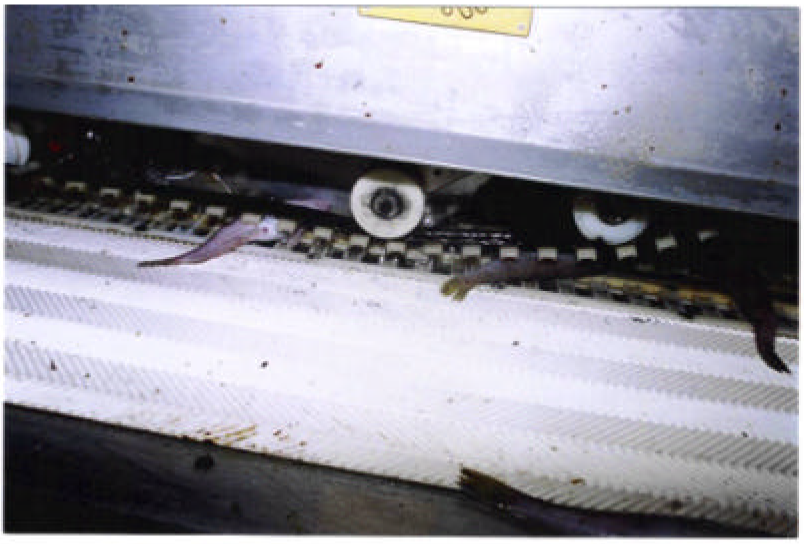


Fig. 6. Cont. *P. Ramsayi* heading at the BAADER 424



Fig, 7. BAADER 424 Cont. The uneven cuts of *P. Ramsayi* bodies at the BAADER 424 is caused by the small size of the fish, the small fishes do not hold to the conveyor belt, when the belt begins to move further the fish position changes causing irregular cuts.

Fig. 8. BAADER 424 Cont. Uneven output of the BAADER 424.

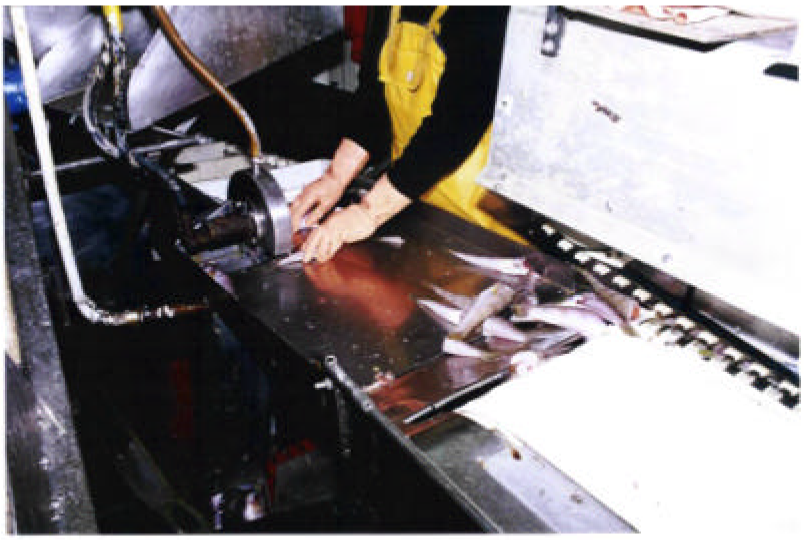


Fig. 9. Once headed the fish pass through a “tail cutter” and then to a gutting basin before to go into the washing machine.

Fig. 10. *P. Ramsayi* trunks (headed, tailless and gutted) going out from the washing machine and ready to be packed.

Fig. 11. *P. Ramsayi* trunks packing

Fig. 12. Packed *P. Ramsayi* trunks going into the Ultra freezing tunnel.

Proposal for more efficient and added value to rock cod processing integrated into existing processing lines. (Optimar Fodema)

Some rebuilding /modifications will be necessary.
According to the previous reports of the Rock cod project for use off the fish for human consumption we have the following proposal.

This report is based on processing of fish with 3 grade.

I) Fish up to 150g:

The small fish with a weight less than 150 g would be allocated to be frozen round and a market could be found.
More size grade can be implemented if the market is demanding other or more grades.

II) Fish between 150g to 200g would be allocated for Headed/Gutted processing (Trunks).

III) Fish of 200g or more would be allocated for fillet processing.

Main challenge for an efficient processing of Rock cod adapted to existing processing line without use of more labour and use as less space as possible.

A) Separating Rock cod from other spices / offal.
B) Space available onboard for necessary processing machinery.
C) Choice of nobbing (cut off the head and suck out the stomach) /filleting machines adapted / adjusted to Rock cod bone structure.

Improvement for new processing.

1) Separating Rock cod from the rest of the catch manually, and transported to buffer bins with RSW or flow ice.

2) The rock cod to be transported to a size grading machine for separating two sizes. The grading machine can also be used for size grading of other species (Hake, Hoki etc.)

3) Nobbing / filleting machine to be installed (Type WMK or Baader)
If two types of machines have to be installed we have the following proposal for efficient and well known machines. One nobbing machine (Type WMK or similar) for size 150g to 200g for processing h/g fish, capacity approx 200fish/min. After the examination of the backbone structure on the Rock cod the Baader 182 filleting machine for size from 200g to 700g is the best and cheapest alternative. Capacity of the Ba-182 is 100 fish/min yield 27% skinless/boneless fillet. One skinning machine type Ba-51 or Trio to be installed after the BA 182 in order to make skin-off fillet.

4) H/g fish to be transported to washing machine and to packing into frames manually for freezing in tunels or horizontal plate freezer. Existing logistic onboard for transport could normally be used.

5) Fillet skin-on / skin-off to be transported to manual inspection / trimming / weighing station. The fillet to be packed in to freezing frames and frozen in tunnels or horizontal plate freezers. Existing logistic onboard for transport could normally be used.

6) H/g fish after frozen, the frame to be removed and the block to be glazed. The block to be packed into master cartons and strapped. Existing logistic onboard for transport could normally be used.

7) Fillet after frozen, the frame to be separated from the block. The block to be packed into master cartons and strapped. Existing logistic onboard for transport could normally be used.

Comments:

The Ba-182 is a flexible solution for the area of Falkland Island and the machine processing also Hake 200g – 600g and Alaska Pollack 200g – 700g. The machine has a approx. Capacity of 2400kg/hour with round fish width head. The machine can be used also for nobbing but then manual removing of guts will be necessary.

Approximately the needed space for Rockcod processing of fillet, headed and gutted and round would be 6.5 x 5.5 meter. The need of space is depending on existing processing equipment on the different Type / Size of vessels.

The bottle neck onboard existing vessels will normally be space available and freezing capacity either in tunnels or in horizontal plate freezers.

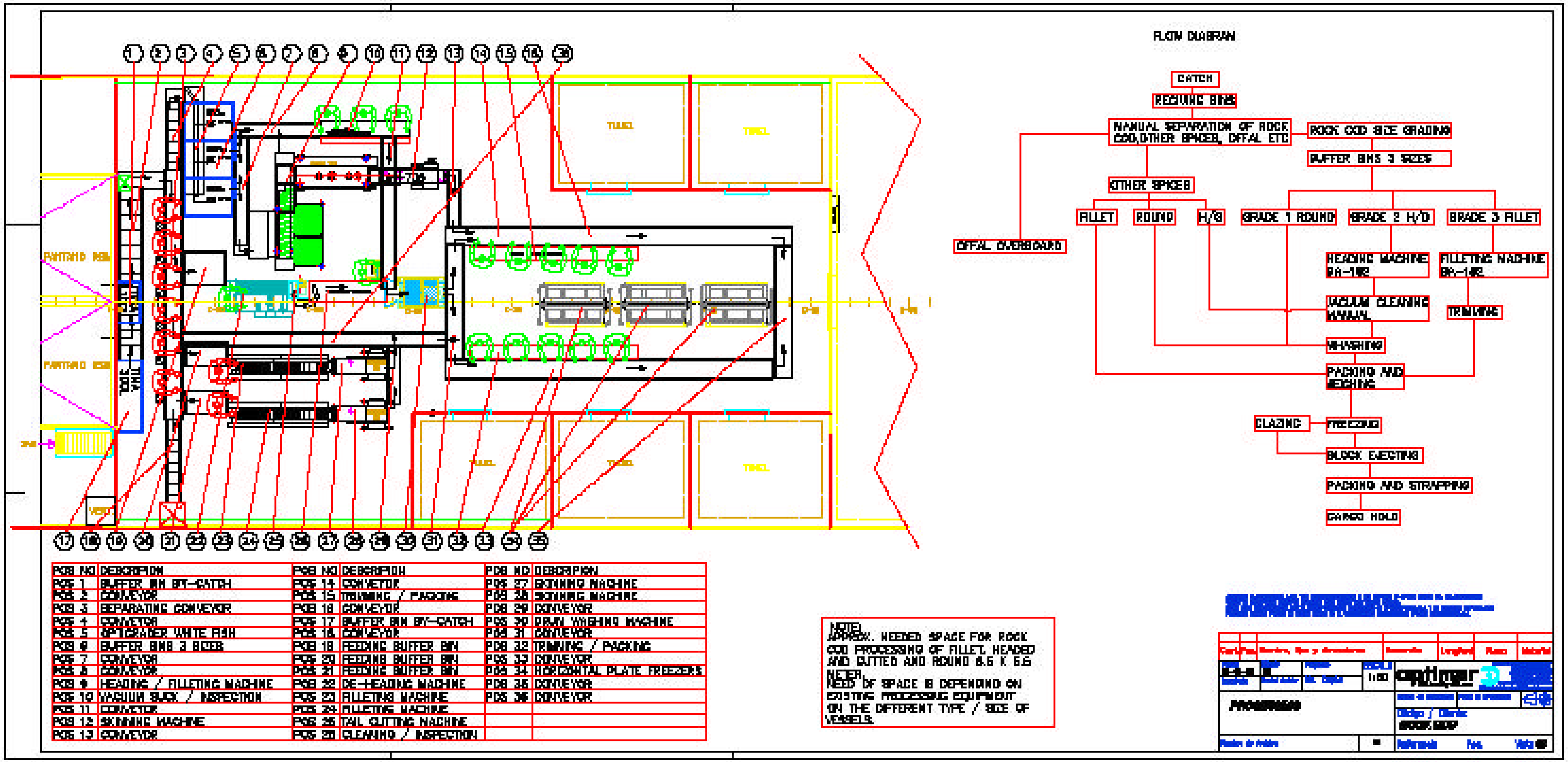


Fig. 13. Vessel layout and flow diagram for Rockcod processing

Task 4.3. Frozen Storage.

Deliverable #12: Spoilage characteristics of the fish during conservation and processing report

This part of the work was aimed to evaluate the aptitude of *P. ramsayi* to be frozen stored. Different individuals corresponding to three different trials, August, October and December, were stored at –20ºC, and analysed during a year. They were studied at 4, 6, 9 and 12 months.

We planned a sampling experiment on board for getting data corresponding to zero point. The observer took fresh samples and prepared three types of samples: small pieces of muscle treated and muscle treated with dichlorometane or perchloric acid depending on the scope of the later analyses at our lab. However, the rapid deterioration of minced muscle avoided the use of these data as commercial zero. For that reason, we have employed as data corresponded to zero those results obtained in frozen samples arrived at our lab into a period of one month after their caught.

Off- flavours were determined with the content of TMA, TVB and ^{i}-TBA.

Rancidity were determined by sensory analysis and the determination of PV and ^{i}-TBA.

Water retention and texture were studied with the determination of protein solubility. Proteolytic activity was also studied for illustrating the possible degradation of texture.

Moreover, nutritional quality was evaluated within the vitamin E degradation and the variation in the fatty acid composition.

Skin-on and skin-off fillets were prepared on board and arrived at our lab after 4 months of frozen storage.

All analyses were duplicate and/or triplicate. More than 6500 analyses were carried out.

Results

Whole fish.

Whole *P. ramsayi* showed an excellent quality during 6 months at –20ºC. No off-flavours related to volatiles amines were detected after 12 months at –20ºC (TMA: Fig. 14 and TVB: Fig. 15). As regards to rancidity, Rockcod showed an excellent odour during 6 months at –20ºC. After that there was an incipient development of rancidity detected by the sensory characteristics and the results of hydroperoxides formation, PV index (Fig. 16). The increase of the values of hydroperoxides at month 6th was followed with an increase in the TBA-index as can be seen in Fig. 17.

In relation to texture and water retention, the study of protein solubility (Fig. 18) showed a significant decrease (round 20%) at month 6^{th}. Data of proteolitic activity corresponding to the commercial zero were in agreement with those data reported for other fish species. They were low as correspond to the high stability found of texture of the initial samples.

In relation to nutritional value, the amount of vitamin E was maintained stable (Fig. 19) in agreement with the results of the other chemical parameters related to quality. Only after six months of frozen storage, there was a significant decrease of the content of vitamin E. No variations in the concentrations of principal fatty acids were observed during the whole storage experiment.

The three different trials of samples stored at –20ºC and studied during one year showed the same results. The overall quality and nutritional valued of whole *P. ramsayi* was maintained stable during 6 months at -20ºC. The quality was low after 9 months at –20ºC mainly due to the development of rancidity.

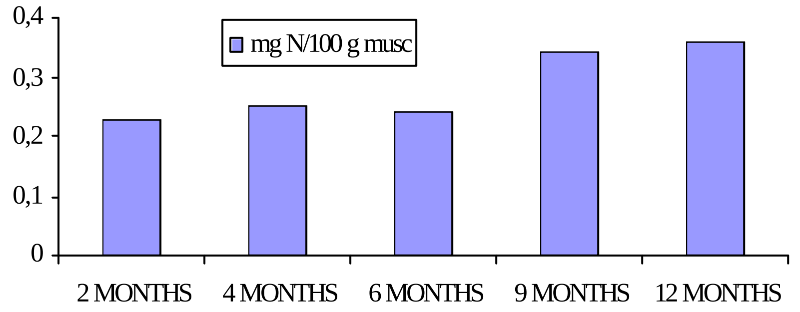


Fig 14. TMA formation during frozen storage

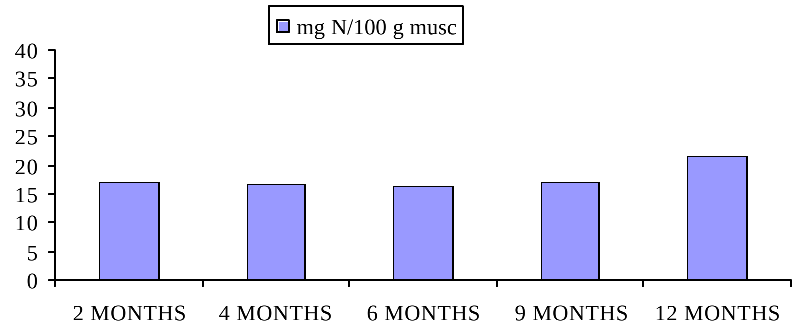


Fig 15. TVB Formation during frozen storage

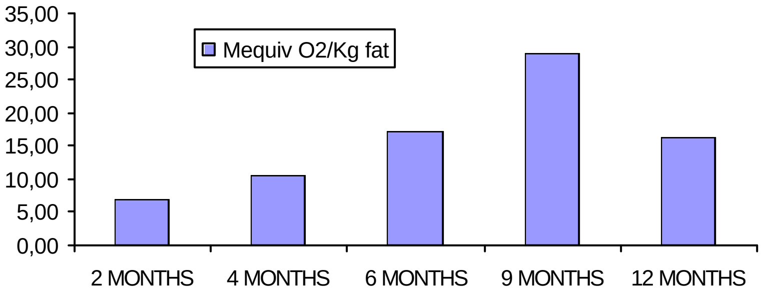


Fig. 16 Evaluation of hydroperoxides formation during frozen storage

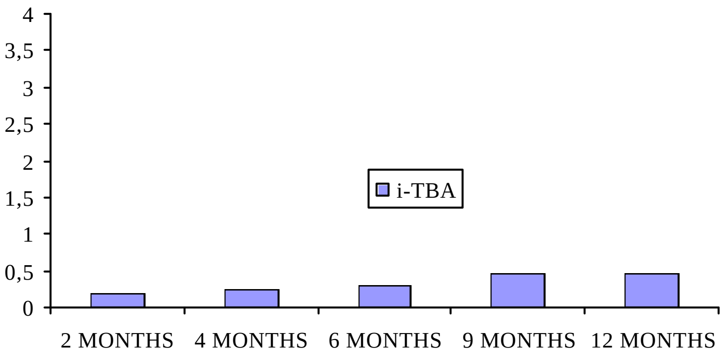


Fig 17. [i]-TBA during frozen storage

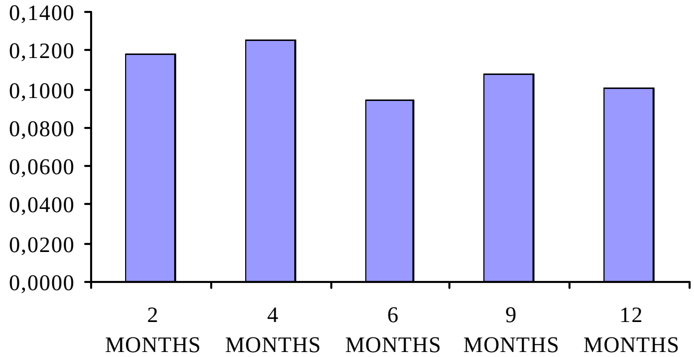


Fig. 18. Protein solubility during frozen storage

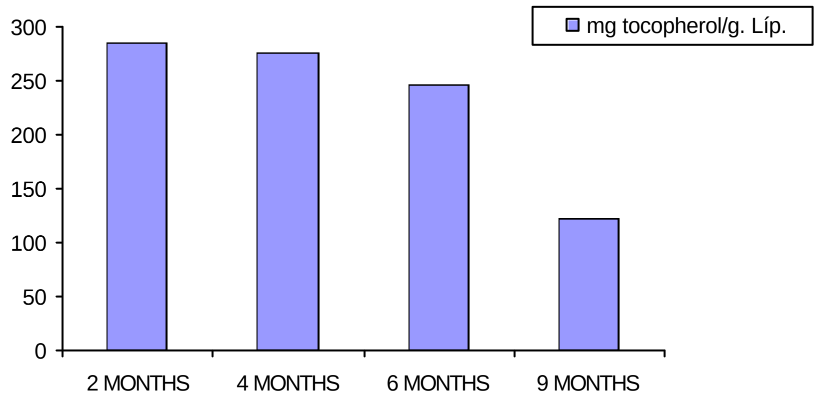


Fig. 19 Degradation of Vitamin E during frozen storage

Skin-on and skin-off fillets arrived at our lab after 4 months of frozen storage, showed poor organoleptic characteristics. Sensory and chemical analyses showed a clear development of rancidity and a high loss of water, specially in skin-off fillets. The colour was slightly yellow and the texture wasn't firm and elastic. Therefore, the analyses performed indicated that, after 3-4 months of frozen storage, the fish fillets were quite deteriorated (Fig. 20).

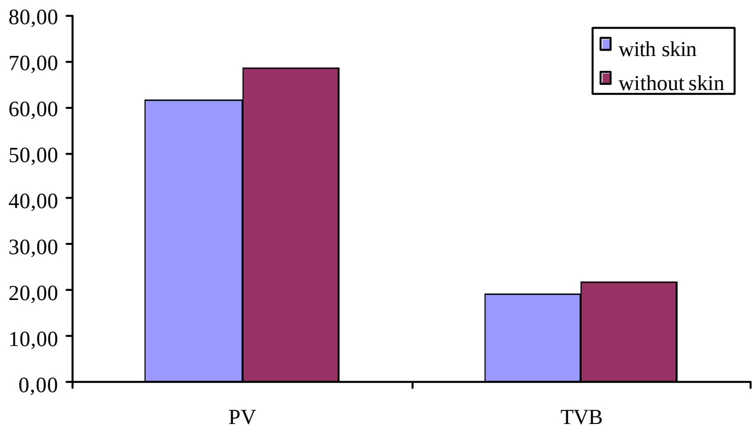


Fig. 20. Off flavours and quality index. Comparison between fillets with skin and skin-off PV expressed as mequiv O_2/kg lipid and TVB expressed as mg N/100 g muscle.

Deliverable 15: Shelf-life of whole Rockcod and Rockcod fillets under frozen conditions report

The aptitude of whole and fillets of *P. ramsayi* to be frozen stored was determined. Different individuals corresponding to three different trials, August, October and December, were stored at –20ºC and analysed during a year. They were studied at 4, 6, 9 and 12 months.

We planned a sampling experiment on board for getting data corresponding to zero point. The observer took fresh samples and prepared three types of samples: small pieces of muscle treated and muscle treated with dichlorometane or perchloric acid depending on the scope of the later analyses at our lab. However, the rapid deterioration of minced muscle avoided the use of these data as commercial zero. For that reason, we have employed as data corresponded to zero those results obtained in frozen samples arrived at our lab into a period of one month after their caught.

Skin-on and skin-off fillets were prepared on board and arrived at our lab after 4 months of frozen storage.

All analyses were duplicate and/or triplicate. More than 6500 analyses were carried out.

Results.

a) Whole fish.

Whole *P. ramsayi* showed an excellent quality during 6 months at –20ºC. No off-flavours related to volatiles amines were detected after 12 months at –20ºC. As regards to rancidity, Rockcod showed an excellent odour during 6 months at –20ºC. After that there was an incipient development of rancidity detected by the sensory characteristics and the results of hydroperoxides formation.

In relation to texture and water retention, the study of protein solubility showed a significant decrease (round 20%) at month 6th. Data of proteolytic activity corresponding to the commercial zero were in agreement with those data reported for other fish species. They were low as correspond to the high stability found in texture of the initial samples.

In relation to nutritional value, the amount of vitamin E were maintained stable during 6 months in agreement with the results of the other chemical parameters related to quality. Only after six months of frozen storage, there was a significant decrease of the content of vitamin E. No variations in the concentrations of principal fatty acids (Fig. 21) were observed during the whole storage experiment.

The three different trials of samples stored at –20ºC and studied during one year showed the same results. The overall quality and nutritional valued of whole *P. ramsayi* was maintained stable during 6 months at -20ºC. The quality was low after 9 months at –20ºC mainly due to the development of rancidity.

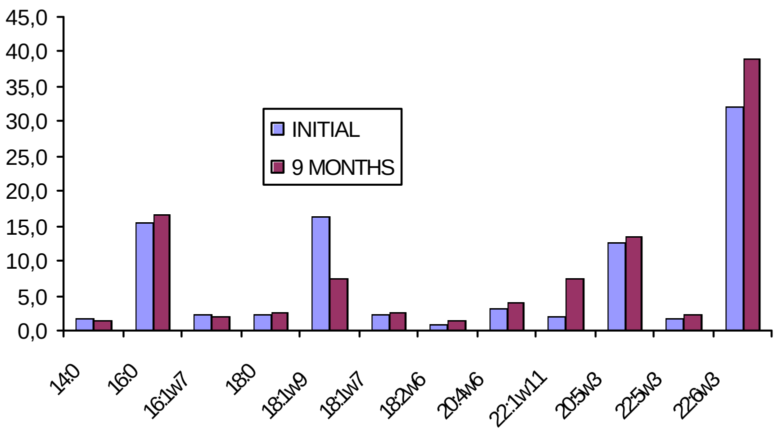


Fig. 21 Variation in the principal fatty acids under frozen storage

Skin-on and skin-off fillets arrived at our lab after 4 months of frozen storage, showed poor organoleptic characteristics. Sensory and chemical analyses showed a clear development of rancidity and a high loss of water, specially in skin-off fillets. The colour was slightly yellow and the texture wasn't firm and elastic. Therefore, the analyses performed indicated that, after 3-4 months of frozen storage, the fish fillets were quite deteriorated.

Task 4.4. Development of processed products from frozen rockcod

(Leader: Crown Seafoods assisted by the project sponsor Pez Austral).

Sub-Task 4.4.1. Routine controls for Raw Materials:

The Rockcod passed all routine quality controls needed to fulfil the Good Manufacturing Practises:

- Physical Control:

  This control was not needed because the fish was not send in the fish block format. All fish was presented to the manufacturing companies as trunks (headed, gutted and tailless). The fish delivered was clean without any remain of guts, fins, etc.

- Microbiological Control:

  Microbiological data corresponding to fresh samples of *P. ramsayi* were negative. Data of coliforms, *E. coli* and Salmonella were negative.

  Total microbial content of frozen samples were low: 785 UFC and analyses of coliform colonies were negative.

- Sensorial Control:

  Al processed batches underwent sensorial tests carried out by skinned testers. None of the tested batches presented off-flavours.

Sub-Task 4.4.2. and 4.4.3(Pez Austral) Industrial Process and Adaptation to different processing formats

The commercial vessels implicated in the project could not to process the fish into fish block because of their multipurpose process line. This kind of line implies machines specialized in big fish that cannot process small fish like Rockcod.

So hand made fillets with skin were battered/breaded using an industrial machine. The battered portions were pre-fried in oil, using a combination time/temperature of 15 seconds at 180ºC. The pre-fried portions were deep frozen using a Frigoscandia frozen tunnel, being the combination time/temperature of between 20 to 40 minutes at -45ºC. An Ishida automatic filling-weighing machine was used to put the frozen portions into bags. These bags were maintained at below – 18º C in frozen storage till their preparation as dishes to be tested.

Sub-Task 4.4.4. (Crown Seafoods) Industrial Process:

Fig. 22 Samples of Rockcod

Taste

After defrosting various samples, a taste panel was arranged, to ascertain whether the fish was similar to known species for tasting score recognition. The taste panel consisting of 2 people trained in Tory scoring and 1 sales person, who was asked to do blind tastes. Having all agreed to use the Whiting Taste score analysis, we scored all the samples 8.5, being consistent with Frozen At Sea fish. The skin was tasted and discarded, as having no taste, just unpleasant scales and bits in the mouth. The fish was good tasting, with no odours or off flavours when cooked, similar to the Patagonian Silver Hake (Merluccius Hubsi) caught in south-western Atlantic. This Hake is very sweet when fresh or fresh frozen, but does have a deep fat layer, that quickly turns rancid, even in frozen fillets, so must be removed. There was no evidence of this fat layer in the samples tasted but then again the fish are so small, they have not yet developed fat. The Rock Cod has a clean taste that you would expect from colder water fish, the flesh could become softer & mushy if the species were caught in the warmer waters of the mid Atlantic, again like Hake. The normal reaction to Hubsi Hake, is of a cheap, fairly mediocre white fish fillet, sometimes strong tasting and attracts the lowest price of any other white fish, so care should be taken as not to follow the shoals North, into the warmer water.

Filleting

The size of fish makes it totally impractical to fillet this fish in Europe. The fish are too small to go through any of the known filleting machines in the UK and if the hand filters could process the fish, the time and cost would prohibit the sale. Comparing the product to Patagonian Silver Hake, the fish are so small, they would need to be skinned & boned, then paired together. Size of skinless single fillets range from 16 to 37 gram This would still only give a 30 to 70 gram portion.

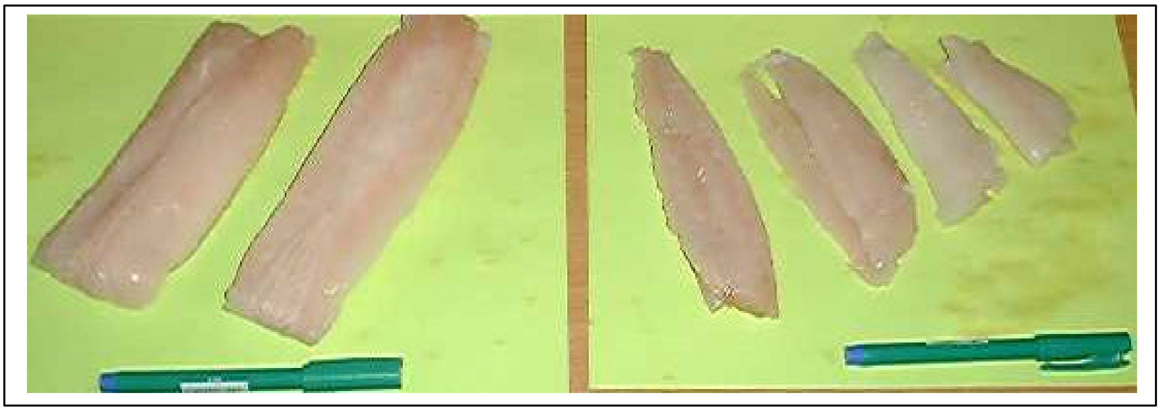


Fig. 23 HAKE and ROCK COD fillets (left and right respectively)

Mincing

The only process open to me, unless the fish come in larger form, is to put the Headed & Gutted whole fish through a 3 mil mincing machine, to separate the bone and skin. The fish can go into a 7.5 kilo, waxed liner, industrial block, for further processing.

The fish is defrosted, minced and washed. A slight odour was detected in the raw mince, similar to the smell of Loligo Squid. As the species swim with loligo and the boat process mainly loligo, this was to be expected. When the frozen blocks came out of the plate freezers, the smell had disappeared, again we tasted the fish, to see if it had retained the clean taste and the skin had not impaired the flavour. All was ok., but the yield was very poor 57%. The colour of the block was a light grey, caused by the fish being minced with the skin on and this is the standard colour of a grade "B" white fish mince. Fish went whiter when cooked.

Forming

The industrial blocks are now ready for secondary processing, which are formed into marketable shapes, coated, part fried, checked by quality control, scanned and boxed.

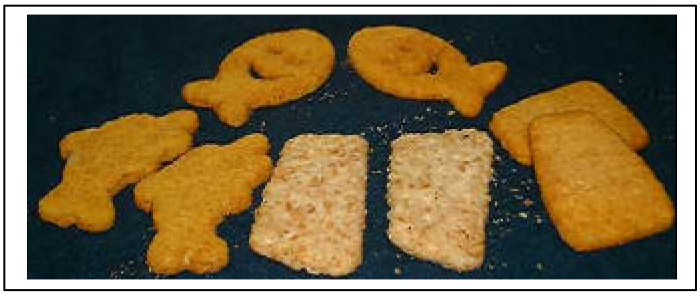


Fig. 24 Crown Seafoods commercial shapes

The above shapes have been coated in various coatings as follows:

- Jimmy the Fish. 57g finished weight. Ingredients: fish 55%, Breadcrumbs, rapeseed oil, water, wheatflour, seasoning (salt, pepper, stabiliser E461, Yeast extract, rusk, onion powder, garlic powder).

- Fish & Potato portion 57g Ingredients : Fish 35% , potato flake, Rice Crispy crumb, Parsley and the usual seasoning.

  These are boxed into 48 portions and are made at 57gram to aim at a retail price 50p for a child's portion or 2 x 57gram for adults.

Cooking

Designed for busy school meal kitchens and easy cooking. Place the coated product on an un-greased baking tray from frozen, Bake for 10-14 mins. in a conventional oven.

Weight Loss

We are finding the product is needing more raw material in the core weight to maintain the minimum fish content in the finished product. (Some 5% more than cod or haddock) This could be due to slightly more oil content in the rock cod and is being absorbed into the coatings. This needs to be monitored very closely as not to cause problems with trading standards.

Tasting the Mince

Again a taste panel has been set up to taste the product against similar products on the market. Although the 5 people involved in tasting the product, said it was good, there was some discoloration of the core and obviously not as white as the grade "A" fish block, stating there customers would rather pay extra money for the whiter fish, than have problems with visual complaints. We also experienced scales from the skin had gone into the mince and although not visible, the feeling in the mouth was unpleasant.

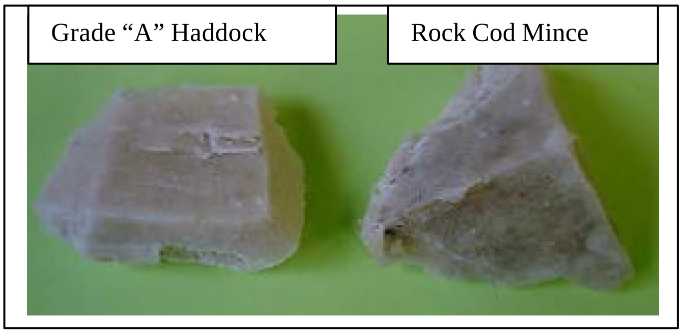


Fig. 25 Mince Haddock and Rockcod

Summary.

The size of the fish is the main problem for the European market. Whole fish of 24 cm, will give a skinless fillet 8-14cm and this is not practical or viable. The only solution is:
Only land the larger fish 33cm + if they are there to be caught.

The fish could be filleted in the Far East, if the logistics of the transportation can be overcome. Bearing in mind the yield will be only 50% of the H&G fish landed. This could set this up if required, to produce skinless boneless blocks of white fish fillets, using the rock cod The current market price would be £2-20 per kilo (3.70 Euro) delivered into the UK.

Deliverable 20: High quality and healthy processed products from Rockcod results

The two fish products manufacturing companies implicated in the Project, Partner A1 Crown Seafoods and Sponsor Pez Austral, processed the fish into their commercial formats. The raw material passed all routine quality controls needed to fulfil the Good Manufacturing Practises that is Physical, Microbiological, Sensorial and Parasitological controls.

In Pez Austral facilities the Rockcod samples suffered the following treatment: hand made fillets with skin were battered/breaded using an industrial machine. The battered portions were pre-fried in oil, using a combination time/temperature of 15 seconds at 180ºC. The pre-fried portions were deep frozen using a Frigoscandia frozen tunnel, being the combination time/temperature of between 20 to 40 minutes at -45ºC. An Ishida automatic filling-weighing machine was used to put the frozen portions into bags. These bags were maintained at below – 18º C in frozen storage till their preparation as dishes to be tested.

The Pez Austral processed Rockcod was well evaluated in all the taste tests carried out during the Project.

The Crown Seafoods products manufacturing implicate a Mincing process because the fish was too small to be filleted with the company machines. The Headed & Gutted whole fish was put through a 3 mil mincing machine, to separate the bone and skin. A yield of the 57 % was obtained and considered very poor. Again a taste panel has been set up to taste the product against similar products on the market. The 5 people involved in tasting the product, said it was good.

So no problems were detected with respect to final products taste in the two companies. On the other hand serious problems have arose with Rockcod as raw material. For Rockcod become a raw material for the fish processing industry it will be necessary produce Rockcod skinless fish block on commercial vessels or in the industry facilities prior to be processed.

But analysis results reveal a reduced self life for filleted fish so the second solution would be more appropriate.

Sub-Task 4.4.5. (Crown Seafoods) Smoked products: Skinless fillets will also be smoked for use in recipe dishes or retail packs and pates.

No smoked products were produced from Rockcod.

Task 4.5. Consumer's acceptance of the final products (Leader IIM with assistance of Crown Seafoods).

Deliverable 22: Consumer's acceptance degree results

I) Test carried out by the IIM expert tester panel

Cooking samples: The expert panel of IIM was formed by 9 trained specialist in fish technology of which the 60% were women. They aged from 26 to 57 years. The measurements of freshness of cooked fish (odour, flavour and texture) were assessed (Howgate, 1982) according to the Torry scheme. A hedonic scale from 10 to ≤ 3 was used, 10 showed absolutely fresh and ≤ 3 completely putrid or spoiled. Fish fillets were cooked in a microwave for 3 minutes then served to the panellist.

The results are the following:

- Odour: Shellfish, seaweed. Value: 9
- Flavour: Sweet and characteristic flavours but reduced in intensity, quite similar to cod. Value: 8
- Texture: Dry, less succulent, fibrous, stick. Value: 8

According to this scale, the general valuation of the product was 8.

II) Crown Seafoods testers panel results

- Tasting the Whole fish

After defrosting various samples, a taste panel was arranged, to ascertain whether the fish was similar to known species for tasting score recognition. The taste panel consisting of 2 people trained in Tory scoring and 1 sales person, who was asked to do blind tastes. Having all agreed to use the Whiting Taste score analysis, we scored all the samples 8.5, being consistent with Frozen At Sea fish. The skin was tasted and discarded, as having no taste, just unpleasant scales and bits in the mouth. The fish was good tasting, with no odours or off flavours when cooked, similar to the Patagonian Silver Hake (*Merluccius Hubsi*) caught in south-western Atlantic. This Hake is very sweet when fresh or fresh frozen, but does have a deep fat layer, that quickly turns rancid, even in frozen fillets, so must be removed. There was no evidence of this fat layer in the samples tasted but then again the fish are so small, they have not yet developed fat. The Rock Cod has a clean taste that you would expect from colder water fish, the flesh could become softer & mushy if the species were caught in the warmer waters of the mid Atlantic, again like Hake. The normal reaction to Hubsi Hake, is of a cheap, fairly mediocre white fish fillet, sometimes strong tasting and attracts the lowest price of any other white fish, so care should be taken as not to follow the shoals North, into the warmer water.

- Tasting the Mince

Again a taste panel has been set up to taste the product against similar products on the market. Although the 5 people involved in tasting the product, said it was good, there was some discoloration of the core and obviously not as white as the grade "A" fish block, stating there customers would rather pay extra money for the whiter fish, than have problems with visual complaints. We also experienced scales from the skin had gone into the mince and although not visible, the feeling in the mouth was unpleasant

III) Hedonistic tests

Two hedonistic tests were carried out, one the 21st of September 2004 and the other one the 15th of December 2004. In both sessions several dishes with Rockcod as principal ingredient were tasted. In each session Rockcod was presented fried and cooked.

For fried Rockcod the Pez Austral Industrial process was followed: hand made fillets with skin were battered/breaded using an industrial machine. The battered portions were pre-fried in oil, using a combination time/temperature of 15 seconds at 180ºC. The pre-fried portions were deep frozen using a Frigoscandia frozen tunnel, being the combination time/temperature of between 20 to 40 minutes at -45ºC. An Ishida automatic filling-weighing machine was used to put the frozen portions into bags. After this industrial treatment the fillets were fried in a standard kitchen and served to the testers.

In these two examinations participated a total of 32 testers of which the 41 % were women. They aged from 26 to 60 years. The 84 % of the check team were fish eaters, it was considered a fish eater the person who ate fish twice a week or more.

The final results were the following.

	% Positive	Negative	Indifferent
Fried Rockcod	90.6	0.0	9.4
Cooked Rockcod	71.9	6.3	21.9

During the test a score ranging from 1 to 4 was requested to the evaluators with the following results:

Mean value (1 to 4)	Positive	Negative
Fried Rockcod	2.9	0.0
Cooked Rockcod	2.6	4.0

Having in mind these tests results we can state that the Rockcod has had a good acceptance among the consumers.

This was the test record Model used during the Hedonistic checks:
<u>Preference Test Record:</u>

Date

Sex.......................Age.....................Profession...................................

Do you usually eat fish?(Twice a week)...

Product: Fried Rockcod

Do you like it? Y ☐ No ☐

Indifferent Y ☐

Mark picture according to your preference

Other comments:

Product: Stewed Rockcod

Do you like it? Y ☐ No ☐

Indifferent Y ☐

Mark picture according to your preference

Other comments:

Strategy of the ANAMER fishing fleet as consequence of the Rockcod Project results.

ANAMER and one of its associates Armadora Pereira SA initiate their activities about the possibilities of exploitation of *Patagonotothen* spp. (Rockcod) around December 1999. As a result of this initiative an Exploratory Award was claimed to the Commission in September 2000 that ended in the Contract nº QLK5-2001-41642. During this Contract the Rockcod Proposal, of which the present contract is a result, and its Consortium were built up.

It is very outstanding that the first year that Rockcod catches appeared reported by ANAMER fleet is year 2001. We could explain this phenomenon by an effect of the noise produced by all the contacts needed with ship owners, fish associations, etc, that has caused the beginning of commercialisation of the former by catch once rejected to the sea.

The following table shows the Rockcod reported catches by the ANAMER fleet, no catches report exits before 2001:

		Year 2001	Year 2002	Year 2003	Year 2004
Commercial Category	Number of SHIPS	3	5	8	11
	Kg. NOTOTENIA	284.582	70.911	241.332	525.459
	Kg. FILET. NOTOTENI/	42.560	5.565	3.395	9.310
	Kg. MARUJITO	0	10.801	68.641	255.261
	TOTAL…	327.142	87.277	313.368	790.030

Catches are shown in Kg of green weight.

Categories Notothenia and Marujito (rockcod) is whole fish headed, gutted and tailless.

As it can be seen in the table catches begin in year 2001. There is an important drop in Rockcod catches during 2002. But it seems like from 2002 to 2004 there is a steadily increase in number of ships and companies fishing Rockcod and also in the whole amount of fish catches.

Despite of this tendency in ANAMER fleet, Armadora Pereira has begun to fish Rockcod in the year 2004, the commercial category used is Rockcod trunks. Following the CSIC-IIM results (see Task 4.3. Frozen Storage), which shows a bad evolution for frozen fillets, has begun the marketing through Rockcod trunks. This commercial format warranties a good preservation of the fish good nutritional qualities and a total absence of off-flavours during the product self life.

Evolution of Rockcod catches

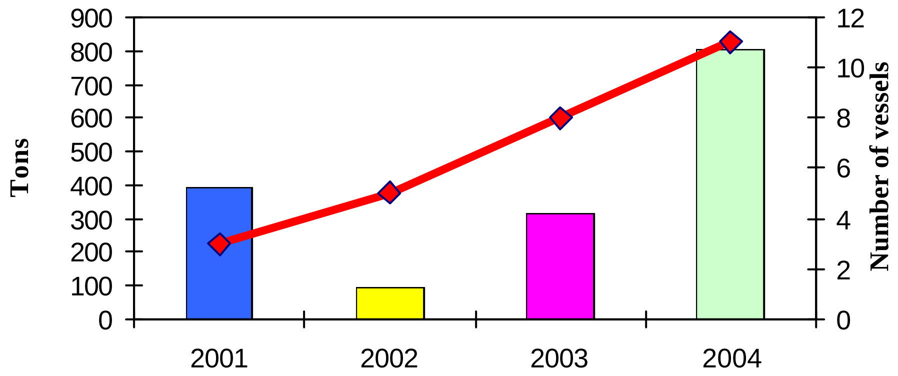


Fig. 26 Evolution of rockcod catches

This last strategy, based in the results of the CSIC-IIM Laboratory, was one of the most important project objectives. Traditionally fishing companies begin to commercialise fishing products without any knowledge about product self life. The time period during which products can be marketed keeping all their nutritional and taste qualities. As far as we know there are ANAMER associates marketing Rockcod fillets despite the poor self life of this commercial category, as we can see in the reported figures. This commercialisation could have a negative effect in the market if consumers begin to find spoiled products, the rancidity has a devastating effect on taste. Normally when a client finds a spoiled new product (new especies) begins to distrust on all manufacturer's new products. So commercialisation of fillets could have a negative effect in trunks commercialisation.

This kind of initiative, without following laboratory results on product self life, could have a negative effect in a short-medium term. So the ANAMER recommended strategy is commercialisation of Rockcod trunks till get a steady market and after that begin the fillets marketing following closely all kind of market devolutions and possible clients complaints.

On the other hand, Argos Ltd has decided not to fish Rockcod. The alleged reasons are the following:

- Although companies marketing Rockcod have not declared where their markets are, it is said that one of these markets are the East Europe countries. This is a market for cheap protein, so companies margins will not be high.

- Another problem would be the possibility of new companies entering this new market causing the Rockcod price falling with the ensuing reduction of profits.

- With the increased oil prices during the last years it is very hazardous try to open a market with low profits.

Based on these reasons Argos will wait till a more stable market could ensure a more reasonable earnings to the Rockcod commercialisation.

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ROLE OF PARTICIPANTS

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ANAMER: is a ship-owners association that covers the entire country (Spain) and includes the largest and most technologically advanced fishing boats of the Spanish fleet. ANAMER has great experience in conducting surveys with on-board scientific observers in collaboration with the IEO in several areas such as the SW Atlantic, NAFO, Svalbard, Reykjanes Ridge, etc.

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Personnel

José Antonio Cordeiro e-mail: antonio@horizon.co.fk

Workplan

Overall co-ordination of the project will be the responsibility of ANAMER who will also be the main interface between the Consortium and the European Commission, with strong collaboration of MG Otero for the correct development of these duties. He will consolidate the project planning, progress reports, milestone reports, cost statements and budgetary overviews etc, using the inputs from the other partners and will co-ordinate the communication between partners.

ANAMER whose vessels have been fishing in the SW Atlantic since the start of the industrial fishery by the EU fleet (1983), will provide fishery information for assessment, and some of the vessels needed for observers and forecast verification.

ANAMER will provide commercial catch and effort data.

ANAMER was involved in tasks corresponding to the following workpackages:

WP1 General Co-ordination and Dissemination plans. Assisted by its subcontractor MG Otero. Person month: 4+1

WP2 Support with commercial vessels to the scientific observation, data and sample collection. Person month: 1.5

Deliverables: The participant was responsible for the following deliverables

Deliverable No.	*Description of deliverable*	*Delivery date*	*Nature*	*Dissem. Level*[1]
1	***First Co-ordination meeting report***	***2***	***R***	***CO***
2	***Signature of the Consortium Agreement***	***6***	***Contract***	***CO***
8	***First consolidated annual periodic report***	***12***	***R***	***CO***
24	***Final Report***	***24***	***R***	***PU***
25	***Brochures for dissemination about project***	***6, 22***	***R***	***PU***
26	***Meeting minutes***	***6,12,18,24***	***R***	***CO***
27	***Annual cost statements***	***12, 24***	***R***	***CO***
28	***Technical Implementation Plan (TIP)***	***24***	***R***	***PU***

Deliverable Nº 1 *First Co-ordination meeting report*: finished. The first annual co-ordination meeting was held at ANAMER on the 2nd of December. The agenda and minutes of the meeting were included in ANNEX I of the First Progress Report.

Deliverable # 2 *Consortium Agreement*: finished. Signed by all partners and sent to the Commission in 2004.
Deliverable # 8 *First consolidated annual periodic report:* finished. Accepted in March 2004.

Deliverable # 24 *Final Report*: finished. The present report

Deliverable # 25 *Brochures for dissemination about project*: the first one was included in the First Year Progress Report. The draft of the second one was included in the Second Year Progress Report. The final version of second brochure will be included in the definitive version of the Final Report.

Deliverable # 26 *Meeting minutes of the second co-ordination meeting*: finished. Included in ANNEX I of the second progress report.

Deliverable # 27 *Annual cost statements*: finished. Cost statements corresponding to the first year were sent to the Commission with the first progress report in January 2004. Cost statements corresponding to the second year and to the whole project were sent to the Commission with the second progress report in March 2005.

Deliverable # 28 *Technical Implementation Plan (TIP)*: finished.

Activities during the project

In 2003, two observers from IEO and ANAMER were selected and deployed to fishing boats belonging to ANAMER and Argos operating in the SW Atlantic after training courses at IEO. A total of 241 observer days were spent by these observers from 2nd March to 11th July.

Monitoring of FIFD observers was made after their trips when they arrived back in Stanley Also during a trip FIFD observers are required to make two radio schedules per week with the observer co-ordinator to brief him on their progress and to pass biological summary statistics. Spanish observers reported fortnightly to IEO about their activities, indicating number of observed trawls, sampling, etc.

In 2004, five Spanish observers (one contracted by ANAMER and the other four by IEO) were selected and deployed to fishing boats belonging to ANAMER and Argos operating in the SW Atlantic after training courses at IEO. A total of 555 observer days were spent by these observers from the start of their activities on the 15th January until the 26th of November.

Monitoring of FIFD observers was made as in the first year.

As agreed during the kick-off meeting, the database structure designed during the former EU funded project *CEC DG Fisheries Study Project 99/016* was used as a starting point for the present project database. The final structure was decided after discussions among IEO, FIFD and UNIABDN and implemented by IEO (Figure 1).

Samples such as whole specimens for morphometric studies and characterization of the raw fish, otoliths, stomachs and gonads for age and growth, diet and fecundity studies were collected by observers during their trips following the sampling protocol. The samples collected were sent to Stanley and Vigo. Once all the samples arrive to IEO, they were allocated among partners (IIM, UNIABDN, OPTIMAR FODEMA and Crown Seafoods) to carry out different studies.

The collaboration of the Patrol Ship from FIFD and the ANAMER' representative in Port Stanley José A. Cordeiro have played an important role in this phase of the project.

An important photographic work was made by the ANAMER observer taking pictures of all species caught during his trip and the rockcod processing onboard the Argos vessel. This material, included in electronic format in ANNEX III of this report, will be used to produce the second edition of the faunal guide of the Patagonian Shelf and Falkland Islands waters, edited by IEO in the frame of the *CEC DG Fisheries Study Project 99/016*.

Significant difficulties or delays experienced during the project

The vessel *Argos Pereira*, on board of which was the ANAMER observer in 2003 was forced by weak fishing catches to abandon Falkland waters so the observer was deployed to Port Stanley. After a stay of several days he was picked up by another vessel, the *Argos Vigo*.

The close collaboration of the Commercial fishing vessels, the Patrol Ship from FIFD and the ANAMER' representative in Port Stanley José A. Cordeiro have played a deciding role in the success of the observation operation.

In the case of Spanish observers the logistics for their deployment to fishing vessels is different than those for FIFD observers:

- the acceptance of observers onboard is absolutely voluntary and dependent on captain and shipowner decision, so sometimes to find a vessel may take several days or weeks;
- the best way to go onboard of a fishing vessel is meanwhile she is at port either for a fishing licence, repairing or for transhipment of the fish;
- the process for embarkation gets much more complicated if the target ship is already in the fishing grounds, as it requires the location of another boat with accommodation for the observer, going to same area;

All this complicated process was simplified by the close collaboration of Armadora Pereira (A3) and Argos (A4) vessels coordinated by MG Otero and Sulivan Shipping Ltd.

The close collaboration of the Commercial fishing vessels, the Patrol Ship from FIFD and the ANAMER' representative in Port Stanley, José A. Cordeiro, have played a deciding role in the success of the observation operation.

Sub-contracted work during the project

MG Otero Consultores SL

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MG Otero has carried out the selection, contracting, training and deployment of ANAMER observer; during this period a contribution of 100 observer days were carried out. MG Otero has collaborated with ANAMER team in all tasks related with the project co-ordination and participated in all meetings. The deliverables in which MG Otero has collaborated are included in the following table:

Deliver-able No.	Description of deliverable	Delivery date	Nature	Dissem. Level[1]
1	First Co-ordination meeting report	2	R	CO
2	Signature of the Consortium Agreement	6	Contract	CO
8	First consolidated annual periodic report	12	R	CO
24	Final Report	24	R	PU
25	Brochures for dissemination about project	6, 22	R	PU
26	Meeting minutes	6,12,18,24	R	CO
27	Annual cost statements	12, 24	R	CO
28	Technical Implementation Plan (TIP)	24	R	PU

OPTIMAR FODEMA SA (A2) (Industry – ES)

Address: Rúa Parrocha,32
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36200, Vigo. Spain
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OPTIMAR FODEMA is a Spanish SME specialised in fish handling systems. It has a wide experience in developing machinery for processing fish on board and in factories.

Role in the project

OPTIMAR FODEMA contribution is to study the possible technical changes and modifications to be made in the fish processing machinery installed on board the commercial vessels to produce different kind of products such as fillets (skinned or not), whole or headed gutted fish, crumbs, blocks, etc. to Rock cod characteristics: Adaptation of the existing processing plant, design the ideal installation for Rockcod, analyse the possibilities of implement the freezing system, etc.

OPTIMAR FODEMA has participated in the project co-ordination carrying out the following tasks:

WP4 Task 4.2 Development of the technical modifications on board commercial vessels. Person month: 3

WP1 Task 1-4 Suitability Co-ordination. Person month:1

Personnel

As stated in the Kick-off meeting minutes staff responsible of OPTIMAR FODEMA has changed.

Marcos Riera e-mail: marcos.riera@optimarfodema.es
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Bjorn Bjorkavaag e-mail: bsb@optimarfodema.es

Deliverables: The participant was responsible for the following deliverables

Deliver-able No.	***Description of deliverable***	***Delivery date***	***Nature***	***Dissem. Level[1]***
10	***Modifications needed for machinery on board***	***15***	***O***	***CO***

Deliverable Nº 10 *Modifications needed for machinery on board*: finished and included in WP4 of this report. (see *Task 4.2 Development of the technical modifications on board commercial vessels.)*

Research activities during the project

See WP4 Task 4.2 Development of the technical modifications on board commercial vessels.

Armadora Pereira S.A. (A3)

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Armadora Pereira S.A. is a Spanish SME. Its main activity is fishing, including extraction and processing. To develop these functions has 6 big bottom trawlers operating in the main fishing grounds all around the world and processing plants onshore. The partner furnishes the EU markets with different frozen fish processed on-board. It has great interest in get new resources from the sea to increase its fleet yield.

Role in the project

ARMADORA PEREIRA personnel and vessels (on board and in land) have given support to the following tasks:

Samples of *Patagonotothen* spp.: collection, transfer to land and shipment to Spain (CSIC-IIM) and England (UNIABDN) of samples for biology, characterisation and industrial process analyses.

Scientific observation: Collection in port of the observer, transfer to the fishing area and return to land at the end of the fishing trips. Feeding and lodging adapted with the necessary space for the accomplishment of scientific tasks. Logistics for observer's transhipment needed.

Armadora Pereira's contribution to the project included the participation in the following tasks:

WP2. Task 2.1 Support with commercial vessels to the scientific observation data and sample collection. Person month: 4

Sub Task 2.4.1 Fishery Forecasting P. Month:0.5

Armadora Pereira provided commercial catch and effort data.

Personnel

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Leopoldo Boado	e-mail: leopoldo@armpereira.es

Activities during the project:

Pereira's staff has collaborated in the logistics and transhipment of Rockcod samples to Stanley and Vigo and in scientific observation.

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Tel: 44 1635 31525
Fax: 44 1635 31520

Argos in an SME established in the Falkland Islands and has seven bottom trawlers operating around the Falkland fishing grounds. It has great interest in get new resources from the sea to increase its fleet yields.

Role in the project

ARGOS personnel and vessels (on board and on land) has given support to the following tasks:

- Sampling of *Patagonotothen* spp.: Collection, transfer to land and shipment to Spain and England of samples.
- Scientific observation: Collection in port of the observer, transfer to the fishing grounds and return to land at the end of the fishing operation. Feeding and lodging adapted with the necessary space for the accomplishment of scientific tasks.

ARGOS' contribution to the project included the participation in the following tasks:

WP2: Task 2.1 Support with commercial vessels to the scientific observation and fishing forecasting. Person month: 6.5.

ARGOS provided commercial catch and effort data.

Personnel

I.M. Thomson e-mail: ian.thomson@argonaut.co.uk
Bob Todd e-mail: bob.todd@argonaut.co.uk

Other specific project contribution/costs by SME partners**,** P1 – ANAMER, P3 – PEREIRA and P4 - ARGOS**.** For the three SME partners activity corresponded to the following tasks:

- *Sampling*. Gathering, shipping to the Falklands and subsequently shipping to Spain and UK of *Patagonotothen* spp. samples.
- *Scientific observer transhipment and subsistence*. To pick up the observer at the port, deployment to fishing grounds and return to port at the end of the campaign. Cost related, 3 vessel days per observer.
- Observers number in the project: 1
- Observers subsistence (100 days) and suitable lodging for scientific work.

Activities during the project:

In 2003 two Argos vessels were used for scientific observation during this period. Argos personnel have collaborated with the ANAMER observer in gathering and shipment of *Patagonotothen* spp. samples to Spain. Argos personnel has also participated in Task 4.2 Development of the technical modifications on board commercial vessels.

One Argos vessels was used for scientific observation in 2004. Argos personnel have collaborated with the ANAMER observer in gathering and shipment of *Patagonotothen* spp. samples to Spain. Argos personnel has also participated in Task 4.2 Development of the technical modifications on board commercial vessels.

Nectarbeck Ltd Crown Seafoods (A5) (Industry – UK)

Address:	Auckland Road	Tel:	44 1472 250244
	DN 31 3RP Grimsby (UK)	Fax:	44 1472 211923

Crown Seafoods is a sales and marketing company, selling to major processing factories whole frozen fish and frozen fish dishes ready to use.

SME Proposer

Role in the project

Technical suitability for processing and storage in an industrial processing line will be determined using the Crown Seafoods fish processing plant for foods adequate to the European market.

This SME has carried out acceptance tests with own specialized panel, in order to verify the suitability of the final product to consumers' taste.

Crown Seafoods participated in the following tasks:

WP4. Task 4.4. (Development of processed products from frozen Rockcod) Leader. Person month: 1.5

Task 4.5 Consumers acceptance. Person month: 0.5

WP1 Task 1-4 Suitability Co-Ordination Person month: 1

Personnel

Tony Hogg — e-mail: hoggwash@ic24.net
P. Patterson
J. Webb
A. Read

Activities during the second reporting period:

The Crown Seafoods activities are described in *Task 4.4. Development of processed products from frozen rockcod*.

Sponsor:

Pez Austral SA (Industry – ES)

Address:	Muelle de Bouzas s/n 36208, Vigo Spain	Tel: Fax:	34 986 213555 34 986 208959

Pez Austral is a Spanish company non-independent. The company main products are frozen fish food ready to eat. The company has great interest in develop new products to furnish the Spanish market with.

Role in the project

Its contribution to the project was as Sponsor, that is, an organisation without contribution to the project costs and without legal connection to the project at all.

WP4: Task 4.4. (Development of processed products from frozen Rockcod) Leader

Personnel

Roi Vilela e-mail: rvilela@islamar.com

Almudena Pena e-mail: apena@islamar.com

Research activities during the second reporting period:

The Pez Austral activities are described in *Task 4.4. Development of processed products from frozen rockcod*.

IIM-CSIC (B1)

Instituto de Investigacións Mariñas, IIM (RTD Performer – ES)

Address:	Eduardo Cabello,6	Tel:	34 986 231930
	36208 Vigo Spain	Fax:	34 986 292762

The Chemistry and Biochemistry Seafood Products Group from the Instituto de Investigaciós Mariñas has been involved in research projects related with fish as food, from processing aspects to quality aspects. This group has worked in several EU projects from 1989, most of them connected with fish biochemistry: UP-2-571, AIR3-94 1921; PL95-1127, PL95-1111, FAIR-CT 97-3061. There are also a number of end-users which has collaborated with the group (i.e. associated partners) during these years, most of them represent the industry and some administration offices related with the interest on the commercialisation of high quality fish products. The Instituto de Investigacións Mariñas has all facilities required to perform all the task involved in this project, (electronic library with access to main literature databases access, equipment for biomolecules analysis and basic equipment. It has also a pilot plant for processing fish products.

RTD Performer

Role in the project

CSIC-IIM was in charge of:

- characterisation of the nutritional and sensorial properties together with the biochemical characterisation that will allow the global quality evaluation of rock cod as a new fish product. The microbiological control of the raw fish will assure prevention of the possible risk associated to its consumption
- analysis of yields of headed and gutted, manually filleted (fillet with skin and skinned fillet) and mechanically filleted.
- determination of the suitability of the whole fish and fish fillets to be stored under frozen conditions
- contrast the suitability of the final product to the consumers' taste

CSIC-IIM was involved in tasks corresponding to the following workpackages:

WP3 (C*haracterisation of the raw fish as food*) Co-ordinator

Responsible of the tasks 3.1, 3.2, 3.3 and 3.4. Person month: 6

WP4 (Technological suitability of Rockcod for an industrial processing line) co-ordinator.

Task 4.1 (Physical Suitability) Leader. Person month: 2

Task 4.3 (Frozen Storage) Leader. Person month: 1.5

Task 4.5 (Consumer's acceptance of the final products) Leader. Person month: 0.5

WP1 Task 1.3 Characterisation Co-ordination. Person month: 1

All analyses described in this workpackages were performed in a representative number of samples according to a statistical design for minimising intra- and inter-specific variations. They were performed in several trials distributed during the project.

Personnel

Isabel Medina e-mail: medina@iim.csic.es
José Manuel Gallardo e-mail: gallardo@iim.csic.es
Carmen Piñeiro e-mail: cpineiro@iim.csic.es
Cruz Núñez e-mail: cruz@iim.csic.es
Mª Jesús González e-mail: mjgp@iim.csic.es

Deliverables: The participant was responsible for the following deliverables.

Deliver-able No.	*Description of deliverable*	*Delivery date*	*Nature*	*Dissem. Level*[1]
3	***Organoleptic characteristics of Rockcod with especial focus in off-flavours***	***9***	***O***	***CO***
4	***Rockcod suitability for physical processing (fillet, gut, etc.)***	***10***	***O***	***CO***
6	***First progress report Characterisation Co-ordination***	***11***	***R***	***CO***
7	***First progress report Suitability Co-ordination***	***11***	***R***	***CO***
9	***Safety and possible toxicological risks associated to Rockcod consumption report***	***13***	***R***	***CO***
11	***Nutritional characteristicsof the fish species as food report***	***16***	***R***	***CO***
12	***Spoilage characteristics of the fish during conservation and processing report***	***16***	***R***	***CO***
13	***Final report Characterisation Co-ordination***	***16***	***R***	***PU***
15	***Shelf-life of whole Rockcod and Rockcod fillets under frozen conditions report***	***19***	***R***	***CO***
20	***High quality and healthy processed products from Rockcod results***	***22***	***O***	***CO***
22	***Consumer's acceptance degree results***	***23***	***O***	***PU***
23	***Final report Suitability Co-ordination***	***23***	***R***	***PU***

Deliverables # 3 (*Organoleptic characteristics of Rockcod with especial focus in off-flavours*), **# 4** (*Rockcod suitability for physical processing (fillet, gut, etc.*), **# 6** (*First progress report Characterisation Co-ordination*), **# 7** (*First progress report Suitability Co-ordination*) **# 9** (*Safety and possible toxicological risks associated to Rockcod consumption report*), **#11** (*Nutritional characteristics of the fish species as food report*), **# 12** (*Spoilage characteristics of the fish during conservation and processing report*), **#13** (*Final report Characterisation Co-ordination*), **# 15** (*Shelf-life of whole Rockcod and Rockcod fillets under frozen conditions report*), **# 20** (*High quality and healthy processed products from Rockcod results*) and **# 22** (*Consumer's acceptance degree results*) and **# 23** (*Final report Suitability Co-ordination*) were finished and are included in WP3 and WP4.

Research activities during the project:

All activities described in **Workpackage 3: CHARACTERISATION OF THE RAW FISH AS FOOD** were carried out by partner B1, which also collaborated in the following tasks of **Workpackage 4**: Task 4.1 (Physical Suitability), Task 4.3 (Frozen Storage) and Task 4.5 (Consumer's acceptance of the final products). IIM has also collaborated in **Workpackage 1.**

FIFD (B2)

Falkland Islands Fisheries Department, FIFD (B2) (RTD Performer – UK)

Address:	PO Box: 598	Tel:	500-27260
	FIPASS.		fax: 500-27265
	Stanley, Falkland Islands		

FIFD is the official body responsible to manage and control the fishery within the jurisdiction of the Falkland Islands. FIFD administers the sale of fishing licenses, conducts research relevant to optimisation of sustainable yields from the fishery, utilises fishery patrol vessels to monitor and control fishing activity within FICZ/FOCZ, and generally develops the fishery and Falklands fishing industry.

Role in the project

- Collection and collation of historical and new data on fishing activity (catches, effort and discards)
- Biological information on rockcod will be collected during research cruises from FIFD including length distributions, maturity, etc. Otoliths and stomachs will be collected for subsequent studies at FIFD of age, growth and feeding of rockcod in different areas and seasons.
- Review of historical data about fishing activities for description of the fisheries in the area with special emphasis in rock cod fisheries. Fishing areas and seasons, fishing gears, characteristics of the vessels, etc, will be included in the description.

All the work related with the fisheries description and the biology of the target species will be in charge of this partner.

FIFD was involved in tasks corresponding to the following workpackages:

WP2.Task 2.1 Data Collection. Person month: 2

Task 2.2. *Fisheries description* (Description of fishing activities, gears, vessels, etc.) Leader. Person month: 4

Task 2.3. *Biology* (Study of biological issues. Leader). Person month: 7

Personnel

Alexander Arkhipkin e-mail: aarkhipkin@fisheries.gov.fk
Paul Brickle e-mail: pbrickle@fisheries.gov.fk

Dr. Alexander Arkhipkin: MSc Invertebrate Biology, Moscow State University, 1982. PhD Marine Biology, Shirshov Institute of Oceanology, Moscow, 1989. Senior Fisheries Scientist, Falkland Islands Government Fisheries Department since 1998. Head of Section, Biological Bases of Fishery Forecasts Laboratory of Commercial Invertebrates, Atlantniro, Kaliningrad from 1990 – 1998. Research Scientist, Laboratory of Commercial Invertebrates, Atlantniro, Kaliningrad from 1982 – 1990. Research Interests: Biology and

Ecology of Marine Living Resources with particular emphasis on squid and commercial fish, age and growth, reproductive biology, feeding spectrum, fisheries forecasts.

Paul Brickle was contracted with charge to the project.

Deliverables: The participant was responsible for the following deliverables.

Deliver-able No.	***Description of deliverable***	***Delivery date***	***Nature***	***Dissem. Level[1]***
19	***Estimate of Fishery long-term sustainable yield***	***22***	***O***	***CO***

Deliverable #19 (*Estimate of Fishery long-term sustainable yield*) was finished and made in collaboration with partners B3, B4 and B5 (see task 2.5) .

Research activities during the project :

Most of the activities described in **Workpackage number 2: FISHERIES, BIOLOGY, DISTRIBUTION AND ASSESSMENT**, Tasks 2.1 (Data collection) 2.2 (Fisheries description) and 2.3 (Biology) were carried out by FIFD in close collaboration with IEO, UINABDN, ANAMER and MG Otero. FIFD also has developed the study of parasites included in **Workpackage number 3: CHARACTERISATION OF THE RAW FISH AS FOOD.**

ICON (B3)

IC Consultants Ltd. (B3) (RTD Centre – UK)

Address:	47 Prince's Gate, Exhibition Road SW7 2QA London (UK)	Tel: Fax:	44 207 594 6565 44 207 594 6570

Members of the group have a wide range of mathematical modelling skills and applied experience of assessment techniques for fisheries. The group's work often involves the analysis of extensive data sets and have the computer resources and personnel required for the design, maintenance and analysis of large fisheries databases. ICON has also extensive experience of analytical GIS applications and in assessment and management of fisheries resources worldwide.

Role in the project

ICON has participated in the following activities:

- general review of assessment and management practices in relation with the task 2.2 Fisheries description.
- estimates of Catch Per Unit Effort (CPUE). Standardised CPUE will be determined for use in assessments. Two assessment models will be examined: production models using trends in CPUE and age-based models. Stochastic yield per recruit analyses will be performed to determine sustainable exploitation rates.
- assessment of rock cod stocks using historical and new scientific data from observer on board commercial vessels.

ICON carried out the following task:

WP2. Task 2.5. *Assessment* (Assessment of rockcod stocks). Leader. Person month: 5,5

Personnel

David Agnew e-mail: d.agnew@ic.ac.uk
Adam Payne e-mail: a.payne@imperial.ac.uk

Appointment of new staff:

Adam Payne was employed in July 2003 to carry out the assessment of rock cod stocks using historical data and data collected at the beginning of the project by observers on board commercial vessels. Adam will also participate in the general review of assessment and management practices and use of assessment models.

Deliverables: The participant was responsible for the following deliverables.

Deliver-able No.	*Description of deliverable*	*Delivery date*	*Nature*	*Dissem. Level[1]*
16	*General review of assessment and management practices of the Fisheries*	*20*	*R*	*CO*

Deliverable # 16 (*General review of assessment and management practices of the Fisheries*) finished and included in task 2.5.

Research activities during the project :

Research activities of partner B3 consisted on a review and description of assessment and management practices in use in the different fisheries on finfish and cephalopods carried out around the Falkland Islands. An specialiced study was made on assessment of rockcod fishery long-term sustainable yield.

IEO (B4)

Instituto Español de Oceanografía, IEO (Centro Oceanográfico de Vigo) (B4) (RTD Performer – ES)

Address: Avda. de Brasil, 31 28020 Madrid ES

Centro Oceanográfico de Vigo
Cabo Estay – Canido
P.O. Box 1552
36200, Vigo. Spain

tel: 34 986 492111
fax: 34 986 492351

The IEO is a Public Research Institution advisor to the Spanish Government in relation with fishing policies. The IEO has carried out many research projects funded nationally and with international (EU and USA) agencies which results have been submitted to ICES and National and EU agencies as a contribution in the assessment of the main stocks.

Role in the project

IEO was in charge of the project scientific co-ordination in close collaboration with general Co-ordinator ANAMER. IEO was responsible of the following activities:

- acquisition of data for a better knowledge of the population dynamics of the species
- description of the fisheries in the area and
- analyses of the main biological features,
- distribution of the species and GIS
- stock assessment.
- data base implementation

IEO was the responsible for the following tasks:
WP1 Task 1.2 Fisheries Co-ordination. Person month: 5
WP2 (Fisheries, biology, distribution and assessment) Co-ordinator.
Task 2.1 (Stock-specific data collection on fishing activity and biology) Leader.
Person month: 11.8

Personnel

Julio M. Portela e-mail: julio.portela@vi.ieo.es
Mar Sacau e-mail: mar.sacau@vi.ieo.es
Xosé A. Cardoso e-mail: jose.cardoso@vi.ieo.es
Guadalupe Ramilo Riveiro e-mail: lupe.ramilo@vi.ieo.es
Carmen Bóveda González e-mail: lali.boveda@vi.ieo.es

Appointment of new staff:

Mar Sacau was chosen after a public selection process to be employed in the second half of 2003 to participate in the scientific co-ordination of the project as a member of the

Steering Committee, monitoring of IEO observers, reporting, database maintenance and exploitation, sampling for morphometric task, analysis of biological and commercial data (length frequencies, sex ratio, CPUE, etc), fisheries description and GIS.

Deliverables: The participant was responsible for the following deliverables.

Deliver-able No.	***Description of deliverable***	***Delivery date***	***Nature***	***Dissem. Level[1]***
5	***First progress report Fisheries Co-ordination***	***11***	***R***	***CO***
14	***Implementation of an actual Database***	***18***	***O***	***CO***
21	***Final report Fisheries Co-ordination***	***22***	***R***	***PU***

Deliverable # 5 *First progress report Fisheries Co-ordination*: finished. Included in the First Year Progress Report.

Deliverable # 14 (*Implementation of an actual Database*) finished. Included in Task 2.1.

Deliverable # 21 *Final report Fisheries Co-ordination*: finished. Included in this Report.

Research activities during the project :

Most of the activities described in **Workpackage number 2: FISHERIES, BIOLOGY, DISTRIBUTION AND ASSESSMENT**, Tasks 2.1. (Data collection), 2.2 (Fisheries description, 2.3 (Biology), 2.4 (GIS) and 2.5 (assessment) were carried out by IEO in close collaboration with FIFD, ANAMER, MG Otero, UNIABDN and ICON.

IEO experts were responsible of scientific co-ordination and participated in all the Steering Committee activities, as well in dissemination activities.

UNIABDN (B5)

University of Aberdeen, UNIABDN (B5) (RTD Centre – UK)

Address:

Kings College AB24 3FX Aberdeen UK
Department of Zoology tel: 44 (0) 1224 272459
Tillydrone Avenue, AB24 3TZ fax: 44 (0) 1224 272396
Aberdeen, Scotland, UK

The University of Aberdeen (Department of Zoology) has participated and led a number of large EU-funded projects and the project staff has extensive experience in diet analysis and GIS, as well as being involved in various modelling studies.

Role in the project

The University of Aberdeen was responsible for analysis of the spatial and temporal distribution of the resource.

A geographical information system for integration of environmental and fishery data (including effort, landings and discards) was developed based in GIS methods and models for visualisation.The GIS has produced analysis and prediction of meso-scale and local dynamics of oceanic environment, its relation to the dynamics of fishery resources, etc.

The fishery forecasts developed by Aberdeen University and IEO could not be tested by the observers at the end of the second fishing season as originally planned in the work programme, due to the fact that the fleet had already stopped their operations. This happened due to an earlier than expected closure of the fishery around Falkland For validation of the forecasts, a model was developed making predictions with historical data and comparing them to the most recent years data, with acceptable results.

The University of Aberdeen was responsible of the following tasks:

WP2. Task 2.2 Fisheries description. Person month: 1.6

Task 2.4. *GIS and Fishery Forecasting* (Analysis of the spatial and temporal distribution of the resource.) Leader. Person month: 6

Personnel

Graham J. Pierce e-mail: g.j.pierce@abdn.ac.uk
Jianjun Wang e-mail: j.wang@abdn.ac.uk
Begoña Santos Vázquez e-mail: m.b.santos@abdn.ac.uk
Gema Hernández-Millán e-mail: g.hernandez-m@abdn.ac.uk

Appointment of new staff:

The project will not employ any new staff at the University of Aberdeen. Some days of Dr Wang's and Dr Santos' time will be charged to the project, relating to data acquisition and analysis attendance at the kick-off meeting and Dr Santos will work full-time on the project during 2004.

Dr. Graham Pierce, Senior Lecturer in Zoology. Dr Pierce holds a lectureship jointly funded by Scottish Executive's Fisheries Research Services Marine Laboratory. He has participated in FAR, AIR, FAIR and Study projects on cephalopods, as well as co-ordinating FW5 and Study projects. Former chairman of *ICES Working Group on Cephalopod Fisheries and Life History* (1998-2001).

Dr Jianjun Wang, PDRA. Experienced researcher working in marine fishery GIS applications and spatial analysis.

Deliverables: The participant is responsible for the following deliverables.

Deliver-able No.	*Description of deliverable*	*Delivery date*	*Nature*	*Dissem. Level*[1]
17	***Fishery forecasting***	***21***	***O***	***CO***
18	***Analysis of the spatial and temporal distribution of the resource***	***21***	***O***	***CO***

Deliverable # 17 (*Fishery forecasting*) finished. Included in the present report (subtask 2.4.1).

Deliverable # 18 (*Analysis of the spatial and temporal distribution of the resource*) finished. Included in the present report (task 2.4).

Research activities during the project :

All activities described in **Workpackage 2: FISHERIES, BIOLOGY, DISTRIBUTION AND ASSESSMENT**, Task 2.4. GIS Analysis of the spatial and temporal distribution of the resource and subtask 2.4.1 Fishery forecasting were carried out by ANIABDN in close collaboration with IEO. ANIABDN has also made an study on diet of rockcod and has participated in the description of the fisheries and disseminationa activities.

<u>Sub-contractor:</u>

<u>NSFO (North Sea Fishermen's Organisation Ltd). (Industry – UK)</u>

Address:

8 Abbey Walk — tel: 01472 241007
DN31 1NB — fax: 01472 355134
Grimsby (UK)

Service provided: Results dissemination.

The North Sea Fishermen's Organisation Limited is a recognised Fish Producer Organisation with quota management rights to approximately 25,000 tonnes of fish a year. Membership consists primarily of beam trawlers but also have pelagic freezer trawlers.

Role in the project

NSFO has contributed to the project in the following aspects:

- dissemination of the results of the project both to its members and the general fishing UK industry
- NSFO have been observers of the work undertaken by Crown Seafoods Ltd of Grimsby, into the potential markets for the species in the UK, and also attended a meeting of all partners in Vigo in September 2004.

<u>Personnel:</u>

Andy Read e-mail: Andy.Read@daff.gov.im

Activities during the second reporting period:

Dissemination of the results of the project, collaboration with Crown Seafoods and participation in the second co-ordination meeting.

PROJECT MANAGEMENT AND COORDINATION

For a more detailed information, see Workpackage nº 1

Task 1.1 (*General co-ordination*)

The Steering Committee, composed by the WP co-ordinators with assistance of MG Otero, was in charge of monitoring and definition of the main co-ordination actions carried out during the whole project's life.

The Steering Committee, set up in January 2003, worked by email for monitoring of project activities during the whole project's life. Its first resolution after consultations with all partners was to hold the kick-off meeting in Vigo on the 6th of February 2003, at ANAMER facilities. The first annual and second co-ordination meetings were also held at ANAMER on the 2nd December 2003 and on the 21st September 2004. Minutes corresponding to these meetings were included in the first and second progress reports;

A talk on the main results achieved during the project was given at ANAMER' facilities on the 15th of December 2004 with attendance of associated companies staff and media (TV, radio and press). The talk was given by IEO and IIM researchers participating in the project, covering aspects such as spatio-temporal distribution and potential of the resource, nutritional value, biology, processing, etc.

Other dissemination activities included articles published in local, regional and international newspapers and specialized magazines, as well as interviews and reports were broadcasted by local, regional and national TVs and radio stations.

Task 1.2 (*Fisheries co-ordination*)

This task included several meetings and contacts by e-mail between ANAMER, MG Otero, IEO, FIFD, Armadora Pereira and Argos Ltd. for logistics of observers, and shipment and tracking of samples. Other activities comprised contacts between ANAMER, MG Otero, IEO, FIFD, Armadora Pereira and Argos Ltd for monitoring of observers' activities, data collection and collation, updating of the database, analyses and reporting. Final report Fisheries Co-ordination is included in this report.

Task 1.3 (*Characterisation co-ordination*)

A number of meetings and contacts by e-mail between ANAMER, MG Otero, IIM and IEO were made for monitoring of tasks included in WP 3 and for traceability and delivery of the samples. Final report Characterisation Co-ordination is included in this report.

Task 1.4 (*Suitability co-ordination*)

Activities included in this task comprised some meetings with OPTIMAR FODEMA, ANAMER, MG Otero, Armadora Pereira, Argos Ltd, and IIM for discussions on freezing and machinery trials included in WP 4. Final report Suitability Co-ordination is included in this report.

An important result related with this project is the contract signed in 2004 between the Fondo de Regulación y Organización del Mercado de los Productos de la Pesca y Cultivos Marinos (FROM), belonging to the Spanish General Directorate for Fisheries and the Spanish National Association of Fish Can Producers (ANFACO). This contract aims to provide technical assistance for the establishment of a quality and safety plan for marketing of fish can products. Among other targets, comprises the use of new fish species in the fish canning industry and will include the rockcod (*Patagonotothen* spp.) in the study. Several canning companies are participating in this pilot plan and will be the final users of the results.

EXPLOITATION AND DISSEMINATION ACTIVITIES

Dissemination of Results (ANNEX II)

During the whole project life a series of articles were published in local, regional and international newspapers and specialized magazines, as well as interviews and reports were broadcasted by local, regional and national TVs and radio stations:

- An article entitled "*Estudio pionero del aprovechamiento de los descartes*" was published during the Exploratory Award phase of the project by the specialized magazine Pesca Internacional edited by the Vigo Shipowners Co-operative, in its issue of July 2002.
- An article entitled "*EU could help rock cod research: possible new South Atlantic fishery*" was published by the specialized magazine Fishing News International edited by Heighway, Agra Europe, in its issue of November 2002.
- An article entitled "*Galicia investiga la explotación del «marujito» para consumo humano*" was published by the regional newspaper La Voz de Galicia in its issue of 7th February 2003.
- An article entitled "*Investigadores vigueses estudian una nueva especie para la flota que faena en Malvinas*" was published by the regional newspaper Faro de Vigo in its issue of 7th February 2003.
- During the kick-off meeting several interviews with project participants were broadcasted by local TV and radio stations.
- An interview with the scientific co-ordinator of the project was broadcasted by the regional TV (TVG) the 28th June on its main weekend news programme.
- An article entitled "*ANAMER lidera un proyecto cofinanciado por la UE para el aprovechamiento de un descarte en Malvinas*" was published by the specialized magazine Pesca Internacional edited by the Vigo Shipowners Co-operative, in its issue of December 2003.
- An article entitled "*Proyecto ROCKCOD: si el fletán tuvo éxito, esta especie podría tener aún más* " will be published by the specialized magazine Europa Azul in its issue of January 2004.
- An interview with ANAMER representative and the scientific co-ordinator of the project was broadcasted by the national TV station (TELE-5) in two different news magazines on the 15th of December.
- A brochure about project objectives and activities during the sixth first months edited by ANAMER for dissemination among the fishing industry is in press. A draft of the brochure was included in ANNEX II of the first year progress report.

- An article entitled *"Los armadores vigueses comenzarán a comercializar pronto el marujito"* by the local newspaper Atlántico Diario in its issue of 11th December 2004.
- An article entitled *"Los armadores potenciarán comercialmente el marujito"* was published by the regional newspaper La Voz de Galicia in its issue of 11th December 2004.
- Two articles entitled *"Los armadores comercializarán un nuevo pescado del Atlántico sur"* and *"Vigo aspira a colocar en el mercado una especie que captura en Malvinas"* were published by the local newspaper Faro de Vigo, in its issue of 16th December 2004.
- Two articles entitled *"Los científicos apuestan por el Rockcod"* and *"Puesta en sociedad de don Marujito"* were published by the specialized magazine Pesca Internacional edited by the Vigo Shipowners Co-operative, in its issue of January 2005.
- During the second co-ordination meeting several interviews with project participants were broadcasted by local TV and radio stations.
- A brochure about project results and activities during the second year project edited by ANAMER for dissemination among the fishing industry is in press. A draft of the brochure was included in ANNEX II of the second year progress report.

A talk on the main results achieved during the project was given at ANAMER' facilities on the 15th of December 2004 with attendance of associated companies' staff and media (TV, radio and press). The talk was given by IEO and IIM researchers participating in the project, covering aspects such as spatio-temporal distribution and potential of the resource, nutritional value, biology, processing, etc.

Information about project objectives, tasks, results and participants is downloadable from the project's website (http://www.arvi.org/I+D+I/principalIrockcod.asp).

ACKNOWLEDGEMENTS

We would like to express our gratefulness to all crews from commercial vessels that since many years ago have collaborated with observers in collection of fishery and biological data.

Also our gratitude to all these anonymous people from SMEs and RTDs not directly participating or mentioned in this report, that have unselfishly collaborated in the achievement of the goals of this project.