Living Resources Committee **ICES CM 2002/G:03**

Ref. ACFM, B

REPORT OF THE

Planning Group on Aerial and Acoustic Surveys for Mackerel

Spain
18–21 February 2002

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

https://doi.org/10.17895/ices.pub.9727

TABLE OF CONTENTS

Section **Page**

1 INTRODUCTION

1.1 Terms of Reference

The Planning Group on Aerial and Acoustic Surveys for Mackerel [PGAAM] (Chair E. Shamray, Russia) met for the first time in A Coruña, Spain, from 18–20 February 2002 to:

a) identify participants to contribute to the Russian aerial surveys for mackerel;
b) co-ordinate collaboration of vessels with the Russian aerial surveys for mackerel in the Norwegian Sea;
c) co-ordinate acoustic surveys in the Viking Bank area to ensure full coverage and appropriate areas and timings;
d) co-ordinate acoustic surveys in Divisions VIII and IX and to seek survey time for the northern extension of these surveys;
e) use the findings of the EU SIMFAMI project to:
    i) provide a universally applicable mackerel target strength to length relationship for use in all acoustic surveys for mackerel,
    ii) provide standard methodologies for the use and analysis of multi-frequency data in acoustic surveys for mackerel.

PGAAM will report by 6 March 2002 for the attention of ACFM, the Fishing Technology Committee and the Living Resources Committee who will parent the Group.

1.2 Participants

Pablo Carrera	Spain
Paul Fernandes	UK (Scotland)
Jan Arge Jacobsen	Faroe Islands
Svein A. Iversen	Norway
Evgeny Shamray (Chair)	Russia
Aril Slotte	Norway
Per Sparre	Denmark
Begoña Villamor	Spain
Vladimir Zabavnikov	Russia

1.3 Background information

The assessment of the NEA mackerel stock complex is currently dependent on a single fishery independent estimate of biomass, derived from the ICES Triennial Mackerel and Horse Mackerel Egg Surveys. This is only available once every three years and makes the assessment increasingly insecure with elapsed time since the last survey. The results from the egg surveys also take a significant time to prepare (almost 1 year). While it is prohibitively expensive to carry out more frequent egg surveys, it may be possible to use other survey methods to provide data in the intermediate years.

Two alternative methods (acoustic and aerial surveys) have been carried out by a number of countries in recent years. Both types of survey have the potential to deliver information on the distribution and abundance of mackerel. However, the surveys have until now, covered only part of the known distribution area and consequently have not been able to deliver a valid stock estimate or complete distribution map. The aim of this Planning Group is to identify the deficiencies in area and timing of these surveys and to remedy these deficiencies.

In the case of the aerial surveys this will initially involve optimizing coverage of the existing Russian survey by involving vessels from other nations to provide baseline biological data. In the longer term it is hoped that other countries could supplement the aerial component directly.

For the acoustic surveys there is a need to:

- identify the optimum spatio-temporal window;
- standardise survey practice for estimating mackerel biomass;

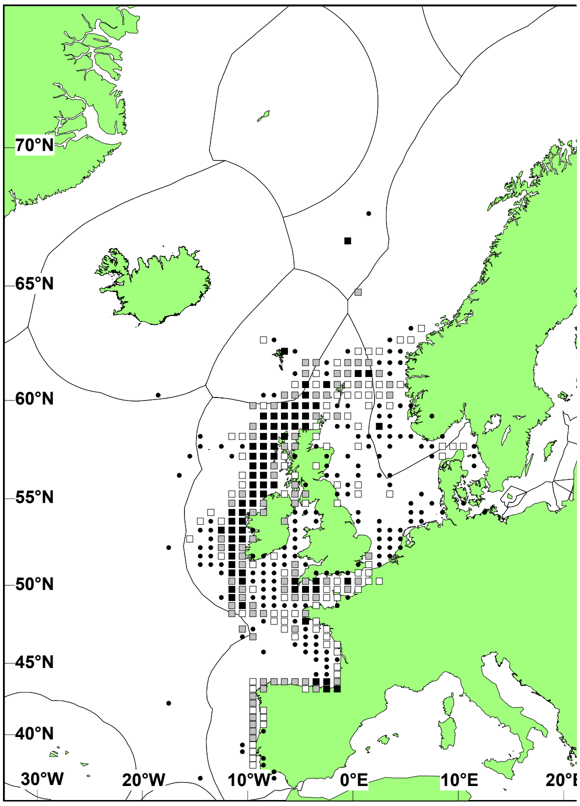
- extend the already substantial coverage of these surveys to the full distribution area;
- coordinate surveys from participating countries.

2 DISTRIBUTION OF MACKEREL FISHERIES

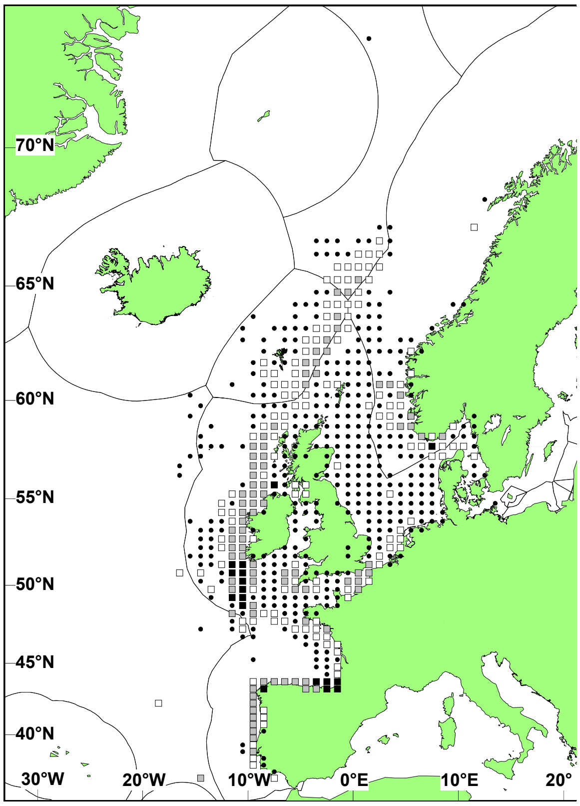
The distribution of the total commercial mackerel catches taken during 1977-2000 is shown by quarter and rectangle in Figure 2.1. These data are based on catches reported by Portugal, Spain, Netherlands, Germany, Denmark, Norway, Russia, Faroes, UK, Ireland, and Sweden. These data were extracted from the NEAFC database (1977-1997), supplemented by official catches reported to the WGMHSA in 1998-2001.

Mackerel is very widely distributed and is caught from the Iberian Peninsula in southern Europe (around 34° N) up to the northern Norwegian Sea (around 73° N) (Fig. 2.1). The distribution of catches is likely to vary from year to year due to environmental factors, stock size, and quota limitations for the participating nations. The distribution by quarter should therefore be interpreted with caution. For example, Russian vessels are not allowed to fish mackerel in the Norwegian zone, and therefore the catch distribution not always reflects the distribution of mackerel. However, the data presented are meant to show only the wide area where mackerel are caught in the Northeast Atlantic, and the quarterly changes in the distribution of the fishery.

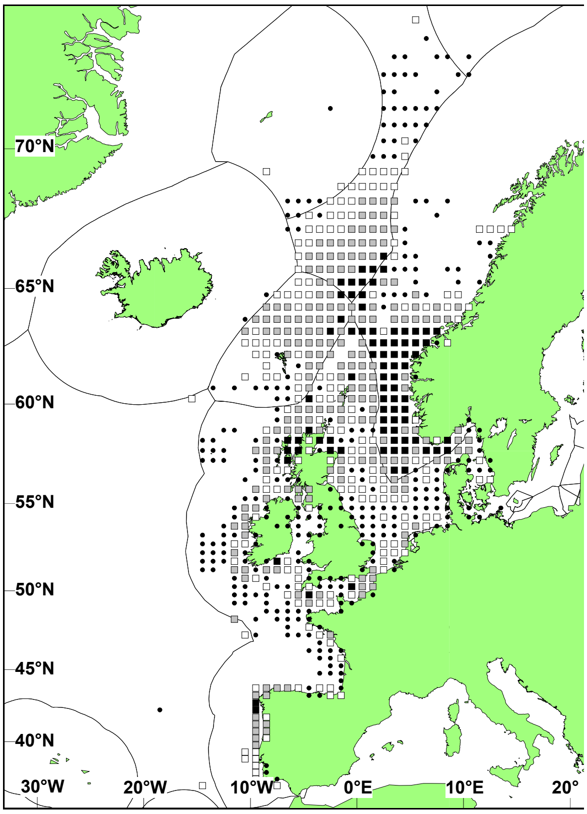
Various research surveys by different countries indicate that mackerel are more widely distributed than shown by the commercial catches.



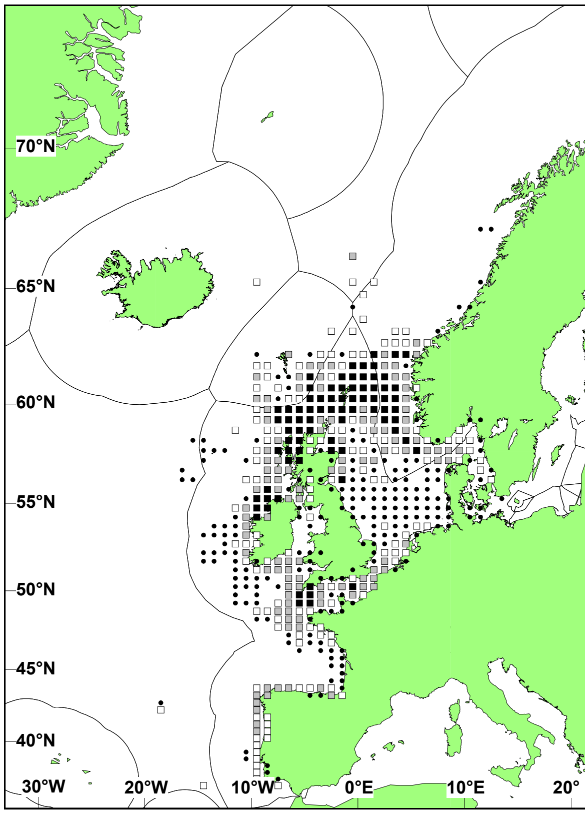
Quarter 1



Quarter 2



Quarter 3



Quarter 4

Fig. 2.1 Distribution of the total mackerel catches by rectangle and by quarter from 1977-2000.

3 MACKEREL TARGET STRENGTH AND ACOUSTIC SURVEY PROCEDURE

Mackerel do not possess a swim bladder. As a result, they are poor reflectors of sound and have a low target strength (TS).

PGAAM recommends that acoustic surveys for mackerel employ similar acoustic survey procedures to that used for herring surveys (Anon. 2001). 38 kHz should be used as the integrating frequency and the following TS to length relationship:

$$TS = 20 \log Length_{(in\ cm)} - 84.9 \text{ (Edwards et al. 1984).}$$

A 35 cm mackerel would therefore have a TS of –54 dB. This compares with a TS for herring of the same size of –40 dB, which is almost 15 dB higher. An acoustic trace from herring, misidentified as mackerel, would consequently overestimate the true numbers of fish by a factor of 32. It is essential, therefore, due to the low TS of mackerel that it is identified correctly.

The SIMFAMI project (see below) aims to provide methods to achieve this. In the meantime, it is recommended that multi-frequency acoustic data should be collected wherever possible using frequencies in the following priority: 38, 200, 120, 18 and 12 kHz. Mackerel have been shown to have a higher acoustic response at 200 kHz than at 38 kHz, while other species such as herring have a similar response at both frequencies. This difference allows for the identification of mackerel traces and so it is recommended that data from at least 38 and 200 kHz be collected. If the stock can be contained, acoustic surveys will then be able to deliver estimates of abundance, which are, at the very least, comparable from year to year. This will allow for a much-needed additional tuning index in the assessment of the mackerel stock. Providing the same TS to length relationship is used from year to year and amongst all participants, the actual TS to length relationship used is not important.

TS modeling investigations in Norway may shed further light on the issue of mackerel TS, taking into account variables such as maturity and fat content. Once more is known about this then it may be possible to consider an absolute abundance estimate from acoustic surveys.

4 THE SIMFAMI PROJECT

Acoustic methods are used extensively within fisheries research for estimating the abundance and distribution of fish. One of the major problems associated with the technique is the correct allocation of observed echoes to species. Currently, the solution to this problem relies on a combination of user experience verified (or "ground-truthed") using trawl samples. SIMFAMI (Species Identification Methods From Acoustic Multi-frequency Information) is a new EC funded project, which aims to apply modern multi-frequency acoustic techniques to establish methods for the acoustic identification of echo traces. The SIMFAMI partnership consists of: FRS Marine Laboratory Aberdeen; IMR, Bergen; IEO, A Coruña; IFREMER, Nantes; and IRD, Brest.

Many of the modern research vessels used by SIMFAMI partners now routinely collect data from more than one acoustic frequency. Computer programs, with specific routines for the analysis of multi-frequency data have also recently become readily available. SIMFAMI aims to develop the algorithms for use in these programs to allow for species identification. These algorithms will ultimately not only incorporate the suite of multi-frequency data, but also parameters from single frequency echo trace classification (e.g., shape, amplitude distribution) and the basic environment (e.g., location in 4D space – i.e., time, location, depth). The project will specifically target the identification of mackerel and other fish that are prevalent in the partnerships' survey programmes. These encompass both those fish which are targeted for stock assessment purposes (anchovy, herring, horse mackerel, and sardine), and some other species which need to be differentiated (capelin, chub mackerel, and Norway pout).

Within the project there are 6 major objectives organised in respective work packages (WP).

WP1: Construction of an echogram library consisting of "ground-truthed" sections of historical acoustic survey data.

WP2: Analysis of extracted data from the library using echo trace classification techniques.

WP3: Development of multi-frequency algorithms for the differentiation of fish from plankton.

WP4: Development of multi-frequency algorithms for identification of fish without swim bladders.

WP5: Development of multi-frequency algorithms for the identification of fish with swim bladders.

WP6: Development of a combined algorithm for fish group, species and stock identification.

By combining the multi-frequency techniques outlined in WP 3, 4 and 5 with those from extracted data (WP2) SIMFAMI aims to produce an algorithm in WP6 which will result in an enhanced probability of identification.

A more detailed description of the project is given in Appendix I.

Of relevance to PGAAM, the SIMFAMI project will develop methods, which will allow for the implementation of acoustic surveys for mackerel. This species has shown the most promise for acoustic identification because it reflects sound much better at higher frequencies compared to many other species.

5 AERIAL SURVEYS

5.1 Previous Russian aerial surveys in the Norwegian Sea

Russia has carried out airborne surveys for the collection oceanographical data and information on the distribution of mackerel in the Norwegian Sea since 1986. Since 1997 these surveys have been carried out with a specially equipped two-engine aircraft Antonov-26 (AN-26) named *Arktika*. This aircraft is equipped with several different remote sensing sensors: IR-radiometer and scanner, LIDAR, SAR-system (with electromagnetic wavelengths of 4 and 23 cm), microwave radiometer, photo- and video cameras. All obtained information is put into a PC and by applying GPS and GIS some of the results can be processed and viewed in real time. Typically, all information is processed and analysed within 2 to 4 hours after a flight. The complex aerial survey was carried out according to methods developed at PINRO (Zabavnikov et al. 1997).

The high speed of the aircraft enables a vast area to be surveyed, providing accurate precursory data on fish schools. However, the aircraft cannot obtain biological data on the [fish] objects studied such that there are difficulties in the identification of the detected fish schools. Furthermore, there will always be the schools which inhabit water depths which are inaccessible to the aircrafts measuring apparatus. Communication between the aircraft and research vessels is therefore vital during the survey.

During the 1997-2000 aerial surveys the aircraft collaborated solely with Russian research and commercial vessels for the calibration of remote sensors and the provision of fish samples. However, the area surveyed by the aircraft was much larger than that supported the vessels.

As a follow up to the recommendation given by WGMHSA (Anon. 2001), two experiments were carried out during the 2001 aerial survey with the co-operation of vessels from foreign countries. The joint venture was local in nature and was principally directed at investigating the possibilities of conducting joint investigations in those cases when a vessel operates according to a joint programme and a RV performs a standard acoustic survey for stock assessment (Anon. 2002).

5.2 Aerial surveys in the Norwegian Sea in 2002

As on previous occasions the aerial surveys are planned during July-August. Two aircrafts will work in the Norwegian Sea in July 2002. The aim is to have several nations supporting the airborne research using their research and commercial vessels. The areas covered by the different aircraft and vessels are given in Figure 5.2.1.

The Russian research aircraft, will carry out its annual programme in the Norwegian Sea from 1 July - 15 August and will mainly work in international waters. The survey is planned to cover areas inside various national EEZs also. About 15 flights are planned in 2002.

The Norwegian flights will primarily cover the Norwegian economical zone (NEZ) of the Norwegian Sea from 15-25 July. These flights will be carried out with a Norwegian aeroplane (about 7 flights) using a LIDAR hired from NOAA Environmental Technical Laboratory, including hardware and software. The Norwegian aircraft will not have any of the other remote sensing equipment available on the Russian aircraft.

There will be an overlapping area covering eastern parts of international waters and parts of the western NEZ which will be covered by both planes for comparing LIDAR observations. A common software package will be used to process the LIDAR data from both of the aircrafts.

A Russian research vessel and several Russian commercial vessels will work/fish in international waters in June-August to identify observations made by the Russian aircraft. Norwegian research vessels will carry out the annual pelagic survey in the Norwegian Sea during summer and will support the aircraft also. Two Norwegian commercial purse seiners will work in Norwegian waters from 15-30 July to identify observations made by the aircraft. They will also investigate the distribution and abundance of mackerel in NEZ using sonar and surface trawling.

Detailed plans for the joint airborne remote sensing and vessels surveys will be exchanged by correspondence and agreed before July. The Russian and Norwegian contacts for the joint aerial survey will be Vladimir Zabavnikov (ltei@pinro.murmansk.ru) and Svein A. Iversen (sveini@imr.no) respectively.

The international survey of North Sea herring will take place during late June and July covering most of the continental shelf north of 54° N to a northern limit of 62° N. Norwegian and Scottish research vessels will possibly co-operate with the Russian aircraft in the area around the Shetland Isles.

The aerial surveys will also be assisted by a Faroese commercial vessel working primarily in the northern part of the Faroese economic zone in the last week of July or first week of August. The Faroese contact for the joint survey will be Jan Arge Jacobsen (janarge@frs.fo).

The Russian aerial surveys in July 2002 will also co-operate with the Icelandic Marine Research Institute with regard to pelagic fish stock distribution and abundance in the western area.

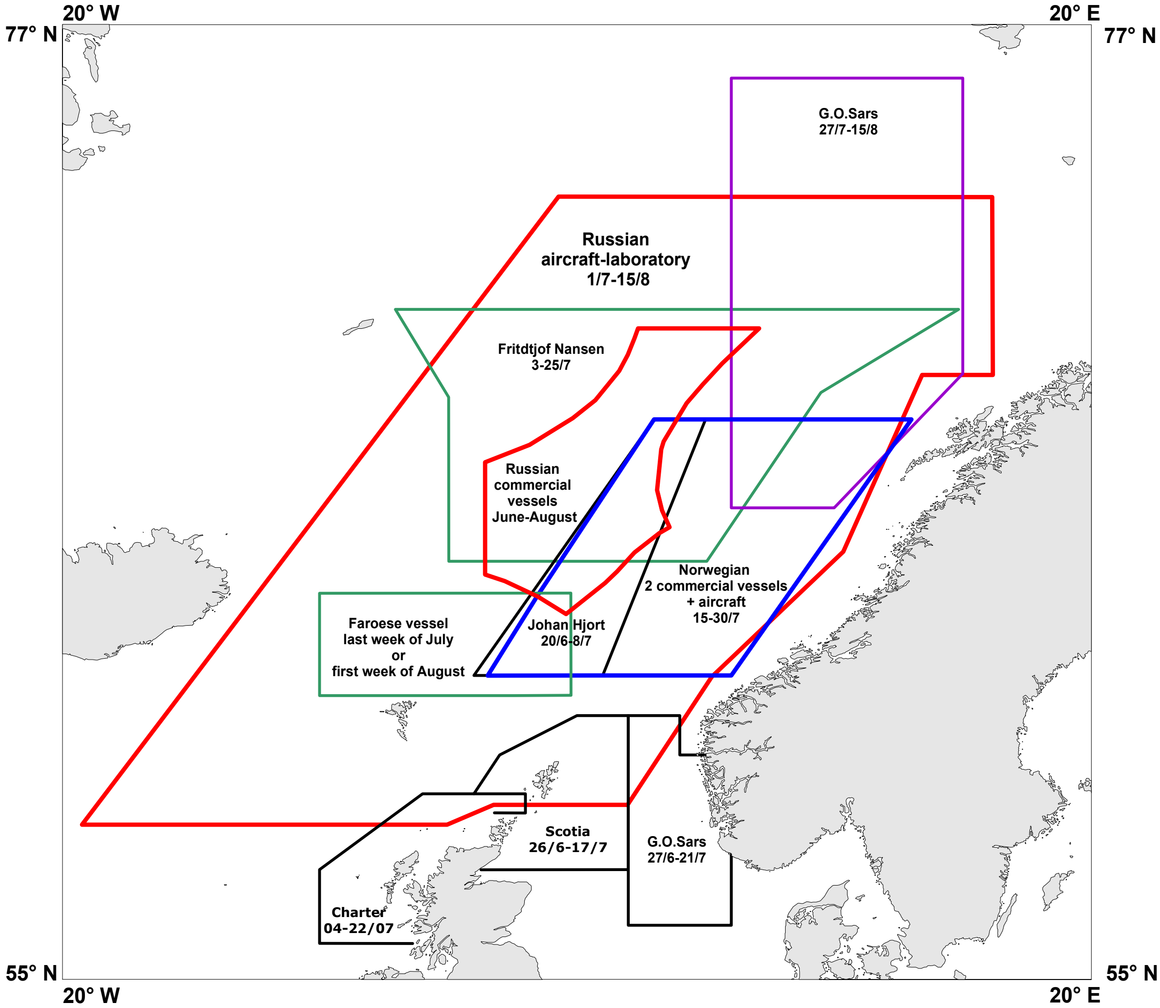


Figure 5.2.1. Map of the north-east Atlantic indicating the areas of the Aerial surveys in July-August 2002 and areas where research/commercial vessels will operate to collaborate with the aircraft.

6 ACOUSTIC SURVEYS IN THE NORTHERN AREA

6.1 Norwegian surveys

The Norwegian surveys for mackerel (excluding acoustics) are listed below.

Standard, Traditional surveys

Survey	Area	Last survey
Egg survey	North Sea	June/July 1999
Egg survey	Western area	June 2001
Tagging	West (SW) of Ireland	May 2001

Egg surveys have been carried out in incidental years in the North Sea since 1968. In the western area, egg surveys have been carried out every third year since 1970 and Norway has participated since 1995.

Norway has tagged mackerel with internal steel tags in Irish, and some years, also in Shetland waters since 1968. Over the years about 490,000 mackerel have been tagged.

New surveys or surveys carried out in later years

Survey	Area	Last survey
Acoustic survey	North Sea (IVa)	8-25 Oct 2001
Russian aerial survey	Norwegian Sea	17-19 July 2001
Commercial vessel	Norwegian Sea	17-25 July 2001
Herring/pelagic species	Norwegian Sea	19 July-15 Aug 2001

Acoustic surveys in the North Sea have been carried out in October/November since 1999. The summer herring/pelagic fish survey is directed at Norwegian spring spawning herring. Norway only participated during a short period in the Russian airborne survey in 2001. During this survey a Norwegian purse seiner was hired to fish in the area surveyed by the aircraft. This vessel worked also partly during the acoustic survey in the North Sea in October 2001.

Planned surveys in 2002 and 2003

Survey	Area	2002	2003
Tagging	West (SW) of Ireland	13 May-13 June	May-June
Egg survey	North Sea	3-26 June[1]	None
Smolt/mackerel	Norwegian Sea	20 June-8 July [2]	(May/June 2002)
Herring/pel. Sp.	Norwegian Sea	27 July-15 Aug [1]	July-Aug
Aerial survey, LIDAR	Norwegian Sea	15-25 July	??
2 purse seiners	Norwegian Sea	15-30 July	15-30 July
Acoustic survey	North Sea (IVa)	15 Oct-4 Nov[1]	Oct-Nov

[1] *G. O. Sars*, [2] *Johan Hjort*

The smolt/mackerel survey aims to map the distribution of smolt and mackerel in the Norwegian Sea (Figure 5.2.1) by trawling in the surface layer. Norway, Russia and USA will co-operate with aerial surveys in the Norwegian Sea in 2002 (section 5.2). The herring/pelagic fish survey in the Norwegian Sea (Figure 5.2.1) is an acoustic/trawl survey investigating the abundance and distribution of Norwegian spring spawning herring and other pelagic species such as mackerel. A Norwegian aircraft will use an American LIDAR in the eastern part of the Norwegian Sea (NEZ) from 15-25 July and the Russian aircraft will cover international waters (section 5.2). Two Norwegian purse seiners will investigate mackerel distribution and abundance of mackerel in NEZ 15-30 July (section 5.2). The Norwegian acoustic survey in October will be part of the SIMFAMI project and *G.O. Sars* will work together with *Scotia* to investigate distribution and abundance of mackerel (section 6.3).

6.2 Scottish acoustic surveys for mackerel

In 2001, FRS Marine Laboratory Aberdeen did not conduct any acoustic surveys for mackerel. Prior to this, four combined acoustic, fishing and hydrographical surveys were carried out as part of the SEFOS project (Shelf Edge Fisheries and Oceanography Study) between January 1994 and December 1996, to study the spatio-temporal pattern of the mackerel spawning migration and its relationship to the hydrography of the area (see Reid & Eltink 1999 for a review). In January 2000, an additional survey was carried out along the continental shelf between 58-62° N to study mackerel distribution and abundance. However, due to significant problems encountered with trawling for mackerel, no abundance estimate was possible from the latter survey.

6.3 Acoustic surveys for mackerel in autumn 2002

In 2002, Scotland (FRV *Scotia*) and Norway (FRV *G.O.Sars*) will conduct a co-ordinated acoustic survey for mackerel in the North Sea and its western approaches (Table 6.3.1 & Fig. 6.3.1). *Scotia* will survey the western approaches along the continental shelf (200 m contour) west of Shetland, using a zigzag pattern similar to that employed in the 2000 survey (Fig. 6.2.1). The intertransect distance will be chosen so that *Scotia* will arrive in the northern part of the North Sea around 16 October to rendezvous with *G.O.Sars*. The two vessels will then survey the northern North Sea using an interlaced parallel transect design, progressing south. Individual ships' transects will be placed at least 30 n.mi. apart to achieve a minimum intertransect spacing of 15 n.mi. for the combined survey. In the area around Viking Bank (shaded area in Fig. 6.3.1), transects will be placed closer together, at 15 n.mi. to achieve a higher density of 7.5 n.mi. between survey transects. The exact location and longitudinal extent of the transects will be determined nearer the time, once local knowledge of the location of the main concentrations of mackerel has been obtained from the fishery. *Scotia* will break off from the survey on 25 October and the remaining (southern) part of the area will be surveyed by *G.O.Sars* until 3 November.

Extension of the survey area in the autumn survey is to be encouraged. Other nations, particularly those with a reasonable share of the mackerel quota, should consider whether they might add ship time. High priority should be given to those areas of high mackerel catches in Quarter 4 (Figure 2.1). In order of priority, these would be namely: the western approaches, in ICES Division VIa; central North Sea; western English Channel; western Celtic Sea; and the Bay of Biscay along the French coast.

Table 6.3.1. Details of the autumn 2002 co-ordinated acoustic survey for mackerel.

Country (Vessel)	Dates	Area	Cruise leader contact
Scotland (FRV *Scotia*)	10-26 October	Western approaches to the North Sea, northern North Sea (Viking Bank)	Paul Fernandes fernandespg@marlab.ac.uk
Norway (FRV *G.O.Sars*)	15 October – 4 November	Northern North Sea (Viking Bank) and central North Sea	Dankert Skagen dankert@imr.no

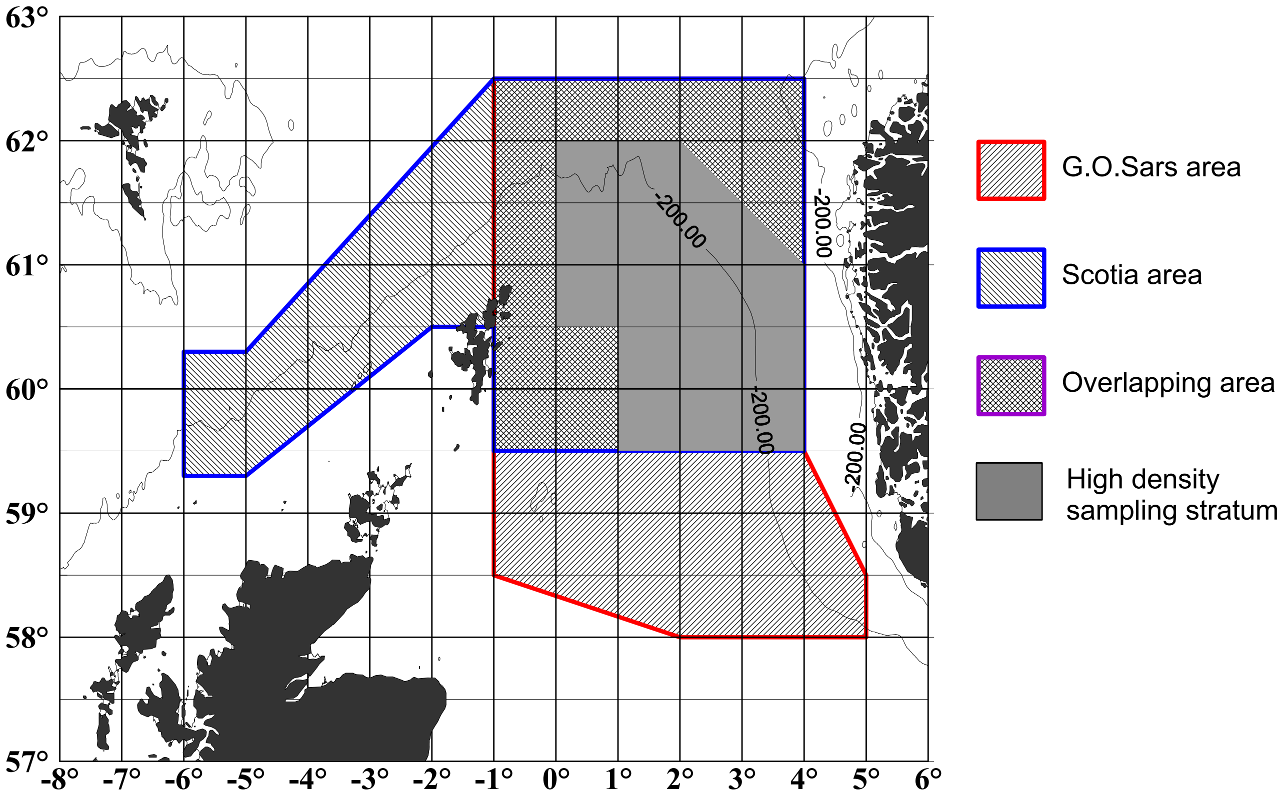


Figure 6.3.1. Approximate survey areas for the autumn 2002 acoustic survey for mackerel in the North Sea and western approaches. RV *Scotia* and RV *G.O.Sars* will overlap in the hatched areas, sampling at higher intensity in the shaded area.

7 ACOUSTIC SURVEYS IN ICES DIVISIONS VIII AND IX

7.1 Portuguese-Spanish–French survey

Acoustic surveys are routinely carried out by Portugal and Spain in southern NEA waters in spring. These surveys have been co-ordinated since 1997 at the ICES Planning Group for Sardine Acoustic Survey in Divisions VIII and IX (Anon 1997). France also undertook surveys in spring covering the French plateau from the Spanish/French border to Brittany. Much of the continental shelf in these waters is covered by these surveys, providing good coverage. Biological data is, however, specific to individual surveys because the Spanish & Portuguese target sardine whilst the French target anchovy.

Since 1998, survey design and survey strategies have been similar for the whole area (Anon. 1998). Acoustic data is only collected during daytime whilst at night oceanographic measurements are made. Fishing is carried out during daytime. Backscattered energy is allocated to fish species according to two different procedures a) Direct allocation (i.e. echogram scrutiny); and b) Allocation on the basis of representative fishing stations. For this purpose, the following TS reference table is used:

Species	Name	b_{20}
Sardine	*Sardina pilchardus*	-72.6
Sprat+clupeids	*Sprattus sprattus*	-71.2/-72.6
Anchovy	*Engraulis encrasicholus*	-71.2/-72.6
Horse Mackerel	*Trachurus spp*	-68.7
Mackerel	*Scomber scombrus*	-82
Chub mackerel	*Scomber japonicus*	-68.7
Bogue	*Boops boops*	-67
Blue whiting	*Micromesistius poutassou*	-72.8*
Other gadoids	-	-67

b_{20} means *TS-20*log(L)*

* this correspond to a relationship in which *log L* is multiplied by 21.8

From 2000 to 2001 a DG XIV Project called "Direct Abundance Estimation And Distribution Of Pelagic Fish Species In North East Atlantic Waters. Improving Acoustic And Daily Egg Production Methods For Sardine And Anchovy", *PELASSES*, co-ordinated the surveys in this area. The main objective of this project was concerned with the acoustic estimation of the sardine and anchovy populations, and to map the distribution (both exploited and non-exploited phases) of the main pelagic fish species in southern NEA waters in relation to several environmental variables (i.e. SSS, SST; S and T, and chlorophyll profiles, plankton abundance, etc). Survey strategies were updated with the inclusion of new sampling procedures. A Continuous Underwater Fish Egg Sampler (CUFES) was installed, providing relative egg abundance at 3-5 metres depth. In addition, together with the 38 kHz, data from the 120 kHz transducer were stored for post-processing.

Figure 7.1.1 shows the acoustic track from 2000. This covered most of the continental shelf (i.e. between 30 to 200 m), providing valuable information for most of the pelagic fish species present in this area. The most important fish species sardine, anchovy, mackerel and horse mackerel. The spawning period for these species in the southern NEA occurs in spring while recruits at age 1 are fully accessible in this period.

Although in the Spanish area mackerel is the most important fish species, it is very difficult to allocate backscattered energy to this species. This is relevant when mackerel occurs in mixed layers with other fish species as shown in Figure 7.1.2. In this situation, energy is distributed according to the fish species proportion found at the representative fishing stations and weighted by the corresponding TS/Length relationship. Therefore, an accurate TS/Length relationship for each fish species will result in an improvement of the final estimates. On the other hand, thick plankton layers located in the upper layers of the water column are often observed in this period in the Cantabrian Sea. In years in which juvenile abundance is high, the total abundance could be biased because this fraction mainly occur in the water column, sometimes inside this plankton layer. In addition, it is very difficult to establish an accurate proportion between the adult and the juvenile fraction because of the different accessibility to the fishing gears of both fractions.

Adult mackerel mostly occurs in this area in spring and only juveniles seem to remain for the whole year in this area. Adult migration to this area seems to occur in pulses, and not in a continuous fashion. These pulses arrive in the inner part of the Bay of Biscay, progressing westward to the NW corner of the Iberian Peninsula (VIIIc-west). The abundance of this fish in IXa is scarce. Despite the short length of transects (16 n.mi. or 1.5 hours) and the intertransect distance (8 n.mi.) the estimation of abundance could be biased because of the migration.

7.2 Spring acoustic survey in 2002

For 2002, the acoustic surveys in southern NEA will be undertaken within the frame of the EU data collection regulations. The Spanish and the French surveys conducted by IEO and IFREMER respectively will follow the same strategy since both institutions are partners in the SIMFAMI project. The surveys will be undertaken on board R/V *Thalassa* using several acoustic frequencies (12, 38, 49, 120 and 200 kHz) aiming at providing data for the project. The Portuguese survey will be carried out on board R/V *Noruega* using two acoustic frequencies (38 and 120 kHz). The areas and periods to be covered are summarised in Figure 7.2.1. and in the following table:

Country	Institution	Vessel	ICES-Division	Month	Contact person
Portugal	IPIMAR	Noruega	IXa-Cadiz; IXa-S; IXa-CS; IXa-CN	March	vmarques@ipimar.pt
Spain	IEO	Thalassa	IXa-CN; IXa-N; VIIIc	March	pablo.carrera@co.ieo.es
France	IFREMER	Thalassa	VIIIb; VIIIa	May	jacques.masse@ifremer.fr

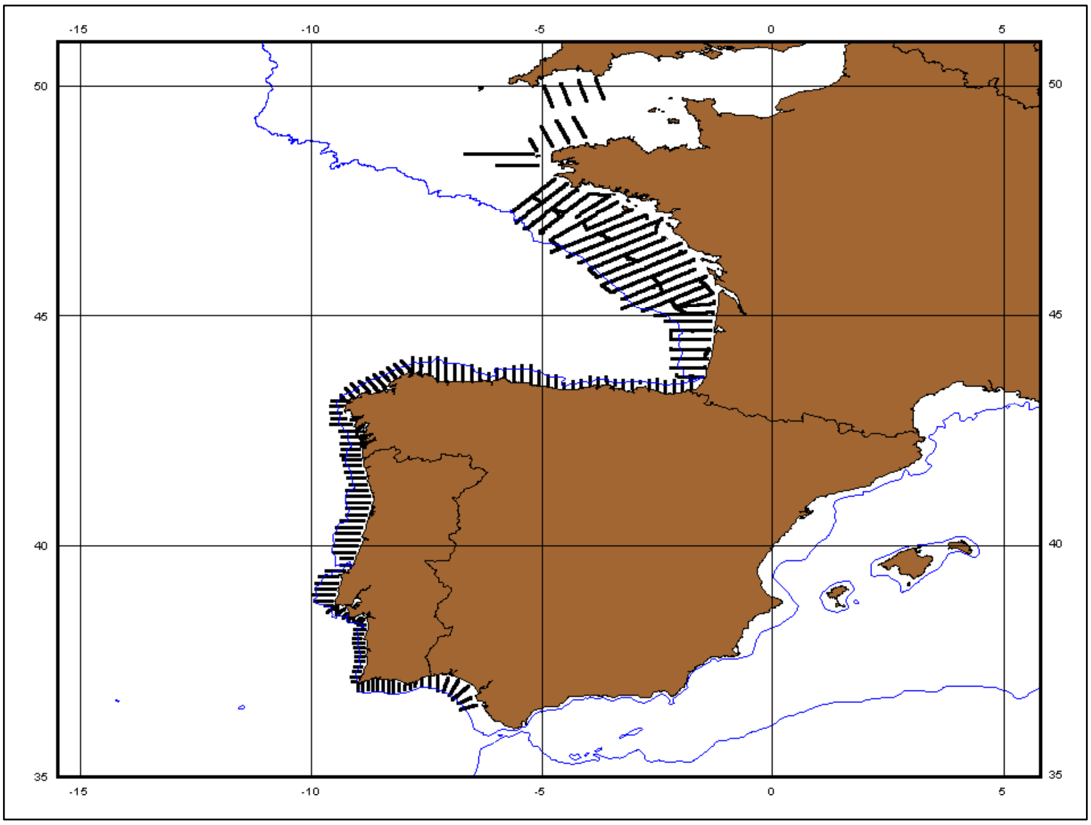


Figure 7.1.1. Survey design implemented during the PELASSES project.

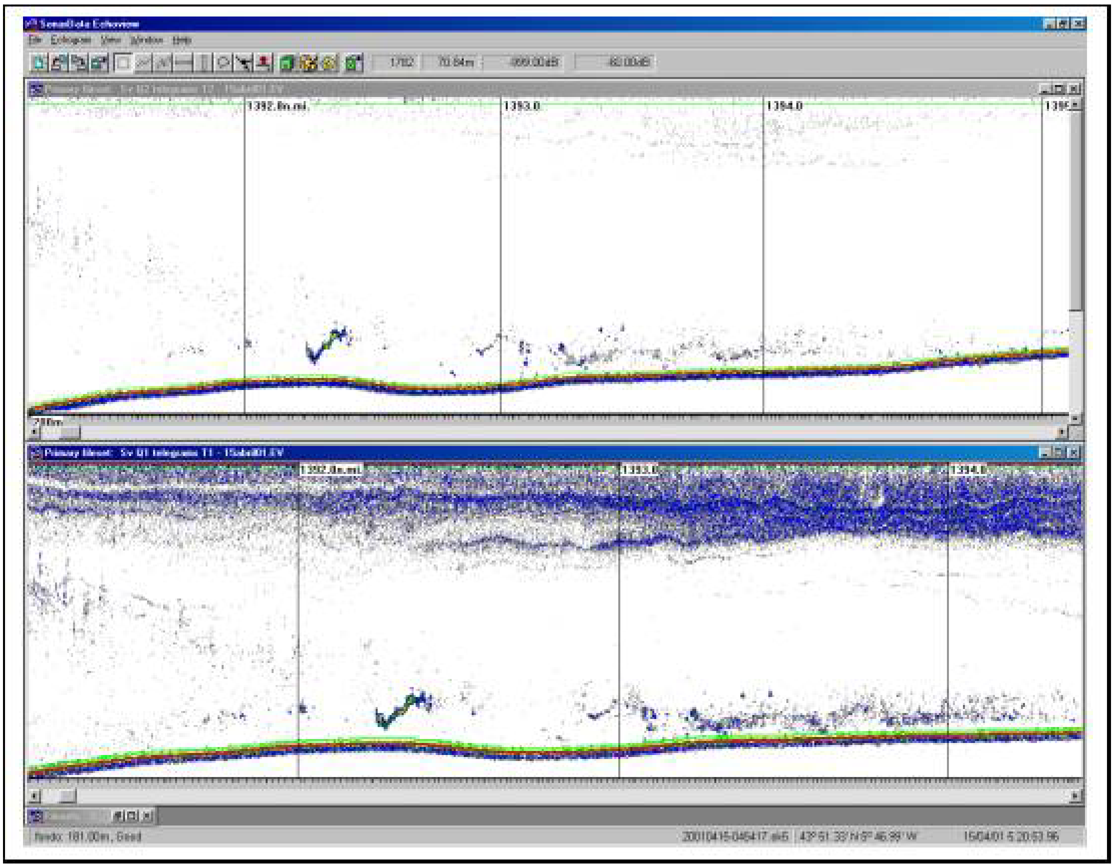


Figure 7.1.2. Echogram at 38 kHz (lower) and 120 kHz (upper) at –60 dB threshold showing the typical bottom layer observed in the Cantabrian Sea containing, in this case, sardine and mackerel (corroborated by fishing). Total displayed depth is 200 m (bottom depth around 180 m). In the left part of the echogram, a "cloud" mainly belonging to mackerel rising into upper layers is also observed. The thick plankton layer is also noticeable at 38 kHz close to the surface.

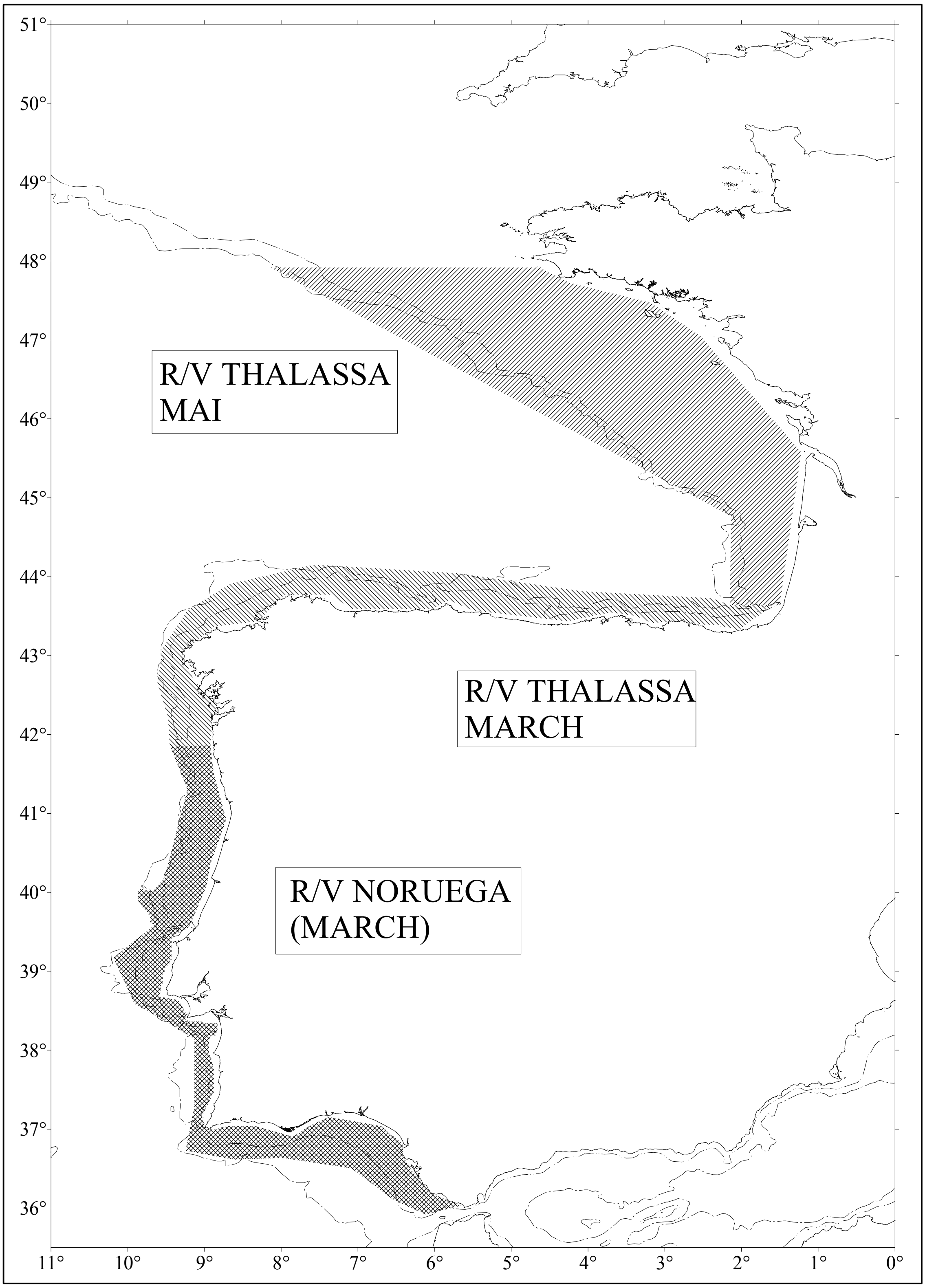


Figure 7.2.1. Spring 2002 acoustic surveys planned in southern NEA.

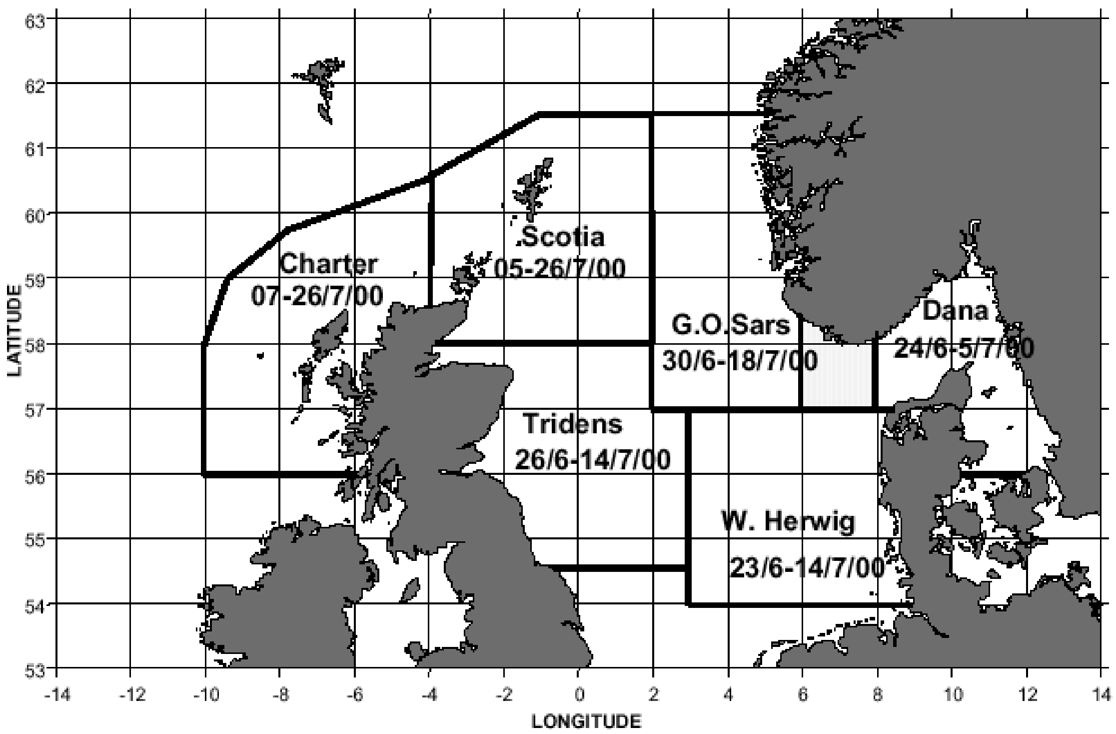
8 INFORMATION FROM OTHER SURVEYS

This chapter lists a suite of surveys which although not targeted at mackerel, may have the potential to estimate mackerel abundance. Some of the surveys mentioned do provide indices of mackerel abundance.

8.1 Acoustic surveys of herring south of 62° N

A number of acoustic surveys target herring south of 62° N, as described in the report of the planning group for herring surveys (Anon. 2001b). The figures and text below are extracted from this report.

Six surveys were carried out during late June and July 2001 covering most of the continental shelf north of 54° N in the North Sea and 56° N to the west of Scotland to a northern limit of 61° N. The eastern edge of the survey area was bounded by the Norwegian, Danish and German coasts, and to the west by the shelf edge at approximately 200 m depth. The areas covered and dates of surveys are shown in Figure 8.1.1.



Survey area layouts and dates for all participating vessels in the 2000 North Sea and west of Scotland herring acoustic survey.

Figure 8.1.1. Acoustic herring surveys south of 62° in 2000 (Anon. 2001b).

8.2 Acoustic surveys of Norwegian spring-spawning herring and blue whiting.

These surveys are described in the report of Northern pelagic and blue whiting fisheries working group (Anon. 2001a) and in Holst et al. (2001), which presents a complete list the Norwegian spring-spawning herring surveys (summarised in the table below).

Research vessel	Country	Survey area	Period
Walther Herwig III	EU	62°-71°N, 6°W-17°E	27.4 - 25.5
Johan Hjort	NO	62°-74°N, 4°W-18°E	3.5 - 28.5
Fridtjof Nansen	RU	68°-73°N, 24°E-40°E	17.5 - 5.6
Arni Fridriksson	IS	66°-72°N, 08°-07°E	25.5 - 8.6
Fridtjof Nansen	RU	60°-71°N, 11°W-15°E	9.6 - 30.7
Arni Fridriksson	IS	62°-66°N, 06°W-27°W	17.6 - 30.7
Magnus Heinason	FA	60°-73°N, 9°W-16°E	2.5 - 27.5
Johan Hjort	NO	67°N-78°N, 4°E-22°E	21.7 - 14.8
G.O.Sars	NO	62°N-70°N, 6°W-14°E	19.8 - 14.8
Bjarni Saemundson	IS	64°-67°N, 24°W-28°W	12.8 - 14.8.

Blue whiting acoustic surveys

Estimates of total and spawning biomass of blue whiting have been made from Russian, Norwegian and Faeroese surveys since 1983. Russian and Norwegian research vessels conduct annual surveys of the blue whiting stock on the shelf edge, bank areas west of The British Isles, and Faeroese waters, in March to April**.**

Since 1995, Norway, Russia, Iceland, the Faroes, and, since 1997, the EU, have coordinated their survey effort on pelagic fish stocks in the Norwegian Sea.

8.3 International bottom trawl surveys (IBTS) and national groundfish surveys

These surveys do not use acoustics for estimation of abundance indices. They do, however, provide estimates of year class strength of mackerel, as shown in the WGMHSA report 2001 (Figures 2.8.2.1-6 in the WGMHSA 2001 report).

These surveys are either IBTS or national surveys as described in the Report of the international bottom trawl surveys working group (Anon. 2001c). Below follows a short summary extract from that report.

The International Bottom Trawl Survey (IBTS) has its origin in the North Sea, the Skagerrak and the Kattegat, where coordinated surveys have been carried out since 1965.

IBTS in the North Sea. Eight vessels took part in the 2000 survey, quarters 1 and 3: *Argos*, *Dana*, *Tridens*, *Michael Sars*, *Walther Herwig III*, *Scotia*, *Cirolana* and *Thalasssa*. All rectangles were sampled using the GOV trawl, and the total number of hauls was 430. A total number of 464 MIK hauls were taken. Indices for age one were obtained for seven species: cod, haddock, whiting, N. pout, herring, sprat and mackerel.

IBTS in the Western Division Groundfish Surveys, quarter 4 of 2000: Four countries participated in these surveys: (1) *Scotia*, UK (Scotland), MARLAB - West coast of Scotland; (2) *Thalassa*, IFREMER, France - Bay of Biscay and the Celtic Sea; (3) *Celtic Voyager*, Ireland - Irish Sea and Celtic Sea, and (4) *Marliona*, Ireland - West of Ireland.

National Surveys For The Western And Southern Areas:

Scottish Surveys:	Q1, Groundfish survey in ICES Division VIa (SGF6a), Q3, Rockall Survey (SGF6b) (every second year) and Q4, Scottish Mackerel Recruit Survey (SMR)
Irish surveys:	Q4, West coast Groundfish Survey (WCGS) and Q4, Irish Sea-Celtic Sea Groundfish Surveys (ISCS)
English Survey:	Quarter 1, Celtic Sea and Western Approaches Groundfish Survey (CSGF)
French surveys:	Q4, Groundfish Survey in the Eastern Channel (Division VIId) (CGF) and Q4, in the Celtic Sea and Bay of Biscay (Divisions VIIf,g,h,j; VIIIa, b) (EVHOE)
Spanish surveys:	Quarter 4, Groundfish Survey in the Cantabrian Sea and Off Galicia (Divisions VIIIc and Northern part of IXa) (SPGFN) and Q2 and Q4, in the Gulf of Cadiz (Southern part of Division IXa) (SPGFS)
Portuguese surveys:	Q3 and Q4, Bottom trawl Survey (Portuguese shelf - Division IXa) (PGF)

9 RECOMMENDATIONS

The Planning Group for Aerial and Acoustic Surveys for Mackerel [PGAAM] will meet as a 3 day extension of WGMEGS meeting in 2003 to:

a) Combine the autumn 2002 survey data to determine the abundance and distribution of mackerel in the North Sea-Shetland area;
b) Co-ordinate the timing, area allocation and methodologies for acoustic and aerial surveys for mackerel in the north east Atlantic;
c) Consider the latest findings from the SIMFAMI project on the identification of mackerel echo traces;
d) Collate and evaluate the data collected by aerial surveys, fishing and research vessels in the Norwegian Sea during late summer and autumn 2002.

The PGAAM recommends that acoustic surveys for mackerel employ the following target strength to length relationship for the conversion of acoustic data to abundance:

$$TS = 20 \log L_{(in\ cm)} - 84.9 \text{ dB.}$$

The PGAAM recommended that multi-frequency acoustic data should be collected when surveying mackerel wherever possible using frequencies in the following priority: 38, 200, 120, 18 and 12 kHz.

The PGAAM recommends that results from surveys not necessarily targeted at mackerel should be monitored for potential use in the estimation of mackerel abundance or in the provision of biological samples.

The PGAAM recommends that Portugal and France should participate in the next PGAAM meeting for effective co-ordination of surveys in the southern area (ICES Divisions VIII and IX) also.

The PGAAM recommends that participants from England, the Netherlands and the Republic of Ireland should participate in the next PGAAM meeting and should consider adding to the autumn survey for mackerel in the North Sea and the western approaches to the north east Atlantic.

10 REFERENCES

Anon. 1997. Report of the Planning Group for Sardine Acoustic surveys in ICES Sub-Areas VIII and IX. Lisbon, 27-28 January 1997. ICES CM 1997/H:1, 17pp.

Anon, 1998. Report of the Planning Group for Pelagic Acoustic surveys in ICES Sub-Areas VIII and IX. A Coruña, 30-31 January 1998. ICES CM 1998/G:2, 17pp.

Anon. 2001a. Report of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy. ICES CM 2001/ACFM:06.

Anon. 2001b. Report of Northern pelagic and blue whiting fisheries working group. ICES CM 2001/ACFM:17.

Anon. 2001c. Report of the international bottom trawl surveys working group. ICES CM 2001/D:05.

Anon. 2001d. Report of the planning group for herring surveys. ICES CM 2001/G:02.

Anon. 2002. Report of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy. ICES CM 2002/ACFM:06.

Edwards, J. I., F. Armstrong, et al. (1984). Herring, mackerel and sprat target strength experiments with behavioural observations. ICES CM 1984/B:34. 21 pp.

Holst, Couperus, Gudmundsdottir, Hammer, Jacobsen, Krysov, Melle, Tangen & Vilhjálmsson. 2001. Report on surveys of the distribution, abundance and migrations of the Norwegian spring-spawning herring, other pelagic fish and the environment of the Norwegian Sea and adjacent waters in late winter, spring and summer of 2002. ICES CM 2001/ D:07, Ref. ACFM.

Reid, D. G. and A. Eltink. 1999. Recent changes in the timing and pattern of the migration of western mackerel from the North Sea from surveys and commercial data and its impact on management measures. In Anon (1999) Report of the working group on the assessment of mackerel, horse mackerel, sardine and anchovy. ICES CM 1999/Assess:06, 468 pp.

Zabavnikov, V.B., Chernook, V.I. 1997. Airborne remote sensing research of marine environment for evaluation of pelagic fish distribution.//Proceedings of the 4th International Conference Remote Sensing for Marine and Coastal Environment, Orlando, Florida, USA, 17-19 March 1997.- Vol. 1.- P. 623-625.

APPENDIX I

Working document for PGAAM – A Coruña, Spain, February 2002

The SIMFAMI project

P. G. Fernandes
FRS Marine Laboratory Aberdeen
PO Box 101, Aberdeen
AB11 9DB
Scotland

Introduction

Acoustic methods are used extensively within fisheries research for estimating the abundance and distribution of fish, and currently, over 20 pelagic fish stocks are surveyed routinely as part of the stock assessment process of the International Council for the Exploration of the Sea. The major problem for estimating indices of abundance from such surveys is the correct allocation of observed echoes to species. The current solution to this problem relies on a combination of user experience "ground-truthed" using trawl samples. This is opportunistic and punctual, giving direct information for only a few kilometres of track, which is then extrapolated to the surrounding area often in an ad hoc manner. There is a need to improve this aspect of routine survey work and provide a well-founded identification procedure.

SIMFAMI (Species Identification Methods From Acoustic Multi-frequency Information) is a new three-year project, started in January 2002, which has been funded by the European Commission to address this issue. The project aims to apply modern multi-frequency acoustic techniques, in addition to the single-frequency methods available previously, to establish methods for acoustic identification of echo traces that are applicable to routine survey procedures. Multi-frequency techniques alone have been shown to have great potential for acoustic species identification, particularly for distinguishing fish with a swim bladder (e.g., herring) from those without one (mackerel). Although this basic premise has been known for many years the equipment required for its practical application has not been generally available.

Two fundamental developments have occurred in recent years which facilitate these techniques to be applied. Firstly, modern research vessels now carry more than one acoustic frequency in their scientific echosounders, such that synchronised multi-frequency data are now routinely collected on acoustic surveys. Secondly, the archiving, processing and analysis of multi-frequency acoustic data are now possible with a variety of readily available computer programs. What is now required is the development of algorithms in these programs to allow for species identification. These algorithms will ultimately not only incorporate the suite of multi-frequency data, but also parameters from echo trace classification (e.g., shape, amplitude distribution) and the basic environment (e.g., location in 4D space – i.e., time, location, depth).

The SIMFAMI partnership consists of: FRS Marine Laboratory Aberdeen, Scotland (scientific co-ordinators); IMR, Bergen, Norway (financial co-ordinators); IEO, A Coruña, Spain; IFREMER, Nantes, France and IRD, Brest, France. The project will specifically target the identification of fish that are prevalent in the partnerships' survey programmes. These encompass both those fish which are targeted for stock assessment purposes, the primary species, and some other (secondary) species, which although not required from acoustic surveys for assessment purposes, nonetheless need to be considered in order to differentiate from primary species. The primary species are anchovy, herring, horse mackerel, mackerel, and sardine; secondary species include capelin, chub mackerel, and Norway pout. For each species, a probability of identification (P_{id}) will be produced based on the algorithms developed and tested on known 'ground-truth' data.

Methodology and project work plan

Within the project there are 6 major objectives organised in respective work packages:

(1) Construction of an echogram library. Currently, there is distinct lack of published material on echograms for the major acoustically surveyed species. SIMFAMI aims to collate "ground-truthed" echograms of the primary as well as secondary species from historical survey data going back at least three years. These echograms will be single and multi-frequency and will be associated with the relevant biological information. The library will be augmented during the course of the project from survey data collected in the course of the project and will form the basis of data for subsequent analysis. As an example, the library would have a certain number of echogram sections which have been "ground-truthed" by trawl catches composed of sardine, such that these echograms represent sardine. Each species will then have a number of echogram sections from throughout the consortium. This task will be led by IEO who will collate all the data into a single database to which all partners will have access.

(2) Analysis of extracted data - echo trace classification and basic environmental parameters. Single frequency echo trace classification techniques will be applied to multi-frequency data from the echogram library to establish the range of features that are typical for each species. This will be married to basic environmental data. This will produce a database which for each species will contain measured extracted parameters (e.g. school height, width, average density, school depth, height above seabed etc). For all known traces of a particular species (contained in the echogram library) there will then be probability of identification (P_{id}) based on these criteria alone.

As an example, we may find that some herring schools are typified by a certain height to width ratio (described metaphorically as "pillars") combined with a threshold average acoustic intensity (mean Sv threshold set to quite a high value). Applying an algorithm which incorporates these parameters as identifiers of herring would then be applied to all echogram sections of known (from ground truth data) to be composed of herring. It is the ratio of [*n* echogram sections identified as species *x* using the algorithm] to [all echogram sections of species *x*] that defines P_{id}. P_{id} will therefore be higher for those algorithms which identify more sections correctly. This emulates the process whereby characteristics of certain types of echogram traces (e.g. herring from "pillar" schools) are recognised as being diagnostic of certain species, something that fishermen and scientists alike have always done subjectively. IFREMER have developed these techniques for a number of species in the Bay of Biscay, hence their lead in this work package. They have, until now, applied these techniques on only one frequency (38 kHz). In this project they will apply these techniques to other frequencies from the (multi-frequency) echogram library. This should enhance the discrimination criteria.

It is recognised that fish do not always behave in the same way, such that in the above example, not all herring occur in such "pillars". Hence, often the methods outlined above may not be sufficient to identify species categorically. The remaining work packages address this by employing multi-frequency techniques.

(3) Development of multi-frequency algorithms for the differentiation of fish from plankton. Multi-frequency data from the echogram library where fish and plankton occur will be analyzed to establish algorithms to differentiate between these two groups where ordinary echo trace classification techniques prove to be ineffective (e.g., scattered fish or dense plankton). Where suitable, theoretical plankton and fish scattering models will be applied. This task will be lead by IRD, who have significant experience in multi-frequency characterization of zooplankton.

(4) Development of multi-frequency algorithms for identification of fish without swim bladders. Multi-frequency echograms from fish without swim bladders (e.g., mackerel) will be analyzed to establish species identification algorithms, primarily based on fish frequency response implemented by combined dB difference methods and echogram masking.

As an example, IMR have evidence which suggests that mackerel produce more acoustic backscatter at higher frequencies (200 kHz) than at lower frequencies (38 kHz). Examination of the difference in acoustic intensity at similar locations on the echogram using an appropriate dB difference algorithm will therefore identify that echogram as being composed of mackerel. This task will be lead by IMR who will provide more evidence and develop these techniques

(5) Development of multi-frequency algorithms for the identification of fish with swim bladders. Multi-frequency echograms from fish with swim bladders will be analyzed to establish algorithms to differentiate between them where ordinary echo trace classification techniques prove to be ineffective (e.g., densely schooling fish such as herring and Norway pout). Where suitable, theoretical fish scattering models will be applied. This task will be lead by FRS whose surveys are dominated by swim bladdered fish.

(6) Development of a combined algorithm for fish group, species and stock identification. By combining the multi-frequency techniques outlined in objectives 3,4 and 5 (above) with those from extracted data (objective 2) we aim to produce an algorithm which will result in an enhanced probability of identification for each of the primary species and where possible individual stocks.

This task will be lead by FRS who as scientific coordinators of the project aim to ensure that all components (but particularly objectives 2-5) can be integrated such that these methods can be combined into a single enhanced algorithm for each species with a better identification probability.

(7) Description of how to implement the identification algorithms in available software packages. A CD-ROM will be produced containing example datasets and describing procedures which will enable any fisheries acoustician to implement the algorithms.

A graphical presentation of the project's components indicating the responsibilities of each partner is given in Figure 1.

Expected achievements:

1. **Construction of an echogram library.** A pan-European database of "ground-truthed" echograms of the principal pelagic species as surveyed by members of the consortium (which constitute the majority of pelagics caught in European waters).

2. **Echo trace classification parameters for European pelagics.** Data from the library will be analysed to extract fish targets where possible, to provide information on the most important extracted characteristics (shape, amplitude distribution) for species recognition.

3. **Development of multi-frequency algorithms.** These will allow species identification by acoustic methods, in a form that is directly compatible with the existing surveys and the analysis methods currently used. These algorithms are the missing keystone in single and multi-species acoustic surveys. There are three specific areas which require algorithms development:

   i) **the extraction of fish from plankton;**

   ii) **identification of fish without swim bladders;**

   iii) **identification of fish with swim bladders.**

4. **Development of combined algorithms for the identification of fish stocks considered in the project.** These algorithms will not only incorporate the multi-frequency data, but will also use parameters from echo trace classification (e.g., shape, amplitude distribution) and the basic environment (e.g., location in 4D space – i.e., time, location, and depth).

SIMFAMI & PGAAM

Of relevance to PGAAM, the SIMFAMI project will develop methods which will allow for the implementation of acoustic surveys for mackerel. This species has shown the most promise for acoustic identification because it reflects sound much better at higher frequencies compared to other species. A method based on the difference in echo amplitude between 38 kHz and higher frequencies (120 or 200 kHz), the so-called "dB difference" algorithm, should be able to distinguish mackerel from herring for example. IMR have already produced evidence of this using a similar method which they refer to as the "frequency response".

It should be noted that because mackerel do not possess a swim bladder they are poor reflectors of sound and have a low target strength (TS). In comparison to herring, for example, the TS at the integrating frequency of 38 kHz is almost 15 dB lower. An acoustic trace from herring, misidentified as mackerel, would overestimate the true numbers of fish by a factor of 32. It is essential, therefore, due to the low TS of mackerel that it is at least identified correctly. SIMFAMI aims to provide this. Acoustic surveys should then be able to deliver estimates which, at the very least, will be comparable from year to year and may, therefore, be used as a tuning index in the assessment of the stock.

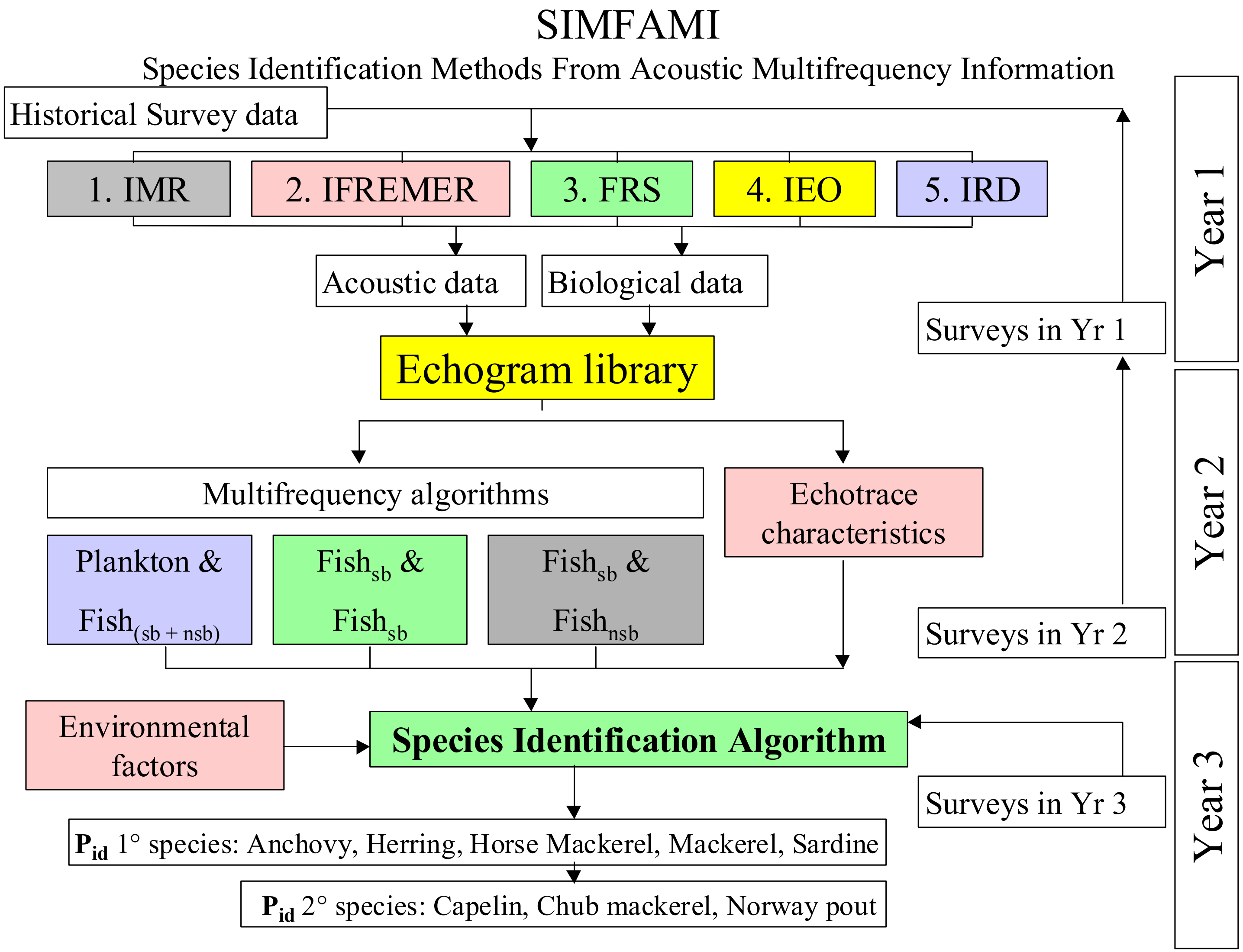


Figure 1. Pert diagram showing how the components of the SIMFAMI project are interlinked and how responsibility for tasks is allocated (partner responsibilities for WP are colour coded e.g. IMR, in gray, is responsible for collecting data and developing algorithms for differentiating between fish with and without swim bladders).