PIP
Petroleum Infrastructure Programme

Petroleum Affairs Division

Cetaceans and Seabirds of Ireland's Atlantic Margin

Volume II

CETACEAN DISTRIBUTION & ABUNDANCE

COASTAL & MARINE RESOURCES CENTRE
ENVIRONMENTAL RESEARCH INSTITUTE
UNIVERSITY COLLEGE
CORK

Irish Petroleum Infrastructure Programme (PIP)

Cetaceans and Seabirds of Ireland's Atlantic Margin

Volume II
CETACEAN DISTRIBUTION & ABUNDANCE

Oliver Ó Cadhla *
Mick Mackey *
Natacha Aguilar de Soto *
Emer Rogan **
Niamh Connolly *

* **COASTAL & MARINE RESOURCES CENTRE,**
ERI, University College Cork,
Naval Base, Haulbowline,
Cobh,
County Cork.
IRELAND

** **DEPARTMENT OF ZOOLOGY, ECOLOGY & PLANT SCIENCE**
Environmental Research Institute,
University College, Lee Maltings,
Prospect Row, Cork.
IRELAND

Citation:
Ó Cadhla, O., Mackey, M., Aguilar de Soto, N., Rogan, E. & Connolly, N. (2004). *Cetaceans and Seabirds of Ireland's Atlantic Margin. Volume II – Cetacean distribution & abundance.* . Report on research carried out under the Irish Infrastructure Programme (PIP): Rockall Studies Group (RSG) projects 98/6 and 00/13, Porcupine Studies Group project P00/15 and Offshore Support Group (OSG) project 99/38. 82pp.

CONTENTS

SUMMARY

The waters surrounding the island of Ireland are home to a wide variety of cetacean (i.e. whale and dolphin) and seabird species. This report presents detailed findings from research conducted under the auspices of the Petroleum Infrastructure Programme set up by Ireland's then Department of the Marine and Natural Resources in 1997. The *Cetaceans & Seabirds at Sea* research programme, which commenced in 1999, has now been completed and the findings are presented in three volumes under the title "Cetaceans and Seabirds of Ireland's Atlantic Margin".

Volume II: Distribution & relative abundance of cetaceans along Ireland's Atlantic Margin.

The primary objectives of the cetacean research reported on in this volume are as follows:

1. **To establish reliable baseline information on the relative abundance of cetaceans in the waters of Ireland's Atlantic Margin throughout the year;**
2. **To identify major areas of concentration for cetaceans in these waters and evaluate seasonal trends in distribution;**
3. **To estimate, where possible, the abundance of key cetacean species inhabiting western Irish waters in the summer of 2000;**
4. **To appraise cetacean surveys using vessels of opportunity and to examine, where possible, alternative methods which may be used in future surveys of this nature;**
5. **To provide high quality independent scientific information essential for conservation and management purposes.**

Chapter 1 – ***Distribution and relative abundance of cetaceans along Ireland's Atlantic Margin***

- Presents data obtained on *Cetaceans & Seabirds at Sea* strip-transect surveys combined with data collected from alternative methods and incidental sightings;
- A total of 442 survey-days at sea were achieved between 1 July 1999 and 30 September 2001;
- Twenty cetacean species were recorded among 772 sighting records. Records include six baleen whale species and 14 toothed whale species;
- Highly important cetacean records include rare, endangered and migratory species of baleen whale (e.g. Northern Right Whale, Blue Whale), and rarely-seen toothed whale and dolphin species (e.g. Sowerby's Beaked Whale, Cuvier's Beaked Whale, False Killer Whale);
- Areas of importance in Ireland's Atlantic Margin, which may represent critical habitats for cetaceans, are identified on the basis of species richness and relative abundance.

Chapter 2 – ***Summer distribution and abundance of cetaceans off western Ireland***

- Presents methods and results from a dedicated 23-day research cruise, which used an optimal visual survey method for cetaceans in addition to an acoustic survey for cetaceans (*see* Vol. III);

- The study area measured ca. 120,000km^2 in size, covering the western Irish continental shelf, central & eastern Rockall Trough and from the Porcupine Bank to the Outer Hebrides;
- 96.5% of the study area was covered using the optimal double-platform visual survey technique;
- A total of 2356 km was surveyed and included a variety of habitat types, including continental shelf and slope, with a significant area surveyed in the deeper Rockall Trough (waters >2000m deep);
- 126 cetacean encounters were recorded with eight baleen and seven toothed whale species;
- Summer population estimates were derived for two most commonly-encountered species: White-sided Dolphins and Common Dolphins;
- Distributions of most commonly recorded species were examined with respect to depth, depth gradient and sea surface temperature;
- More sightings were obtained in the southern part of the survey area, associated with warmer water;
- Multivariate linear discriminant analysis showed differences in the distribution of a number of species with respect to environmental variables.

The results gathered are discussed in their methodological and biological contexts and conclusions are made on the basis of these findings, including proposals for future areas of work, both thematic and geographic, in the Irish Atlantic Margin region.

INTRODUCTION

BACKGROUND

Ireland's offshore territory has been surveyed and explored to establish the extent and commercial viability of its hydrocarbon resources since the early 1970s. During the 1990s this marine research and the associated drilling operations have been largely focused on government-granted licence blocks located along the Irish Atlantic Margin (Fig. 1.0). To date, significant finds of gas have been identified and earmarked for exploitation in the Corrib field off the northwest coast of County Mayo (Plate 1) and the Seven Heads field in the Celtic Sea south of County Cork. However, it is widely acknowledged that little is known about this extensive offshore region from many physical and biological perspectives.

Plate 1. Drilling rig off the west coast of Ireland.

The exploration and exploitation of marine resources may influence the effective conservation and sustainability of Ireland's marine ecosystems. Among the diverse marine fauna, which may be detrimentally affected, are those at the top of marine food webs including seabirds and cetaceans.

Much of the human activity in Ireland's offshore waters occurs in a biological environment, which has seen relatively little non-commercial (i.e. non-fisheries) research until the 1990s. Although dedicated surveys of seabirds at sea in the eastern North Atlantic began in earnest in 1978 (Tasker *et al.*, 1984) and considerable research has been performed in these waters since then (e.g. Evans, 1981; Pollock *et al.*, 1997; Pollock *et al.*, 2000), much of the data gathered in an Irish context have concentrated on inshore coastal and continental shelf waters. Data gathered on cetaceans inhabiting the waters off western Ireland are even more sparse, with few dedicated surveys (i.e. Evans, 1990; Leopold *et al.*, 1992; Gordon *et al.*, 1999) and relatively small-scale coverage throughout Ireland's Atlantic Margin.

The Republic of Ireland is a signatory to conservation-oriented agreements under the Bonn Convention on Migratory Species (1983), the Berne Convention on Conservation of European Wildlife and Natural Habitats (1979), the OSPAR Convention for the Protection of the Marine Environment of the northeast Atlantic (1992) and the EC Habitats Directive on the Conservation of Natural Habitats and of Fauna and Flora (92/43/EEC, 1992). All cetaceans species occurring in European waters are now afforded protection as Annex IV species under the EC Habitats Directive. Two, i.e. Bottlenose Dolphin (*Tursiops truncatus*) and Harbour Porpoise (*Phocoena phocoena*) are Annex II species (i.e. animal species of Community interest, whose conservation requires the designation of special areas of conservation [SACs]).

Against the backdrop of such limited information, the present study was formulated as part of an overall drive to deliver detailed scientific information on the physical and biological resources of the Irish Atlantic Margin. This study formed a three-year *Cetaceans & Seabirds at Sea* research project undertaken by the Coastal & Marine Resources Centre, University College, Cork. The research was performed on behalf of the Rockall Studies Group (RSG) and Porcupine Studies Group (PSG) under the Petroleum Infrastructure Programme set up in 1997 by Ireland's Department of the Marine and Natural Resources (Murphy, 2001). Under the overall *Cetaceans & Seabirds at Sea* project, a number of parallel studies were performed. These consisted of (i) "Seabirds-at-sea" sighting surveys; (ii) Cetacean sighting surveys; and (iii) Acoustic surveys for cetaceans. These studies are presented in three volumes under the title "Cetaceans and Seabirds of Ireland's Atlantic Margin" and Volume II, presented here, is broadly concerned with data collected on ship-based sighting surveys for cetaceans.

RESEARCH OBJECTIVES

The chief research objectives for cetacean sighting surveys in Ireland's Atlantic Margin were as follows:

1. To establish reliable baseline information on the relative abundance of cetaceans in the waters of Ireland's Atlantic Margin throughout the year;

2. To identify major areas of concentration for cetaceans in these waters and evaluate seasonal trends in distribution;

3. To estimate, where possible, the abundance of key cetacean species inhabiting western Irish waters in the summer of 2000;

4. To appraise cetacean surveys using vessels of opportunity and to examine, where possible, alternative methods which may be used in future surveys of this nature;

5. To provide high quality independent scientific information essential for conservation and management purposes.

STUDY AREA

The primary study area for the project consisted of the offshore waters to the southwest, west and northwest of Ireland, an area commonly termed "Ireland's Atlantic Margin" (Naylor *et al.*, 1999). This area stretches from the Goban Spur through the Rockall Trough and includes part of the adjacent Rockall Bank and continental shelf areas, including the prominent western "Porcupine Shelf", a bathymetric high that encompasses the relatively shallow Porcupine Bank. Research effort during the study extended into waters north and east of this region (Fig. 1.0), considering the potential for cetacean movement through the region in space and time.

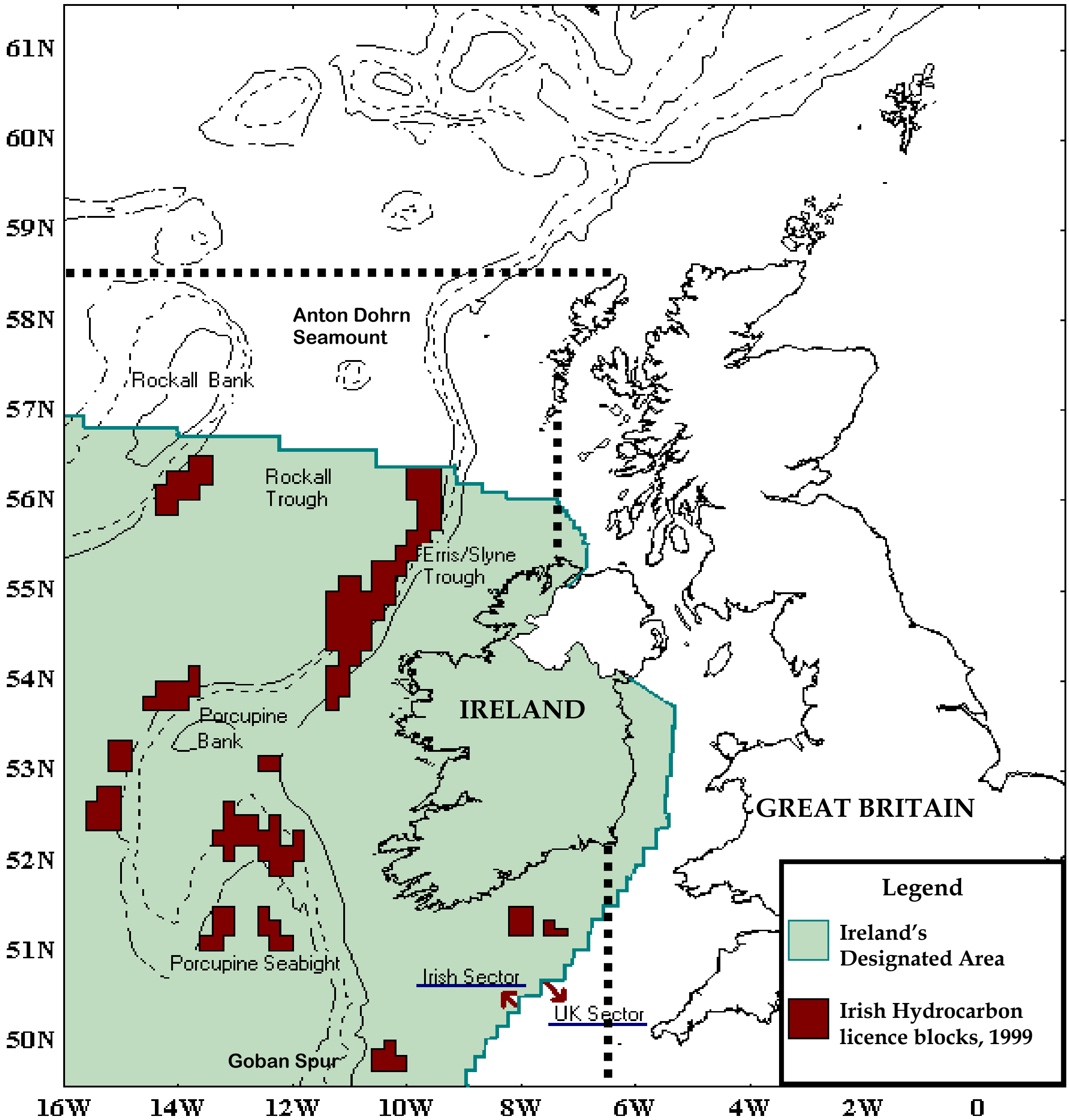

Figure 1.0. Project study area (to left of dotted line ▪ ▪ ▪) showing waters comprising the Republic of Ireland's Offshore Designated Area (shaded) and licence blocks for hydrocarbon exploration held in 1999. [_________ 200m isobath; _ _ _ _ _ _ 500m isobath; ___ _ _ ___ 1000m isobath.]

CHAPTER 1
DISTRIBUTION AND RELATIVE ABUNDANCE OF CETACEANS ALONG IRELAND'S ATLANTIC MARGIN

INTRODUCTION

Ireland's Atlantic Margin is characterised by a number of physical, climatic and oceanographic features, which combine to produce one of the most biologically productive areas of the eastern North Atlantic Ocean. Consequently, the waters off western and southern Ireland contain internationally-renowned commercial fishing grounds (e.g. Porcupine Bank, Celtic Shelf), important nursery and spawning areas for fish and invertebrate species, and areas of concentration for foraging seabirds and other predators (Boelens *et al*., 1999).

In keeping with the ecological importance of the region, there is substantial background evidence promoting the Atlantic Margin as an area of high species richness for cetaceans. Stranding records from 1901-95 indicate that 21 species may inhabit western Irish waters (Berrow & Rogan, 1997) with perhaps as many as 23 species (Rogan & Berrow, 1995), based on whaling records (Fairley, 1981) and rare stranding reports (Berrow & Rogan, 1997). The apparent importance of these waters for cetaceans undoubtedly prompted Irish-based whaling operations in the early 20th century, which saw at least 894 whales killed by Irish-based whalers off the northwest coast (Fairley, 1981), until the practice was restricted under the 1937 Whale Fisheries Act. Similar records and levels of significance have also been attributed to the neighbouring "Atlantic Frontier" waters off Scotland (Murray & Simmonds, 1998; Pollock *et al*., 2000; Harwood & Wilson, 2001).

Information gathered since the 1980s from strandings, land-based cetacean watches (e.g. Berrow, 1993), ship-based seabird surveys (Evans, 1981; Evans, 1990) and a voluntary sighting scheme established by the Irish Whale & Dolphin Group (Berrow *et al*., 2001) have bolstered recent knowledge of Ireland's cetaceans. In 1991 the waters of Ireland's Exclusive Fishery Zone (EFZ) were officially declared a whale and dolphin sanctuary by the Irish Government (Rogan & Berrow, 1995). Under this legislation, the 1976 Wildlife Act and a 1982 amendment to the Whale Fisheries Act, cetaceans were afforded protection within the 200-mile EFZ limit of the State. In spite of these measures and conservation-oriented declarations under the Bonn and Berne Conventions and the EC Habitats Directive, quantifiable data on the natural history, population status and distribution of cetacean species in Irish waters have been relatively deficient. This has been of particular concern in the productive and heavily fished Atlantic waters to the west of Ireland (Wood *et al*., 1996).

Perhaps the most important factors determining cetacean distribution and abundance along Ireland's Atlantic Margin are the availability and distribution of prey (Evans, 1990). Cetaceans are equipped to ingest aquatic prey by one of two means, using: (i) teeth, to assist in prey capture (species known as *Odontocetes*, i.e. toothed whales, dolphins and porpoises), or (ii) rows of porous fibrous plates (baleen), to strain zooplankton, fish and invertebrate prey out of the water column (species known as *Mysticetes*, i.e. baleen whales) (Evans, 1987). Although the North Atlantic Ocean and its adjacent seas contain a myriad of species that may be exploited by either means, the distribution of prey is never uniform in space or time and dynamic physical and oceanographic features prevail to maintain this characteristically heterogeneous environment. Such features occur on a range of scales, from large-scale processes (e.g. oceanic circulation routes) to smaller-scale local systems (e.g. tidal races) (Hunt & Schneider, 1987). Some of these processes carry the potential to concentrate prey in areas of high productivity (Raine *et al*., 1990), thereby making them more available to predators.

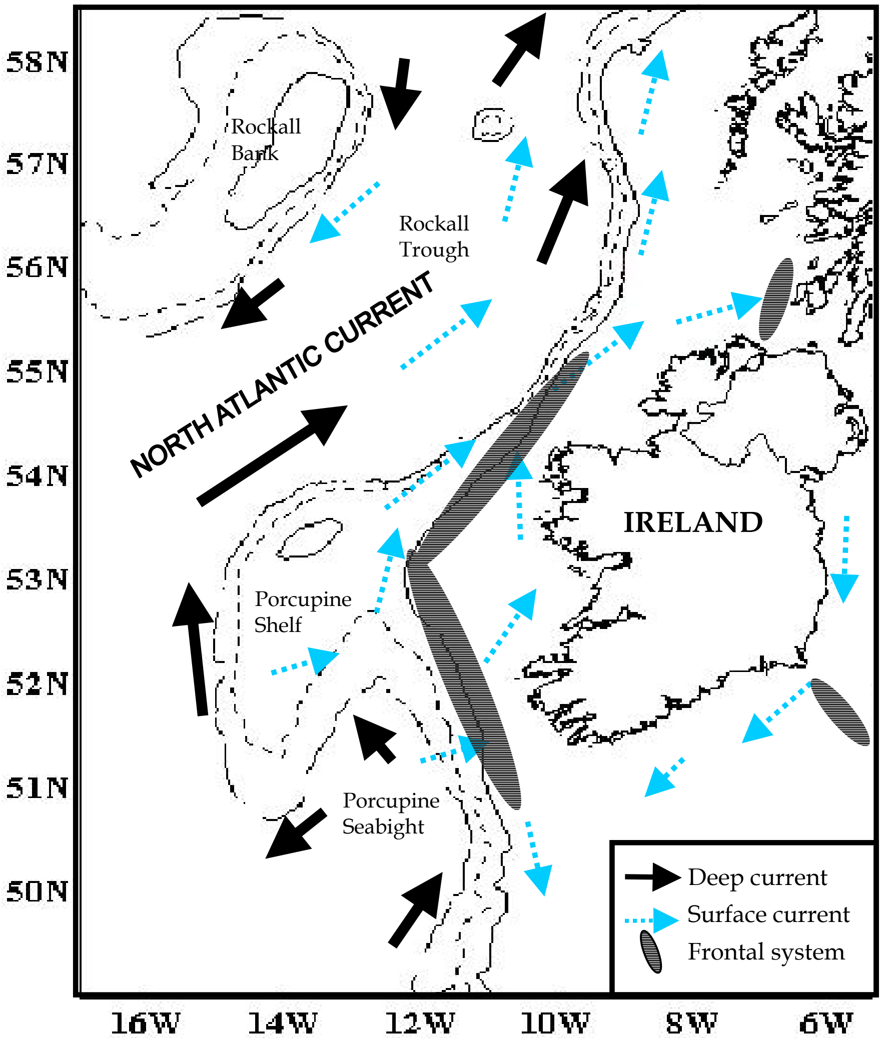

Figure 1.1. General representation of deep water and surface currents occurring in Ireland's Atlantic Margin, including well--known frontal systems operating in the region. (*Adapted from* Vermeulen, 1997; Boelens *et al*., 1999).

The natural features, environmental conditions and resource-utilisation evident along much of Ireland's Atlantic Margin, were reviewed in detail by Boelens *et al.* (1999). A number of characteristics, which may play an important role in the distribution and abundance of cetaceans in the region, are briefly described here: The waters to the west of Ireland are influenced by a significant northeast-heading component of the Gulf Stream, known as the North Atlantic Current or North Atlantic Drift (Fig. 1.1). The complex hydrography resulting from the meeting of this warm oceanic current and the western European continental shelf along Ireland's Atlantic Margin is not fully known. The literature generally describe the greater component of oceanic current moving northwards in the deep Atlantic waters of the Rockall Trough. At its southeastern and northwestern margins, a system of weaker large-scale eddies are established along the relatively shallow Rockall Bank and continental shelf areas off western Ireland (Wood *et al*., 1996). To the north of the basin-like Porcupine Seabight, the oceanic and inshore shelf currents, separated year-round by the haline Irish Shelf Front (Huang *et al*., 1991), tend toward the northeast. To the south, along the western margin of the Celtic Sea, there are both southward and northward current components in operation (Boelens *et al*., 1999). Regional eddy systems also occur in shelf waters of the Porcupine Shelf and central Celtic Sea (Pingree & Le Cann, 1989).

As a result of the complex interactions between these shelf and oceanic water bodies, seasonal climatic, sea temperature and salinity conditions, and regional upwelling of deep, nutrient-rich oceanic water, areas of seasonally high productivity are known to occur along Ireland's Atlantic Margin. These areas see dense concentrations (blooms) of phytoplankton promoted by seasonal light levels and vertical mixing in the water column. Where periodic upwelling or significant terrestrial freshwater input occurs, the influx of nutrient-rich water may maintain locally high productivity levels for a period of weeks or even months. Such events have been shown to significantly boost local primary production off southwestern Ireland (Raine *et al.*, 1990). Similar episodic upwellings are likely to occur off the west and northwest coasts (Boelens *et al*., 1999).

The significance to marine predators of spatial and temporal patterns in primary production is perhaps self-evident. In the case of baleen whales, for example, populations of their zooplankton prey are directly dependent on phytoplankton availability. However, the distribution and abundance of zooplankton, which form a major link in the food chain between phytoplankton and fish/squid populations, are also influenced by sea temperature, predation and water currents. Such factors contribute further to the patchy distribution of food resources for cetaceans and other predators.

Despite the apparent significance of Irish territorial waters for cetaceans, there have been few studies of individual species' distribution and abundance at sea until the 1990s. Notably, a number of surveys have taken place in the last decade, seeking to determine the abundance of species such as Harbour Porpoises (Leopold *et al*., 1992), Bottlenose Dolphins (Berrow *et al*., 1996; Ingram, 2000) and larger whale species (Gordon *et al*., 1999) in proximity to the Irish coast. Furthermore, considerable data collected on combined seabird and cetacean surveys since the late 1970s (e.g. Evans, 1981; Northridge *et al*., 1995; Pollock *et al*., 1997) have yielded vital information on individual species' distribution and relative abundance on a broader scale. The 1994 SCANS survey for small cetaceans (Hammond *et al*., 1995), which extended into southern Irish waters, was undoubtedly the most comprehensive cetacean survey previously conducted in the region, yielding summer population estimates for a number of key species in western Europe's North, Baltic and Celtic Seas and setting the benchmark for future studies of this nature.

From geographic and oceanographic perspectives, however, previous surveys tended to focus on relatively shallow waters overlying the continental shelf (<200m water depth), while areas off western Ireland, including a range of physical habitats from continental shelf, slope, the deeper Rockall Trough and its offshore banks, have seen little dedicated cetacean research. While a number of studies suggest the importance for cetaceans of shelf waters off southwestern Ireland (Evans, 1981) and waters overlying the shelf edge (e.g. Evans, 1990; Pollock *et al*., 1997; Gordon *et al*., 1999), there were fewer data available further offshore. Consequently, the importance of deeper offshore waters of the Porcupine Abyssal Plain and Rockall Trough may have been overlooked, particularly in the light of whaling records and recent studies which highlighted the potential importance of offshore Atlantic Margin waters for three species of larger whales (i.e. Stone, 1997; Clark & Charif, 1998; Charif *et al*., 2001).

The present study has sought to address many of the above concerns by conducting broad-scale cetacean research along the entire Irish Atlantic Margin to its westernmost limits, favouring survey effort outside those areas covered in previous studies in order to break new ground and maximise the opportunity presented.

METHODS

Between July 1999 and September 2001, experienced cetacean observers from the Coastal & Marine Resources Centre (CMRC) *Cetaceans & Seabirds at Sea* team conducted ship-based surveys throughout the Irish Atlantic Margin study area. Surveys were conducted year-round on "vessels of opportunity" (e.g. international research vessels, naval vessels: Plate 2), which were scheduled to be at sea in the study area for a period of days or weeks, and whose host organisations were able to provide a spare berth for one or more observers. Thanks to friendly collaboration with a wide range of Irish, British and mainland European host organisations operating in the study area, 18 such survey vessels were used on a total of 35 research cruises (*see* Appendix A).

In order to optimise sea time and data collection capabilities, sightings of cetaceans were recorded on all occasions and in all possible weather conditions using a number of methods outlined below:

1. STRIP-TRANSECT SURVEYS FOR SEABIRDS AND CETACEANS

The primary visual survey method used aboard vessels of opportunity was that proposed by Tasker *et al.* (1984) of the UK Joint Nature Conservation Committee (JNCC) based in Scotland. Originally designed as a standard method for counting seabirds at sea, the survey technique has been expanded to include cetacean sighting records, since cetaceans are regularly seen in the field by observers conducting ship-based seabird surveys. Often referred to as the "JNCC" or "Seabirds at Sea" method, it has been used for many years throughout western European waters and is a cost-effective and logistically comprehensive means of counting seabirds and marine mammals in the open sea. The method generally consists of a strip-transect survey (Buckland *et al.*, 1993a) conducted by a single scientific observer who records survey effort, environmental conditions (e.g. glare, wind strength, swell height, water depth), positional data, and sightings of the various species encountered to one side of the vessel's trackline.

In the present *Cetaceans & Seabirds at Sea* project, as in other "Seabirds at Sea" surveys, the method required that the host vessel should travel on a straight course, at a constant speed of 5-15 nautical miles per hour (knots), and in sea conditions no greater than those of *Beaufort* Force 6. Observers were normally situated on the ship's bridge-wings or on the monkey-island (i.e. above the bridge) at a platform height of ≥ 9-10m, depending on the vessel. Where these general criteria were met, the observer conducted visual scans with the naked eye in a 90° bow-to-beam sector forward of the ship, concentrating on a 300m-wide strip, from which seabird density estimates may be calculated (*see* Vol. I). Water-resistant binoculars (*LEICA* 10x42) were used to confirm parameters such as species identification, group size and behaviour.

Sighting data collected while on full transect effort were used to determine year-round species distribution, in addition to seabird abundance and density estimates, which ultimately contribute to a central European Seabirds at Sea (ESAS) database. Cetaceans were surveyed in the same manner as seabirds associated with the water (*see* Vol. I). In addition, data concerning the angle of the initial sighting from the ship's course and the approximate distance from the observer were also recorded. Cetacean group sizes, group composition (number of adults, immatures, calves), sighting cues, surfacing intervals, behaviour (normal swimming, foraging, breaching, etc.) and any associations with birds or other cetacean species were also noted.

2. INCIDENTAL SURVEYS

Point-survey methods were employed when "off-effort" during unsuitable weather conditions (e.g. sea conditions greater than Beaufort Force 6 [Plate 3], heavy mist, extreme glare), during periods of frequent fluctuation in vessel course and speed, or when the host ship was stationary. Such surveys involved the observer performing scans in all directions, using both the naked eye and *LEICA* 10x42 binoculars from a suitable platform height. All data parameters collected on full transect surveys (i.e. species, group size, behaviour, distance from ship, etc) were also recorded during incidental surveys. In addition, environmental conditions and the host vessel activity and position were recorded every 90 minutes, or as required (e.g. if the vessel changes course, if wind conditions changed, etc.).

Plate 2. The Irish Naval Service's flagship, L.E. *Eithne*, which was an ideal observation platform throughout the study period.

3. ALTERNATIVE SURVEY METHODS

During the study it became clear to observers in the field that primary use of the JNCC "Seabirds at Sea" method, which was designed for counting seabirds at sea and requires strict adherence to a 300m-wide strip-transect sampling protocol, significantly reduced the observer's likelihood of detecting cetaceans outside the relatively narrow field-of-view on one side of the moving vessel. Consequently, a number of single- and dual-observer methods were conducted to examine alternative means of simultaneously counting seabirds and cetaceans. In such surveys while the standard "Seabirds at Sea" approach was maintained in parallel with trial alternative methods. Sighting data collected by observers in these trials are collated here under the *incidental sightings* category. These data will be analysed further at a later date.

4. DATA COLLECTION AND ANALYSIS

Cetacean sighting data and all associated effort, environmental and positional data were recorded on paper and subsequently coded for entry into a standard computer database system using Corel Paradox® 9 software. Database coding manuals and support were provided by the JNCC in Aberdeen.

Positional and effort-related data gathered during full surveys form the basis of effort plots, generated using *Dmap for Windows* version 7.0 (Morton, 1999). These distribution maps are displayed as ¼ International Council for the Exploration of the Sea (ICES) area units, each measuring 15′ latitude x 30′ longitude. These area blocks are the units of coverage used by the JNCC and other international research groups as a standard means of displaying survey effort and animal density, thereby allowing the direct comparison of international research results.

Due to reduced detectability of cetaceans in the field when conducting the single-observer "Seabirds at Sea" method, it was considered that true cetacean abundance per ¼ ICES block could not be accurately represented here via an analysis of "on-effort" sightings. Nor did incidental surveys conform to dedicated point transect sampling theory. Nevertheless, such data are important in the context of the overall programme, which covered a very large study area through all months of the year. As a result, the data collected for cetaceans are considered most appropriate in the presentation of relative abundance and species distribution patterns. With this purpose in mind, all cetacean sighting data, collected both on- and off-effort were included in the analysis and graphical representation of results presented below. The dataset includes cetaceans seen outside of the 90° bow-to-beam survey zone and beyond the 300m strip-transect area utilised in previous studies of this kind (e.g. Pollock *et al*., 1997; Pollock *et al*., 2000). Bathymetric contours in all associated survey effort maps and distribution/abundance maps are represented in the following manner:

_________ 200m isobath	_ _ _ _ _ 500m isobath	___ _ _ ___ 1000m isobath

Where seasonal trends in cetacean distribution are investigated, seasons have been defined as follows, on the basis of seasonal daylight levels and average monthly sea surface temperatures for the west of Ireland which peak in late August and reach their lowest annual level in the month of February (Bowyer & Ward, 1995; Boelens *et al*., 1999):

SPRING	April, May, June
SUMMER	July, August, September
AUTUMN	October, November, December
WINTER	January, February, March

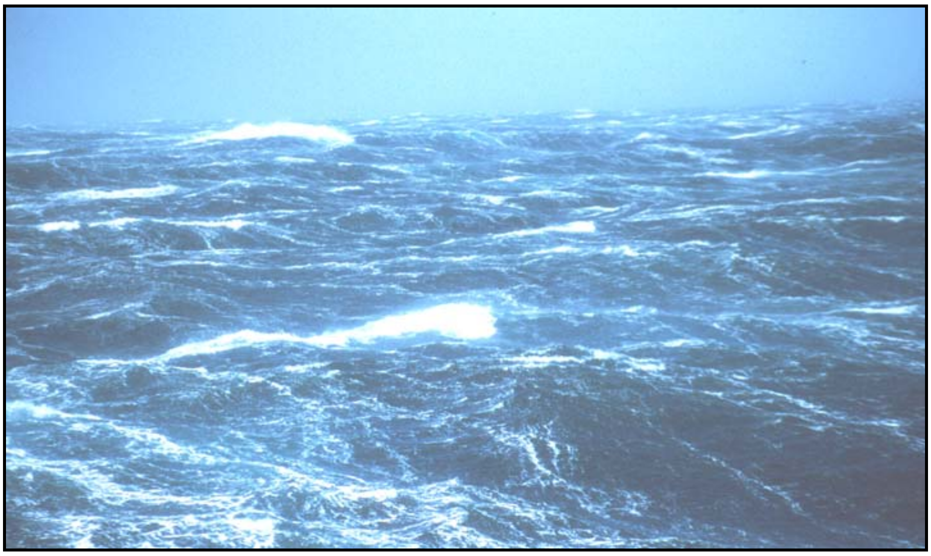

Plate 3. Rough weather conditions in the Rockall Trough, which reduce available survey time, particularly in autumn and winter.

RESULTS & DISCUSSION

1. STRIP-TRANSECT SURVEY EFFORT

Figure 1.2 outlines the *full transect* survey coverage achieved during the 27 months of the study, including the *SIAR* survey. It represents a total of 442 survey-days at sea, most of which (296 survey-days) were achieved during the spring/summer months (April - September) (Figs. 1.3b, 1.3c).

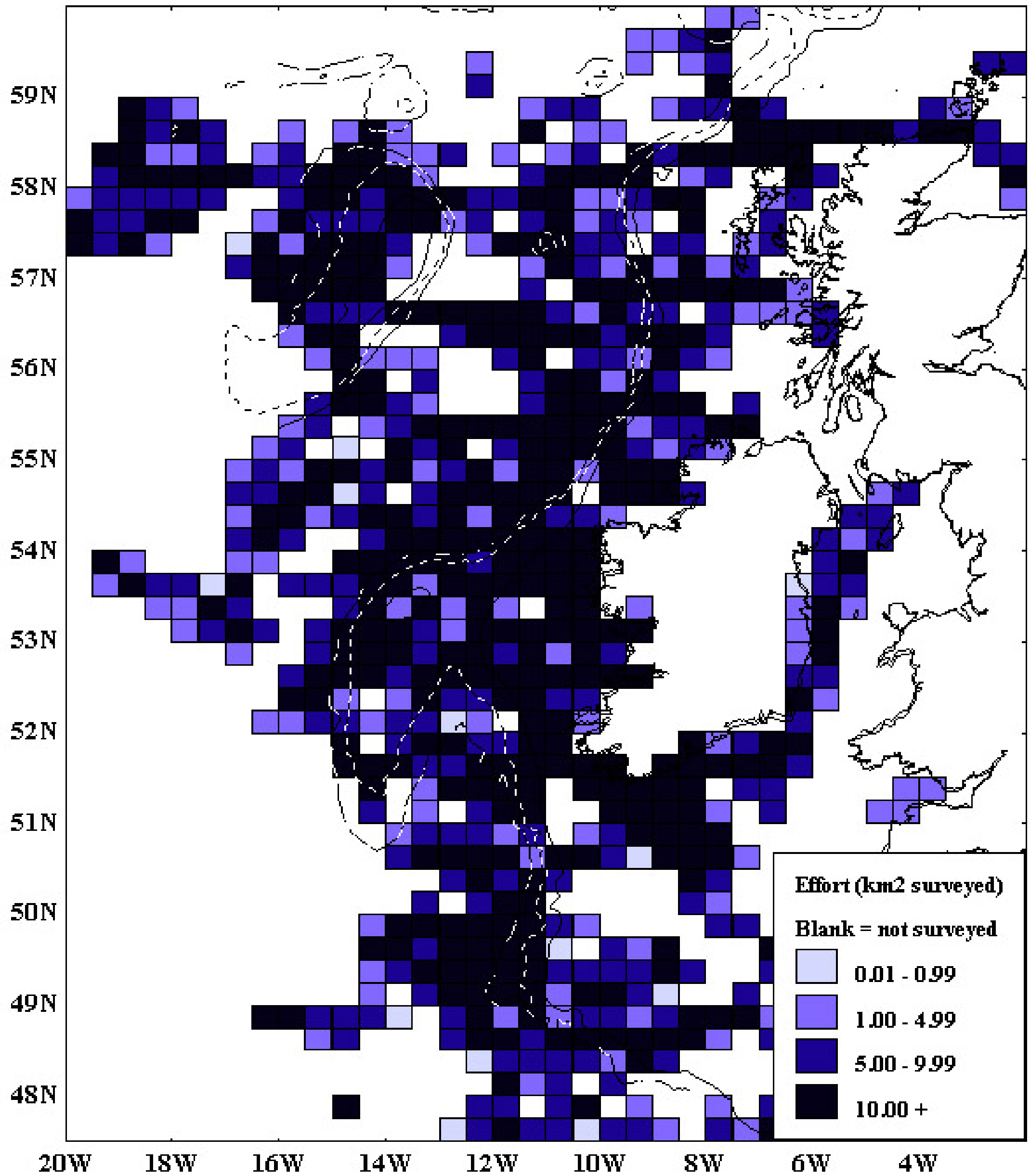

Figure 1.2. Total survey effort (i.e. area covered per ¼ ICES block) achieved by CMRC scientific observers in the study area between 1 July 1999 and 30 September 2001. Each ¼ ICES block transected on one or more occasions is colour-coded to reflect the level of survey effort performed within its borders during the study.

Although 146 survey-days were achieved during the autumn/winter (October - March) (Figs. 1.3a, 1.3d), considerably less full-transect survey-time was obtained due to poor weather conditions occurring along Ireland's Atlantic Margin during these months. This seasonal deterioration in weather conditions generally curtails annual research activity in these waters after mid-October.

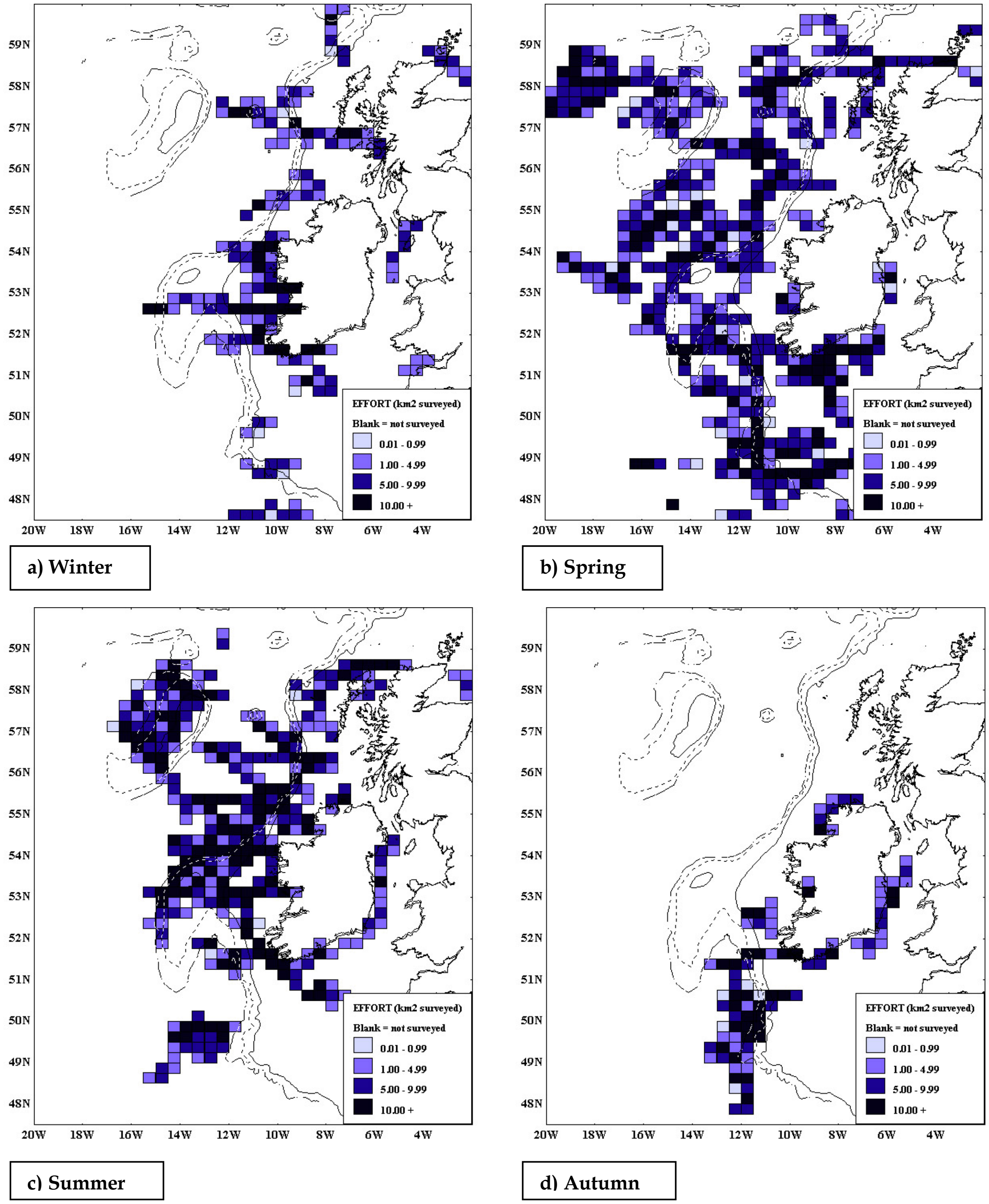

Figure 1.3. Total strip-transect survey effort achieved by CMRC observers, separated by season. [a) *Winter*– January, February, March; b) *Spring*– April, May, June; c) *Summer*– July, August, September; d) *Autumn*– October, November, December].

3. SPECIES DISTRIBUTION AND RELATIVE ABUNDANCE

A total of 772 cetacean sightings were recorded during this research programme. Twenty cetacean species, comprising six mysticete and 14 odontocete species, were positively identified at sea by CMRC observers during the July 1999 to September 2001 study period (Table 1.1). All 20 species were recorded during dedicated strip-transect surveys aboard vessels of opportunity, while 14 were also recorded on incidental surveys. Eighteen species were observed in the waters of Ireland's Atlantic Margin, confirming the Irish Atlantic Margin as an area of high species richness, as suggested by Irish stranding records (*see* Berrow & Rogan, 1997). Cetaceans were recorded throughout the region, from continental shelf waters < 50m deep to the offshore Rockall Bank, the Rockall Trough and the adjoining oceanic basin in excess of 4000m depth.

TABLE 1.1. Summary of cetacean sighting records from strip-transect (ST) and incidental (IC) surveys conducted by CMRC observers between July 1999 and October 2001. Numbers (N) of animals recorded in various age classes are shown. (*N* = All ages; *Imm.* = Immature/juvenile).

Species	*No. of records* ST	IC	TOTAL *N*	*Adult n*	*Imm. n*	*Calf n*	*Unknown n*	Group Size Range
MYSTICETES								
Northern Right Whale	1	0	1	*1*	*0*	*0*	*0*	1
Humpback Whale	2	0	4	-	-	-	*4*	1-3
Blue Whale	1	0	1	*1*	*0*	*0*	*0*	1
Fin Whale	9	1	16	*8*	*3*	*0*	*5*	1-4
Sei Whale	16	20	43	*21*	*1*	-	*21*	1-5
Minke Whale	26	6	36	*22*	*4*	*4*	*6*	1-2
ODONTOCETES								
Sperm Whale	15	17	56	*25*	*5*	*3*	*23*	1-4
Northern Bottlenose Whale	1	0	2	*2*	*0*	*0*	*0*	2
Cuvier's Beaked Whale	1	0	1	*1*	*0*	*0*	*0*	1
True's Beaked Whale	1	0	5	*4*	*0*	*1*	*0*	5
Killer Whale	2	2	12	*9*	*2*	*1*	*0*	3-6
False Killer Whale	4	3	43	*21*	*7*	*2*	*13*	2-15
Long-finned Pilot Whale	49	25	686	*217*	*41*	*59*	*369*	1-70
Risso's Dolphin	4	1	13	*5*	*5*	*0*	*3*	1-10
Bottlenose Dolphin	26	11	551	*259*	*34*	*47*	*211*	1-60
White-beaked Dolphin	22	3	212	*108*	*7*	*14*	*83*	1-35
Atlantic White-sided Dolphin	34	36	1005	*364*	*83*	*62*	*496*	1-130
Short-beaked Common Dolphin	192	44	2735	*771*	*72*	*80*	*1812*	1-120
Striped Dolphin	14	3	135	*12*	*1*	*2*	*120*	1-30
Harbour Porpoise	27	25	173	*14*	*3*	*4*	*152*	1-20
UNIDENTIFIED SPECIES								
Blue/Fin/Sei whale	11	6	24	*8*	*1*	*0*	*15*	1-3
Beaked whale species	1	0	1	*0*	*0*	*0*	*1*	1
Unidentified whale species	21	13	47	*11*	*1*	*2*	*33*	1-4
Unidentified dolphin species	43	20	330	*12*	*0*	*2*	*316*	1-15
Unidentified cetacean	9	4	42	*4*	*2*	*0*	*36*	1-12
TOTALS	532	240	6174					

The most commonly encountered cetaceans recorded during surveys were groups of Short-beaked Common Dolphins (*Delphinus delphis; a.k.a.* Common Dolphin), Atlantic White-sided Dolphins (*Lagenorhynchus acutus; a.k.a.* White-sided Dolphin) and Long-finned Pilot Whales (*Globicephala melas*), indicating their comparative abundance in these waters (Fig. 1.4). Sperm

Whale (*Physeter macrocephalus*), Sei Whale (*Balaenoptera borealis*) and Minke Whale (*Balaenoptera acutorostrata*) were the whale species most commonly encountered during the study. Several rarely-seen species were also recorded, including two species of beaked whale, while exceptional sightings of a single Northern Right Whale (*Eubalaena glacialis*) and a Blue Whale (*Balaenoptera musculus*) occurred several hundred kilometres to the west of Ireland. In addition, there were multiple sightings by independent observers of Striped Dolphin (*Stenella coeruleoalba*) and False Killer Whale (*Pseudorca crassidens*) groups, both of which are generally considered warm-temperate species (Evans, 1980; Leatherwood & Reeves, 1983).

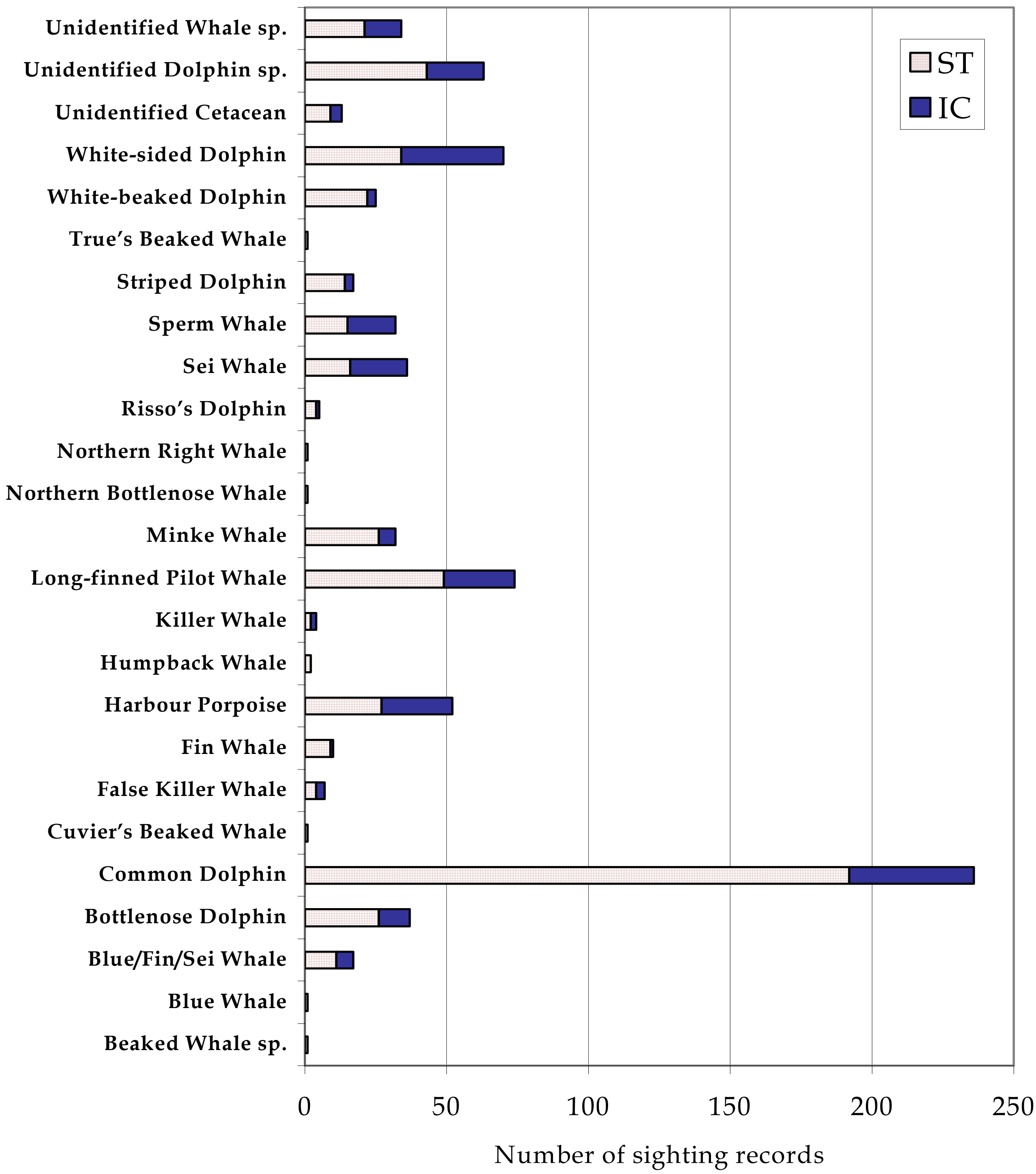

Figure 1.4. Representation of the relative occurrence of cetacean species in the waters of Ireland's Atlantic Margin, from sighting records obtained by CMRC observers on strip-transect (ST) and incidental (IC) surveys between July 1999 and September 2001.

3A. *Mysticetes* (Baleen whales)

Six species of baleen whale were positively identified and recorded by observers during strip-transect surveys conducted between July 1999 and September 2001:

Plate 4. A surfacing adult Fin Whale encountered in August 2000 off western Ireland.

Northern Right Whale *Eubalaena glacialis*

A single Northern Right Whale was recorded on 28 May 2000, in waters approximately 1000m deep, several hundred kilometres to the northwest of Ireland and Britain (Fig. 1.5). The animal was observed in excellent sighting conditions on board the R.V. *Colonel Templer* during a seismic investigation of the Hatton Bank undertaken by the British Geological Survey (Edinburgh). The sighting of a Northern Right Whale was undoubtedly a rare occurrence, considering the present depleted state of the global population (300-350 animals; IWC, 2000) and the scarcity of biological information from this remote region of the North Atlantic. Nevertheless, it is the third record of this species in the eastern North Atlantic in recent years. Lone individuals were recorded (a) on 5 July 1987 during the NASS-87 survey west of Iceland (Sigurjónsson *et al*., 1989) and (b) in Kvaenangen fjord in Norway (69°57' N, 21°38' E) between 17th and 28th September 1999 (Øien *et al*., 2000). The latter individual was subsequently identified as a member of the western Atlantic stock (Harwood & Wilson, 2001).

Although Northern Right Whales were once relatively abundant, centuries of whaling (they were historically seen as the "right" whale to hunt) led to the massive depletion of stocks on both sides of the North Atlantic. Historically, Northern Right Whales ranged throughout eastern North Atlantic, from lower-latitude winter breeding grounds off northwestern Africa to high-latitude summer feeding grounds. During the early 1900s the species was exploited in commercial whaling operations off the west coast of Ireland and Scotland (Burfield, 1912; Thompson, 1928). Such hunting occurred as the animals moved briefly into range on their northward migration between the months of May and July.

The current distribution of the remnants of this whale population is largely concentrated off the eastern coast of North America from Florida to the Bay of Fundy, although occasional records from the Canary Islands and the Atlantic coasts of western Europe exist (Øien *et al*., 2000). Prior to 1999, there were fewer than ten reliable sightings of Northern Right Whales in the eastern North Atlantic in the 50-year period between 1945 and 1995 (Martin & Walker, 1997). Relatively recent sightings occurred off the coast of northern Spain (Aguilar, 1981; Arcos & Mosquera, 1993) and notably, an adult and calf were recorded in February 1995 off southwest Portugal (Martin & Walker, 1997). Although such sightings suggest that small remnants of the eastern Atlantic stock might still exist, it is more likely that such animals are vagrants from the remaining western Atlantic stock (Harwood & Wilson, 2001).

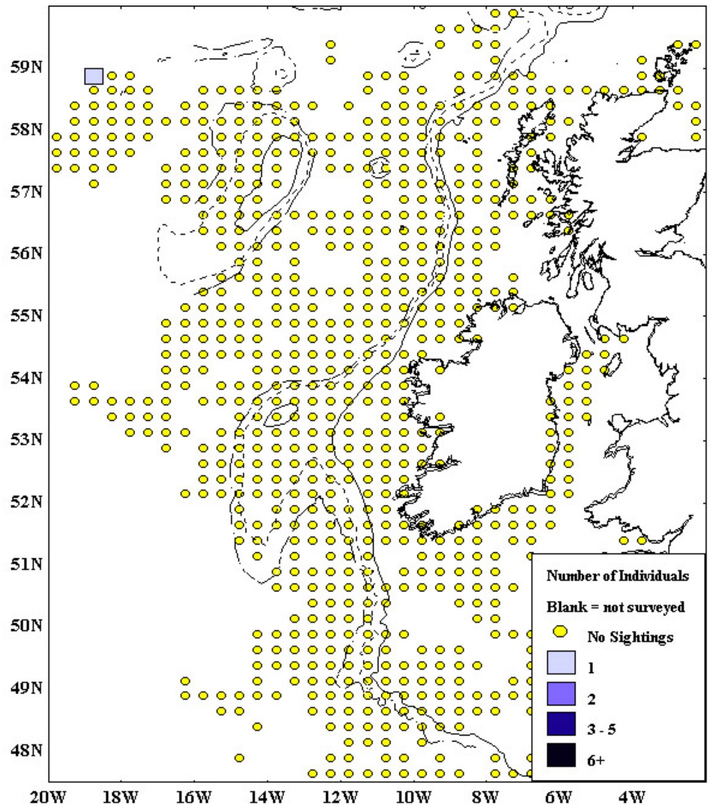

Figure 1.5. Sighting location of a single Northern Right Whale recorded in May 2000 over the Hatton Bank.

Humpback Whale *Megaptera novaeangliae*

A total of four Humpback Whales were recorded during the study in two on-effort sighting encounters. One individual was recorded over the continental slope to the northwest of Ireland (Fig. 1.6), while the remaining three animals were observed outside the study area during a single encounter in the southeastern Bay of Biscay in April 2001.

Humpback Whales are a migratory species believed to range widely throughout the North Atlantic from their winter breeding grounds in the West Indies to feeding areas throughout middle-high latitudes. Although a question remains over the post-whaling fate of an eastern Atlantic breeding stock centred around the Cape Verde archipelago (Reiner *et al.*, 1996), some whales of unknown northern origin migrate there. Photo-identification studies (Stevick *et al.*, 1998) and genetic evidence (Larsen *et al.*, 1993; Palsboll *et al.*, 1997) suggest that whales observed in the eastern North Atlantic are part of the West Indies breeding stock.

Humpback Whales are described as relatively uncommon in the waters north and west of Ireland and Britain (Rogan, 2001) and whaling records suggest their occurrence predominantly in the summer months (Thompson, 1928; Fairley, 1981). The SCANS survey recorded a single animal off Shetland in the summer of 1994 (Hammond *et al.*, 1995). Pollock *et al.* (2000) outline four ESAS records from waters to the north and west of Scotland since 1979, all occurring between the months of May and September. In addition, the species was sighted from UK seismic vessels in the summer months on five occasions in 1996 and 1997 (Stone, 1997; Stone, 1998).

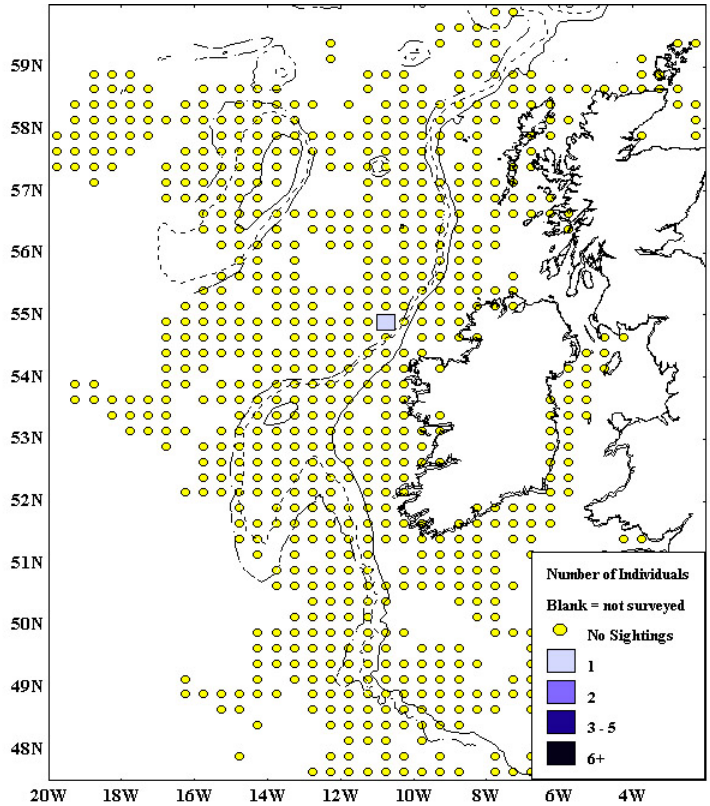

Figure 1.6. Sighting location of a single Humpback Whale off northwest Ireland.

The sighting reported here was made on 3 September 2001, while a previous sighting was made on 3 August 2000 during the *SIAR* survey (*see* Chapter 2). There have also been numerous recent anecdotal and photographic records of the species off southern Ireland in late summer 2001 (S. Fennelly, Irish Whale & Dolphin Group, *pers. comm*). Although a seasonal trend in occurrence may be suggested by these records, care must be taken in the interpretation of sighting data for this species. For example, the results of year-round acoustic monitoring (Clark & Charif, 1998) indicate that vocalising humpbacks move in a southwesterly direction within the Atlantic Margin regions of Ireland and Britain between the months November and March. This information has lead to the suggestion that the offshore waters of the British Isles represent a migratory corridor for Humpback Whales, at least some of which summer in Norwegian (and possibly Icelandic) waters (Charif *et al*., 2001).

Blue Whale *Balaenoptera musculus*

A single Blue Whale was recorded in the deep waters of the Rockall Trough on 30th May 2001 (Fig. 1.7). This adult animal was observed surfacing on two occasions several minutes apart, as it headed in a northward direction across the path of the survey vessel *G.O. Sars*. This sighting was highly significant, since it represents the first visual record of this endangered species in Irish Atlantic Margin waters since the cessation of whaling operations in the region. However, Blue Whales have been recorded acoustically in the region using military sonar systems (Clark & Charif, 1998) and the sparsity of previous sighting records may be partly explained by previously low survey coverage in the offshore waters of Ireland's Atlantic Margin.

It is estimated that the current North Atlantic population of Blue Whales numbers in the hundreds (Leatherwood & Reeves, 1983). In spite of considerable survey effort undertaken in western European waters in recent years (Sigurjónsson *et al*., 1989; Hammond *et al*., 1995; Murray & Simmonds, 1998; Pollock *et al*., 2000), few sightings of Blue Whales have been recorded in the scientific literature. Consequently, information on the distribution of Blue Whales in the Atlantic Margin is relatively scarce and there is some uncertainty with respect to the species' migratory pathways (Harwood & Wilson, 2001).

Recent acoustic monitoring indicates that individuals of this deepwater species may occur within Ireland's Atlantic Margin primarily between the months of October and January (Clark & Charif, 1998), although individual detections have been made in all months of the year. This contrasts with available sighting and whaling records, which suggest a peak in Blue Whale occurrence off Ireland and Britain between July and September (Thompson, 1928; Fairley, 1981; Stone, 1997). However the discrepancy between both scenarios may be partly explained by vastly improved sighting conditions, and hence survey effort, in the summer months.

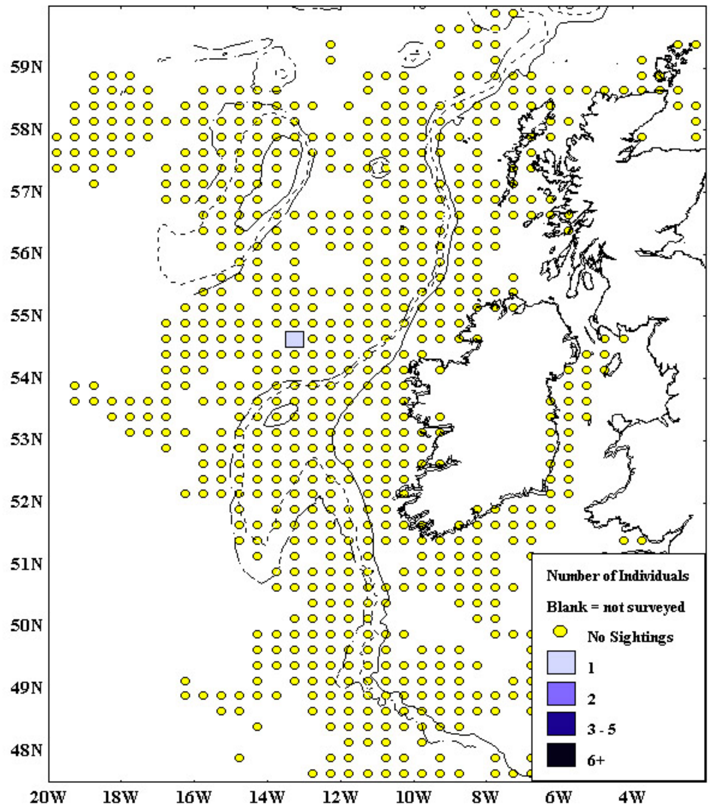

Figure 1.7. Sighting location of a single adult Blue Whale in the Rockall Trough, May 2001.

Fin Whale *Balaenoptera physalus*

A total of sixteen Fin Whales (Plate 4) were recorded on one incidental and nine on-effort sighting encounters between July 1999 and October 2001. The species was recorded throughout Atlantic Margin waters (Fig. 1.8) from the offshore Hatton Bank and Rockall Bank to the Porcupine Seabight and inshore coastal waters of southern Ireland, from which numerous verifiable sightings were also reported in 2000 and 2001 (Irish Whale & Dolphin Group, *unpublished data*). No sightings were recorded in the Rockall Trough or waters off northwestern Ireland, where the species was previously hunted. Groups of up to four animals were recorded at sea during the study and immature animals were recorded in association with adult Fin Whales on three separate occasions.

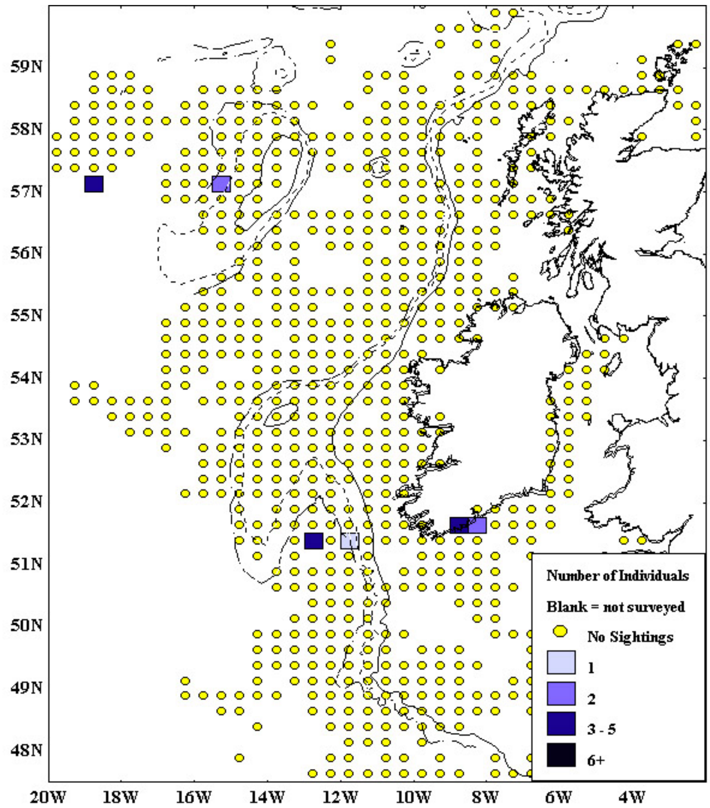

Figure 1.8. Sighting distribution and total numbers of Fin Whales observed between July 1999 and September 2001.

In spite of a history of exploitation, Fin Whales are thought to be relatively common in the eastern North Atlantic (Harwood & Wilson, 2001). During Ireland's whaling past, the species was the most frequently captured whale off the northwest coast, accounting for 66% of all landings (Gordon *et al*., 1999). Catches of Fin Whales occurred predominantly in the summer months (Hamilton, 1914; Fairley, 1981). Records from Scottish whaling stations show that most Fin Whales were caught in waters > 200m deep during the months of May to August; smaller numbers were taken in April, September and October (Thompson, 1928). This seasonal trend in species occurrence, although tentative, is also supported by ESAS sighting records from the waters of northwestern Britain and Ireland (Pollock *et al*., 1997; Pollock *et al*., 2001). The species was also recorded in summer on dedicated cetacean surveys to the north and west of Britain (Sigurjónsson *et al*., 1989; Hammond *et al*., 1995; Murray & Simmonds, 1998). In contrast, analyses of acoustic data (Clark & Charif, 1998) show that the species may be detected in western Irish and Scottish offshore waters throughout the year with higher detection rates from October to mid-December.

Although the annual movements of this large species are poorly understood, it has been suggested that the continental shelf may form an important migration guide for Fin Whales, as animals move between high latitude summer feeding grounds and their low latitude wintering grounds (Evans, 1987). While the species generally appears to be distributed in offshore waters of ≥ 1000m depth, animals may also be found closer to shore. Fin Whales were once hunted in continental shelf waters off Iceland (Sigurjónsson, 1995) and there is considerable evidence from recent Irish stranding (S. Murphy, University College Cork, *pers. comm.*) and land-based sighting data (P. Whooley, Irish Whale & Dolphin Group, *pers. comm.*) that Fin Whales may occur inshore off the south coast through the summer months and from late winter onwards. It is not known what environmental or behavioural factors influence the distribution of Fin Whales off southern Ireland. However, the waters of southwest Ireland demonstrate relatively high seasonal levels of primary productivity (Raine *et al*., 1990) and it is likely that this feature plays a role in the provision of prey concentrations for Fin Whales in the region.

Sei Whale *Balaenoptera borealis*

A total of forty-three Sei Whales were recorded among thirty-six encounters between July 1999 and September 2001; 16 records occurred while on-effort and twenty while off-effort. Generally considered to be a deepwater, pelagic species, sightings were also recorded throughout the Irish Atlantic Margin in continental slope and shelf habitats (Fig. 1.9).

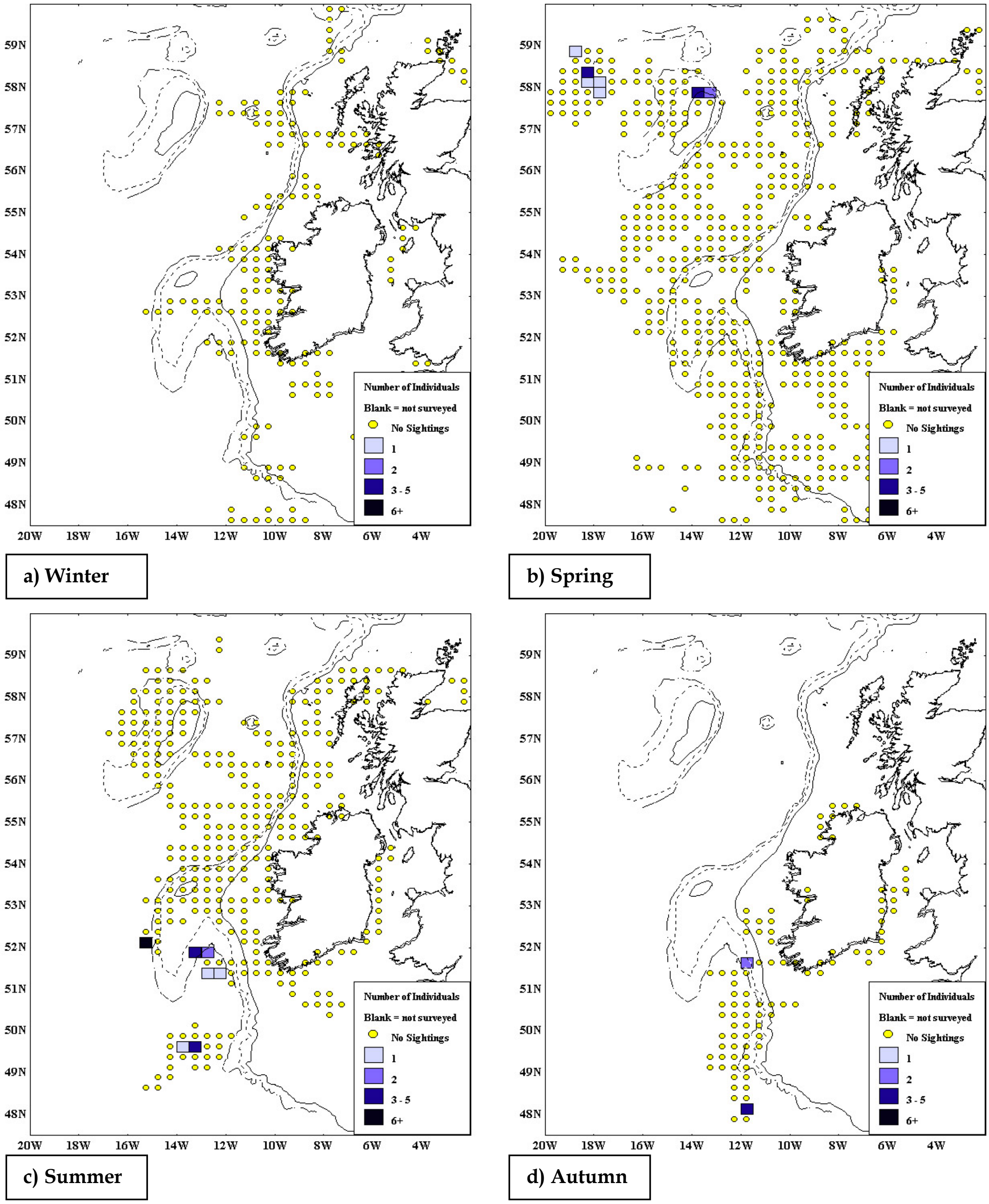

Figure 1.9. Seasonal sighting distribution and total numbers of Sei Whales observed between July 1999 and September 2001.

As with Fin Whales, no sightings were recorded in the Rockall Trough or waters off northwestern Ireland. The data suggest that this species occupies a more northerly distribution in Irish Atlantic Margin waters between April and June and a more southerly distribution in late summer and autumn. Group sizes of up to five individuals were recorded and a concentration of sightings occurred in waters overlying the Hatton Bank between 20th May and 20th June 2000.

The large-scale migrations and distribution of Sei Whales in the eastern North Atlantic are not fully understood. It is believed that Sei Whales move northward through Irish and UK waters in spring, returning southwards in autumn to winter grounds off the western Iberian Peninsula and North Africa (Harwood & Wilson, 2001). Whaling records from Icelandic and Norwegian waters describe how numbers of the species may be highly variable, occasionally reaching large regional aggregations, once termed "invasions" by whalers (Christensen *et al*., 1992). Thompson (1928) also reported a large variation in the inter-annual catches of Sei Whales in Scottish whaling operations, suggesting that in some years the species was absent from whaling grounds off northwestern Scotland. Catches were generally made from April to October with an annual peak in June. This seasonal trend is apparent in data from the whaling stations in Ireland, which suggest that the species was more common in the months of May and June (Fairley, 1981). More recently, Sei Whales have been recorded relatively frequently southwest of Iceland (Sigurjónsson *et al*., 1989) and in the months of July and August in deep waters to the north and west of Scotland (Murray & Simmonds, 1998; Pollock *et al*., 2000).

Blue/Fin/Sei whale (*undifferentiated*)

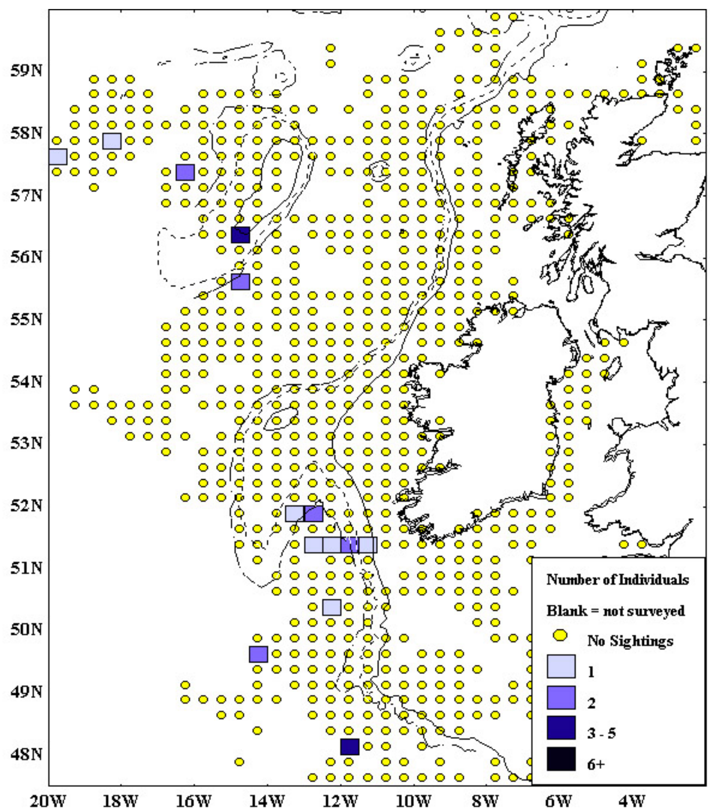

Figure 1.10. Sighting distribution and total numbers of unidentified Blue/Fin/Sei whales observed between July 1999 and September 2001.

Observers recorded a total of twenty-four large baleen whales that could not be confidently identified to species level. Nevertheless, these animals could be distinguished as larger *Balaenoptera* species, using a variety of cues (e.g. characteristic body features, surfacing behaviour, blow characteristics, blow intervals). In such cases, the above species grouping was applied. A total of seventeen sightings of Blue/Fin/Sei whales were recorded during the study. These records were distributed far offshore in the vicinity of the Rockall Bank and Hatton Bank and in deep or continental slope and oceanic waters southwest of Ireland (Fig. 1.10).

- -

Minke Whale *Balaenoptera acutorostrata*

Thirty-six Minke Whales (Plate 5), including four immature individuals and four calves were recorded on surveys conducted between July 1999 and October 2001. Most of these animals were sighted singly during observers' full survey effort (26 records), although six incidental sightings of the species were also recorded.

Minke Whale sightings were distributed throughout the Irish Atlantic Margin, stretching from the offshore Rockall Bank to continental slope and shelf waters (Fig. 1.11). All but one animal were recorded in waters less than 800m deep. Several sightings were recorded in southwestern Irish and western Scottish coastal waters both areas of which may be favoured by the species in late spring and summer (Northridge *et al*., 1995; Pollock *et al*., 1997).

Plate 5. An adult Minke Whale surfacing beside a stationary research vessel. Note the white colouration on the pectoral fins and sharp pointed jawline, both characteristic of this species.

Minke Whales were generally not exploited by the whaling industry until recently and consequently historical information on the species is relatively sparse. ESAS data and records collected in UK waters between 1979 and 1990, from vessels of opportunity and dedicated inshore surveys, suggest that the species moves southwards to inshore UK Atlantic Margin waters in spring and summer, remaining until late autumn when numbers decline sharply (Northridge *et al*., 1995; Pollock *et al*., 2000). Recent surveys off northwest Ireland have also noted sightings of the species in early summer (Gordon *et al*., 1999) and between the months of April and October (Coastal & Marine Resources Centre, 2001/2002, *unpublished data*). The 1994 SCANS survey recorded comparatively high densities of the species in the northern Celtic Sea in summer with concentrations off Ireland's southern and southwestern coasts (Hammond *et al.*, 1995). A population estimate of 1,195 Minke Whales (Coefficient of Variation = 0.49) was subsequently derived for the Celtic Sea from SCANS sighting data (Hammond *et al.*, 2002). However, annual abundance and distribution patterns for the species in the Irish Atlantic Margin remain poorly understood.

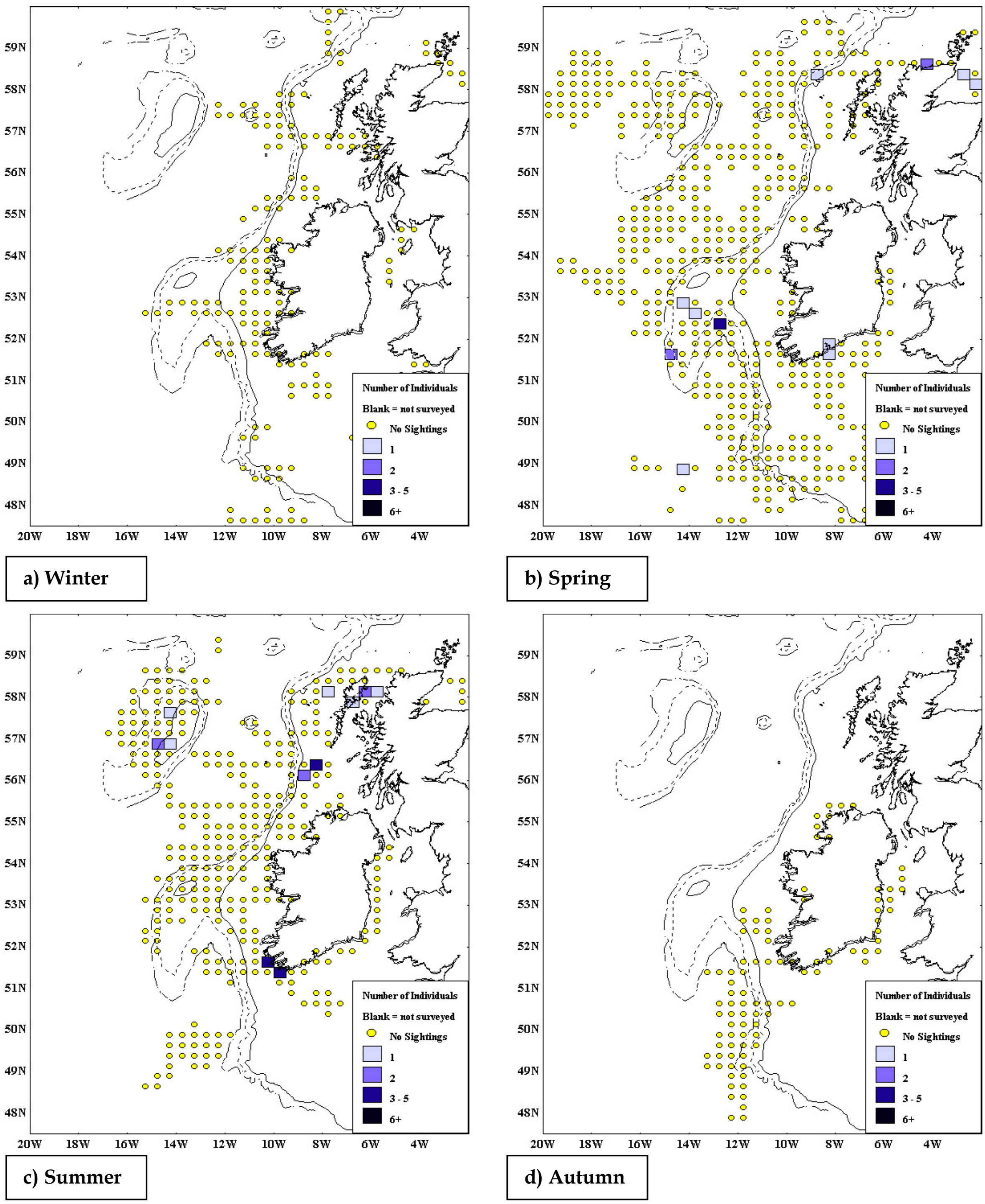

Figure 1.11. Seasonal sighting distribution and total numbers of Minke Whales observed between July 1999 and September 2001.

3B. *Odontocetes* (Toothed whales, dolphins & porpoises)

Fourteen species of toothed cetacean were positively identified during surveys between July 1999 and September 2001; they include larger species (e.g. Sperm Whale, beaked whales) and various members of the Family *Delphinidae* (i.e. dolphins).

Plate 6. An adult Sperm Whale resting at the surface in deep waters off the continental slope. Note the forward-pointing, bushy blow and small hump-like dorsal fin characteristic of the species.

Sperm Whale *Physeter macrocephalus*

Sperm Whales (*see* cover, Plate 6) were one of the most frequently recorded large whale species during the study, a feature that may be partly explained by the comparative ease with which the species is identified in the field. A total of 56 animals, including five immature individuals and three calves, were recorded on visual surveys. Sperm Whales were recorded with greater frequency during surveys between the months of April and June (Fig. 1.12). Sightings in the Irish Atlantic Margin were generally distributed in waters >1000m depth; the Rockall Trough appeared to be seasonally important for the species. More than 50% (n = 17) of sightings were recorded during incidental surveys and group sizes of two to four animals were commonly observed during the study. An interesting cluster of sightings was recorded over the Hatton Bank in May-June 2000, during which period animals were recorded in waters <800m depth. The Hatton Bank records included a pair of adults observed with an immature animal (3rd June) and a lone immature animal observed on 10th June.

Sperm Whales are primarily squid feeders and, like many of the larger whale species, were generally hunted in waters off Ireland and Britain between the months of June and August, as male members of the species migrated northwards from low latitude winter grounds (Thompson, 1928; Fairley, 1981). However, stranding records from Ireland (Rogan & Berrow, 1997) suggest that male Sperm Whales may be present in the Irish Atlantic Margin throughout the year. In view of increased strandings in Britain and Ireland, Berrow *et al.* (1993) suggested that numbers of the species in Atlantic Margin waters may be increasing since the cessation of commercial whaling. However, historical information from Irish offshore waters was sparse prior to the present study, while voluntary sighting schemes (e.g. Berrow *et al.*, 2001) and incidental records have possibly been too coastal in nature to detect this deep-water species.

The frequency with which Sperm Whales were detected in the present study on both visual (*see also* Chapter 2) and acoustic surveys (*see* Vol. III) certainly indicate that the waters of Ireland's Atlantic Margin provide important habitats for Sperm Whales in spring and early summer.

During this time of year, Sperm Whales were recorded in deeper offshore waters in addition to the Hatton-Rockall region. However, poor coverage in the present study during the autumn and winter months prevents interpretation of year-round abundance patterns. Studies elsewhere in the Atlantic Margin (e.g. Hammond *et al*., 1995; Murray & Simmonds, 1998; Pollock *et al*., 2000) indicate that the deep waters of the Faroe-Shetland region may also be seasonally important for the species.

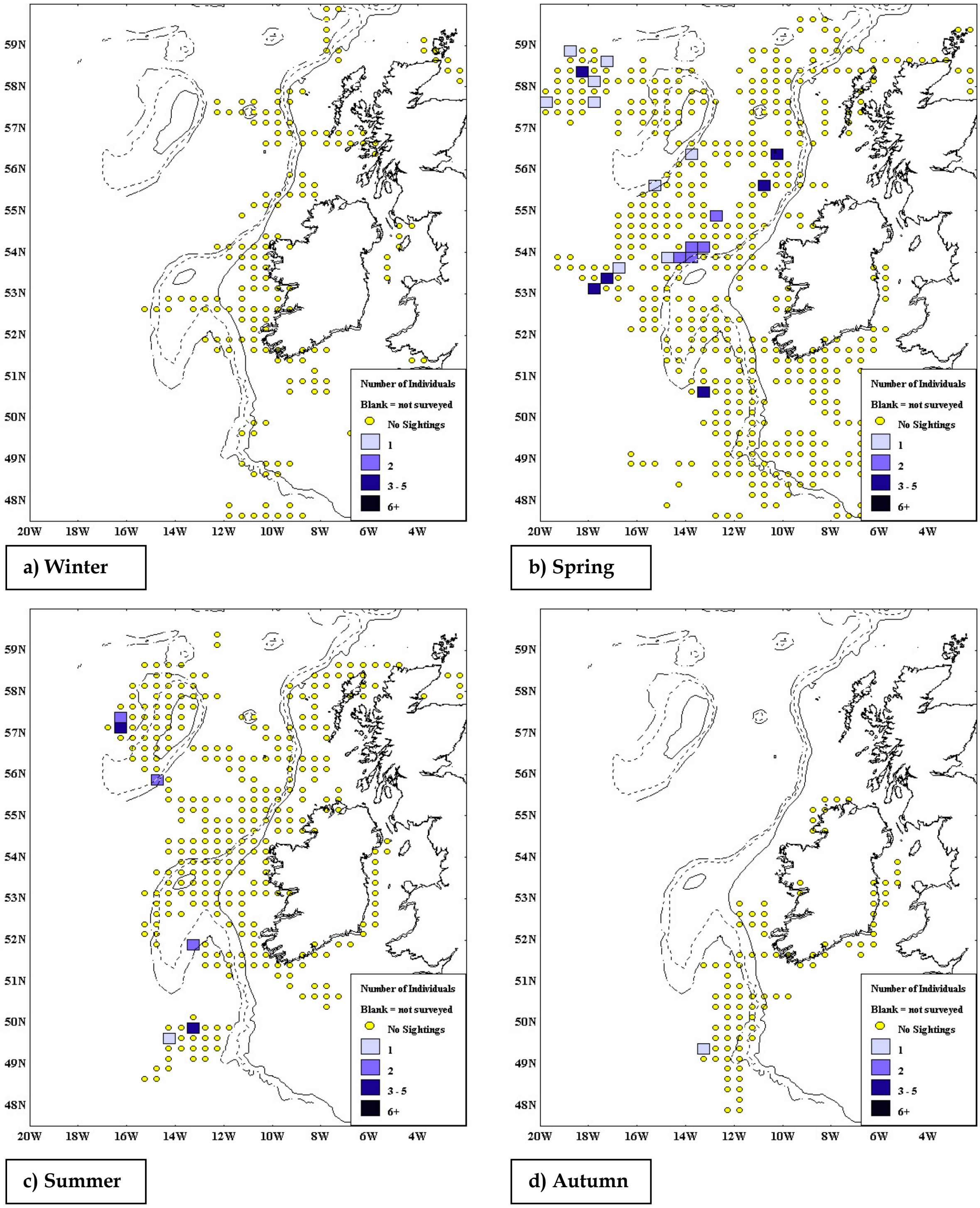

Figure 1.12. Seasonal sighting distribution and total numbers of Sperm Whales observed between July 1999 and September 2001.

Sighting records in the present study of young Sperm Whales in Atlantic Margin waters is noteworthy, since calves and adult females are usually restricted in distribution to tropical and subtropical waters. However, the live-stranding of a lone Sperm Whale calf (female) in southern Ireland in June 1995 (Berrow & Rogan, 1997), and observations in the present study, indicate that younger animals may also inhabit Irish Atlantic Margin waters on occasion.

Northern Bottlenose Whale *Hyperoodon ampullatus*

A pair of adult Northern Bottlenose Whales was observed at close range (< 200m from vessel) on 18th August 2001 in waters overlying the Hatton-Rockall Basin (Fig. 1.13). This record was the only definitive sighting of the species during surveys on vessels of opportunity, although two further Northern Bottlenose Whale sightings were obtained on 3rd August and 16th August 2000 during the *SIAR* survey (*see* Chapter 2).

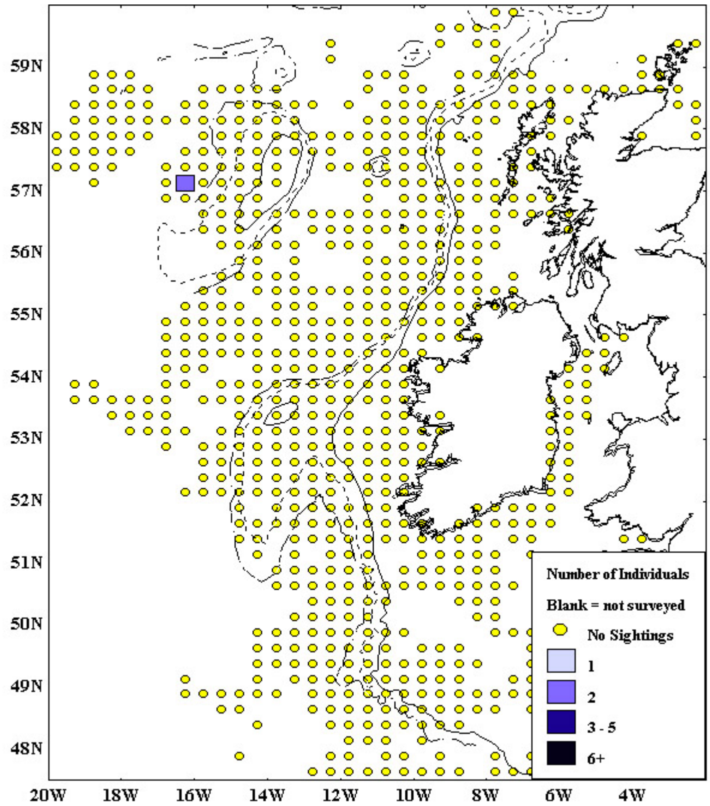

Figure 1.13. Sighting location of two adult Northern Bottlenose Whales in waters overlying the Hatton-Rockall Basin, August 2001.

Northern Bottlenose Whales are members of the beaked whale family (*Ziphiidae*), many members of which are poorly described to science and difficult to identify in the field. This species is thought to range throughout the North Atlantic from subtropical to polar waters, where it may occur in small local populations, feeding predominantly on squid of the genus *Gonatus* (Benjaminsen & Christensen, 1979; Lick & Piatkowski, 1998; Hooker *et al*., 2001). Northern Bottlenose Whales were once hunted in the North Atlantic and such operations saw both opportunistic and directed removal of over 40,000 animals in the eastern North Atlantic (Harwood & Wilson, 2001) over a century or more until ca. 1973. The current population status of Northern Bottlenose Whales in the northeast Atlantic is not known. In spite of significant cetacean survey efforts undertaken in Atlantic Margin waters in recent years (Sigurjónsson *et al*., 1989; Hammond *et al*., 1995; Murray & Simmonds, 1998; Pollock *et al*., 2000) there have been few sightings of Northern Bottlenose Whales recorded in the literature. A number of sightings of this species were recorded in UK Atlantic Margin waters during the NASS-87 survey

(Sigurjónsson *et al*., 1989). Pollock *et al*. (2000) describe seven sightings of the species in these waters since 1979, all of which occurred in waters exceeding 1000m depth.

Stranding and sighting records from Ireland (Fairley, 1981; Berrow & Rogan, 1997) indicate that Northern Bottlenose Whales show a predominant occurrence in Atlantic Margin waters in late summer and autumn and may occasionally move into continental shelf waters and the Irish Sea (Evans, 1980). Records in the present study and distribution data from waters to the northwest of Britain (Thompson, 1928; Pollock *et al*., 2000; Harwood & Wilson, 2001) are in broad agreement with this hypothesis. It is thought that this apparent seasonal pattern in occurrence in Atlantic Margin waters represents a southward movement of animals following a spring and early summer distribution in northern latitudes (Harwood & Wilson, 2001). Further study may determine if this is the case, yet a large information gap still exists concerning the distribution of this species outside the summer months.

Cuvier's Beaked Whale *Ziphius cavirostris*
A single adult Cuvier's Beaked Whale was observed at close range on 25th August 2001 in continental slope waters overlying the western margin of the Porcupine Seabight (Fig. 1.14). This record was the only definitive sighting of the species during surveys on vessels of opportunity, although sightings of groups of this species were obtained during the *SIAR* survey, on 9th August 2000 and 17th August 2000 respectively (*see* Chapter 2). These latter records represent the first definitive live sightings of the species in Irish waters.

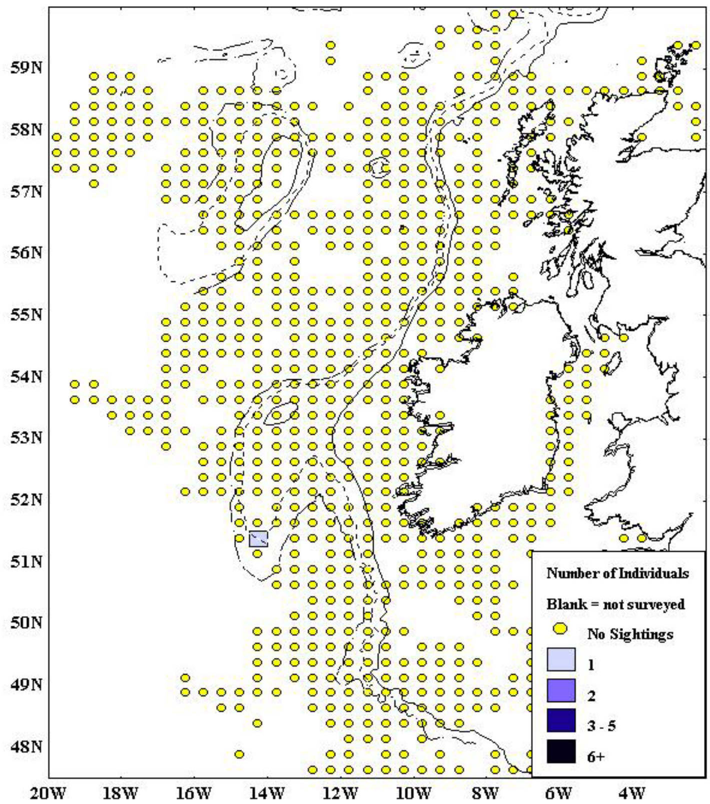

Figure 1.14. Sighting location of an adult Cuvier's Beaked Whale over the western margin of the Porcupine Seabight, August 2001.

Cuvier's Beaked Whales are one of three (and up to five) members of the beaked whale family (*Ziphiidae*) thought to frequent the Atlantic Margin waters of Ireland and Britain. Although rarely seen in UK waters (Harwood & Wilson, 2001), the species was the most commonly recorded beaked whale in Irish stranding records from 1901 to 1995 (Berrow & Rogan, 1997) with a total of 21 records, 86% of which occurred along the western seaboard. Prior to the present study, cetacean surveys undertaken to the north and west of Ireland and Britain (Sigurjónsson *et al*., 1989; Hammond *et al*., 1995; Pollock *et al*., 1997; Murray & Simmonds, 1998; Pollock *et al*., 2000) did not definitively record Cuvier's Beaked Whales. In contrast, Sowerby's Beaked Whales (*Mesoplodon bidens*) have been recorded in Atlantic Margin waters on a number of occasions (MacLeod, 2000; Pollock *et al*., 2000), in addition to the present study during the *SIAR* survey (*see* Chapter 2).

Cuvier's Beaked Whales were recorded on numerous occasions in the summer of 1998 and 1999 in the Bay of Biscay (Carlisle *et al*., 2001). While such findings may indicate that Cuvier's Beaked Whales occupy a more southerly distribution along the Atlantic Margin than that of Sowerby's Beaked Whales, the offshore distribution of many beaked whale species, poor knowledge of their relative population status and inherent difficulties in identifying beaked whales at sea (Coles, 2001) make such interpretation difficult at this stage. Nevertheless, sightings in the present study certainly indicate that areas of the Irish Atlantic Margin represent seasonally important habitats for a number of beaked whale species. This is supported by stranding records for five beaked whale species from the Irish coastline in the last century (Berrow & Rogan, 1997).

True's Beaked Whale *Mesoplodon mirus*

On 31st May 2001 a lone cetacean, measuring approximately 3.0m in length was observed breaching repeatedly at a distance of approximately 800m from a slow-moving research vessel. The sighting took place in waters approximately 2,070m deep over the southeastern margin of the Rockall Trough (Fig. 1.16). Resembling an adult Bottlenose Dolphin in body length, colouration and body profile, the animal breached a total of three times in full view of the observer, rotating slightly each time to land on its right flank, before disappearing. Less than 10 seconds later, three to four larger animals began breaching consecutively in the same location, whereupon the observer continued to watch the group with the aid of LEICA 10x42 binoculars as the vessel approached. These latter individuals were of the same species as the first animal but were estimated by eye to measure approximately 5.0-6.0m in length. They were obviously beaked whales, due to various diagnostic features including the position of the dorsal fin towards the rear of the body, the head profile, body size, etc. A total of eleven further breaches were observed from a distance ≥500m before the group disappeared beneath the surface. All but one breach involved lone individuals, a single breach being performed simultaneously by two adult-sized animals.

Given the obvious rarity of the sighting, detailed field notes were made immediately after the encounter. The experienced observer, familiar with both Cuvier's and Sowerby's Beaked Whales in the field, noted the presence of a distinctive melon-shaped head profile with a curving jaw-line, both closely resembling that of a Bottlenose Dolphin. The dorsal fin, positioned two-thirds along the body length, was relatively small and falcate, reminiscent of the dorsal fin of a Minke Whale. The beak, though obvious in all animals, was markedly shorter and "stubbier" relative to head size, than that of Sowerby's Beaked Whales. The body form had a somewhat stocky appearance, particularly in the pectoral-thoracic region. The dorsal surface and narrow pectoral fins were mid-grey in colour while the ventral surface was pale grey to white, again resembling the colouration of Bottlenose Dolphins. No obvious scarring was observed on the body surface of individual animals nor were the presence of prominent teeth or an eye patch observed, in spite of the use of excellent binoculars during the observation. However, the latter features may have been missed due to the unpredictability and speed with which the animals were moving into the air. The aerial behaviour of all animals was noticeably agile, resembling that of larger dolphin species more so than that of baleen whales. On careful consultation with the available scientific literature (e.g. Tove, 1995; MacLeod, 2000) and identification guides (e.g. Coles, 2001), photographic records from Irish strandings and new sighting records (Walker & Diamond, 2001), and by a process of elimination, it is confidently considered that the species seen was the True's Beaked Whale. This sighting would represent the first recorded live sighting of this rare species in Irish waters.

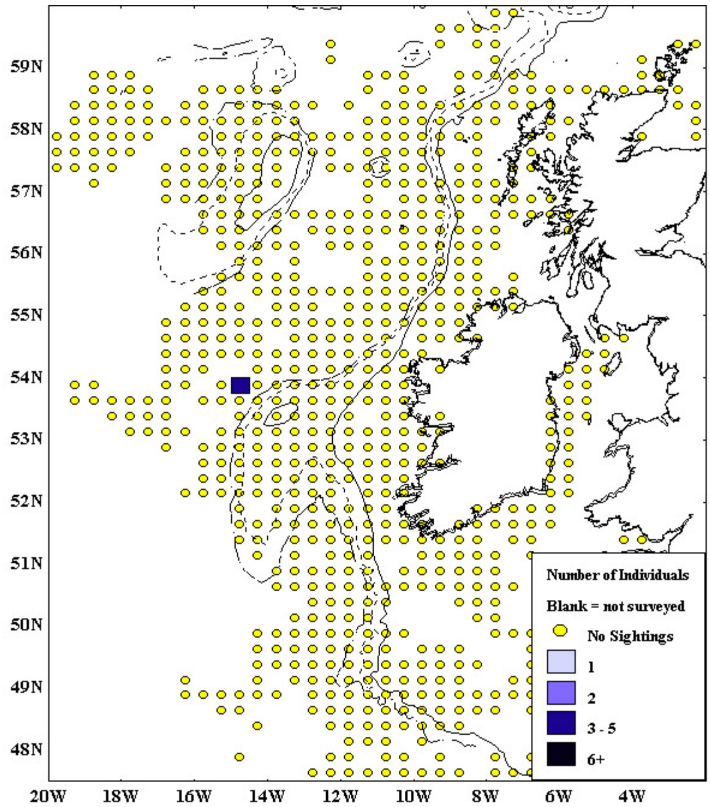

Figure 1.15. Sighting location of a group of animals identified as True's Beaked Whales, 31 May 2001.

Little is known about the natural history, population status, distribution or behaviour of this species and there have been few confirmed sightings in recent history. Possibly the best recent sighting of a live True's Beaked Whale in the North Atlantic occurred in the Bay of Biscay on 9th July 2001 (Walker & Diamond, 2001), when the observers obtained photographs of a lone breaching animal. Unfortunately a photographic record was not possible in the present encounter, due to the observer's focus on collecting as much visual data as possible in the short time available. It is noteworthy, however, that there are many parallels in the various cues and diagnostic features observed in both encounters, though these were made independently of one another. Most striking perhaps was the resemblance noted in both records to "oversized" Bottlenose Dolphins, in terms of general body proportions (with the exception of the position of the dorsal fin), head and beak shape and colouration.

True's Beaked Whales are generally believed to be a relatively rare, temperate-water species preferring deep-water habitats (Mead, 1989). Nevertheless, strandings of individual True's Beaked Whales have historically occurred in Ireland (Berrow & Rogan, 1997); a total of six events were recorded between 1917 and 1995, predominantly on southwestern and northwestern coasts. In fact, nine out of ten True's Beaked Whale strandings in Europe since 1899 occurred along the west coast of Ireland (Evans, 1998). Elsewhere around the North Atlantic, strandings have been recorded from the east coast of the USA to southwestern France and northwestern Britain (Fairley, 1981). These data and recent sightings indicate that the species may occur year-round in the Irish Atlantic Margin.

Killer Whale *Orcinus orca*

Three groups of Killer Whales (*a.k.a.* "orca", Plate 7) were recorded at sea during the study period (Fig. 1.16). The first sighting record was obtained incidentally during a seismic survey on 7th June 2000, in waters approximately 1000m deep along the northwestern edge of the Hatton Bank. The group consisted of six animals: two large adult males, an adult female, a mother-calf pair and an immature animal. The group approached the slow-moving survey vessel and, although most animals maintained a distance of >400m from the vessel while passing across its bow, a lone adult male appeared to direct its attention towards the active air-gun array trailing at the stern, turning toward the rear and approaching within 100m of the array.

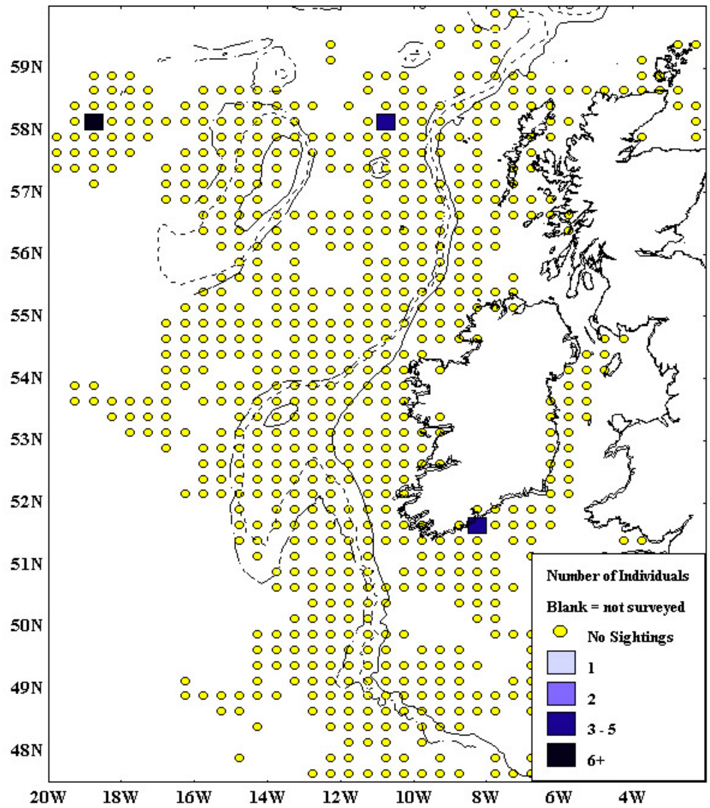

Figure 1.16. Sighting distribution and total numbers of Killer Whales observed between July 1999 and September 2001.

Further sightings of Killer Whales involved two groups of three animals, one in waters >2000m deep, the second outside Cork Harbour. The latter group, consisting of an adult male, an adult female and an immature animal, entered the harbour on 6 June 2001 and maintained a presence in the area for several weeks. The adult female died during this period, as a result of acute septicaemia (S. Murphy, University College Cork, *pers. comm.*). The remaining two individuals remained in the area until early September 2001 before returning to Celtic Sea waters.

An estimated 10,000-15,000 Killer Whales are thought to inhabit eastern North Atlantic waters (Øien, 2000), and the species appears to be continuously distributed from Iceland-Norway to the Atlantic Margin waters of northwestern Britain and Ireland (Hammond & Lockyer, 1988). All recent cetacean investigations in Atlantic Margin waters (Hammond *et al.*, 1995; Pollock *et al.*, 1997; Murray & Simmonds, 1998; Pollock *et al.*, 2000) have recorded sightings of the species, predominantly in waters overlying the continental shelf and slope (<1000m depth). Killer Whales do not regularly strand in Ireland (Berrow & Rogan, 1997) and all documented stranding records of the species have occurred on the north, west and south coasts. In a review of sightings from Ireland and Britain, Evans (1988) also documented records of Killer Whales from offshore Atlantic Margin waters and determined that there was little evidence of change in the population status of the species since the 1960s.

Plate 7. A surfacing male Killer Whale showing its distinctive tall dorsal fin and grey "saddle-patch" (to the rear of the dorsal fin), which are used in identifying individual Killer Whales. The species' distinctive white eye-patch can also be seen.

Seasonal changes in the regional occurrence of Killer Whales appear to be commonly recorded throughout the eastern North Atlantic (Harwood & Wilson, 2001), underlining the comparatively wide-ranging nature of this member of the dolphin family *Delphinidae*. There is some suggestion from sighting records (e.g. Fairley, 1981; Evans, 1988; Hammond *et al*., 1995) that Killer Whales may predominantly occur in Irish Atlantic Margin waters between spring and autumn. Records compiled from voluntary sighting schemes (e.g. Evans, 1988; Berrow *et al*., 2001; Coastal & Marine Resources Centre, 2002, *unpublished data*) tentatively suggest the species' annual presence in southern and western Irish coastal waters and in the Celtic Sea between the months of July and October. Although records suggest an offshore movement of the species in winter (Evans, 1988), spatial and seasonal variation in survey effort make the species' true distribution patterns in Atlantic Margin waters difficult to determine at this stage.

False Killer Whale *Pseudorca crassidens*

Seven groups of False Killer Whales were recorded offshore between July 1999 and September 2001. These sightings took place exclusively in deep waters of the Porcupine Seabight/Goban Spur region or overlying the northern margins of the Rockall and Hatton Banks at depths >720m (Fig. 1.17). Six of the sightings occurred in 2000. All but one record were made in June or early July. The southernmost sighting occurred in November 2000, approximately 150 km northwest of the Goban Spur.

Particular care was taken in confirming the species identification of False Killer Whales, since these sightings constitute the first live record of the species in Irish waters. Although several sighting records of animals collectively referred to as "blackfish" (i.e. Killer/False Killer/Pilot whale) were made by all observers during the study, many could not be confidently identified to species level and they were thus assigned a suitable "unidentified cetacean" category. It is likely that identification of the seven False Killer Whales groups to species level was assisted by the observers' previous experience of seeing these animals in the field. Identification was confirmed in all cases using 10x42 or 7x50 binoculars and upon consulting suitable illustrated literature (e.g. Leatherwood & Reeves, 1983). Characteristic features, which acted as aids in identification, included the distinctive size and shape of the dorsal fin, body dimensions, the shape of the head, body colouration, and behaviour.

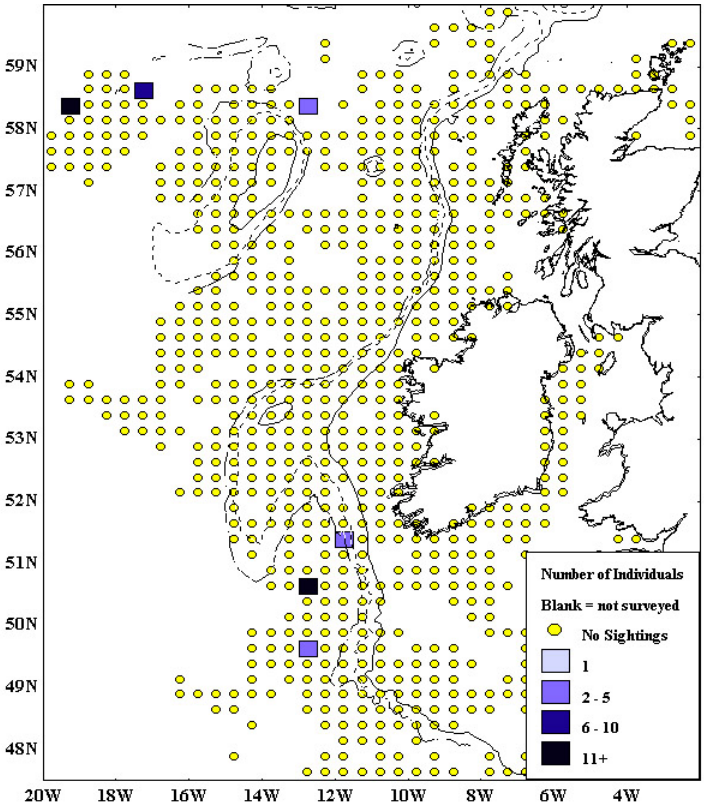

Figure 1.17. Sighting distribution and total numbers of False Killer Whales observed between July 1999 and September 2001.

Although False Killer Whales were generally observed in solitary groups of two to seven animals, one group recorded in the Hatton Bank region on 15th June 2000 consisted of five adults and an immature animal. This sighting record also included nearby groups of Long-finned Pilot Whales, White-sided Dolphins and Common Dolphins. This multi-species encounter appeared to be a foraging event, with the False Killer Whale group and subgroups of both dolphin species separately performing surface-rushes, rapid direction changes and breaches in the apparent pursuit of pelagic prey over a horizontal distance of 1.5-2.0 km.

The dolphin-like, racy nature of False Killer Whale behaviour, well-described for the species (Leatherwood & Reeves, 1983; Acevedo-Gutiérrez *et al*., 1997), was clearly observed during several encounters at sea, as individual animals leapt acrobatically clear of the water, often rotating in mid-air before landing on their sides or dorsal surfaces. In contrast, a single group recorded on 10th June 2001 in waters of the Porcupine Seabight consisted of a group of fifteen animals in very tight formation, with animals breathing repetitively while lying at the surface, producing small energetic vapour-like blows. This group, first observed in calm seas at a distance of almost 10 km ahead of the approaching survey vessel, remained slow-moving, occasionally performing synchronised shallow dives of 15-20 seconds' duration over a period of 22 minutes before becoming more active as the vessel passed by. Potentially confused at a distance with Long-finned Pilot Whales, this group was positively identified when the animals were perpendicular to the vessel. In addition, a number of individuals breached clear of the surface, clearly showing the characteristic blunt head profile and other key features with which they could be identified.

False Killer Whales are described as having a warm-temperate or tropical oceanic distribution (Leatherwood & Reeves, 1983) and are thought to be opportunistic predators, consuming a wide range of prey types from squid and fish species to other cetaceans (Stacey & Baird, 1991). Little is known of their population status or natural history throughout the North Atlantic. A possible, yet unconfirmed, stranding record has been postulated from northwest Ireland (Fairley, 1981; Berrow & Rogan, 1997). In contrast, 75 strandings of False Killer Whales were reported to occur on the British coastline between 1927 and 1935 (Fraser, 1974). Sixty-seven of these occurred along the North Sea coastline in 1935. It is not clear why such an unusual collection of events occurred in the region, nor why further strandings of False Killer Whales in the eastern North Atlantic are relatively scarce. Although the species may prey on other cetaceans, groups of False Killer Whales have also been previously observed in multi-species groups (Scott & Chivers, 1990), as documented in the present study.

Long-finned Pilot Whale *Globicephala melas*

Long-finned Pilot Whales (Plate 8) constituted the most commonly recorded of the larger odontocete species. An estimated total of 686 individuals were encountered during the study in 49 strip-transect and 25 incidental sightings (Table 1.1). These included significant numbers of immature individuals and calves recorded in association with adults.

Plate 8. A pair of adult Long-finned Pilot Whales encountered in the deep waters of the Rockall Trough, June 2000.

Records of this species were distributed throughout the Irish Atlantic Margin (Fig. 1.18) with additional records from the westernmost Hatton and Rockall Banks. Long-finned Pilot Whales were predominantly recorded in waters exceeding 1000m depth, between the months of April and September. However, reduced survey coverage in autumn and winter do not permit effective interpretation of true seasonal distribution patterns. Yet it is noteworthy that, in spite of poorer survey effort, limited sightings of the species also occurred in these seasons.

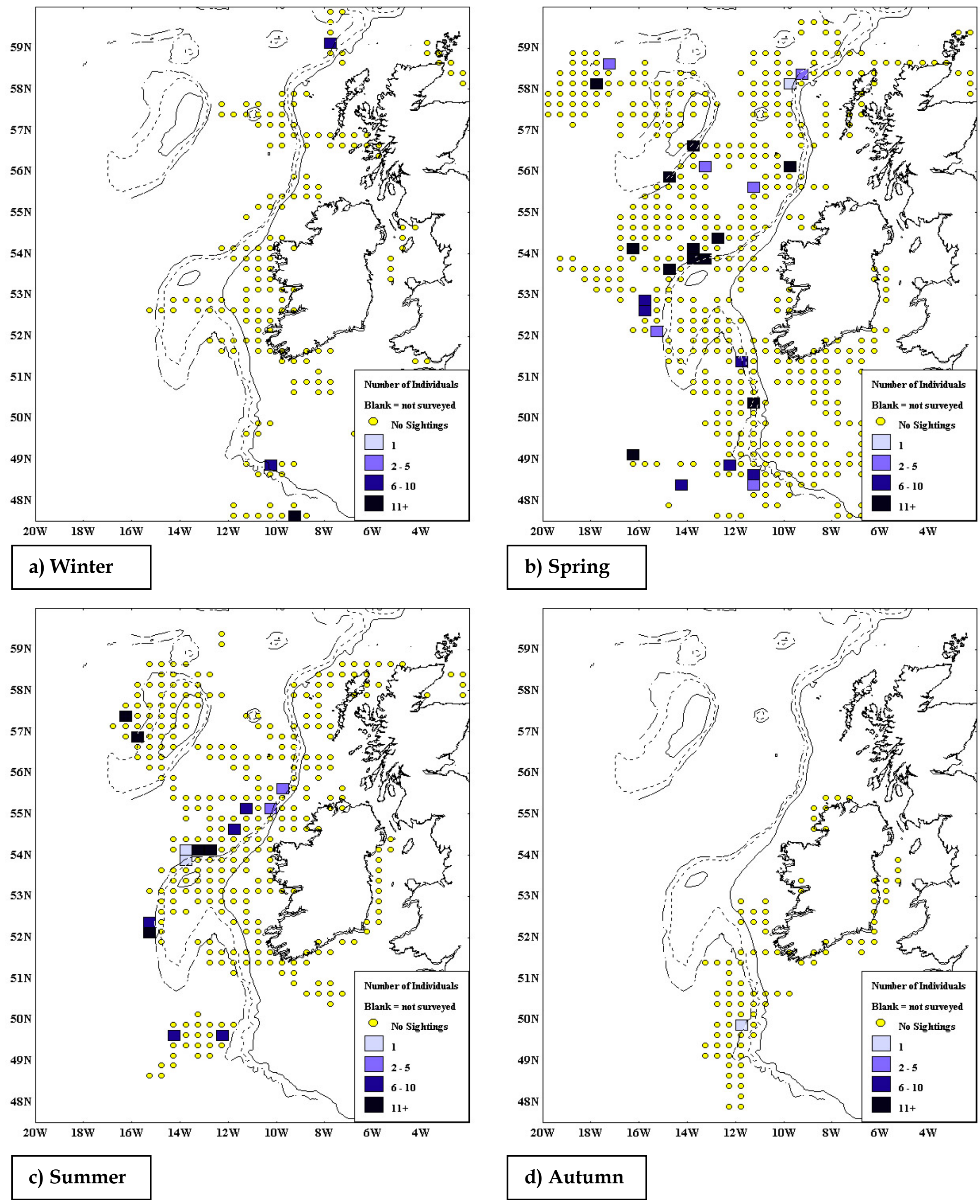

Figure 1.18. Seasonal sighting distribution and total numbers of Long-finned Pilot Whales observed between July 1999 and September 2001.

Although group sizes of up to 70 animals were recorded, the species was generally recorded in pods (or sub-groups) of 4-8 individuals, and was occasionally recorded in association with groups of Common Dolphins, White-beaked Dolphins, White-sided Dolphins, Bottlenose Dolphins, False Killer Whales and Sei Whales. It is also noteworthy that Long-finned Pilot Whales showed an apparent interest in the activities of two seismic vessels, with individual animals situating themselves within 10m of the active airgun arrays on both occasions.

Long-finned Pilot Whales are deep-water squid feeders whose distribution may be related to the occurrence of their prey (Bloch *et al.*, 1993). They appear to be common in the continental slope waters of northwest Europe from the Bay of Biscay to the Norwegian Sea. While research (e.g. Buckland *et al*., 1993b; Bloch *et al*., 1993; Stone, 1997) suggests that concentrations of these whales may occur in the Faroe-Shetland region, the species has also been recorded with relatively high frequency in previous studies in the Atlantic Margins of Britain and Ireland (Pollock *et al*., 1997; Murray & Simmonds, 1998; Gordon *et al*., 1999; Pollock *et al*., 2000; Weir *et al*., 2001). There have also been records of opportunistic hunting (O' Riordan, 1975) and regular strandings from Ireland (Berrow & Rogan, 1997). These records, in combination with the sightings data herein, suggest that the species may be present along the Irish Atlantic Margin throughout the year.

Risso's Dolphin *Grampus griseus*

A total of five Risso's Dolphin sightings were recorded during the study, four of which occurred in the waters of Ireland's Atlantic Margin (Fig. 1.19). Although most sightings consisted of one or two animals, a single group of ten dolphins which included four immature individuals, was recorded in continental slope waters to the north of the Porcupine Shelf.

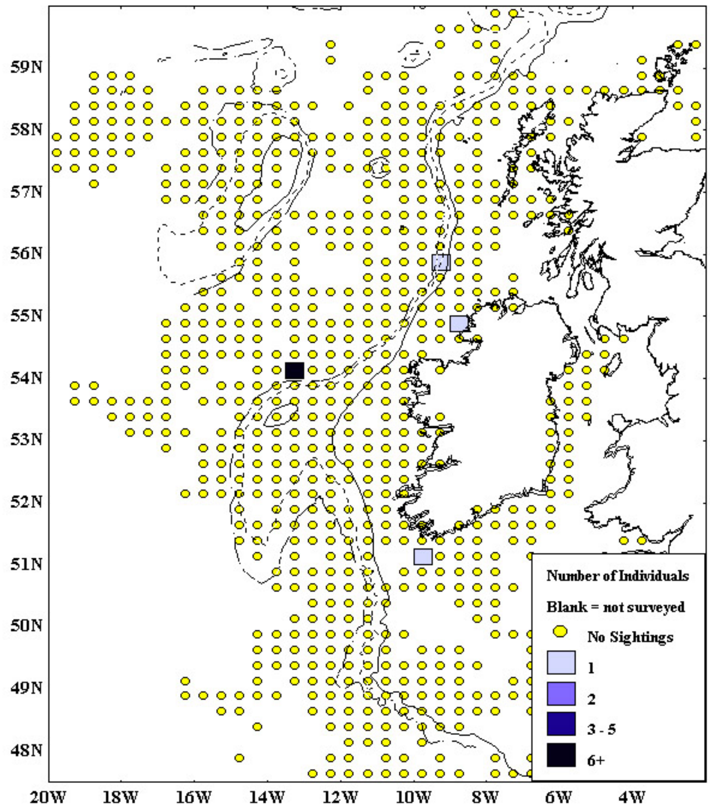

Figure 1.19. Sighting distribution and total numbers of Risso's Dolphins observed between July 1999 and September 2001.

Risso's Dolphins are thought to prey exclusively on squid; in many parts of their distribution they occur in deeper continental slope and oceanic waters (Leatherwood & Reeves, 1983). In Britain and Ireland, Risso's Dolphins have generally been recorded close to the coast (Hammond *et al*., 1995; Pollock *et al*., 1997; Pollock *et al*., 2000), a feature that may be due to significantly lower research effort offshore. In the UK there appears to be an area of concentration for the species around the Outer Hebrides (Pollock *et al*., 2000), where local groups may even be resident (Atkinson *et al*., 1997).

In Ireland, strandings of Risso's Dolphins have occurred in most months of the year (Berrow & Rogan, 1997). The SCANS survey held in June-July 1994 also recorded a cluster of sightings off southwestern Ireland (Hammond *et al*., 1995). Studies by Pollock *et al.* (1997) recorded a greater number of inshore sightings of Risso's Dolphins between August and February, while a higher percentage of shelf-edge sightings were noted between May and July. Little is known of the natural history of this species in Irish waters. Considering the available sighting records (Fairley, 1981; Hammond *et al*., 1995) and stranding information (Berrow & Rogan, 1997), the species may be relatively uncommon except in select areas of the northwest, southwest and southeast coasts. No strandings of this species have yet been recorded from the east coast of Ireland (Berrow & Rogan, 1997).

Bottlenose Dolphin *Tursiops truncatus*

An estimated 551 Bottlenose Dolphins (Plate 9) were recorded in 26 on-effort and 11 incidental sighting encounters between July 1999 and September 2001. These sighting data indicate that the species may be continuously distributed along Ireland's Atlantic Margin (Fig. 1.20) from relatively shallow coastal waters to the margins of the continental slope and oceanic waters in excess of 2000m depth. It is noteworthy, however, that the species was not recorded in the Rockall Trough, nor in waters overlying either the Rockall Bank or Hatton Bank. Recorded group sizes of Bottlenose Dolphins were variable during the study period, from single adults to larger groups of approximately 60 dolphins of all ages. Individual group sizes of 11-20 animals were most commonly recorded and calves were recorded with adult and immature individuals in coastal, inshore and offshore areas. Seasonal trends in abundance or distribution were not immediately apparent from the sighting data due to seasonal variation in survey coverage. However, the records suggest that the Porcupine Seabight, Porcupine Bank and its adjacent continental shelf and slope habitats may form a region of importance for the species.

Plate 9. A group of Bottlenose Dolphins encountered off western Ireland. Groups of this species were recorded in inshore and offshore Irish Atlantic Margin waters up to 2000m deep.

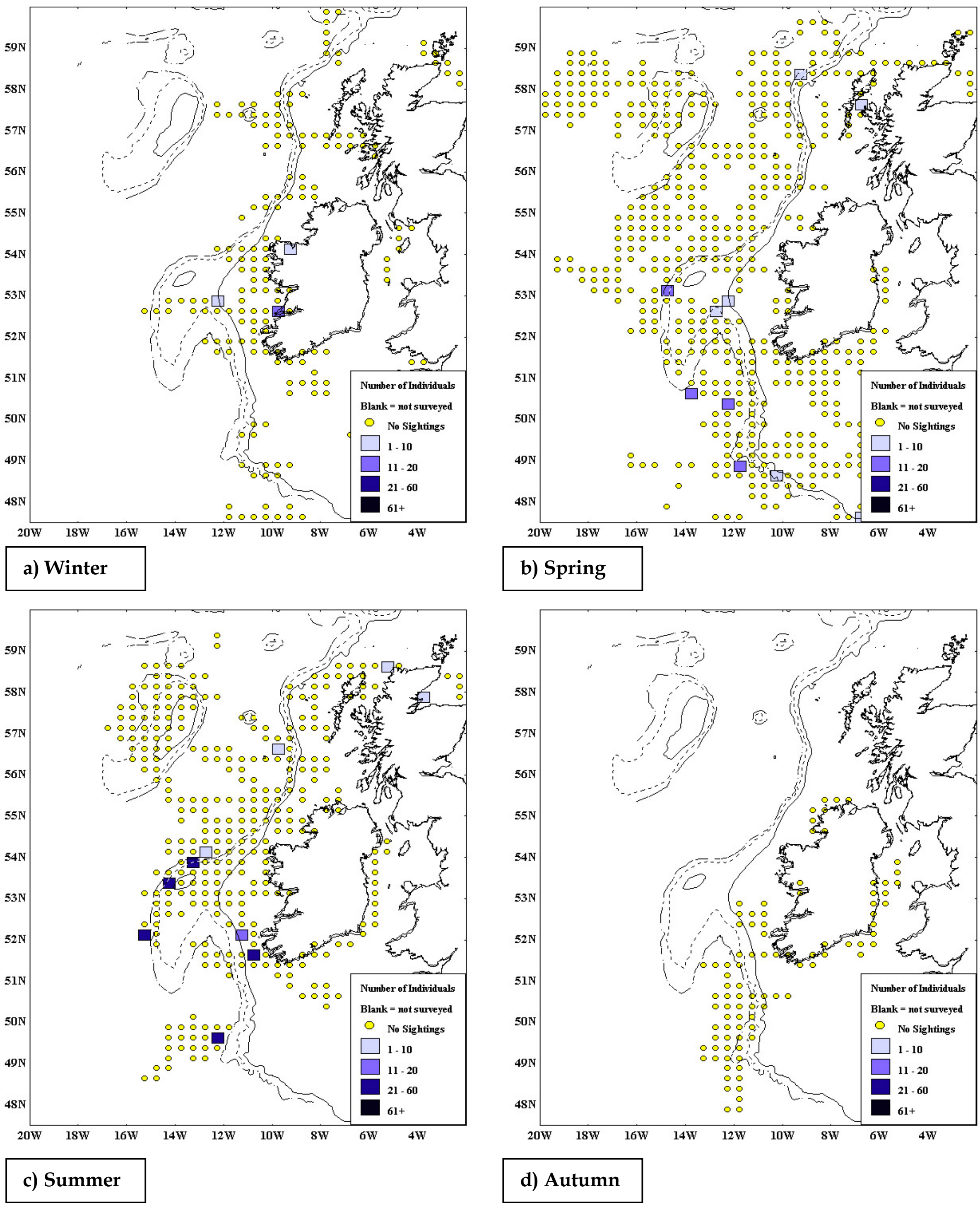

Figure 1.20. Seasonal sighting distribution and total numbers of Bottlenose Dolphins observed between July 1999 and September 2001.

Bottlenose Dolphins are found throughout the temperate and tropical oceans (Leatherwood & Reeves, 1983). In the present study the species was recorded with significantly higher frequency than in similar cetacean studies conducted over two decades along Britain's Atlantic Margin (Pollock *et al*., 2000). Although further data are required, the present study provides important evidence that the Irish Atlantic Margin may represent an important European habitat for this species, as suggested by Evans (1980). Data collected in the 1994 SCANS survey (Hammond *et al*., 1995) also indicated the relative importance of the western Celtic Sea for Bottlenose Dolphins.

Bottlenose Dolphins, an Annex II species (EC Habitats Directive), are widely described from Irish waters (Fairley, 1981; Pollock *et al*., 1997; Gordon *et al*., 1999; Berrow *et al*., 2001), and western Ireland is home to at least one resident Bottlenose Dolphin population, centred around the Shannon Estuary (Ingram 2000). Studies in this region commenced in 1993 (Berrow *et al*., 1996) and a long-term monitoring programme yielded a minimum population estimate of 113 animals of all ages (95% Confidence Interval = 94-161; Ingram, 2000). The study also underlined the importance of the area as an annual calving and feeding ground for the species.

With the exception of the Shannon Estuary population, little is known of the ecology of Bottlenose Dolphins in Irish coastal or offshore waters. Recent west coast surveys have confirmed that identifiable groups of Bottlenose Dolphins frequent a number of different bays along the west coast of Ireland (Ingram *et al*., 2001; Coastal & Marine Resources Centre, 2002, *unpublished data*). In addition to sightings from voluntary schemes, there have been relatively frequent strandings of the species in Ireland, most of which have been recorded along the western seaboard (Berrow & Rogan, 1997). Studies elsewhere have proposed that inshore and offshore populations of Bottlenose Dolphins may be separated ecologically (Evans, 1981; Scott & Chivers, 1990; Wells & Scott, 1999). However, the sighting data collected in the present study do not permit a spatial separation between inshore and offshore groups in Ireland's Atlantic Margin. Further study will be required to determine the population status of Bottlenose Dolphins throughout the region.

White-beaked Dolphin *Lagenorhynchus albirostris*

Twenty-five sightings of White-beaked Dolphins were recorded during the study, the majority of which (n = 22) occurred during full strip-transect survey effort. The species was observed throughout the continental shelf and slope waters of Ireland's Atlantic Margin yet never recorded in waters overlying the offshore Rockall and Hatton Banks (Fig. 1.21). A few sightings of White-beaked Dolphins were also obtained in Rockall Trough and Porcupine Seabight waters exceeding 1500m in depth. Groups encountered during the study included immature animals and calves. Groups ranged in size from one to 35 animals, although the number of dolphins present was commonly between two and six individuals. Most sightings occurred between the months of June and August. However, declining survey coverage in autumn and winter did not allow the determination of seasonal abundance patterns for the species at this stage.

In contrast to similar studies in Britain (Pollock *et al*., 2000), White-beaked Dolphins were comparatively less common in western Irish shelf waters than a number of other dolphin species. Data obtained in the present study support previous indications from Irish sighting surveys (Pollock *et al*., 1997) and infrequent stranding records (Berrow & Rogan, 1997) that the species is predominantly distributed in waters overlying the continental shelf and slope to the west of Ireland. The absence of sighting of White-beaked Dolphins in the Celtic Sea during the 1994 SCANS survey (Hammond *et al*., 1995) also agrees with this finding. This spatial variation in abundance in the Atlantic Margins of Britain and Ireland was clearly indicated in studies by Northridge *et al*. (1995), which determined that White-beaked Dolphins are more commonly distributed in the continental shelf waters of northern, eastern and western Britain, centring around northwestern Scotland and the Outer Hebrides.

White-beaked Dolphins are thought to feed predominantly on fish, such as members of the cod family *Gadidae* and herring family *Clupeidae* (Reeves *et al*., 1999a) but little is known of their diet in Irish waters. The species is known to inhabit the eastern North Atlantic from the Norwegian and the Barents Seas through western European waters including the Mediterranean, with a predominant occurrence in northwestern European waters (Northridge *et al*., 1997). Harwood & Wilson (2001) suggested that animals occurring along the Atlantic Margins of Ireland and Britain may represent a single stock since there appears to be little variation in the species' distribution throughout the year (Northridge *et al.*, 1995). However, further study from continued sighting records and stranded animals may be necessary to determine the population status and seasonal distribution of the species within the Irish Atlantic Margin.

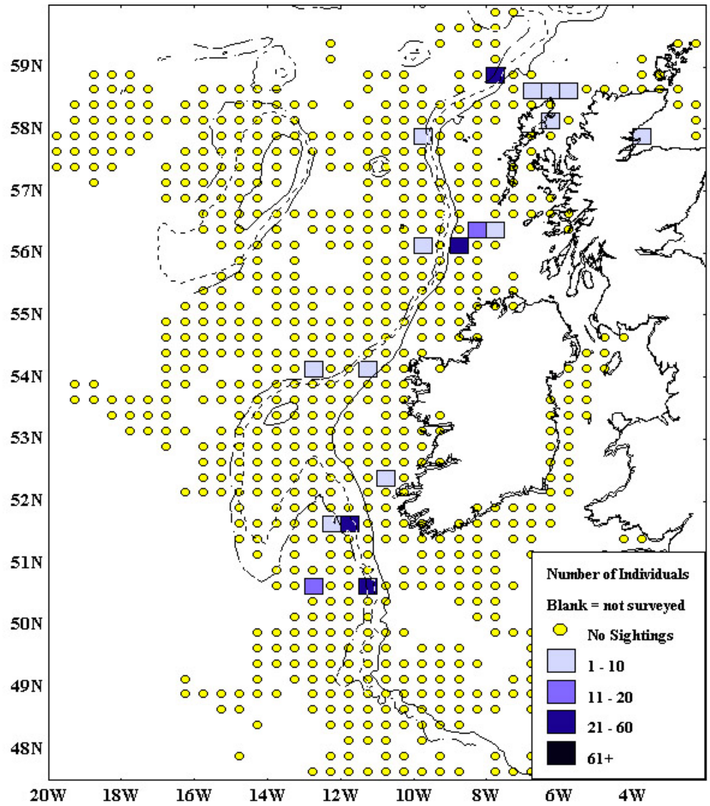

Figure 1.21. Sighting distribution and total numbers of White-beaked Dolphins observed between July 1999 and September 2001.

Atlantic White-sided Dolphin *Lagenorhynchus acutus*

The Atlantic White-sided Dolphin (Plate 10) was the second most numerous cetacean species recorded during the study with over 1000 animals observed among 70 sighting records (Table 1.1). The species was observed throughout the entire Irish Atlantic Margin, and records included sightings in waters overlying the Rockall Trough, the Hatton Bank and Rockall Bank (Fig. 1.22). White-sided Dolphins were predominantly recorded in waters overlying the continental slope and the species was generally not recorded in coastal waters with the exception of sporadic sightings in shelf waters off the Aran Islands, Co. Galway and southwest of the Outer Hebrides (Fig. 1.22c).

Although the year-round survey coverage was somewhat limited, there appeared to be a difference between spring and summer in the distribution of White-sided Dolphins along the Atlantic Margin with a more northerly distribution of sightings between the months of July and September. It was not possible to determine in the present study whether the species is present in large numbers throughout the autumn and winter months due to reduced survey coverage. However, significant stranding data from the months of March and April (Berrow & Rogan, 1997) and a single sighting record from the Porcupine region in the present study certainly indicate the species' occurrence along the Irish Atlantic Margin in late winter and early spring.

Plate 10. An adult White-sided Dolphin encountered off western Ireland in August 2000. Summer population estimates of this species off western Ireland were derived from data collected during the *SIAR* survey (*see* Chapter 2).

Observed group sizes of White-sided Dolphins were higher than those of any other cetacean species in the Irish Atlantic Margin; up to 130 animals occurred in a single encounter. Such large groups, also recorded in previous studies (Leopold & Couperus, 1995; Pollock *et al*., 2000), were seen exclusively in the summer during what is believed to be the species' calving and breeding season (Berrow & Rogan, 1997; Rogan *et al*., 1998; Reeves *et al*., 1999b). When such large group sizes were observed in the present study, the animals tended to be arranged in subgroups generally consisting of three to eight animals of various ages, including calves on occasion, which were spread over distances > 0.5 km^2.

White-sided Dolphins are generally found in the eastern North Atlantic from the Bay of Biscay to waters off Iceland and Norway and the species may make large-scale seasonal movements within this range (Northridge *et al*., 1997). Described in recent studies (Murray & Simmonds, 1998; Pollock *et al*., 2000; Weir *et al*., 2001) as the most abundant cetacean species in Britain's Atlantic Margin, White-sided Dolphins are certainly seasonally abundant in neighbouring Irish continental shelf and slope waters according to indication in the present study. Consequently, sightings during the *SIAR* survey in July-August 2000 allowed for the first summer population estimates of this species off western Ireland (*see* Chapter 2).

Previous cetacean surveys in Irish waters (Evans, 1981; Pollock *et al*., 1997; Gordon *et al*., 1999), commonly recorded White-sided Dolphins along the continental shelf and slope off western Ireland. However, the 1994 SCANS survey failed to find significant numbers of the species in the Celtic Sea or North Sea in summer (Hammond et *al*., 1995).

Although it is believed that the species may move offshore in the winter months (Northridge *et al*., 1997; Pollock *et al*., 2000), White-sided Dolphins were recorded in the present study over the offshore Rockall and Hatton Bank in spring and summer months. It could not be determined if White-sided Dolphins remained in this offshore region during the autumn or winter due to reduced survey coverage in these seasons. Nevertheless, it would appear from the available information that the species may move east and northwards along the Irish Atlantic Margin in spring and summer either from oceanic waters of the Porcupine Abyssal Plain-Rockall Trough or the Celtic Sea-Bay of Biscay region.

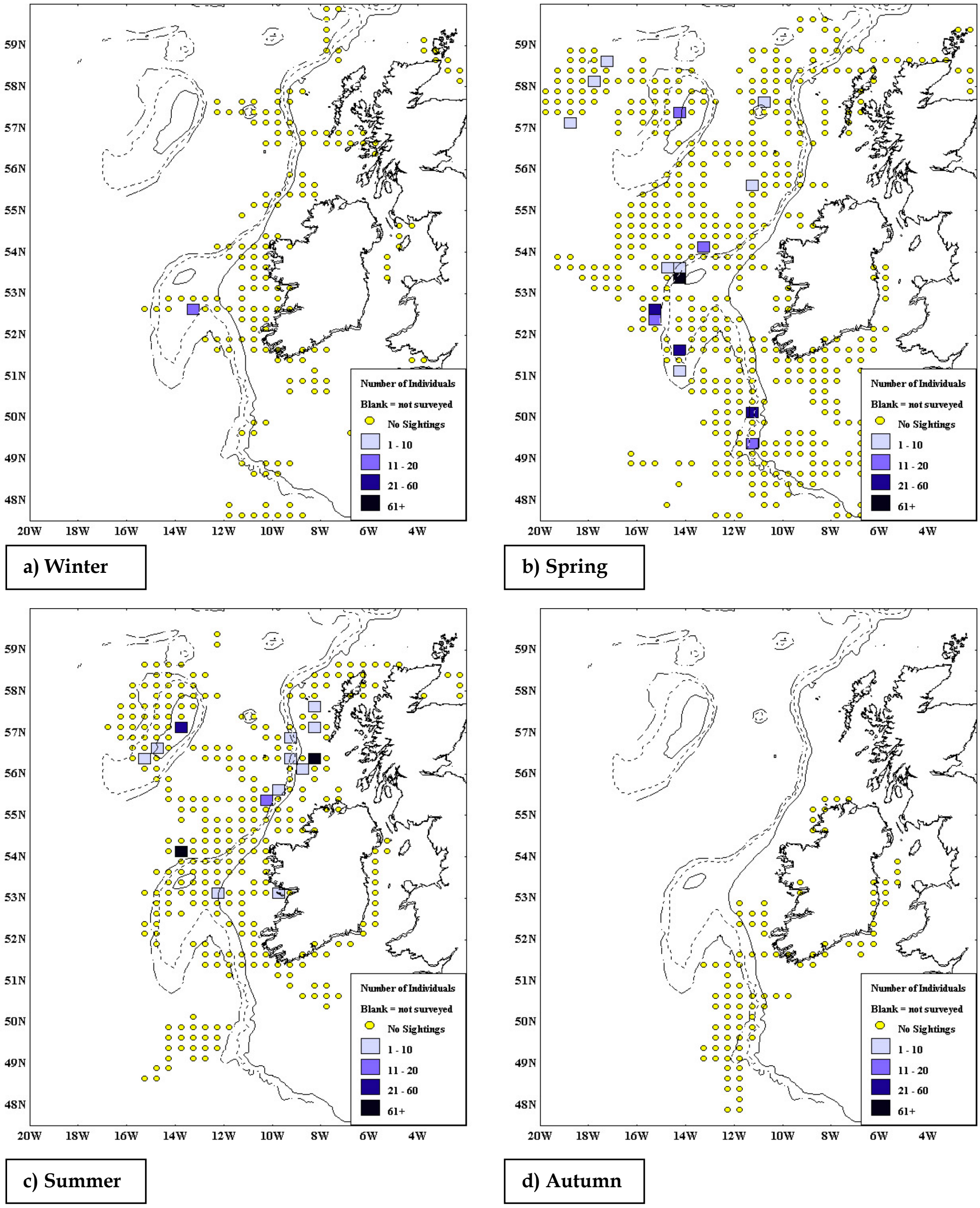

Figure 1.22. Seasonal sighting distribution and total numbers of White-sided Dolphins observed between July 1999 and September 2001.

Short-beaked Common Dolphin *Delphinus delphis*

In contrast with data from the Atlantic Margin of Britain (Pollock *et al*., 2000), Short-beaked Common Dolphins (Plate 11) were the most abundant cetacean species in the Irish study area year-round; they were sighted on 236 occasions between July 1999 and September 2001 (Table 1.1). In interpreting these data, however, it must be remembered that Common Dolphins are strongly attracted to moving vessels. Thus their detectability is comparatively higher than that of many other species, a characteristic that is accentuated in poorer weather conditions. Common Dolphins were recorded throughout the Irish Atlantic Margin from coastal waters and the Celtic Sea to the margins of Ireland's continental slope, the Rockall Bank and the deeper

Rockall Trough (Fig. 1.23). Sighting records of this species were obtained in all seasons in spite of significantly reduced coverage in the autumn and winter months.

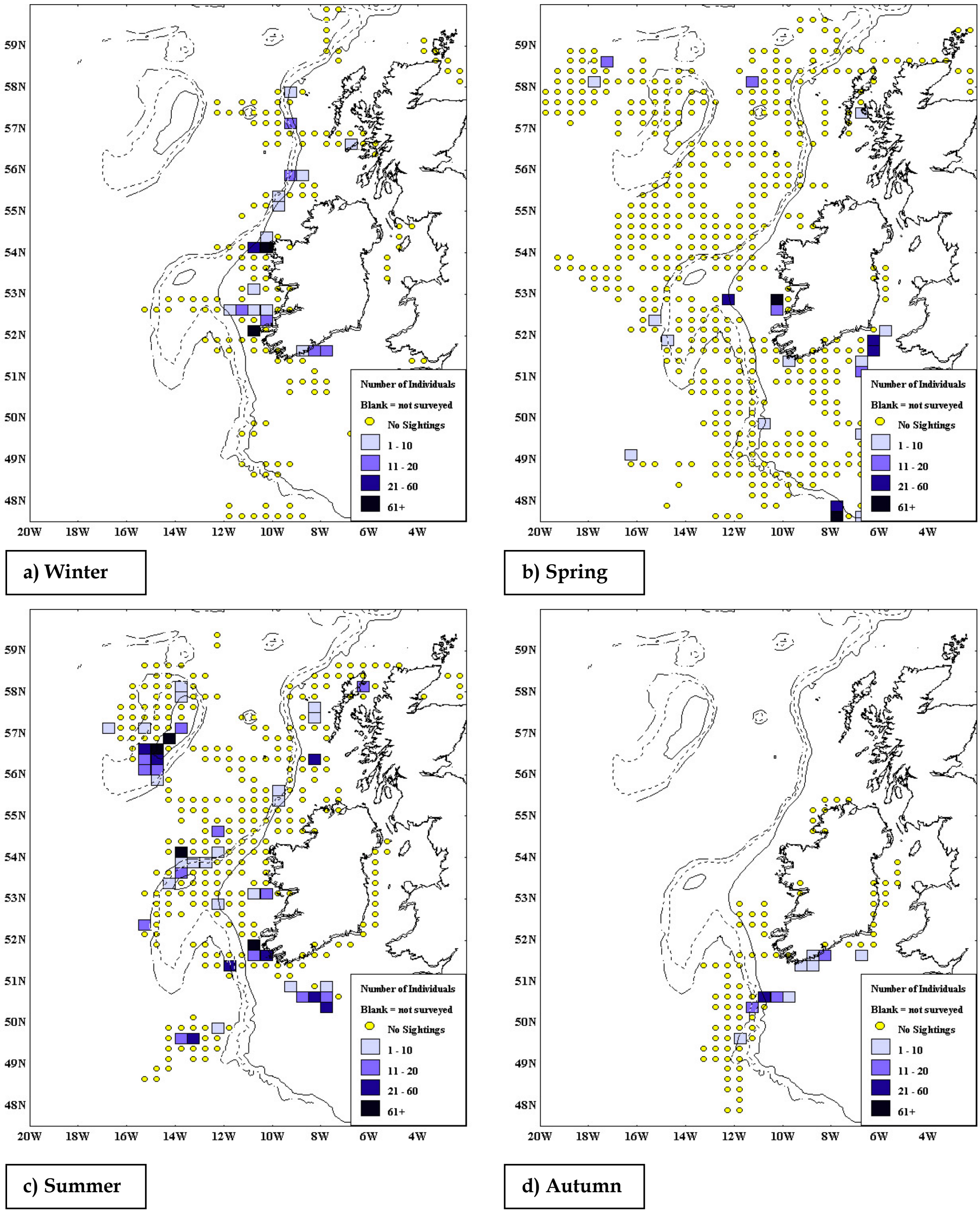

Figure 1.23. Seasonal sighting distribution and total numbers of Common Dolphins observed between July 1999 and September 2001.

There appeared to be a relative increase in the abundance of Common Dolphins along parts of Irish Atlantic Margin between spring and summer, seasons in which comparatively good survey coverage was obtained (Fig. 1.23). The species was recorded in a wide range of group sizes and groups in excess of 50 animals, which contained newborn calves, were recorded between the months of July and September off western Ireland. Sightings of Common Dolphin groups including newborn calves were also recorded in Atlantic Margin waters overlying the Rockall Bank in the summer (Fig. 1.23c).

Previous studies in Irish waters (e.g. Evans, 1981; Pollock *et al*., 1997; Gordon *et al*., 1999) have also recorded Common Dolphins with relatively high frequency; the species is one of the most commonly stranded cetaceans around the Irish coast (Berrow & Rogan, 1997). Summer abundance estimates for the species were derived for the Celtic Sea from SCANS survey data (75,450 animals, Coefficient of Variation = 0.67; Hammond *et al*., 2002) and in the present study for western Ireland, from data collected during the *SIAR* survey (*see* Chapter 2).

Plate 11. An adult Common Dolphin racing alongside a fast-moving research vessel. These dolphins are attracted to boats and ships of all sizes.

Striped Dolphin *Stenella coeruleoalba*
Seventeen sighting records of Striped Dolphins were obtained during the study and an estimated total of 135 animals of this species were recorded from vessels of opportunity (Table 1.1). These observations were made along the Irish Atlantic Margin in the summer and early autumn months, centring predominantly in the offshore waters of southwestern Ireland (Fig. 1.24). Sightings of Striped Dolphins were also recorded in the present study to the west of Ireland during the *SIAR* survey (*see* Chapter 2), along the southern margin of the Rockall Bank, off the western margin of the Celtic Sea and in the Bay of Biscay. Estimated group sizes ranged from one to thirty individuals, and calves were recorded in association with adult Striped Dolphins on two occasions during the study. Records also included occasional single and paired individuals seen in mixed-species groups with Common Dolphins.

Although the Striped Dolphin is generally considered to be a warm-temperate oceanic species (Leatherwood & Reeves, 1983; Forcada *et al*., 1990), it may range into cold temperate climates and occur in continental shelf habitats, as seen in the present study. These data and previous studies by Bloch *et al*. (1996) suggest that Striped Dolphins may occur relatively frequently off southwestern Ireland and in offshore Atlantic Margin waters during the summer months.

Stranding records of Striped Dolphins have increased in recent years along the Irish coastline (Berrow & Rogan, 1997) and they appear to occur in all seasons. Records from incidental entanglement in fishing gear (Rogan *et al*., 1997) and the present research programme certainly indicate that the species may have extended its range northwards in summer-early autumn. The distribution of Striped Dolphins in western European waters in the autumn, winter and spring is as yet undetermined.

The concept of seasonal incursions along the Atlantic Margin may be supported by records from Scottish waters in which the species was detected for the first time in the 1990s (Reid *et al.*, 1993). Further Striped Dolphin records have occurred in summer in waters west of the Celtic Sea during the 1994 SCANS survey (Hammond *et al.*, 1995), as well as off Iceland and the Faroe Islands (Bloch *et al.*, 1996; Stone, 1997). It is not yet clear what factors may drive the species northwards along the Atlantic Margin, although Bloch *et al.* (1996) suggest a link to changes in sea temperature.

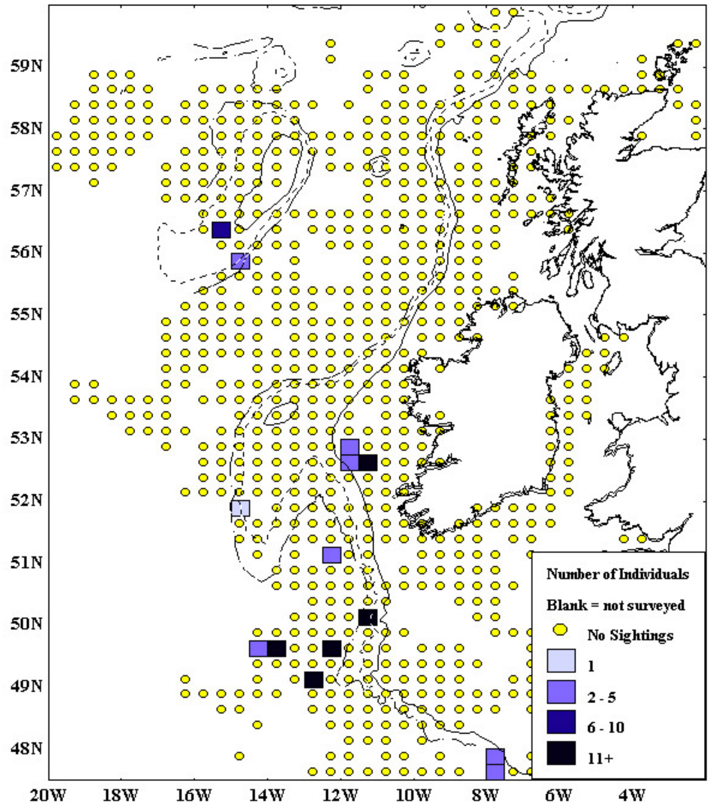

Figure 1.24. Sighting distribution and total numbers of Striped Dolphins observed between July 1999 and September 2001.

Harbour Porpoise *Phocoena phocoena*

Europe's smallest cetacean species, the Harbour Porpoise, was sighted on a total of fifty-two occasions between July and September 2001, yielding a total of 173 individuals recorded during the study period. Records were obtained in all seasons and the majority of sightings in the study area were made close to the Irish coast; no records occurred on the offshore Rockall or Hatton Banks and just two records occurred in summer in continental shelf waters away from the coast (Fig. 1.25). On one such occasion, three Harbour Porpoises were seen in a large multi-species aggregation over the Stanton Banks, which lie in continental shelf waters off the Outer Hebrides. This concentration of cetaceans included groups of White-sided Dolphins, White-beaked Dolphins, Common Dolphins and Minke Whales.

Group sizes of Harbour Porpoises recorded during the present study generally ranged between one and three animals, although one group of 14 porpoises was noted in the North Minch Basin and as many as 80 individuals were observed over a 20-minute period in groups of 1-20 animals off southwest Ireland on 25th July 1999 (Fig. 1.25c).

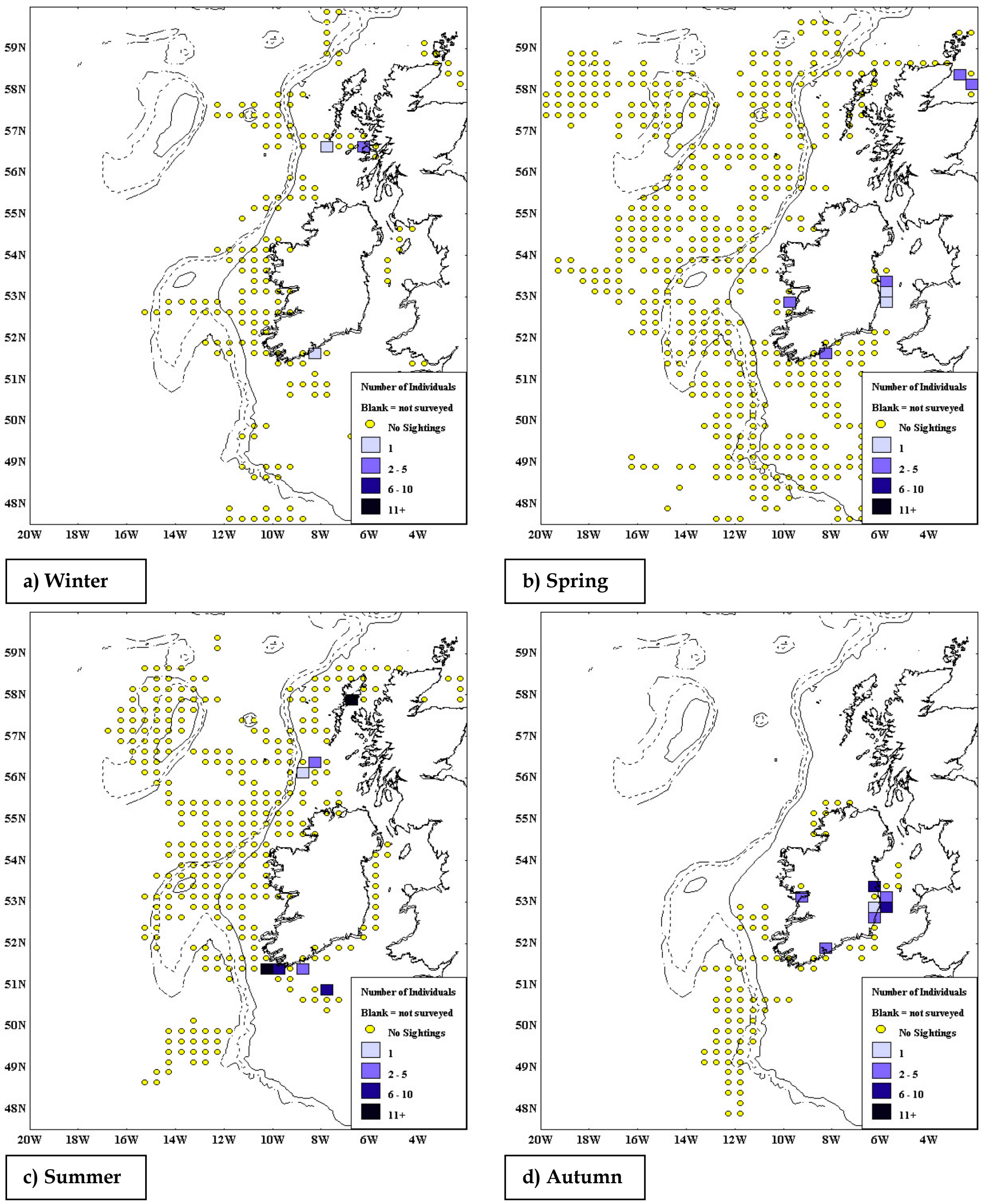

Figure 1.25. Seasonal sighting distribution and total numbers of Harbour Porpoises observed between July 1999 and September 2001.

The relative abundance of this inconspicuous Annex II species may be underestimated due to the difficulty with Harbour Porpoises may be detected in sea states greater than Beaufort Force 2 (Hammond *et al*., 1995). Considering the continuation of strip-transect survey effort in the present study in sea states up to and including Beaufort Force 6, there is no doubt that considerable numbers of this species were missed by observers in the field. Consequently, care must be taken in interpreting the distribution and frequency of the sighting records presented.

It is interesting to note that sightings of Harbour Porpoises from vessels of opportunity were relatively common off southern and southwestern coasts and in the Irish Sea. Previous studies

(Leopold *et al.*, 1992; Hammond et al., 1995; Northridge *et al.*, 1995; Pollock *et al.*, 1997) have indicated that both regions, and particularly the inshore waters of southwestern Ireland, contain high densities of Harbour Porpoises. Data collected for the Celtic Sea during the SCANS survey yielded summer abundance estimates of 36,280 Harbour Porpoises (Coefficient of Variation = 0.57; Hammond *et al.*, 2002). When conditions allowed, Harbour Porpoises were also recorded off western and northwestern Ireland during the present research programme (Fig. 1.25; also *see* Chapter 2) and it is considered that relatively low previous research coverage and poorer weather conditions off western Ireland may have mask other areas of importance for the species. While sightings during the *SIAR* survey (*see* Chapter 2) were too few to allow for abundance estimation, sighting rate may have been due in part to the survey design which focused research efforts on the offshore waters of the Rockall Trough and northern Porcupine region. Previous studies (Northridge *et al.*, 1995; Rogan & Berrow, 1996; Pollock *et al.*, 1997; Gordon *et al.*, 1999) also indicate that some areas along the western continental shelf of Ireland may be seasonally important for Harbour Porpoises and may require further research effort. Sightings of Harbour Porpoises are limited west of the Rockall Trough but the species has been documented in waters overlying the Rockall Bank by Northridge *et al.* (1995) and more recently by Cronin & Mackey (2002).

Extensive stranding records indicate that Harbour Porpoises are present in Irish waters year-round and the species was the most commonly stranded cetacean between 1901 and 1995 (Berrow & Rogan, 1997). Dietary studies by Rogan & Berrow (1996) from stranded and by-caught specimens indicate that Harbour Porpoises in Irish waters feed on a range of fish, particularly *Trisopterus* species, whiting (*Merlangius merlangus*), herring (*Clupea harengus*), sprat (*Sprattus sprattus*) and, to a lesser extent, on squid.

3C. *Unidentified cetaceans*

Approximately 7% of all cetaceans (n = 444) recorded during the study could not be identified to species level, due to a variety of factors (e.g. weather conditions, distance from vessel, indistinct cues, etc). With the exception of seventeen sighting records of large whales that could confidently be assigned to the Blue/Fin/Sei whale category (Fig. 1.10), a total of 420 cetaceans recorded in 74 on-effort and 37 incidental sighting encounters were classified under various unidentified cetacean categories (Table 1.1).

Among 237 whales recorded by observers, from the smaller toothed whales to the largest baleen whale species, the Blue Whale, approximately 30% (n = 72) could not be confidently identified. In contrast, among the dolphin species observed, 5.6% of all animals (n =330) among 63 sighting records could not be identified to species level. Records for cetaceans along the Irish Atlantic Margin, which could not be identified to species level, are pooled into a number of categories below, based on the available sighting information:

Unidentified beaked whale species

A single adult beaked whale of unknown identity was observed during the study in deep waters along the northern margin of the Porcupine Seabight (Fig. 1.26). This record is not surprising, since beaked whales are notoriously difficult to identify in the field due to their behaviour and the limited cues by which these animals may be separated from other species (Leatherwood & Reeves, 1983; Coles, 2001). Further sightings of beaked whales that could not be discriminated from other small whales may also have been assigned to the remaining categories below.

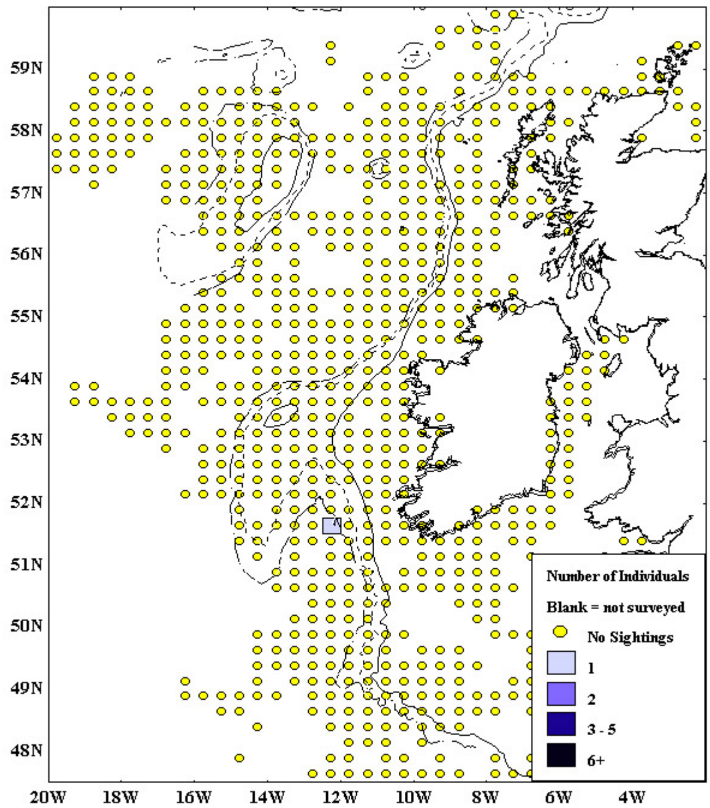

Figure 1.26. Sighting location of an unidentified beaked whale over the northern margin of the Porcupine Seabight, off southwest Ireland.

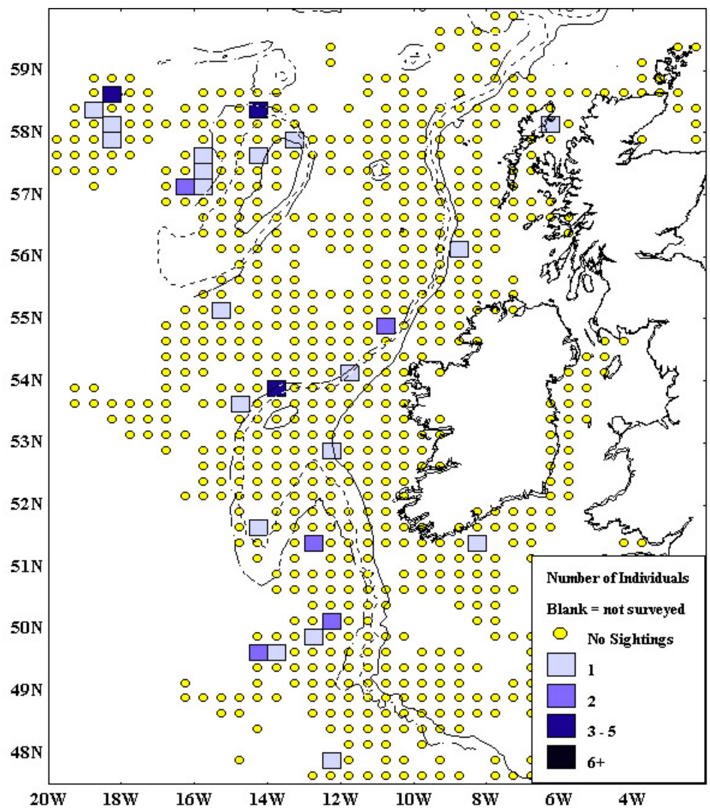

Figure 1.27. Sighting distribution and total numbers of unidentified whales observed between July 1999 and September 2001.

Unidentified whale species

In spite of the use of larger vessels and relatively good observation platforms during the study period, sighting records under the prevailing weather conditions did not allow proper body size estimation or other cues to be confidently determined in many cases. For example, the sole use of larger whales' blow shape and height as an identifying cue could not be reliably adopted, even by experienced observers, in many wind and sea conditions. All such sightings of small-sized to larger whales, which were recorded but not identifiable under aforementioned species/categories by the observers, were ascribed to the above group. The distribution of these records along the Irish Atlantic Margin and the associated numbers of unidentified animals are shown above (Fig. 1.27).

Unidentified dolphin species

All other unidentified animals were attributed to either of two categories. Those that could not be identified in the field with the strictest confidence, yet were recognised as dolphins of various types (e.g. unidentified *Lagenorhynchus* species, Common/Striped dolphins, patterned dolphins) were assigned to the present group. The distribution and numbers of unidentified dolphin species recorded in the study area are shown below (Fig. 1.28).

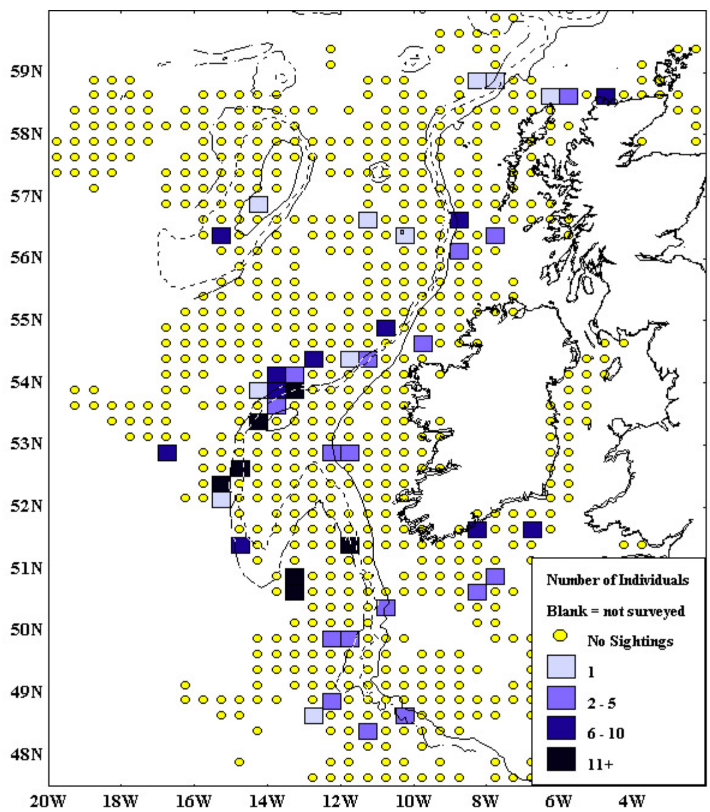

Figure 1.28. Sighting distribution and total numbers of unidentified dolphins observed between July 1999 and September 2001.

Unidentified cetacean species

The remaining category applies to those sighted animals which were identifiable as cetaceans, yet which could not be assigned to any of the previous categories. A total of 42 such animals were recorded among 13 records between July 1999 and September 2001.

CONCLUSIONS

Research conducted aboard vessels of opportunity achieved extensive coverage throughout the waters of Ireland's Atlantic Margin. While there was considerable variation in the full-transect effort obtained in each season, this was unavoidable due to (i) the few available outgoing ships between the months of November and March and (ii) poor weather conditions during these months, which reduce the available survey time aboard deployed vessels. Nevertheless substantial survey effort conducted in the spring and summer months certainly allowed the investigation of cetacean species richness and patterns in relative abundance and distribution for frequently occurring species.

The number of cetacean species recorded by CMRC observers aboard vessels of opportunity is a key indication of the importance of European Atlantic Margin waters for cetaceans. Eighteen species were identified from surveys in Irish territorial waters, which definitively underpins indications from strandings and other sources that Ireland is home to significant cetacean populations including diverse dolphin species, odontocete species poorly described in these waters (e.g. Cuvier's Beaked Whale, False Killer Whale) and rare, migratory species of baleen whale (e.g. Blue Whale).

The surveys conducted aboard vessels of opportunity indicate a number of areas within Ireland's Atlantic Margin that may represent important habitats for cetaceans on the basis of species richness and relative abundance. These include the Porcupine Shelf region, consisting of the Porcupine Bank and its surrounding continental shelf and slope margins, the Porcupine Seabight off southwestern Ireland and parts of the Rockall Trough and Rockall Bank. Furthermore, the Hatton Bank yielded a surprising number and range of species including a single Northern Right Whale and numerous sightings of Sei and Sperm Whales and warrants further investigation.

Data collected under the above programme indicated that Common Dolphins may be the most abundant species occurring in Irish Atlantic Margin waters year-round. However, the methods used, based as they normally were on a single-observer approach, fall short of being able to determine animal abundance for most species or to investigate true patterns in distribution, due to the reliance on vessels of opportunity. These factors supported the case for conducting a dedicated multi-observer cetacean survey in the study area (*see* Chapter 2) which sought to address shortcomings in the above research programme and investigate a number of hypotheses raised by the above information and other sources.

CHAPTER 2
SUMMER DISTRIBUTION AND ABUNDANCE OF CETACEANS OFF WESTERN IRELAND

INTRODUCTION

In spite of the potential importance of Irish waters for cetaceans, there have been few studies to estimate their numerical abundance at sea. Combined seabird and cetacean surveys (e.g. Evans, 1981; Northridge *et al*., 1995; Pollock *et al*., 1997), including those in the present study (*see* Chapter 1) have yielded important information on individual species' relative abundance and distribution patterns throughout Irish waters. Although these studies have covered large areas of Ireland's marine territory through different seasons, data gathered on cetaceans in this manner may be less than optimal. For example, such surveys are generally performed aboard ships-of-opportunity, which restrict the observer's choice of survey area and may hamper the use of equal coverage probability designs implicit in line-transect surveys. In addition, these surveys are often conducted by a single observer who must maintain survey effort for seabirds and cetaceans simultaneously, presenting further difficulties in the interpretation of sighting data and the determination of animal abundance.

Two dedicated cetacean abundance surveys took place in Irish waters in the 1990s (Leopold *et al*., 1992; Hammond *et al*., 1995). These research efforts focused predominantly on waters overlying the continental shelf and slope. The 1994 SCANS line-transect survey (Hammond *et al*., 1995) was the most comprehensive, yielding summer population estimates for Harbour Porpoises, Common Dolphins, *Lagenorhynchus* species and Minke Whales in the Celtic Sea (Hammond *et al*., 2002).

Under the research programme reported here, funding was allocated by the RSG/PSG for a dedicated three-week cetacean survey, conducted by the CMRC team, off western Ireland. The rationale behind the proposed survey was to allow the team to independently investigate a key region within the broader study area, while also filling gaps in survey coverage caused by the reliance on vessels of opportunity. In addition to its spatial objectives, this *Survey In Western Irish Waters And The Rockall Trough* (*S.I.A.R.* – after an Irish word for "*to the west*") aimed to greatly enhance the data gathered under the overall research programme by systematically surveying the target region using more powerful visual and acoustic survey methods.

Relationships between the distribution of cetaceans and physiographic features have been previously demonstrated for several species, including Common Dolphins (Gaskin, 1968), Bottlenose Dolphin (Ingram & Rogan, *in press*), Risso's Dolphin (Baumgartner, 1997), Long-finned Pilot Whales (Cañadas & Sagarminaga, 2000) and Sperm Whale (Griffin, 1999). Larger scale, multidisciplinary marine ecosystem studies (e.g. Reilly & Fiedler, 1994; Tynan, 1998; Thiele *et al*., 2000) have further increased our knowledge of cetacean habitats in ocean basins. These relationships suggest that complex seafloor relief can concentrate prey species through oceanographic mechanisms such as upwellings or frontal systems, concentrating nutrients, increasing primary productivity with subsequent enhanced secondary production, leading to prey aggregations.

Consequently, an added objective of the *SIAR* survey was to examine the species composition and distribution of cetaceans with respect to three immediately measurable variables (i) sea surface temperature, (ii) water depth, and (iii) depth gradient (seafloor slope).

STUDY AREA FOR THE *SIAR* SURVEY

In order to enhance the coverage and methods in the overall research programme, and to better investigate the hypothesis that cetaceans may exhibit a preference for waters overlying the continental shelf edge, the area chosen for the *SIAR* survey included the inshore and offshore waters of western Ireland (Fig. 2.1) and centred around an area off Co. Mayo, northwest Ireland, in which the Corrib field has been earmarked for commercial exploitation of its natural gas reserves. The *SIAR* survey also aimed to cover a substantial portion of the Rockall Trough, a deep-water Atlantic basin poorly studied for cetaceans. Thus, approximately 50% of the *SIAR* area consisted of waters >1000m depth, the remainder consisting of continental slope and shelf waters. The northern limit of the survey approximated the northern limit of Ireland's Exclusive Fishery Zone (EFZ) while, at its southern limit, the study area incorporated the Porcupine Bank. This is an area of great importance to commercial fisheries, situated on a prominent submarine shelf extending westwards into the Atlantic Ocean.

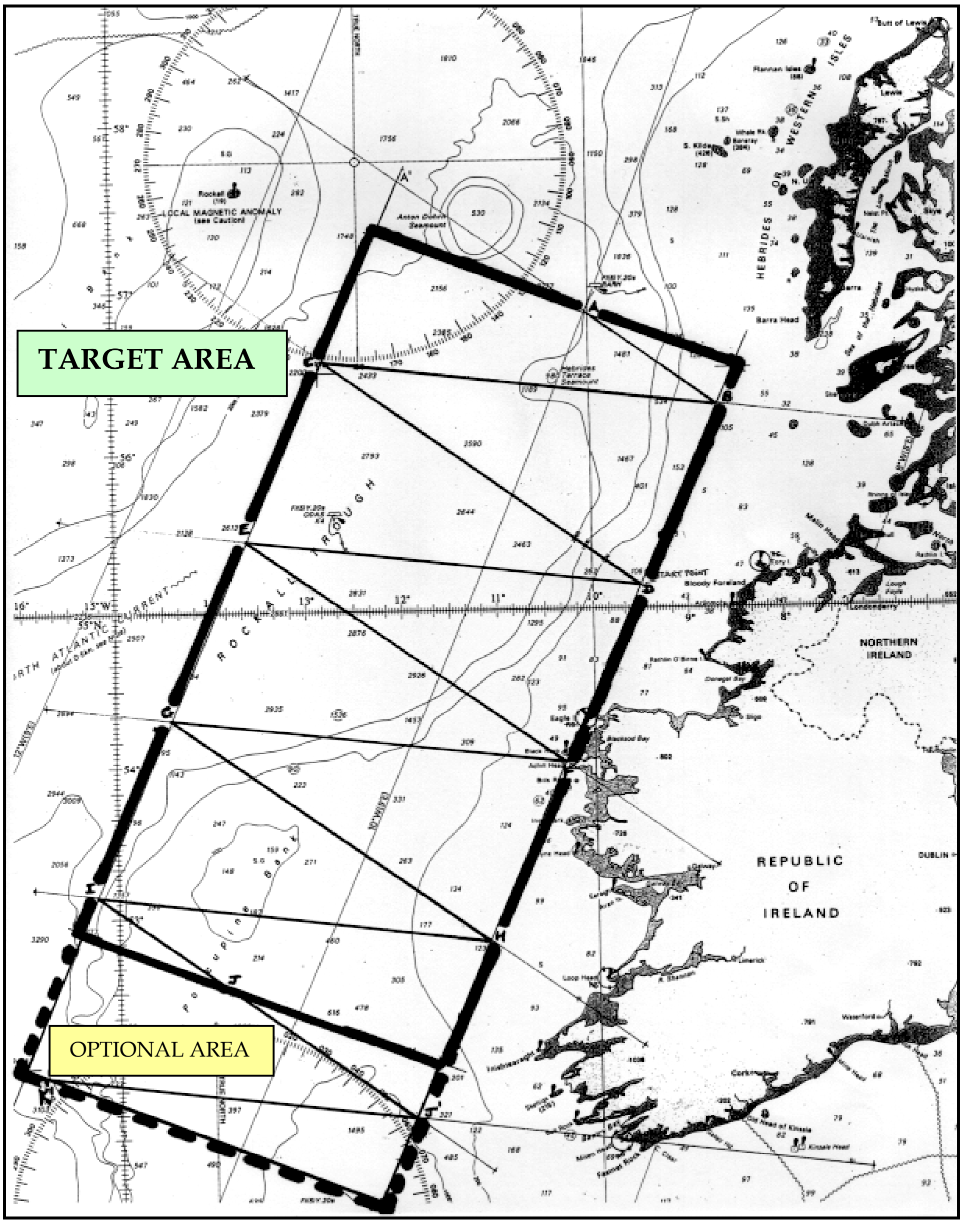

Figure 2.1. Map of the *SIAR* survey area (within thick border) including the target area, optional extension and survey transect lines.

METHODS

1. SURVEY DESIGN

The vessel chartered for the *SIAR* survey was a 35m deep-water trawler, the M.V. *Emerald Dawn* (Plate 12), which provided three suitable observation platforms at 7.7m, 9.7m and 10.4m respectively and berths for up to eight observers. The survey was scheduled to take place between 30th July – 22nd August 2000, a period during which weather conditions would be optimal. An allowance for 25% downtime due to poor weather conditions was built into the survey design.

Using an equal-coverage probability "saw-tooth" design (Hiby & Hammond, 1989) in planning the survey, a random start point was selected and a series of transect lines were subsequently plotted within the margins of the study area. A hypothetical potential gradient in animal density lay between the deeper waters of the Rockall Trough and those of the continental shelf. In designing the survey, therefore, care was taken to ensure that transect lines should lie parallel to the direction of this east-west gradient, while intersecting the potentially important physical/biological feature of the continental shelf edge. Due to these design considerations (*see* Buckland *et al*., 1993a) and the time available, the target area of 119,861.4 km^2 was assigned a series of seven full transect legs (Fig. 2.1) measuring approximately 272.5 km in length and two shorter legs at the northern and southern margins measuring approximately 95.9 km and 109.6 km respectively. An optional extension to the study area, which consisted of a southward continuation of the transect design, was included in the survey plan with the proviso that this could be surveyed when the target area was covered satisfactorily.

Plate 12. The vessel used for the *SIAR* survey, the M.V. *Emerald Dawn*.

2. SURVEY METHODS

Methods used in the study included two visual survey modes conducted during daylight hours, to which the research team was assigned according to the prevailing weather conditions:

(1) **Double Platform *(DP)* mode** (Beaufort 0-4): a mark-recapture line-transect survey (Borchers *et al*., 1998b) based on the approach of Buckland & Turnock (1992) and following closely the SCANS survey method (Hammond *et al*., 1995);

(2) **Single Platform *(SP)* mode** (Beaufort 4-6): a simple line-transect survey consisting of one platform of primary observers.

Incidental sightings were also recorded when off-effort (e.g. on transit to transect lines or outside acceptable daylight or weather conditions). For standardisation purposes, sightings and effort data were collected in accordance with the SCANS survey (Hammond *et al*., 1995) and a distance estimation trial was conducted during the survey period in order to assess the ability of individual observers to accurately determine the radial distances to cetacean groups.

When observers were operating in **DP mode**, the vessel navigated along a selected transect line at a steady speed of approximately 8 knots. Six observers, equipped with synchronised digital watches, worked through a maximum 3.5-hour shift, rotating through respective 30-minute session positions. In order to allow visual observers to obtain sufficient rest, the maximum sustained observation period per shift was 1 hour and it was followed by a 30-minute non-observer role. A single "effort logger" role, consisted of recording the relevant navigational, effort and environmental data from the bridge/upper deck. This observer otherwise remained off-effort but available to assist the data logger (*see* below) in his/her duties should a high-density situation arise.

Two "primary observers", seated on the main mast (Plate 13), were each equipped with a fixed angle board for angle estimation, calibrated vernier calipers to assist in distance estimation (Heinemann, 1981), a handheld VHF set, a dictaphone, datasheets and *LEICA* 10x42 binoculars for species confirmation. These observers worked independently of one another and used the naked eye for making sightings, focusing their search effort within 500m of the vessel as it moved along the transect line. Their angle of view was from 90° on one side of the trackline to 10° on the opposing side.

Two "trackers" (Plate 13), standing on the upper deck, used monopod-mounted *Steiner* 7x50 reticle binoculars for making sightings and were also equipped with fixed angle boards, dictaphones, and datasheets. Trackers focused search effort beyond 500m from the vessel, from 60° on one side of the trackline to 30° on the opposing side. These observers co-operated with one another in recording data for tracked cetacean groups, thereby operating as a single tracking team which was acted independently of and was not visible to primary observers.

Plate 13. Cetacean observers (centre) and a seabird scientist (left) on double-platform survey effort during the *SIAR* survey. Cetacean primary observers and trackers worked independently and out of sight of one another, in accordance with the double platform method.

A "data logger" (or *duplicator*) was positioned on the tracker platform to monitor primary platform sightings and to oversee the tracking of cetacean groups. The data logger provisionally allocated sightings to duplicate or non-duplicate classes in real-time and assigned a measure of certainty (*Definite*: >90%; *Likely*: 71-90%; *Possible*: 51-70%) to potential duplicate records on the basis of exact primary and tracker sighting times, sighting angles and estimated radial distances from the vessel. Final decisions on the status of duplicate sightings were made each evening upon consulting all detailed sighting data transcribed from the primary and tracker dictaphone cassettes.

Survey effort in DP mode was primarily conducted with the vessel travelling in a downwind direction (i.e. wind direction = 90° to 270° relative to the vessel's track). This strategy was deliberately chosen in order to optimise the vessel's stability, to reduce strain on observers' eyes and to optimise sighting conditions in Beaufort sea states >1. The SP mode was adopted when weather conditions did not allow the double-platform method to be used. This occurred when sea state exceeded Beaufort 4 or if the vessel was required to travel against (+90° to –90°) Beaufort 3-4 conditions.

SP mode consisted of two independent primary observers, in addition to the data logger and effort logger roles. Sightings were no longer tracked and observers used 7x50 reticle binoculars to assist in distance estimation and species identification where necessary. When operating in SP mode, the vessel maintained a speed along the transect line of approximately 7 knots.

The *SIAR* survey also incorporated an acoustic survey for cetaceans, the first of its kind in Irish waters (*see* Vol. III), a full seabird survey conducted by a single dedicated observer (*see* Vol. I), the recording of sea surface temperature, and sampling for plankton. Sea surface temperature was recorded using a Hugrun Seamon© Mini device deployed at approximately 1-meter depth between 31 July and 21 August 2000.

3. DATA ANALYSIS

The abundance estimation and statistical analysis was conducted using S-PLUS software developed by the Research Unit for Wildlife Population Assessment, University of St. Andrews. Assistance with the data preparation and analysis was kindly provided by Dr M. Louise Burt and Dr David Borchers of the University of St Andrews.

For the purposes of the analysis described here, the data collected during the *SIAR* survey were assigned to a single geographic stratum. Only data collected under suitable sea conditions (i.e. Beaufort 0 to 4) were used in the estimation of animal abundance. Duplicate sightings were restricted to those defined as *Definite*. Using data gathered in the distance estimation trial, individual correction factors were derived by weighted linear regression and applied to each observer's radial distance estimates. The perpendicular distances of cetacean groups to the vessel's trackline were then calculated using recorded angles and corrected radial distances to sightings (Lerczak & Hobbs, 1998). Exploratory plots of perpendicular distance to cetacean sightings were used to determine an appropriate right truncation distance for the dataset.

For species with a sufficient number of sightings, the number of animals within the study area was estimated using methods developed for the SCANS survey (Borchers *et al.*, 1998a, b). Primary detection probability on the trackline, $g_{(0)}$, was modelled as a function both of perpendicular distance (X) and explanatory variables ($\underline{z}$) which may affect detection probability (e.g. group size, environmental conditions), using a generalised linear model (GLM) with a logistic link function. Covariates incorporated as potential main effects in estimating the primary detection function were: group size, swell height and Beaufort sea state. Nominal descriptors for the degree of precipitation and glare were also included in the model as factors. Variables were selected for inclusion in the abundance estimation model using Akaike's

Information Criterion (AIC) (Akaike, 1973). Associated variance and 95% confidence intervals were estimated using a nonparametric bootstrap (Efron & Tibshirani, 1993) with effort segments within transects as resampling units (Borchers *et al.*, 1998a; Forcada *et al.*, 1998).

Seawater temperature was recorded using the deployed device at 10-minute intervals and, in processing the data, the vessel's latitude/longitude readings were decimalised and the temperature gridded into a 20X20 grid to the limits of the area covered. This grid setting was chosen to give a smooth representation of the temperature contours and to remove noise visible at higher resolutions.

As an index of gradient (or slope), the difference in water depth was calculated every 30 minutes (equivalent to a distance travelled of 7.4km) along a chosen transect line. For the analysis of distribution and relative abundance, the study area was divided into three major regions, based on depth: Continental shelf area (<500m), Continental slope (500 – 2000m) and Trough area (>2000). To obtain a relative index of abundance, encounter rate was calculated by dividing the number of groups encountered in each habitat type by the number of kilometres travelled while on-effort. This was then multiplied by 100 to give sightings per 100km traveled:

$$\text{Encounter rate} = \frac{\text{number of groups encountered}}{\text{km on-effort}} \times 100$$

Encounter rates for different habitats or depth ranges, gradients and temperature regimes were compared. A group was defined as all animals sighted at the same time showing similar behavioural patterns and at distances of < 500m from each other. In instances where mixed species groups occurred, this was considered as one encounter for each species.

RESULTS

1. SURVEY COVERAGE

The entire study area was covered using line-transect methods during the survey period. Due to the 25% allowance for weather-related downtime, favourable weather conditions and the operational flexibility of the vessel's crew, the *SIAR* survey saw the opportunistic reworking of a number of transects which were initially covered in poorer weather. As a result, approximately 96.5% of the 2,113 km transect length was successfully surveyed in DP mode (Fig. 2.2). The remainder of the study area was surveyed in SP mode and could not be surveyed otherwise due to persistently poor weather conditions. Due to the resurveying of selected transects in DP mode, the effective total transect length (*L*) measured 2,356km. The optional southward extension to the survey was not conducted due to time constraints.

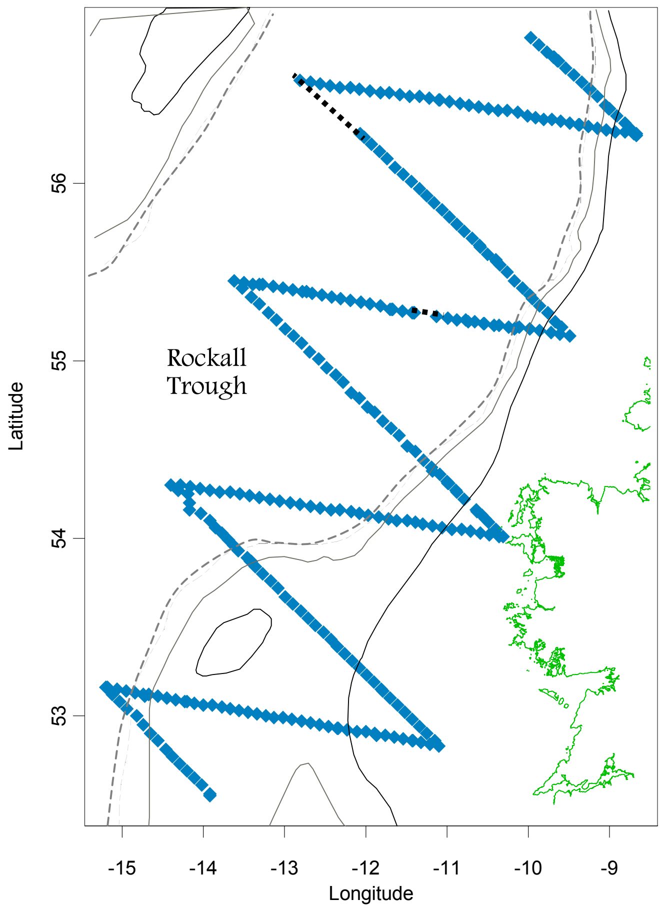

Figure 2.2. Summary of double platform (DP) survey effort conducted along transect lines through the *SIAR* survey target area. Gaps shown (dotted lines) were covered in single platform (SP) mode. (Depth contours shown are 200m, 500m and 1000m isobaths).

2. SIGHTING RECORDS

A total of 126 cetacean sightings were obtained during the course of the survey, 116 of which were made while observers were on-effort and 10 of which were incidental sightings. An analysis of on-effort sightings data against Beaufort sea state determined that over 93% of sightings were made in sea states ≤4. Sighting numbers declined sharply thereafter to approximately 4% and 3% in Beaufort 5 and 6 respectively. Cetaceans were recorded throughout the study area (Fig. 2.3) and fifteen identifiable species were recorded (Table 2.1). The most frequently encountered species were Common Dolphins and White-sided Dolphins. Four on-effort and two incidental sightings consisted of multi-species encounters, where groups of two or more species were observed travelling in the same direction and in close proximity to one another. Four species of baleen whale were observed during the survey, including a single Humpback Whale seen in the northern Rockall Trough (Fig. 2.4). Among the odontocetes, three members of the beaked whale family (*Ziphiidae*) were sighted during the survey: Cuvier's Beaked Whale (1st Irish live record), Sowerby's Beaked Whale (1st Irish live record) and Northern Bottlenose Whale (Fig. 2.5). There were also records of Striped Dolphins in continental shelf waters off western Ireland (Fig. 2.6).

A significantly greater number of sightings (χ^2=10.992, *d.f.*=1, P<0.001) was obtained in waters ≤1000m deep (n_1=80) than in waters exceeding 1000m depth (n_2=46). On examining sighting encounters across total effort in DP mode, there was a detectable difference between the number of encounters for each species (Wilcoxon's test: T_w=25, *d.f.*=15, P<0.1) within the chosen depth strata. Although this was not statistically significant at the 95% level, it indicated a level of association between species occurrence and bathymetry, warranting further analysis. Among several species that showed apparent bathymetry-related preferences were Sperm Whales, which were recorded exclusively in waters exceeding 1000m depth (Fig. 2.5). In contrast, Minke Whales (Fig. 2.4), Harbour Porpoises and Striped Dolphins (Fig. 2.6) were solely recorded in continental shelf waters.

TABLE 2.1. Summary of all encounters with cetacean groups during the *SIAR* survey. Data are composed of non- and definite-duplicate sightings (Letters [a-f] link species seen together in multi-species encounters).

SPECIES / CATEGORY	On-effort encounters (N_{ON})	*DP Mode* (N_{ON})	*SP Mode* (N_{ON})	Incidental encounters (N_{OFF})	Group size *Mean ± S.E.*	Group size *Range*
White-sided Dolphin [a,b]	30	29	1	1	12.3 ± 5.4	1 - 170
Common Dolphin [a,b,c]	27	21	6	3	5.6 ± 1.3	1 - 30
dolphin– unidentified	10	10	0	2	2.1 ± 0.5	1 - 6
Minke Whale [d]	8	8	0	0	1	
Bottlenose Dolphin	5	5	0	1	6.2 ± 2.8	1 - 20
Sperm Whale	4	4	0	1	1.6 ± 0.6	1 – 4
Fin Whale [e]	4	4	0	1	1.2 ± 0.2	1 - 2
Harbour Porpoise	5	5	0	0	1.2 ± 0.2	1 – 2
White-beaked Dolphin [d,f]	4	4	0	0	3.8 ± 1.0	2 – 6
whale (medium) – unidentified	3	3	0	0	1	
whale – unidentified	3	3	0	0	1	
Sei Whale [e]	1	1	0	1	1.5 ± 0.5	1 - 2
Striped Dolphin [a,c]	2	2	0	1	11.3 ± 9.4	3 – 30
dolphin- Common/Striped	2	2	0	0	2.5 ± 1.5	1 - 4
Northern Bottlenose Whale	2	2	0	0	1.5 ± 0.5	1 - 2
whale (large) – unidentified	2	2	0	0	1.5 ± 0.5	1 - 2
dolphin– Lagenorhynchus sp.	2	2	0	0	5	
beaked whale – unidentified	2	2	0	0	2.5 ± 1.5	1 - 4
Cuvier's Beaked Whale	1	1	0	1	4.0 ± 1.0	3 - 5
Humpback Whale	1	1	0	0	1	
Sowerby's Beaked Whale	1	1	0	0	4	
Long-finned Pilot Whale [f]	1	1	0	0	8	
dolphin (patterned)- unknown	1	1	0	0	8	

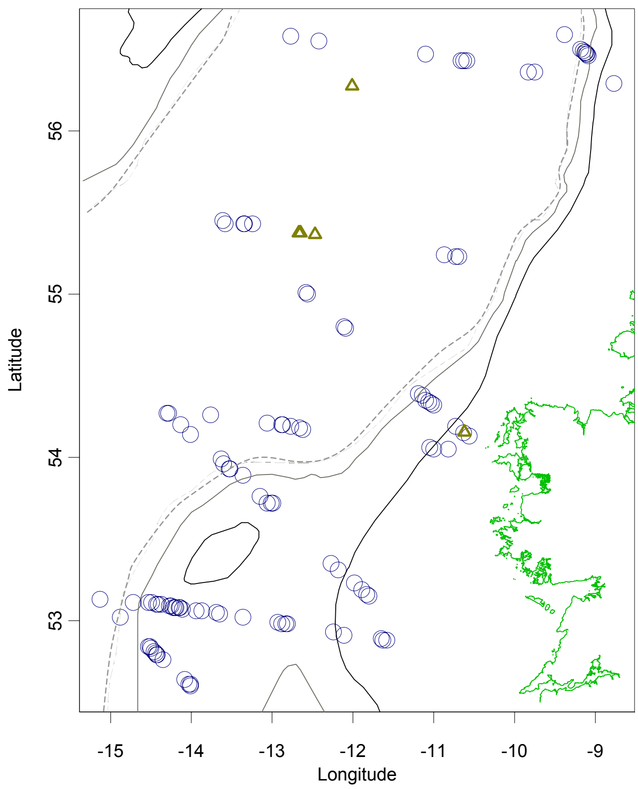

Figure 2.3. Distribution map for all cetacean sightings recorded in double platform (DP) and single platform (SP) modes during the *SIAR* survey.

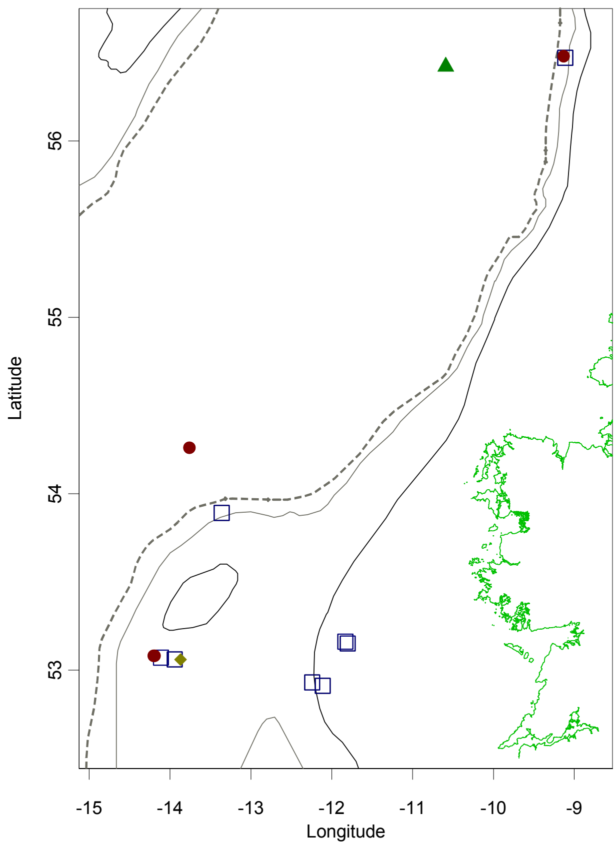

Figure 2.4. Distribution of on-effort sightings of baleen whales during the *SIAR* survey.

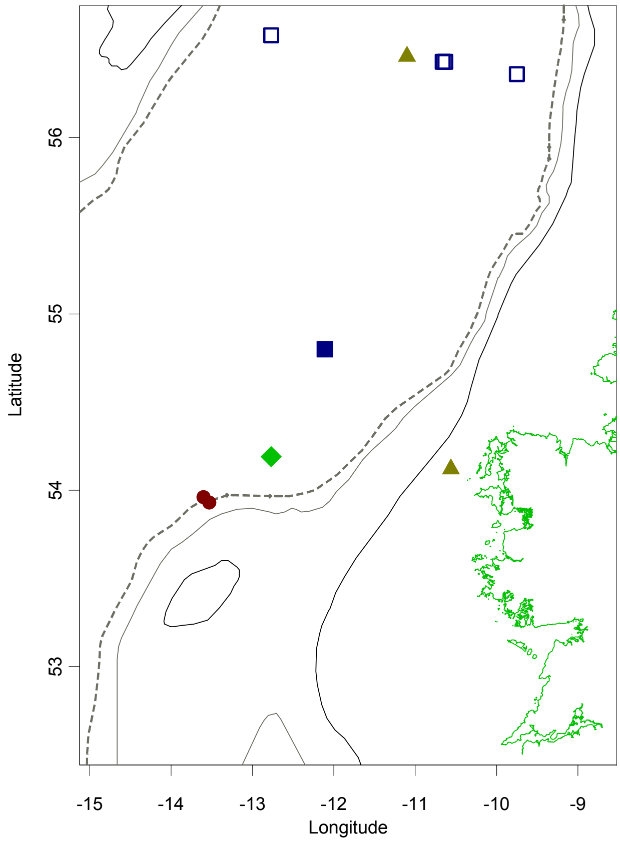

Figure 2.5. Distribution of on-effort sightings of large odontocetes during the *SIAR* survey.

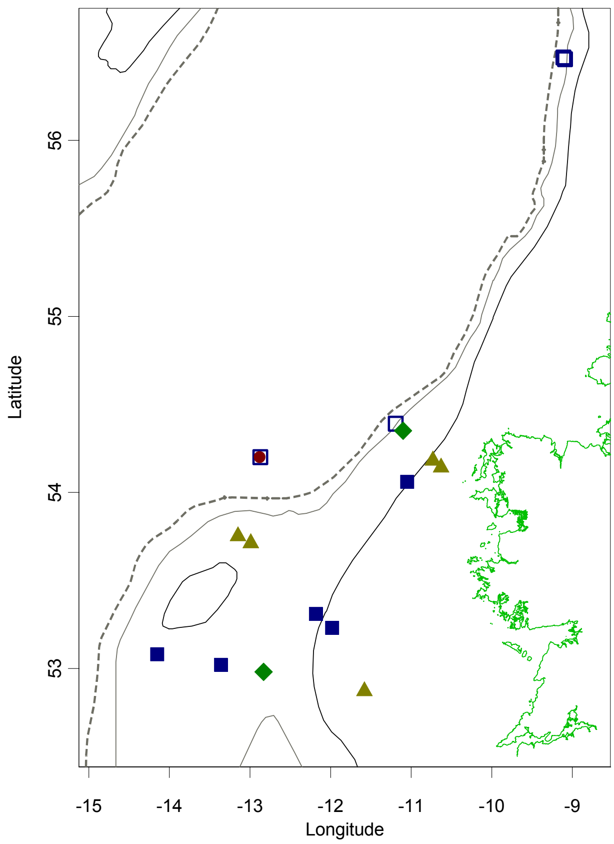

Figure 2.6. Distribution of on-effort sightings of several smaller odontocete species during the *SIAR* survey.

3. COMMON DOLPHIN AND WHITE-SIDED DOLPHIN ABUNDANCE

By far the most commonly encountered species during the *SIAR* survey were White-sided Dolphins (Fig. 2.7) and Common Dolphins (Fig. 2.8). Individuals and groups of both species were observed throughout the study area, from continental shelf waters to the deeper waters of the Rockall Trough. Relatively high densities of both species were recorded over continental shelf waters southwest of the Porcupine Bank.

Examination of the data revealed a sufficient number of on-effort sightings of White-sided Dolphins and Common Dolphins to derive estimates of animal density and abundance. Consequently, data for both species were right-truncated to a perpendicular distance of 1.5km, eliminating a single outlier sighting at the largest perpendicular distance. Of the remaining Common Dolphin and White-sided Dolphin groups encountered while on visual effort, 50 sightings were obtained on DP mode in Beaufort states ≤ 4. Twenty-one of these were duplicate sightings classified as *Definite* (Table 2.2).

TABLE 2.2 Summary of sighting data that were used in abundance estimation. Data used are composed of distinct non-duplicate and definite-duplicate sightings, right-truncated at a perpendicular distance from the vessel of 1.5km.

SPECIES	No. of schools	No. of Duplicates *Definite*	No. of sightings *Beaufort scale* *1*	*2*	*3*	*4*	Group size *Mean ± S.E.*	Group size *Range*
White-sided Dolphin	29	12	5	12	6	6	6.6 ± 33.7	1 - 31
Common Dolphin	21	9	0	10	5	6	6.4 ± 37.8	1 - 30

Because of small sample sizes, pooled sightings data from both species were used to estimate detection probability. This use of combined data from two species seems reasonable on the basis of the similar detection cues of Common Dolphins and White-sided Dolphins, similar mean group sizes observed in the field (Table 2.2) and non-significant differences in calculated perpendicular distances to sightings of both species (Mann-Whitney *U*-test, $P>0.05$). Although a single detection function was estimated from the pooled sightings data, estimates of mean school size, density and abundance were calculated both (i) for both species combined, and (ii) separately for each species (using the pooled detection function).

In exploring GLM model fits to the data, the effects of environmental covariates and other factors on estimates of $g_{(0)}$, dolphin school density (D_{school}), estimated mean school size ($E_{(s)}$) and animal abundance (N_{indiv}) were examined. The best model fit to the observed data, determined by the lowest AIC, residual deviance and coefficients of variation (CV) over 100 bootstrap resamples, were given by incorporating the single covariate of school size (S_{size}). It is possible that the estimates from this model are somewhat negatively biased because of unmodelled heterogeneity due to variables such as perpendicular distance and sea state but the sample size was inadequate to support estimation with these variables. In particular, their inclusion resulted in frequent failures to converge when bootstrapping.

The selected model yielded a combined abundance estimate for both species in the study area of 10,186 dolphins (CV=0.34, 95% CI: 3,499 – 18,114; Table 2.3) and an animal density in the study area of 0.085 individuals per km^2 (CV=0.34, 95% CI: 0.029 - 0.151; Table 2.3). When separated by species, the model yielded abundance estimates for the study area of 5,490 White-sided dolphins (Table 2.4) and 4,496 Common Dolphins (Table 2.5).

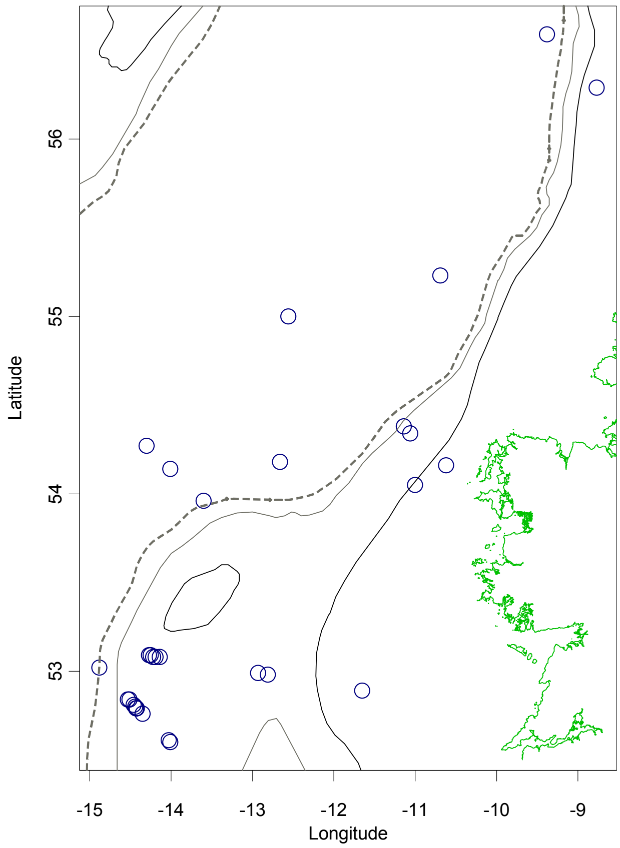

Figure 2.7. Distribution of sightings of White-sided Dolphins during the *SIAR* survey. Data shown are distinct records comprising non-duplicate and definite-duplicate sightings obtained in DP survey mode.

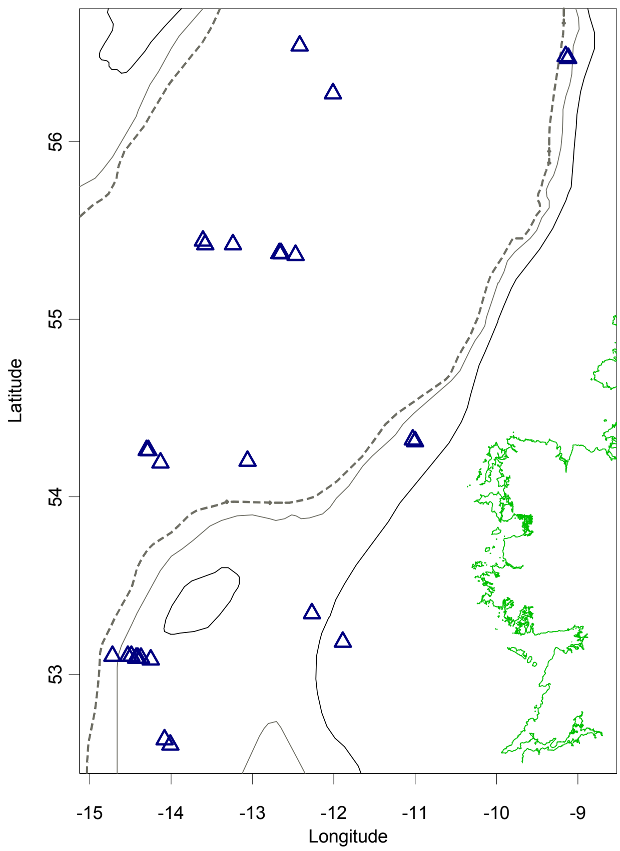

Figure 2.8. Distribution of sightings of Common Dolphins during the *SIAR* survey. Data shown distinct records comprising non-duplicate and definite-duplicate sightings obtained in DP survey mode.

TABLE 2.3. Estimates of combined school abundance, mean school size, animal abundance and animal density for Common Dolphins and White-sided Dolphins in the *SIAR* study area with coefficients of variation and 95% confidence intervals estimated by bootstrapping (no. of resamples = 100).

	School abundance	Mean school size	Animal abundance	Animal density
	$\check{N}_{school}$	$\bar{E}(S)$	$\check{N}_{indiv}$	$\check{D}_{indiv}$ (km^{-2})
Model estimate	2,289	4.45	10,186	0.085
CV	0.66	0.26	0.34	0.34
95% C.I.	1,309 – 8,309	1.54 – 5.66	3,499 – 18,114	0.029 – 0.151

TABLE 2.4. Estimates of White-sided Dolphin school abundance, mean school size, animal abundance and animal density in the *SIAR* study area with coefficients of variation and 95% confidence intervals estimated by bootstrapping (no. of resamples = 100).

	School abundance	Mean school size	Animal abundance	Animal density
	$\check{N}_{school}$	$\bar{E}(S)$	$\check{N}_{indiv}$	$\check{D}_{indiv}$ (km^{-2})
Model estimate	1,147	4.78	5,490	0.046
CV	0.96	0.39	0.43	0.43
95% C.I.	250 – 2,894	2.47 – 8.40	1,134 – 10,015	0.010 – 0.084

TABLE 2.5. Estimates of Common Dolphin school abundance, mean school size, animal abundance and animal density in the *SIAR* study area with coefficients of variation and 95% confidence intervals estimated by bootstrapping (no. of resamples = 100).

	School abundance	Mean school size	Animal abundance	Animal density
	$\check{N}_{school}$	$\bar{E}(S)$	$\check{N}_{indiv}$	$\check{D}_{indiv}$ (km^{-2})
Model estimate	1,141	4.11	4,496	0.039
CV	1.07	0.27	0.39	0.39
95% C.I.	439 – 3,126	1.85 – 6.31	2,414 – 9,320	0.017 – 0.078

4. DISTRIBUTION OF CETACEANS IN RELATION TO PHYSICAL FACTORS

In general, sea surface temperature data for the *SIAR* study area showed a typical summer temperature profile. Surface water temperatures ranged from 14.2˚C to 17.2˚C while much of the study area experienced temperatures ranging from 15.5˚C to 16.2˚C (Fig. 2.9). There was, as expected, an obvious south-north reduction in sea surface temperature and also an inshore-offshore decrease (Table 2.6). The south-north gradient may have been slightly accentuated by an inevitable time-lag in data collection between areas. Nevertheless, a distinctive warm-water gyre (Fig. 2.9; J. Silke, Marine Institute FRC, *pers. comm.)* was identified off the northwest of Ireland during the *SIAR* survey period.

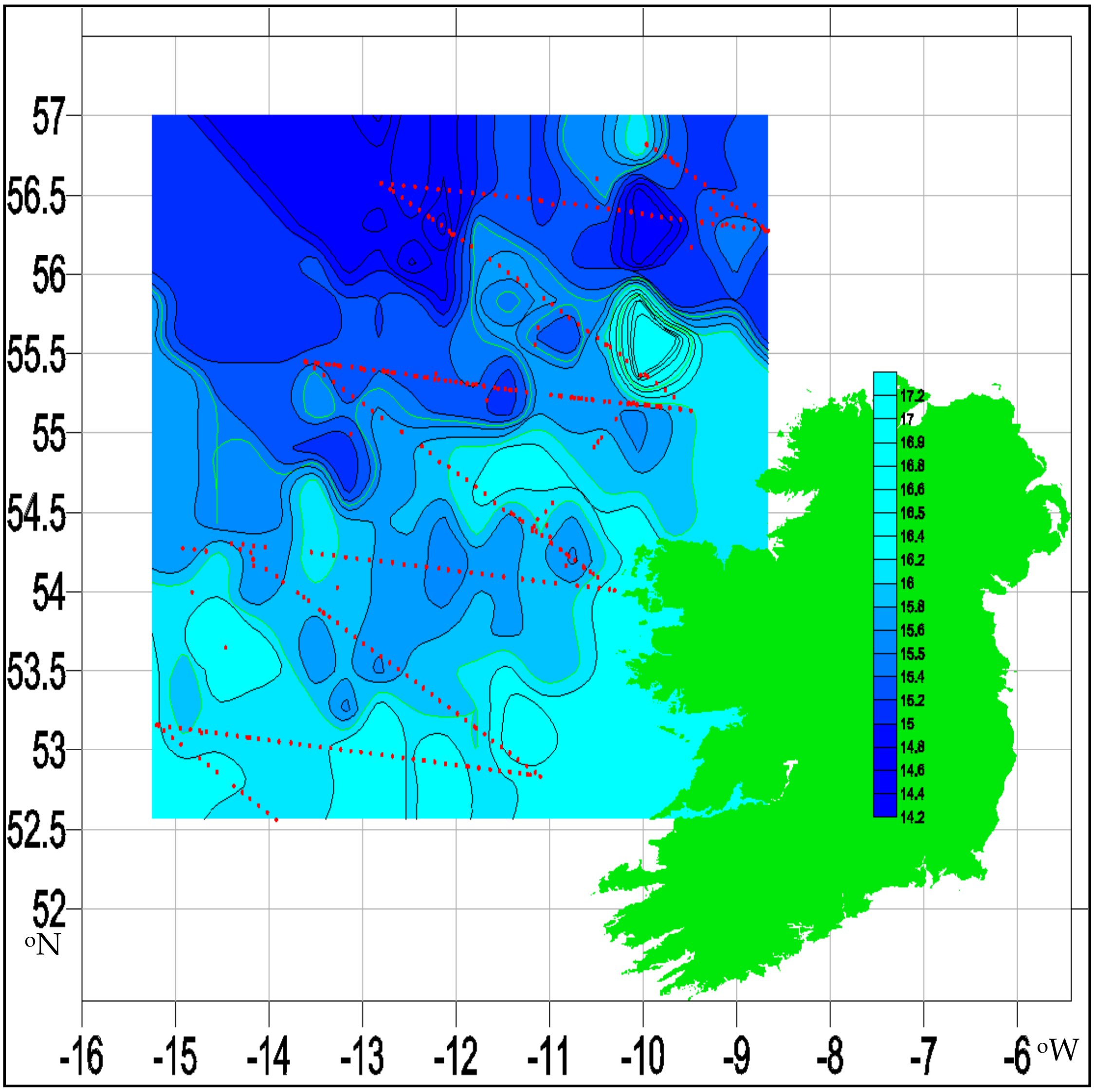

Figure 2.9. Map of the *SIAR* study area showing latitude and longitude grid, sea surface temperature contours and transect lines performed during the survey.

The *SIAR* study area was an area of complex topography - with an extensive continental shelf in the southern section of the survey area, the deep Rockall Trough to the west, and, along the edges of the Rockall Trough, a relatively steep continental slope (Fig. 2.1). Water depths ranged from 60m to 3,133m. Seabed gradient through the study area was also variable and the survey track covered areas with little or no differences in gradient (< 1m vertical displacement per 7.4 km travelled) to areas of very sharp changes in bottom topography (> 500m per 7.4 km). Summary data for each of these putative habitat types is shown in Table 2.6 below.

In analysing cetacean sighting rates in relation to physical parameters, individual sighting records were removed from the analysed dataset if depth readings were not available. The revised dataset therefore accounted for 116 sightings (Table 2.7) over a total transect length of 2,681 km (Table 2.6).

TABLE 2.6. Distribution of effort per habitat type (% of total effort) and water depth (in metres), gradient (displacement in metres per 7.4km) and sea surface temperature (°C) with standard errors.

Habitat type	Effort (km traveled)	Water Depth (mean ± SE)	Gradient (mean)	Sea Temperature (mean ± SE)
Shelf	1044	239 ± 8.5	36.1	15.96 ± 0. 065
Slope	748	1264 ± 37.4	192.7	15.56 ± 0. 045
Trough	889	2687 ± 19.5	87.6	15.45 ± 0. 033

TABLE 2.7 Summary of all cetacean species recorded among the selected habitat types during the *SIAR* survey and sighting rates for all identified and unidentified species encountered.

Habitat type (depth)	Species	Number of encounters	Sighting rate (per 100 km)
Continental Shelf (<500m)	White-sided Dolphin	20	1.91
	Common Dolphin	12	1.15
	Unidentified dolphins	*8*	*0.77*
	Minke Whale	6	0.57
	Bottlenose Dolphin	5	0.48
	Harbour Porpoise	5	0.48
	White beaked Dolphin	1	0.21
	Striped Dolphin	1	0.21
	Fin Whale	2	0.19
	Unidentified whale	*2*	*0.19*
	Sei Whale	1	0.10
	Northern Bottlenose Whale	1	0.10
Continental Slope (500–2000m)	White-sided Dolphin	5	0.67
	Common Dolphin	4	0.53
	Unidentified dolphin	*4*	*0.53*
	Sperm Whale	3	0.40
	Unidentified whale	*3*	*0.40*
	Striped Dolphin	1	0.13
	Humpback Whale	1	0.13
	Long-finned Pilot Whale	1	0.13
	Minke Whale	1	0.13
	Sowerby's Beaked Whale	1	0.13
	Unidentified beaked whale	*1*	*0.13*
Rockall Trough (>2000m)	Common Dolphin	10	1.12
	White-sided Dolphin	5	0.56
	Unidentified whale	*3*	*0.34*
	Northern Bottlenose Whale	2	0.22
	Lagenorhynchus species	*2*	*0.22*
	Fin Whale	1	0.11
	White-beaked Dolphin	1	0.11
	Sperm Whale	1	0.11
	Cuvier's Beaked Whale	1	0.11
	Unidentified dolphin	*1*	*0.11*

Most cetacean sightings recorded during the *SIAR* survey were obtained in waters overlying the continental shelf (<500m; Fig. 2.3), characterised by a mean depth of 239m (± 8.5m). This habitat type received 38.9% of the survey effort included in the analysis. In analysing cetacean sighting rates by habitat type, a similar result was obtained with a maximum sighting rate recorded for the study area (55.17% of sightings; n = 64; 6.13 sightings per 100 km travelled). In contrast, the continental slope habitat type, which was characterised by very steep topography (Table 2.6), received 27.9% of total survey effort and saw considerably fewer sighting records (21.55%; n= 25; Table 2.7). This apparent contrast in relative abundance was reflected by a significantly lower sighting rate within this habitat type (3.34 sightings per 100 km). In the deep waters of the Rockall Trough, which received 33.2% of survey coverage, the total cetacean sighting rate was lowest among the three selected habitat types, in spite of a higher total number of sightings than were recorded in continental slope habitats (23.28%; n=27; 3.03 sightings per 100 km).

In broad agreement with the pattern described for all cetacean sightings combined, sighting rates for individual species tended to decline in deeper waters of the continental slope and Rockall Trough. Sighting rates calculated for each identified species and unidentified cetacean groupings are also shown in Table 2.7.

White-sided Dolphins were recorded in all three habitat categories (Fig. 2.7). The species was the most frequently sighted cetacean, and the most numerous, in two of the three habitats (Table 2.7). Common Dolphins were the second most frequently sighted species in the continental shelf and slope area and the most frequently sighted cetacean in the Rockall Trough during the survey (Fig 2.8; Table 2.7).

A number of other species were generally recorded in only one of the three habitat categories, albeit at comparatively low sighting rates, suggesting a level of species partitioning across habitat types, as indicated in Figs. 2.4-2.6. For example, Harbour Porpoises and Bottlenose Dolphins were only seen on the continental shelf area, whereas Minke Whales were primarily detected on the continental shelf (n= 6) with one sighting in the continental slope area. In contrast, Sperm Whales were solely recorded in deeper continental slope waters exceeding a depth of 1000m (Fig. 2.5) and a higher sighting rate for this species (Table 2.7) was recorded in this habitat type than in the deep waters of the Rockall Trough (>2000m; 1 sighting record).

DISCUSSION

The *SIAR* survey was the first of its kind in the waters off western Ireland and it represents an important milestone in cetacean research along the Atlantic Margin of Europe. In its operation alongside *Cetaceans & Seabirds at Sea* surveys on vessels of opportunity, it further highlighted the variety and abundance of cetaceans in the waters off western Ireland.

The successful coverage achieved on the *SIAR* survey using optimal survey methods was possible, to a large extent, by the careful planning and execution of the survey, by the use of a suitable large research vessel (35m = minimum vessel-length required), by relatively good weather conditions and assistance of the vessel's crew. Prior to completion of the *SIAR* survey, the informational context for other surveys performed in Ireland's Atlantic Margin (e.g. Leopold *et al*., 1992; Pollock *et al*., 1997; Gordon *et al*., 1999) was yet unclear and, in assessing the importance of western Irish waters for cetaceans, one was reliant on data collected using sub-optimal methods and even on stranding information. Consequently, the authors hope that the success of the *SIAR* survey may (i) contribute key scientific information that was lacking heretofore and (ii) assist in the development of improved methods for cetacean surveying in waters of Ireland's Atlantic Margin, which present a significant operational challenge to marine scientists irrespective of the time of year.

In evaluating methods for surveying cetacean populations, no one technique will cover all operational eventualities in Atlantic Margin waters and, in researching marine mammals, which spend much of their time below the sea surface, this is particularly the case. The *SIAR* survey allowed the Coastal & Marine Resource Centre's *Cetaceans & Seabirds at Sea* team to conduct a number of methods (single-observer, multiple-observer and acoustic) simultaneously and to evaluate the data gathered using each mode (*see also* Vols. I & III) over a range of weather conditions. This allowed the team to strengthen its data collection capabilities in the remaining months of the research programme (Sept 2000-Sept 2001) and to commence tackling important operational (e.g. method improvement, equipment provision) and biological issues (e.g. seismic activity, areas of importance). An immediate improvement, from a methodological standpoint, was facilitated by the ongoing use in 2000 and 2001 of acoustic equipment first used in the *SIAR* survey (*see* Vol. III). A second post-*SIAR* improvement was brought about by the opportunistic use of dual (instead of single) observers aboard vessels of opportunity, which greatly enhanced the cetacean data collected in the field, and by the incorporation (when two observers were deployed) of experimental visual and acoustic methods alongside the normal strip-transect approach. This is an area that requires further development if the quantity and quality of cetacean data collected aboard vessels of opportunity are to be optimized for future research programmes of this nature.

The sighting data collected during the *SIAR* survey were highly significant for a number of reasons. Firstly, the information gathered during the *SIAR* survey allowed, for the first time, the estimation of animal abundance and population density for two species (i.e. White-sided Dolphin and Common Dolphin) occurring in summer off western Ireland. The data also greatly enhanced the quantity of information gathered under the overall research programme, almost matching in three weeks, what had been recorded over 12 months research (July 1999-July 2000) aboard vessels of opportunity. Several "new" (to the research programme) species of cetacean were observed in the Irish Atlantic Margin study area for the first time during the *SIAR* survey (e.g. Cuvier's Beaked Whale, Northern Bottlenose Whale, Sowerby's Beaked Whale). Excellent observations of these animals in the field subsequently facilitated the identification of another rarely sighted species in 2001 (i.e. True's Beaked Whale, p. 32).

In addition, sightings information gathered during the *SIAR* survey allowed the authors to explore and validate hypotheses on the distribution and abundance of various species along

Ireland's Atlantic Margin in summer, the period during which most survey effort aboard vessels of opportunity (present study) and previous cetacean surveys in Irish waters (e.g. Leopold *et al*., 1992; Hammond *et al*., 1995;) also focused. For example, surveys aboard vessels of opportunity (data presented herein) might lead one to the conclusion that Common Dolphins are by far the most abundant cetacean species in Ireland's Atlantic Margin (Fig. 1.4; Table 1.1). The *SIAR* survey allowed this impression to be explored further in the context of a defined study area and season, yielding population estimates considerably lower than those produced in the Celtic Sea (Hammond *et al*., 2002).

Similarly, one might have expected the sparse occurrence of cetaceans in the deep Rockall Trough, considering data for many species collected from vessels of opportunity (also herein). However, this was shown not to be the case by sighting data collected during the *SIAR* survey (Fig. 2.3), which indicates that the Rockall Trough, particularly its eastern and northern margins, may represent an important habitat for several cetacean species, including the rarely sighted beaked whales. These and the *SIAR* survey's many other findings justified the choice of study area and methods employed, since it was not possible to cover the entire Irish Atlantic Margin within the temporal and financial constraints under which any such survey operates.

One hypothesis also explored was that relating to the physical processes that may determine cetacean distribution and abundance. Previous authors (e.g. Evans, 1990; Pollock *et al*., 1997; Gordon *et al*., 1999) and data collected in the present study (*see* Chapter 1) indicated that there might be a link between the distribution and abundance of various cetacean species along Ireland's Atlantic Margin and the presence of the continental shelf edge. However information from the *SIAR* survey suggests that this hypothesis may be an over-simplification in the context of western Irish waters where inter-specific variation in distribution appears to be quite pronounced. Furthermore, no direct association was detected between any recorded cetacean species and sea surface temperature data, nor the presence of a distinct warm-water gyre located off northwestern Ireland, during the survey period.

According to results in the overall research programme, a few species (e.g. Long-finned Pilot Whales; White-beaked Dolphins and perhaps beaked whales) do appear to be associated with continental shelf-edge/slope habitats. However, White-sided Dolphins and Common Dolphins, which were the most abundant cetacean species recorded during the *SIAR* survey, overlapping in their distribution from continental shelf to deep-water areas, showed no clear habitat preferences. In contrast, Selzer & Payne (1988) working in the northeastern United States found strong associations between the distribution of these species and areas of high sea floor relief with White-sided Dolphins more frequently sighted in areas where sea surface temperature and salinities where low while Common Dolphins were sighted in warmer more saline waters. It may be that differences in prey distribution and availability introduce heterogeneity in the distributions of many cetacean species along Ireland's Atlantic Margin. White-sided and Common Dolphins are believed to be primarily piscivorous (i.e. fish-eating) along Ireland's Atlantic Margin, consuming a wide variety of prey including *Trisopterus* species (e.g. pout), whiting, hake, and mackerel (Rogan & Berrow, 1995, Rogan *et al.* 1998). In deeper waters, Common Dolphins are known to feed on a variety of *Myctophid* fish species (Rogan & Mackey, 1999), which occur in the deep scattering layer.

In contrast to the widespread distribution of White-sided and Common Dolphins, Harbour Porpoise and Bottlenose Dolphins were only recorded in continental shelf waters during the *SIAR* survey. Results from the current study on the distribution of Harbour Porpoises are consistent with findings elsewhere. Throughout its North Atlantic range, this species appears to be limited to continental shelf waters, probably due to its demersal foraging behaviour and diving capacity (Read, 1999). Analysis of their distribution over several spatial scales indicate that porpoises are most frequently found in cool waters (< 17°C) where aggregations of prey are concentrated (Gaskin *et al*., 1993; Palka, 1995). Bottlenose Dolphins tend to be primarily coastal, but may also be found in offshore waters (Kenney, 1990; Scott & Chivers, 1990). This was also demonstrated in the present study, which recorded Bottlenose Dolphins in deep offshore areas in spring, with perhaps a little more concentration over continental shelf and slope habitats in the summer months (*see* Figs. 1.20). It may be that groups of animals range widely throughout the Irish Atlantic Margin as the species also appears to have a relatively wide sea temperature-distribution relationship. Off the coast of North America, Bottlenose Dolphins are found in waters with sea surface temperatures of 10 - 32˚C (Wells & Scott, 1999).

Sperm Whales were recorded solely in the north of the *SIAR* study area, in relatively cold waters (14.5°C) of the Rockall Trough. Most Sperm Whales in the northern hemisphere are believed to spend the winter months in warm temperate or subtropical waters, before travelling north to their summer feeding grounds. Data from strandings in the northeast Atlantic generally support the principle that segregation of the sexes takes place outside the breeding season (Leatherwood & Reeves, 1983), with male Sperm Whales travelling considerably farther north than females. As a result, Sperm Whale distribution in summer may extend in the northeast Atlantic as far as the Arctic Circle for males of the species.

The distribution of Sperm Whales recorded during the *SIAR* survey in July/August 2000 may reflect a more southerly distribution of the summer feeding grounds for Sperm Whales in the northeast Atlantic than previously reported. However, the sex of the recorded animals could not be determined and, in view of the occasional sighting of Sperm Whales calves and juveniles along Ireland's Atlantic Margin from vessels of opportunity (*see* Chapter 1), the possibility that groups of adult female and young Sperm Whales may be seasonally distributed as far north as Ireland's Atlantic Margin cannot be discounted. The diet of Sperm Whales consists almost entirely of cephalopods, and appears to vary from region to region. Santos *et al*. (1999) reported that *Gonatus* was the most commonly reported cephalopod species recovered from the stomach contents of Sperm Whales in the North Sea. In contrast, Sperm Whales from the northeast Atlantic, including one stranded on Tory Island, Co. Donegal, showed a more diverse diet, including the octopus *Haliphron atlanticus*, a *Gelatinus* octopus normally found in depths of up to 3,180m, the squid *Histhioteuthis bonnelli*, which are found in depths ranging from 100-2,000m and the giant squid species, *Architeuthis* (Santos *et al*., 2002).

Beaked whales were mainly recorded in the deeper waters of the Rockall Trough. Very little information is published on the diet of deep-water cetacean species such as Northern Bottlenose Whales or Cuvier's Beaked Whale, in the northeast Atlantic. In a study of beaked whale (i.e. Cuvier's Beaked Whale, *Mesoplodon* species) and Sperm Whale distribution in northeastern US waters, Waring *et al*. (2001) determined that during the summer these deep-diving cetaceans frequent continental shelf edge habitats (200m-2000m depth) with beaked whales concentrated along the colder shelf edge waters and Sperm Whales showing a preference for warmer off-shelf waters. The authors suggested that these species' habitats could be predicted by using topographic features such as canyons, shelf edges, sea-mounts and other bathymetric features that are known to influence oceanographic processes and concentrate prey species. In addition, these authors differentiated between permanent foraging areas (e.g. shelf-slope interface) and ephemeral habitats (e.g. transient warm-water cores, seasonal frontal boundaries).

Very little is known of beaked whale biology in the waters of Ireland's Atlantic Margin and the sightings recorded during the *SIAR* survey and aboard vessels of opportunity (*see* Chapter 1) represent an important collection of sightings. Stomach content analysis of a single Northern Bottlenose Whale stranded in County Mayo in 1999 recorded a number of cephalopod species, including *Gonatus* species, *Teuthowenia* species, *Taonius* species and a smaller number of *Histioteuthis* and *Haliphron* species (M.B. Santos, University of Aberdeen, *pers. comm.*). It is likely that differences in prey selection could be an important factor contributing to habitat partitioning in this region between Sperm Whales and beaked whales. Little is known of the distribution of cephalopod species in Irish waters, particularly the deep-water species (Lordan, 2001). A number of surveys have been carried out on commercial fishing and fisheries research vessels, including a deep water trawl survey off the west coast of Ireland along the continental slope. Of the six cephalopod species caught during this survey, *Todarodes sagittatus* was the most common species, being concentrated northwest of Donegal along the continental slope. *Teuthowenis magalops*, *Histioteuthis* species and *Benthoctopus piscatorum* were also recorded in this area, but in lower numbers (Lordan, 2001).

While data collected during the *SIAR* survey (a) highlight the cetacean species richness along Ireland's Atlantic Margin; (b) demonstrate the inter-specific variation in abundance and distribution of cetaceans, and (c) underscore the complexity of ecosystems along Ireland's Atlantic Margin, a number of findings of the *SIAR* survey may be more clearly defined. Firstly, a seasonally important area for the more abundant cetacean species, namely Common Dolphins and White-sided Dolphins, was identified in continental shelf/slope waters surrounding the Porcupine Shelf. Secondly, although the waters overlying the continental shelf-edge to the west of Ireland did not wholly demonstrate high concentrations of cetaceans, the continental slope and deep Rockall Trough waters immediately north of the Porcupine Shelf represented a highly significant area for many cetacean species, including both pelagic and deep-diving odontocete species. A second area of potential importance was found in the northeastern part of the study area, near the sub-sea Hebrides Sea Terrace.

The abundance estimates for White-sided Dolphins and Common Dolphins inhabiting waters to the west of Ireland in summer, represent the first estimates for any cetacean population in these waters. The estimate derived in the present study for White-sided Dolphins (5,490 animals; 0.046 animals per km^2; CV = 0.43) greatly exceeded a Celtic Sea estimate from the 1994 SCANS survey for both *Lagenorhynchus* species combined (833 animals; 0.0041 animals per km^2; CV = 1.02) (Hammond *et al*., 2002). The calculated density of White-sided Dolphins (no. of animals per km^2) in the *SIAR* area was over 11 times that observed in the Celtic Sea. These figures highlight the major importance of Irish Atlantic Margin waters for White-sided Dolphins in summer, which is the breeding period for this species.

In contrast, the summer abundance estimate derived for Common Dolphins in the Celtic Sea (75,450 animals; CV = 0.67; 95% Confidence Intervals: 23,000 - 249,000; Hammond *et al*., 2002) was much greater than those produced from the *SIAR* survey data (4,496 animals; CV = 0.39; 95% C.I.: 2,414 - 9,230). However, the former estimate was derived by primary line-transect methods alone -- i.e. no correction was made for animals missed on the track-line (implicit in the *SIAR* survey), nor for responsive movement relating to the vessel. While the SCANS estimate for Common Dolphins, therefore, cannot be strictly compared with the results of the *SIAR* survey, it would nevertheless appear that the numbers of Common Dolphins recorded in the Celtic Sea and *SIAR* study area were somewhat different. This potential difference in Common Dolphin abundance between southern and western Irish waters may be due, in part, to the *SIAR* survey design, which sought to cover significant portions of the Rockall Trough and Porcupine Shelf in a single survey. This feature of the *SIAR* survey, and normal constraints which did not allow the survey to extend into other Atlantic Margin regions of importance to cetaceans (e.g. Porcupine Seabight, *see* Chapter 1), may have meant the under-recording of Common Dolphin abundance off western Ireland.

Results from strip-transect surveys in the present study (Fig. 1.23) and those presented by Pollock *et al*. (1997) highlight the noticeably wide distribution of Common Dolphins throughout the Irish Atlantic Margin in summer, from the Celtic Sea and inshore waters to the offshore Rockall Bank. While care must be taken in interpreting sighting data for such a "vessel-friendly" species, it would appear that significantly larger co-ordinated survey effort, using several dedicated research vessels, is required to accurately determine the size and density of stocks of this ubiquitous species in Atlantic Margin waters, as a whole.

In summary, the abundance estimates given here may be considered as baseline data for the region. The *SIAR* survey represented a unique opportunity to conduct a major offshore cetacean survey in the Irish Atlantic Margin. The survey certainly yielded significant data and it is hoped that the experience gained in planning and successfully completing the *SIAR* survey may be a useful platform upon which to build in future years.

CONCLUSION

Sighting surveys for cetaceans conducted along Ireland's Atlantic Margin under the *Cetaceans & Seabirds at Sea* research programme have proven extremely successful to date, both in informational and operational terms. These studies have scientifically confirmed, for the first time, a high species richness of cetaceans in Irish Atlantic Margin waters. The research programme has thus underlined the international importance of Ireland's Atlantic Margin for cetacean populations, indicating areas of high cetacean abundance and potential habitats of high biodiversity. In management terms, consideration should be given to the dynamic nature of many cetacean species' distribution, as shown in the present study. Conservation of cetacean populations along Ireland's Atlantic Margin, therefore, may require dynamic boundaries and extensive buffer zones, rather than strict delineation of specific areas. This may not be the case for all cetacean species occurring along Ireland's Atlantic Margin and further research will be necessary to determine the most effective conservation strategies for such diverse species.

Key conclusions from the study may be summarised as follows:

1. Sighting surveys for cetaceans, conducted between July 1999 and September 2001, led to the gathering of highly significant data on cetaceans in the waters of Ireland's Atlantic Margin.

2. Distribution and relative abundance data were obtained from 898 sightings of 21 cetacean species occurring in Atlantic Margin waters. These included sighting records of rare and endangered large whales such as the Blue Whale (seen in the Rockall Trough) and the Northern Right Whale (observed in waters overlying the Hatton Bank).

3. Among the rare toothed whales encountered were members of the deep-diving beaked whale family, including the first definitive live records of Cuvier's Beaked Whale, Sowerby's Beaked Whale and a highly probable record of True's Beaked Whale in Irish waters. Groups of False Killer Whales were also recorded on several occasions, representing the first live records of this species in Irish waters.

4. Key regions identified as areas of significant importance for cetacean abundance and species richness were identified along the northern/western margins of the Porcupine Shelf and parts of the Porcupine Seabight, off southwestern Ireland.

5. Other areas of potential significance for various cetacean species are identified throughout Ireland's Atlantic Margin. These include parts of the offshore Rockall Bank, Rockall Trough, in addition to the Hatton Bank and continental slopes bordering the territorial waters of Ireland and Britain.

6. The research programme provided the first opportunity for a dedicated cetacean line-transect survey in the waters of western Ireland and the Rockall Trough (*S.I.A.R.*) in the summer of 2000. Using optimal visual survey methods, this survey determined that Atlantic White-sided Dolphins and Short-beaked Common Dolphins were the most abundant species in summer in the *SIAR* study area off western Ireland.

7. Summer abundance estimates for Atlantic White-sided Dolphins and Short-beaked Common Dolphins were derived from *SIAR* survey data and are presented in the report. These are the first such estimates for any cetacean species occurring in western Irish waters.

8. Surveys aboard ships of opportunity combined a number of techniques during the lifetime of the research programme and provided a platform for the improvement of survey methods in these waters.

9. It is envisaged that this work will provide an important step forward in the formulation of effective management strategies for cetaceans and the habitats that they occupy. In this respect, Volumes I, II & III of the report may constitute an important contribution to the knowledge on cetacean and seabird abundance and distribution in Ireland's Atlantic Margin, particularly in deep offshore waters, from which little information was available prior to this study.

10. Priority research areas for the future include furthering knowledge of the distribution, abundance and ecology of the rarer species observed in the present study, focal studies on key areas of importance for cetacean species (e.g. Porcupine Shelf and Porcupine Seabight) with a view to their effective management, improved data for cetacean populations throughout all seasons and a better understanding of the ecology of all cetacean species of the Irish Atlantic Margin.

11. In order to interpret the results in a wider context and provide a more effective management tool, a future analytical objective of the CMRC *Cetaceans & Seabirds at Sea* programme would be to integrate cetacean data with fisheries data and various physical and oceanographic parameters, such as bathymetry, seabed composition, sea surface temperature, salinity and descriptors of biological productivity. The scope of the present study did not cover this area. In this regard, the Coastal & Marine Resources Centre has good working relationships with several other institutions in Ireland (e.g. Marine Institute, Geological Survey of Ireland) and elsewhere (e.g. Southampton Oceanographic Centre, Norwegian Institute of Marine Research) which also have expertise in these fields and it would be extremely useful to conduct the kind of detailed analysis necessary, should the opportunity arise.

ACKNOWLEDGEMENTS

The *Cetaceans & Seabirds at Sea* programme was undertaken on behalf of the Rockall Studies Group (RSG) and Porcupine Studies Group (PSG) of the Irish Petroleum Infrastructure Programme. The survey was initially funded by RSG project 98/6 in 1999 and later extended through RSG project 00/13 and comprised: Agip (UK) Ltd (RSG), Agip Ireland BV (PSG), Anadarko Ireland Company (RSG), ARCO Ireland Offshore Inc (RSG), BG Exploration & Production Ltd (RSG), BP Exploration Operating Company Ltd (RSG), British-Borneo International Ltd (RSG), Chevron UK Ltd (PSG), Elf Petroleum Ireland BV (both groups), Enterprise Energy Ireland Ltd (both groups), Marathon International Hibernia Ltd (PSG), Mobil Oil North Sea Ltd (RSG), Murphy Ireland Offshore Ltd (RSG), Phillips Petroleum Exploration Ireland (RSG), Phillips Petroleum Company United Kingdom Ltd (PSG), Saga Petroleum Ireland Ltd (RSG), Shell EP Ireland B.V. (RSG), Statoil Exploration (Ireland) Ltd (both groups), Total Oil Marine plc (RSG), Union Texas Petroleum Ltd (RSG) and the Petroleum Affairs Division (PAD) of the Department of the Marine and Natural Resources (both groups). The cetacean surveys also utilised acoustic monitoring equipment funded by project 99/38 of the programme's Offshore Support Group (OSG), which is managed by the Petroleum Affairs Division.

We would like to acknowledge the role of RSG/PSG, PAD, in funding this project and providing the Coastal & Marine Resources Centre with the opportunity to greatly advance seabird and cetacean research in Ireland We are also very grateful to Agnes McLaverty (Enterprise Energy Ireland, Ltd.) and Mr Noel Murphy (PAD) for support, help and advice in logistics and project management. We also extend our thanks to Mr Nick O'Neill and Mr Martin Davies (CSA) for their assistance in obtaining berths aboard vessels of opportunity. We would also like to thank Dr Mark Tasker and Dr Eugene Nixon for their assistance as members of the project's Steering Committee. Special thanks to Ciarán Cronin for kick-starting the practical aspects of the fieldwork, and for his patient tuition of observers. The constant advice of Andy Webb and Jim Reid from the JNCC was of vital importance and is greatly appreciated. The CMRC would like to thank also all the primary contacts and host organizations that provided the platforms for the surveys and some people that have played an important role in facilitating our work on the vessels. These are Lt. Comdr. Hugh Tully & Commodore Frank Lynch of the Irish Naval Service, Commander Eugene Ryan of the L.E. *Eithne* and Capt. Jim Robinson, Prof. Jean-Pierre Henriet, Ms Veerle Huvenne and Dr Ben de Mol (University of Gent), Dr Tjeerd van Weering (NIOZ), Mr Ken Hitchen, Dr Alistair Skinner and Dr Colin Brett (BGS), Mr Kevin Peach and Dr Andrew Newton (FRS), Mr Jon Campbell and Mr Edward Cooper (SOC), Dr Terje Monstad and Dr Svein Iversen (IMR), Dr Genevra Harker (Fugro GEOS), Mrs Helen Gwinnutt, Mr Deepak Inamdar and Mr Mick Geoghegan (GSI) and Mr Ciarán Lawless.

We are also sincerely grateful to Michael Flannery, Andrew Lecher, the crew of the M.V. *Emerald Dawn* and Benjamin Roe for their enormous help and flexibility in undertaking, provisioning and successfully completing the *SIAR* survey. The authors would like to thank Dr Phil Hammond, Dr Jonathan Gordon, Dr Sharon Hedley and Prof David Borchers (U. of St. Andrews) for their helpful advice during the survey's planning stages. Of course the survey would not have been the success it was without the efforts of Agnes McLaverty (Enterprise Energy Ireland Ltd.) and our hard-working co-observers: Julia Carlström, Valerie Cummins, Dr Simon Ingram and Dr Emer Rogan. Thanks also to Joe Silke, Fisheries Research Centre, Marine Institute for use of the temperature probe and assistance in the analysis of sea surface temperature data from the *SIAR* survey.

Go raibh míle maith agaibh go léir.

PHOTOGRAPHIC CREDITS

REFERENCES

Acevedo-Gutiérrez, A., Brennan, B., Rodriguez, P. & Thomas, M. (1997). Resightings and behavior of false killer whales (*Pseudorca crassidens*) in Costa Rica. *Mar. Mamm. Sci.* **13:** 307-314.

Aguilar, A. (1981). The black right whale in the Cantabrian Sea. *Rep. Int. Whal. Comm.* **31:** 457-459.

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. *In*: B.N. Petran & F. Csaaki (eds.). *International symposium on Information Theory*. 2nd edition. Akadeemiai Kiadi, Budapest, Hungary. p 267-281.

Arcos, F. & Mosquera, I. (1993). Observacion dun exempler de balea basca, *Eubalaena glacialis*, en Galicia. *Eubalaena* **3:** 21-25.

Atkinson, T., Gill, A. & Evans, P.G.H. (1997). A photo-identification study of Risso's dolphins (*Grampus griseus*) in the coastal waters of the Eye Peninsula, Isle of Lewis, Scotland. *In* P.G.H. Evans, E.C.M. Parsons & S.L. Clark (eds.) *European Research on Cetaceans 11 – Proceedings of the 11th European Cetacean Society Conference*. 170pp.

Baumgartner, M.F. (1997). The distribution of Risso's dolphin (*Grampus griseus*) with respect to the physiography of the northern Gulf of Mexico. *Mar. Mamm. Sci.* **13 (4)**: 614 - 638.

Benjaminsen, T. & Christensen, I. (1979). The natural history of the bottlenose whale, *Hyperoodon ampullatus*. *In* H.E. Winn & B.L. Olla (eds.) *Behaviour of marine animals: current perspectives in research*. Plenum Press. New York and London. p 143-164.

Berrow, S.D. (1993). Constant effort cetacean sighting survey of Ireland. *Ir. Nat. J.* **24**: 344.

Berrow, S.D., Evans, P.G.H. & Sheldrick, M.C. (1993). An analysis of sperm whale (*Physeter macrocephalus* L.) strandings and sightings data from Britain and Ireland. *J. Zool. Lond.* **230**: 333-337.

Berrow, S.D., Holmes, B. & Kiely, O.R. (1996). Distribution and abundance of bottle-nosed dolphins *Tursiops truncatus* in the Shannon Estuary. *Biol. and Env: Proc. Roy. Ir. Acad.* **96B (1)**: 1-9.

Berrow, S.D. & Rogan, E. (1997). Review of cetaceans stranded on the Irish coast, 1901-95. *Mammal Rev.* **27 (1)**: 51-76.

Berrow, S.D., Whooley, P. & Ferriss, S. (2001). *Irish whale and dolphin group cetacean sighting schemes. Development of a system to record sightings of cetaceans (whales, dolphins and porpoises) in Irish waters.* Final report to the Heritage Council (Ireland). Irish Whale & Dolphin Group. 29pp.

Bloch, D., Desportes, G., Mouritsen, R., Skaaning, S. & Stefansson, E. (1993). An introduction to studies of the ecology and status of the long-finned pilot whale (*Globicephala melas*) off the Faroe Islands, 1986-88. *Rep. Int. Whal. Commn. Special Issue* **14**: 1-32.

Bloch, D., Desportes, G., Petersen, A.E. & Sigurjónsson, J. (1996). Strandings of striped dolphins (*Stenella coeruleoalba*) in Iceland and the Faroe Islands and sightings in the northeast Atlantic, north of 50°N Latitude. *Mar. Mamm. Sci*. **12 (1)**: 125-132.

Boelens, R.G.V., Maloney, D.M., Parsons, A.P. & Walsh, A.R. (1999). *Ireland's marine and coastal areas and adjacent seas. An environmental assessment.* Marine Institute. Dublin. 388pp.+ appendices.

Borchers, D.L., Buckland, S.T., Goedhart, P.W., Clarke, E.D. & Hedley, S.L. (1998a). Horvitz-Thompson estimators for double platform line transect surveys. *Biometrics* **54**: 1221-1237.

Borchers, D.L., Zucchini, W. & Fewster, R. (1998b). Mark-recapture models for line-transect surveys. *Biometrics* **54**: 1207-1220.

Bowyer, P. & Ward, B. (1995). Sea temperatures off the Irish coast. *In* Keegan, B.F. & O' Connor, R. (eds.) *Irish Marine Science.* Galway University Press. Galway. p 391-413.

Buckland, S.T. & Turnock, B.J. (1992). A robust line-transect method. *Biometrics* **48**: 901-909.

Buckland, S.T., Anderson, D.R., Burnham, K.P. & Laake, J.L. (1993a). *Distance sampling. Estimating abundance of biological populations*. Chapman & Hall, London. 446pp.

Buckland, S.T., Bloch, D., Cattanach, K.L., Gunnlaugsson, T., Hoydal, K., Lens, S. & Sigurjónsson, J. (1993b). Distribution and abundance of long-finned pilot whales in the North Atlantic, estimated from NASS-87 and NASS-89 data. *Rep. Int. Whal. Commn. Special Issue* **15**: 33-49.

Burfield, S.T. (1912). Belmullet Whaling Station – Report of the Committee. *Reports on the state of Science, 1912*: p 145-186.

Cañadas, A. & Sagarminaga, R. (2000). The northeastern Alboran Sea, an important breeding and feeding ground for the long-finned pilot whale (*Globicephala melas*) in the Mediterranean Sea. *Mar. Mamm. Sci.* **16 (3)**: 513 - 530.

Carlisle, A., Coles, P., Cresswell, G., Diamond, J., Gorman, L., Kinley, C., Rondel, G., Sellwood, D., Still, C., Telfer, M. & Walker, D. (2001). A report on the whales, dolphins and porpoises of the Bay of Biscay and English Channel 1999. *In* G. Cresswell & D. Walker (eds.) *ORCA No. 1 – A report on the* *whales, dolphins and seabirds of the Bay of Biscay and English Channel*. Organisation Cetacea (ORCA). p 5-53.

Charif, R., Clapham, P.J. & Clarke, C. (2001). Acoustic detections of singing humpback whales in the deep waters off the British Isles. *Mar. Mamm. Sci.* **17 (4)**: 751-769.

Clark, C.W. & Charif, R.A. (1998). *Acoustic monitoring of large whales to the west of Britain and Ireland using bottom-mounted hydrophone arrays, October 1996 – September 1997*. JNCC Report No. 281. JNCC. Peterborough. 25pp.

Christensen, I., Haug, T. & Øien, N. (1992). Seasonal distribution, exploitation and present abundance of stocks of large baleen whales (Mysticeti) and sperm whales (*Physeter macrocephalus*) in Norwegian and adjacent waters. *ICES J. Mar. Sci.* **49**: 341-355.

Cronin, M. & Mackey, M. (2002). Cetaceans and seabirds in waters over the Hatton-Rockall region. Unpublished cruise report to the Geological Survey of Ireland, May 2002. 70 pp.

Coles, P. (2001). Identifying beaked whales at sea in North Atlantic waters. *In* G. Cresswell & D. Walker (eds.) *ORCA No. 1 – A report on the whales, dolphins and seabirds of the Bay of Biscay and English Channel*. Organisation Cetacea (ORCA). p 81-90.

Efron, B. & Tibshirani, R.J. (1993). *An introduction to the bootstrap.* Chapman and Hall. London.

Evans, P.G.H. (1980). Cetaceans in British waters. *Mammal Rev*. **10**: 1-52.

Evans, P.G.H. (1981). *Report of N.E. Atlantic scientific cruise, 1980.* Mammal Society Occasional Publication. London.

Evans, P.G.H. (1987). *The natural history of whales and dolphins*. Academic Press. London.

Evans, P.G.H. (1988). Killer whales (*Orcinus orca*) in British and Irish waters. *Rit. Fiskideildar* **11**: 42-54.

Evans, P.G.H. (1990). European cetaceans and seabirds in an oceanographic context. *Lutra* **33 (2)**: 95-125.

Evans, P.G.H. (1998). Biology of cetaceans of the Northeast Atlantic (in relation to seismic energy). *In* M. Tasker & C. Weir (eds.). *Proceedings of the Seismic and Marine Mammals Workshop*. UKOOA. London.

Fairley, J.S. (1981). *Irish whales and whaling*. Blackstaff Press. Dublin. 218pp.

Forcada, J., Aguilar, A., Evans, P.G.H. & Perrin, W.F. (1990). Distribution of common and striped dolphins in the temperate waters of the eastern North Atlantic. *In* P.G.H. Evans (ed.) *European research on cetaceans 8 – Proceedings of the 8th annual conference of the European Cetacean Society*. p 64-66.

Forcada, J. & Hammond, P.S.H. (1998). Geographical variation in abundance of striped and common dolphins of the western Mediterranean. *J. Sea Res.* **39**: 313-325.

Fraser, F.C. (1974). *Report on Cetacea stranded on the British coast from 1945 to 1966. British Museum (Natural History) Report No. 14.* 65pp.

Gaskin, D. (1968) Distribution of Delphinidae (Cetacea) in relation to sea surface temperature off the eastern and southern New Zealand. *N.Z. J. mar. Freshwat. Res.,* **2**: 527 - 534.

Gaskin, D., Yamamoto, S. & Kawamura, A. (1993). Harbour porpoise *Phocoena phocoena* (L.) in the coastal waters of northern Japan. *Fish. Bull.* **91**: 440 - 454.

Gordon, J. Berrow, S.D., Rogan, E. & Fennelly, S. (1999). Acoustic and visual survey of cetaceans off the Mullet Peninsula , Co. Mayo. *Ir. Nat. J.* **26 (7/8)**: 251-259.

Griffin, R.B. (1999). Sperm whale distributions and community ecology associated with a warm-core ring off Georges Bank. *Mar. Mamm. Sci.* **15 (1)**: 1 - 33.

Hamilton, J.E. (1914). Belmullet whaling station. Report of the committee appointed to investigate biological problems incidental to Belmullet whaling station. *British Assoc. Advancement Sci. (Australia)*: p 125-161.

Hammond, P.S. & Lockyer, C. H. (1988). Distribution of killer whales in the eastern North Atlantic. *Rit. Fiskideildar* **11**: 24-41.

Hammond, P.S., Benke, H., Berggren, P., Borchers, D.L., Buckland, S.T., Collet, A., Heide-Jørgensen, M.P., Heimlich-Boran, S., Hiby, A.R., Leopold, M.F. & Øien, N. (1995). *Distribution & abundance of the harbour porpoise & other small cetaceans in the North Sea & adjacent waters.* Final report to the European Commission under *LIFE* contract 92-2/UK/027. 240pp.

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jørgensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F. & Øien, N. (2002). Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *J. Appl. Ecol.* **39**: 361-376.

Harwood, J. & Wilson, B. (2001). The implications of developments on the Atlantic Frontier for marine mammals. *Cont. Shelf Res.* **21**: 1073-1093.

Heinemann, D. (1981) A range finder for pelagic bird censusing. *J. Wildl. Manage.* **45 (2)**: 489-493.

Hiby, A.R. & Hammond, P.S. (1989). Survey techniques for estimating abundance of cetaceans. *Rep. Int. Whal. Commn. Special Issue* **11**: 47-80.

Hooker, S.K., Iverson, S.J., Ostrom, P. & Smith, S.C. (2001). Diet of northern bottlenose whales inferred from fatty-acid and stable-isotope analyses of biopsy samples. *Can. J. Zool.* **79**: 1442-1454.

Huang, W.G., Cracknell, A.P., Vaughan, R.A. & Davies, P.A. (1991). A satellite and field view of the Irish shelf front. *Cont. Shelf Res.* **11**: 543-562.

Hunt, Jr. G.L. & Schneider, D.C. (1987). Scale dependent processes in the physical and biological environment of marine birds. *In* J.P. Croxall (ed.) *Seabirds: Feeding ecology and role in marine ecosystems*. p 7-41. Cambridge University Press. Cambridge.

Ingram, S.N. (2000). *The ecology and conservation of bottlenose dolphins in the Shannon Estuary, Ireland.* Unpublished PhD thesis, University College Cork. 213pp.

Ingram, S., Englund, A. & Rogan, E. (2001). *An extensive survey of bottlenose dolphins (Tursiops truncatus) on the west coast of Ireland.* Final report to the Heritage Council (Ireland). Grant WLD/2001/42. 17pp.

International Whaling Commission (2000). *Comprehensive assessment of whale stocks*. *In* G.P. Donovan (ed.). Report of the International Whaling Commission Scientific Committee. *J. Cetacean Res. Manage.* 2 (Supplement): p 26-34.

Kenney, R.D. (1990). Bottlenose dolphins off the north-eastern United States. *In* S. Leatherwood & R.R. Reeves (eds.). *The Bottlenose Dolphin*. Academic Press. San Diego. p 369-386.

Larsen, A.H., Sigurjónsson, J., Øien, N., Víkingsson, G. & Palsboll, P. (1993). Population genetic analysis of nuclear and mitochondrial loci in skin biopsies collected from central and northeastern North Atlantic humpback whales (*Megaptera novaeangliae*): Population identity and migratory destinations. *Proc. Royal Soc. Lond. B* **263**: 1611-1618.

Leatherwood, S. & Reeves, R.R. (1983). *The Sierra Club handbook of whales and dolphins*. Sierra Club Books. San Francisco. 302pp.

Leopold, M.F., Wolf, P.A. & Van Der Meer, J. (1992). The elusive harbour porpoise exposed: strip transect counts off southwestern Ireland. *Neth. J. Sea Res.* **29 (4)**: 395-402.

Leopold, M.F. & Couperus, A.S. (1995). Sightings of Atlantic white-sided dolphins *Lagenorhynchus acutus* near the southeastern limit of the known range in the northeast Atlantic. *Lutra* **38**: 77-80.

Lerczak, J.A. & Hobbs, R.C. (1998). Calculating sighting distances from angular readings during shipboard, aerial and shore-based marine mammals surveys. *Mar. Mamm. Sci.* **14 (3)**: 590-599.

Lick, R. & Piatkowski, U. (1998). Stomach contents of a northern bottlenose whale (*Hyperoodon ampullatus*) stranded at Hiddensee, Baltic Sea. *J. Mar. Biol. Assoc. U.K.* **78**: 643-650.

Lordan, C. 2001. Investigations into the fisheries and biology of omnastrephid squid species in Irish waters. Unpublished PhD thesis, University College Cork, 272pp.

MacLeod, C.D. (2000). Review of the distribution of *Mesoplodon* species (order Cetacea, family Ziphiidae) in the North Atlantic. *Mammal Rev.* **30**: 1-8.

Martin, A.R. & Walker, F.J. (1997). Sighting of a right whale (*Eubalaena glacialis*) with calf off S. W. Portugal. *Mar. Mamm. Sci.* **13 (1)**: 139-140.

Mead, J.G. (1989). Beaked whales of the genus *Mesoplodon*. *In* S.H. Ridgeway & R. Harrison (eds.) *Handbook of marine mammals, Volume 4: River dolphins and toothed whales*. Academic Press. San Diego. p 349-430.

Morton, A.J. (1999). *Dmap for Windows. A computer program for distribution and coincidence mapping*. Blackthorn Cottage, Chawridge Lane, Winkfield, Windsor, Berkshire SL4 4QR, U.K.

Murphy, N.J. (2001). PIP – Meeting the challenge of new frontiers. *In* Murphy, N.J. & Davies, M. (eds.) *Ireland's Deepwater Frontier: Results from the Petroleum Infrastructure Programme*. p 2-5. Conference proceedings. Petroleum Affairs Division, Department of the Marine and Natural Resources, Dublin. 139pp.

Murray, L. & Simmonds, M. (eds.) (1998). *The Atlantic Frontier. Britain's last ocean wilderness.* Report by Greenpeace UK and Whale and Dolphin Conservation Society (WDCS). 38pp.

Naylor, D., Shannon, P. & Murphy, N. (1999). *Irish Rockall region – a standard structural nomenclature system*. Petroleum Affairs Division, Department of the Marine and Natural Resources, Dublin. *Special Publication* 1/99.

Northridge, S.P., Tasker, M.L., Webb, A. & Williams, J.M. (1995). Distribution and relative abundance of harbour porpoises (*Phocoena phocoena* L.), white-beaked dolphins (*Lagenorhyncus albirostris* Gray), and minke whale s (*Balaenoptera acutorostrata* Lacepède) around the British Isles. *ICES J. Mar. Sci.* **52**: 55-66.

Northridge, S.P., Tasker, M., Webb, A., Camphuysen, K. and Leopold, M. (1997). White-beaked *Lagenorhynchus albirostris* and Atlantic White-sided Dolphin *L. acutus* distributions in northwest European and US North Atlantic waters. *Rep. Int. Whal. Commn.* **47**: 797-805

O' Riordan, C.E. (1975). Long-finned pilot whales, *Globicephala melaena*, driven ashore in Ireland, 1800-1973. *J. Fish. Res. Board Can.* **32**: 1101-1103.

Palka, D. (1995). Influences on spatial patterns of Gulf of Maine harbour porpoises. *In* A.S. Blix, L. Walløe & Ø. Ulltang. (eds.) *Whales, seals, fish and man.* Elsevier Science. Amsterdam. p 69-75.

Palsboll, P.J., Allen, J., Bérube, M., Clapham, P.J., Feddersen, T.P., Hammond, P., Jorgensen, H., Katona, S., Larsen, A.H., Larsen, F., Lien, J., Matilla, D.K., Sijurjónsson, J., Sears, R., Smith, T., Sponer, R., Stevick, P. & Øien, N. (1997). Genetic tagging of humpback whales. *Nature* **388**: 767 - 769.

Pingree, R.D. & Le Cann, B. (1989). Celtic and Armorican slope and shelf residual currents. *Proc. Oceanogr.* **23**: 303-338.

Pollock, C.M., Reid, J.B., Webb, A. & Tasker, M.L. (1997). *The distribution of seabirds and cetaceans in the waters around Ireland*. *JNCC Report* No. 267. JNCC. Peterborough. 167pp.

Pollock, C.M., Mavor, R., Weir C.R., Reid, A., White, R.W., Tasker, M.L., Webb, A. & Reid, J.B. (2000). *The distribution of seabirds and marine mammals in the Atlantic Frontier, north and west of Scotland*. JNCC. Peterborough. 92pp.

Raine, R., O' Mahony, J., McMahon, T. & Roden, C. (1990). Hydrography and phytoplankton of waters off southwest Ireland. *Estuar. Coast. Shelf Sci*. **30**: 579-592.

Read, A. (1999). The harbour porpoise. *In* S.H. Ridgeway & R. Harrison (eds.) *Handbook of Marine Mam*mals, *Vol. 6: The second book of dolphins and the porpoises*. Academic Press. London. p 323 - 355.

Reeves, R.R., Smeenk, C., Kinze, C.C., Brownell Jr., R.L. & Lien, J. (1999a). White-beaked dolphin *Lagenorhynchus albirostris* Gray, 1846. *In* S.H. Ridgeway & R.L. Harrison (eds.). *Handbook of marine mammals, Volume 6: The second book of dolphins and the porpoises*. Academic Press. London. p 1-30.

Reeves, R.R., Smeenk, C., Kinze, C.C., Brownell Jr., R.L. & Lien, J. (1999b). White-sided dolphin *Lagenorhynchus acutus* Gray, 1828. *In* S.H. Ridgeway & R.L. Harrison (eds.). *Handbook of marine mammals, Volume 6: The second book of dolphins and the porpoises*. Academic Press. London. p 31-56.

Reid, R., Kitchener, A., Ross, H. & Herman, J. (1993). First records of the striped dolphin, *Stenella coeruleoalba,* in Scotland. *Glasgow Naturalist* **22**: 243-245.

Reilly, S.B. & Fiedler, P.C. (1994). Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. *Mar. Ecol. Prog. Ser.* **66**: 1 - 11.

Reiner, F., Dos Santos, M.E. & Wenzel, F.W. (1996). Cetaceans of the Cape Verde archipelago. *Mar. Mamm. Sci.* **12 (3)**: 434-443.

Rogan, E. & Berrow, S.D. (1995). The management of Irish waters as a whale and dolphin sanctuary. *In* A.S. Blix, L. Walløe & Ø. Ulltang. (eds.) *Whales, seals, fish and man.* Elsevier Science. Amsterdam. p 671-681.

Rogan, E. & Berrow, S.D. (1996). A review of harbour porpoises, *Phocoena phocoena*, in Irish waters. *Rep. Int. Whal. Commn*. **46**: 595-605.

Rogan, E., Gassner, I., Mackey, M.J. & Berrow, S.D. (1997). A review of striped dolphins *Stenella coeruleoalba*, in the waters around Ireland. Paper SC/49/SM40 presented to the 49th International Whaling Commission, Bournemouth.

Rogan E., Baker J.R., Jepson P.D., Berrow S.D. & Kiely O. (1998). A mass stranding of white-sided dolphins (*Lagenorhynchus acutus*) in Ireland: biological and pathological studies. *J. Zool. Lond.* **242**: 217-227

Rogan E. & Mackey M. (1999). *Incidental capture of cetaceans in the Irish drift net fishery for albacore tuna.* BYCARE - Final report to DG IV, European Commission.

Rogan, E. (2001). A review of humpback whales from Irish waters. Paper SC/53/NAH 26 to the 53rd Meeting of the International Whaling Commission, London.

Santos, M.B., Pierce, G., Boyle, P.R., Reid, R.J., Ross, H.M., Paterson, I.A.P., Kinze, C.C., Tougaard, S., Lick, R., Piatkowski, U. & Hernandez-Garcis, V. (1999). Stomach contents of sperm whales (*Physeter macrocephalus*) stranded in the North Sea 1990 - 1996. *Mar. Ecol. Prog. Ser.* **183**: 281 - 294.

Santos, M.B., Pierce, G.J., Kuiken, T., Garcia-Hartmann, M., Smeenk, C., Addink, M.J., Reid, R.J., Patterson, I.A.P., Lordan, C. & Rogan, E. (2002). Additional notes on stomach contents of sperm whales *Physeter macrocephalus* stranded in the NE Atlantic. *J. Mar. Biol. Assoc. (UK).* **82**: 501-507.

Scott, M.D. & Chivers, S.J. (1990). Distribution and herd structure of bottlenose dolphins in the eastern tropical Pacific Ocean. *In* S. Leatherwood & R.R. Reeves (eds.). *The bottlenose dolphin*. Academic Press. London. p 387-402.

Selzer, L.A. & Payne, P.M. (1988). The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States. *Mar. Mamm. Sci.* **4(2)**: 141 - 153.

Sigurjónsson, J., Gunnlaugsson, T. & Payne, M. (1989). NASS-87: Shipboard sightings surveys in Icelandic and adjacent waters, June-July 1987. *Rep. Int. Whal. Comm.* **39**: 395-409.

Sigurjónsson, J. (1995). On the life history and autecology of North Atlantic rorquals. *In* A.S. Blix, L. Walløe & Ø. Ulltang. (eds.) *Whales, seals, fish and man.* Elsevier Science. Amsterdam. p 671-681.

Stacey, P.J. & Baird, R.W. (1991). Status of the false killer whale, *Pseudorca crassidens*, in Canada. *Can. Field-Nat*. **195**: 189-197.

Stevick, P.T., Øien, N. & Mattila, D.K. (1998). Migration of a humpback whale (Megaptera novaeangliae) between Norway and the West Indies. *Mar. Mamm. Sci*. **14 (1)**: 162-165.

Stone, C.J. (1997). *Cetacean observations during seismic surveys in 1996.* JNCC Report No. 228. JNCC. Peterborough. 41pp + appendices.

Stone, C.J. (1998). *Cetacean observations during seismic surveys in 1997.* JNCC Report No. 278. JNCC. Peterborough. 57pp + appendices.

Tasker, M.L., Jones, P.H., Dixon, T.J. & Blake, B.F. (1984). Counting seabirds at sea from ships: A review of methods employed and a suggestion for a standardised approach. *Auk* **101**: 567-577.

Thiele, D., Chester, E.T., & Gill, P.C. (2000). Cetacean distribution off Eastern Antarctica (80° - 150°E) during the Austral summer of 1995/1996.

Thompson, D'A. W. (1928). On whales landed at the Scottish whaling stations during the years 1908-1914 and 1920-1927. *Scientific investigations of the fishing board of Scotland* **3**: 1-40.

Tove, M. (1995). Live sighting of *Mesoplodon cf. M. mirus*, True's beaked whale. *Mar. Mamm. Sci*. **11**: 80-85.

Tynan, C. (1998). Ecological importance of the southern boundary of the Antarctic Circumpolar Current. *Nature* **392**: 708-710.

Vermeulen, N.J. (1997). Hydrography, surface geology and geomorphology of the deep water sedimentary basins to the west of Ireland. *Marine Resource Series* No. 2. Marine Institute. Dublin. 41pp.

Walker, D. & Diamond, J. (2001). First confirmed sighting of True's beaked whale in European waters. (*in press*). Details posted on the International Society for Marine Mammalogy *MARMAM* network (19/07/01) and available with photographic evidence on www.orcaweb.org.

Waring, G.T., Hamazaki, T., Sheehan, D., Wood, G. & Baker, S. (2001). Characterization of beaked whale (Ziphiidae) and sperm whale (*Physeter macrocepahalus*) summer habitat in shelf edge and deeper waters off the northeast U.S. *Mar. Mamm. Sci.* **17 (4)**: 703 - 718.

Weir, C.R., Pollock, C., Cronin, C. & Taylor, S. (2001). Cetaceans of the Atlantic Frontier, north and west of Scotland. *Cont. Shelf Res.* **21 (8-10)**: 1047-1071.

Wells, R.S. and Scott, M.D. (1999). Bottlenose dolphin. *In* S.H. Ridgeway & R. Harrison (eds.). *Handbook of Marine Mam*mals, *Vol. 6.* Academic Press. London & New York. pp 137 - 182.

Wood, E., Hoagland-Grey, H. & Smith, J. (1996). *The west coast of Ireland. An environmental appraisal*. Report commissioned jointly by Texaco, Enterprise Oil PLC, Kerr-McGee Oil (UK) PLC and Statoil (UK) Limited. London, Dames & Moore. Pembroke, OPRU. 76 pp.

Øien, N. (2000). Bestandsforhold og fangst. *Ottar* **230**: 3-9.

Øien, N., Marx, M.K. & Donovan, G. (2000). *A note on sightings from the eastern North Atlantic. Report of the Workshop on Status and Trends of Western North Atlantic Right Whales*. Report (SC/52/Rep 1) presented to the IWC Scientific Committee, Adelaide, June 2000.

Appendix A : Offshore survey programme, July 1999–September 2001.

Survey Dates	Vessel Name	Host Organisation	Vessel Activity	Main Location
05/07/99 – 26/07/99	M.V. *Bucentaur*	British Geological Survey, Edinburgh	Deep Coring	Porcupine Seabight
09/08/99 – 18/08/99	M.V. *Pelagia*	Netherlands Institute of Sea Research (NIOZ)	2D Seismic	North Porcupine Basin
27/08/99 – 07/09/99	F.R.V. *Scotia*	FRS, Aberdeen	Trawling Survey	Rockall Bank
23/09/99 – 30/09/99	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	Western and Eastern Ireland
18/10/99 – 05/11/99	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	Western and Eastern Ireland
23/11/99 – 10/12/99	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	Southern and Southeastern Ireland
03/01/00 – 08/01/00	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	Western Irish Shelf
27/01/00 – 20/02/00	R.R.S. *Discovery*	Southampton Oceanographic Centre/ DML	Oceanographic	Rockall-Iceland
16/02/00 – 08/03/00	M.V. *Scotian Shore*	Fugro GEOS	Oceanographic	Porcupine Basin
07/04/00 – 17/04/00	R.V. *Johan Hjort*	Institute of Marine Research, Bergen	Fisheries Research	Rockall Bank
20/04/00 – 03/05/00	R.R.S *Charles Darwin*	Southampton Oceanographic Centre	Oceanographic	Rockall Trough
09/05/00 – 11/05/00	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	Irish Sea
22/05/00 – 25/05/00	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	Porcupine Seabight
25/05/00 – 11/07/00	R.V. *Colonel Templer*	British Geological Survey, Edinburgh	2D Seismic	Hatton & Rockall Banks
09/06/00 – 28/06/00	R.V. *Belgica*	University of Gent	Benthic Biology/ 2D Seismic	Porcupine Basin
31/07/00 – 22/08/00	M.V. *Emerald Dawn*	University College Cork	Cetacean/Seabird Survey	Rockall Trough/ Porcupine Basin
12/09/00 – 18/09/00	S.V. *Siren*	Geological Survey of Ireland	Multibeam/ Side-Scan Sonar	Western Irish Shelf
18/09/00 – 28/09/00	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	Southwestern Irish Shelf
05/10/00 – 24/10/00	S.V. *Bligh*	Geological Survey of Ireland	Multibeam/ S-S Sonar	Goban Spur/ Celtic Basin
14/11/00 – 26/11/00	S.V. *Bligh*	Geological Survey of Ireland	Multibeam/ S-S Sonar	Goban Spur
15/01/01 – 18/01/01	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	Southwest shelf of Ireland
05/02/01 – 13/02/01	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	West shelf of Ireland
31/03/01 – 08/04/01	R.R.S. *Discovery*	Southampton Oceanographic Centre	Equipment Trials	Porcupine Seabight
17/03/01 – 06/04/01	*Walther Herwig III*	Institute of Sea Fisheries, Hamburg	Fish Egg Survey	Continental Slope
30/04/01 – 07/06/01	S.V. *Bligh*	Geological Survey of Ireland	Multibeam/ S-S Sonar	Rockall Trough
03/05/01 – 10/05/01	R.V. *Belgica*	University of Gent	Seismic Survey, Box Coring	Goban Spur / Porcupine Seabight
24/05/01 – 14/06/01	R.V. *G.O. Sars*	Institute of Marine Research, Bergen	Fish Egg Survey	Continental Slope
04/06/01 – 08/06/01	L.E. *Roisin*	Irish Naval Service	Fisheries Patrol	South & East Coasts
19/06/01 – 28/06/01	F.R.S. *Scotia*	FRS, Aberdeen	Fish Egg Survey	Continental Slope
30/06/01 – 03/07/01	S.V. *Siren*	Geological Survey of Ireland	Multibeam/ S-S Sonar	Porcupine Seabight
16/07/01 – 18/07/01	L.E. *Eithne*	Irish Naval Service	Fisheries Patrol	Continental Shelf
07/08/01 – 21/08/01	R.R.S. *James Clark Ross*	British Geological Survey, Edinburgh	Sediment/Bedrock Coring	Rockall Bank / Rockall Trough
16/08/01 – 03/09/01	R.R.S. *Discovery*	Southampton Oceanographic Centre	Fishing Trials	Goban Spur / Porcupine Seabight
02/09/01 – 04/09/01	F.R.S. *Scotia*	FRS, Aberdeen	Trawling Survey	Rockall Bank
11/09/01 – 12/09/01	L.E. *Niamh*	Irish Naval Service	Fisheries Patrol	West shelf of Ireland