Maritime Ireland / Wales
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Grey Seals : Status and Monitoring in the Irish and Celtic Seas.

June 2000

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Measure 1.3: Protection of the Marine and Coastal Environment and Marine Emergency Planning

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Maritime (Ireland / Wales) INTERREG Programme- Building Bridges.

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This project (Contract EU/100/13) is supported under Protection of the Marine and Coastal Environment of the Maritime (Ireland-Wales) INTERREG Programme (1994-1999) administered by the Marine Institute (Ireland) and the National Assembly for Wales (Wales) and is part funded by the European Union's Regionl Development Fund.

Maritime (Ireland/Wales) INTERREG Programme (1994 – 1999)

The EU Maritime (Ireland / Wales) INTERREG II Programme (1994 - 1999) was established to:

1. promote the creation and development of networks of co-operation across the common maritime border.
2. assist the eligible border region of Wales and Ireland to overcome development problems which arise from its relative isolation within the European Union.

These aims are to be achieved through the upgrading of major transport and other economic linkages in a way that will benefit the constituent populations and in a manner compatible with the protection and sustainability of the environment. The Maritime INTERREG area includes the coastlines of counties Meath, Dublin, Wicklow, Wexford and Waterford on the Irish side and Gwynedd, Ceredigion, Pembrokeshire and Carmarthenshire on the Welsh side and the sea area in between.

In order to achieve its strategic objectives the programme is divided into two Areas:

Sub-Programme 1: **Maritime Development:** transport, environment and related infrastructure (59 mEuro)

Sub-Programme 2: **General Economic Development:** Economic growth, tourism, culture, human resource development (24.9 mEuro)

The Marine and Coastal Environment Protection and Marine Emergency Planning Measure (1.3) has a total budget of 5.33 mEuro of which 3.395 mEuro is provided under the European Development Fund. EU aid rates are 75% (Ireland) and 50% (Wales).

The specific aims of Sub-Programme 1.3 are:

- to promote the transfer of information between the designated areas.
- to establish an in-depth profile of marine/coastal areas for conservation of habitat/species.
- to explore, survey, investigate, chart the marine resource to provide a management framework.
- to develop an integrated coastal zone management system.
- to improve marine environmental contacts and co-operation.
- to promote the sustainable development of the region.
- to improve nature conservation.

Joint Working Group

The Joint Working Group, established to oversee the implementation of Measure, consists of 5 Irish and 5 Welsh representatives.

Irish representation: Department of the Marine & Natural Resources, Department of the Environment & Local Government, Department of Transport, Energy & Communications, Local Authority and Marine Institute.

Welsh representation: National Assembly for Wales, Countryside Council for Wales, National Trust, Local Authority (Dyfed), Local Authority (Gwynedd).

This Report series is designed to provide information on the results of projects funded under Measure 1.3 Protection of the Marine & Coastal Environment and Marine Emergency Planning.

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SUMMARY

The population size and seasonal distribution of grey seals at principal haul-out sites in the central and southern Irish Sea were investigated in a co-ordinated transnational study conducted between 1996 and 1998. Concurrent studies on human interactions with this population focused on Seal - Fisheries interactions in the western Irish Sea and eastern Celtic Sea, and on the impacts of the *Sea Empress* oil spill and eco-tourism on breeding colonies in the eastern Irish Sea

- ***Grey seal population estimates for the Irish Sea***
  Ground counts of annual pup production recorded 177 newborn pups at Irish study sites and 744 at sites in south-west Wales. Lambay Island (Co. Dublin) and the Great Saltee (Co. Wexford) were identified as the most important pupping sites in the eastern Irish Sea while Ramsey Island, north-west Pembrokeshire, Cardigan Bay and Skomer Island contained the most important sites in the western Irish Sea. The pup census data collected in Ireland and Wales yielded a minimum all-age population estimate for the Irish Sea of 5,198-6,976 grey seals. This estimate was supported by photo-identification mark-recapture data which delivered an estimate of 5,613 seals (0.2% CV).

- ***Patterns of abundance and distribution***
  The results of this study underline the site-specific and seasonal nature of grey seal abundance patterns. The largest grey seal haul-outs on the east coast of Ireland were recorded during the months of July and August, the most important site being Lambay Island. Sites on the south-east coast of Ireland contained significant numbers of grey seals year-round, peaking during the annual breeding (Sept.-Dec.) and moulting seasons (Nov.-Mar.). The most important of these sites were the Great Saltee and The Raven Point (Co. Wexford). On the south-west coast of Wales, The Smalls islands and Grassholm were the most important sites during the summer season, while Camaes Head, Newport and Skomer Island were the most important sites during the moult season.

- ***Movements of grey seals in the Irish Sea***
  Individually-identified adult seals, 'marked' and 'recaptured' using a photo-identification technique and the EIRPHOT database system, were shown to move between sites in the Irish Sea study area. Individual seals were observed to have travelled freely across the Irish Sea during the study period, with animals being recorded at sites on the east and south-east coasts of Ireland and in south-west Wales. No movement of identifiable seals was recorded between sites in Co. Wexford and Co. Dublin, though, on a smaller scale, individual seals were recorded moving between local sites in east and south-east Ireland. Repeated photographic captures suggested that adult female grey seals may show a level of inter-annual faithfulness to particular sites, otherwise known as site fidelity. The strong associations of individual seals with particular areas were noteworthy at Lambay Island, the Great Saltee, Coningmore Rocks (Co. Wexford) and Blackrock (Co.Wexford).

- ***Operational seal - fishery interactions in the western Irish Sea & easter n Celtic Sea***
  A questionnaire survey targeting fishermen highlighted the perception that seals may be a growing problem for commercial fisheries in the Irish INTERREG region. Objective scientific research into the problem of seal - fisheries interactions centred on problematic inshore fisheries in south-eastern Ireland. The results showed that damage inflicted by seals could be significant depending on the season and type of fishery. Boat-based monitoring of the 1998 monkfish tangle-net fishery out of Dunmore East determined that catches were damaged on approximately 60% of fishing trips. This led to an average of 10% of the total catch by weight being damaged by seals with an economic loss to the tangle-net fishery of approximately £1,533 in 1998. By simple extrapolation the interaction would thus equate to an average of approximately £50 per vessel per month. These figures should be interpreted cautiously for a number of reasons. Firstly

objective boat-based monitoring was conducted on 9.7% of fishing trips. Secondly, true landing figures for the fishery were not available during the study. It is also noteworthy that considerable variation in monkfish catches and the scale of the interaction were observed over the duration of the fishery. A peak in seal-inflicted damage was apparent in April/May and lower than average levels of damage occurred in July/August. This study also found that damage to fish by scavenging crustaceans may exceed that inflicted by seals by a factor of two, incurring significant losses for the industry. Eighteen by-caught grey seals were landed by vessels during the monkfish fishery between 1997 and 1998, the majority of which were juvenile animals. Due to an inherent difficulty in landing entangled seals and obtaining reliable by-catch figures, these animals were considered as a sample of the total by-catch in the fishery.

- ***Studies of seal diet in the western Irish Sea***
  Seventeen (94%) of the by-caught seals contained prey remains in their stomachs. This contrasted greatly with nineteen seals stranded ashore in the INTERREG region during the study, only two of which had prey remains in their stomachs. Gadoids (i.e. both commercial and non-commercial whitefish species) were the predominant prey species among the 19 species identified in stomach samples. In contrast, seal faecal samples collected at haul-out sites from November to March in 1997 and 1998 yielded 23 species of prey with gadoids and flatfish co-dominant in the diet. Prey occurrence in the diet showed an important geographic variation between haul-out sites with an increase in the relative proportion of gadoids and a corresponding decrease in the proportion of flatfish from sites on the east coast to the south-east coast. Overall, the predominant prey species in the diet of grey seals were not the principal target species for commercial fisheries in the Irish Sea. *Trisopterus* species (Bib, Norway Pout and Poor Cod), plaice and whiting appeared to be the most important species in the diet of grey seals in the western Irish Sea.

- ***The impact of selected human activities on the Irish Sea grey seal population***
  A study of the physical effects of the Sea Empress oil spill on the eastern Irish Sea grey seal population showed no immediate evidence of a detrimental effect on the study population. This may have been due (a) to the relatively short time period after the accident during which the study was conducted which may have masked more long-term effects, and (b) the timing of the oil spill which was at least six months before the normal grey seal breeding season. Seal-watching in south-west Wales, by land and boat, is a locally important tourism industry. Although grey seals are known to be sensitive to disturbance particularly during the breeding season, preliminary research into the effects of tourism on grey seal breeding performance in the area showed no evidence of a reduction in pup production or an increase in pup mortality at sites exposed to seal watching.

This report discusses the research results in detail and makes a number of important recommendations which it is hoped will play a key part in the search for sustainable marine resources and coastal zone management strategies for the Irish Sea.

CHAPTER 1. INTRODUCTION

1.1 Research objectives

The main objectives of the study were:

- to estimate the size of the grey seal population at key Irish and Celtic Sea haul-out sites throughout its annual cycle, and to examine the seasonal variation in distribution and abundance;
- to assess the level and dynamics of grey seal movements in the study area and examine the degree of interchange between grey seals in Irish and Welsh waters;
- to establish an Irish & Celtic Sea Database for grey seals, which may be updated and used as a means of monitoring the seal population and specific haul-out areas;
- to provide relevant population-based information on specific interactions between seals and human activities, namely seal - fisheries interactions in Ireland and the effects of marine tourism and the *Sea Empress* oil spill on the south-west Wales grey seal population;
- to highlight areas of special importance for grey seals which have conservation and/or recreational potential and to provide recommendations for the management of these coastal areas and the subsequent development of emergency response capabilities;
- to establish a network of co-operation, expertise and information transfer between Ireland and Wales, more specifically between relevant bodies involved in research and management of the coastal zone and its resources;
- to assist in the upgrading of data and technologies within the INTERREG region by incorporating research techniques and assessment methods developed to a high standard elsewhere in the research framework of this region.

1.2 Seal populations in Ireland and Britain

Seals, walruses and sea lions belong to the Pinniped order of mammals. Ireland and Britain are a breeding home to two species of seal which belong to the family Phocidae, known as the "true seals". They are the grey seal *(Halichoerus grypus)* and the harbour or common seal *(Phoca vitulina)*. There are also occasional incursions by more northerly-based species such as the harp seal *(Phoca groenlandica)*, the hooded seal *(Crystophora crystata)*, and the walrus *(Odobenus rosmarus rosmarus)*.

Grey seals and harbour seals are listed in Appendix III of the Berne Convention, and in Annexes II and V of the EC Habitats and Species Directive. They are documented as species whose conservation may require the designation of Special Areas of Conservation (SACs). In Ireland, seals have been legally protected since the adoption of the 1976 Wildlife Act which states that it is an offence to hunt or injure them, or to wilfully interfere with their breeding place. Prior to that, bounties were paid on both grey and harbour seals since they were commonly regarded as unwanted predators in some commercial fishery situations. In the UK seals have been a protected species in Scotland since 1914, while in England, Wales and Northern Ireland seals are protected by the Conservation of Seals Act 1970, which makes it an offence to kill or take seals at certain times of the year or by the use of certain prohibited means. In the UK, they may be shot under licence if seen taking fish from fixed engine salmon nets and a similar licence may be obtained in Ireland where there is evidence that they are acting as significant "pests" in a commercial situation. However, in spite of the legal protection measures, illegal culls have occasionally been performed in Ireland, most notably in 1979 and 1981 on islands in the Inishkea Group, Co. Mayo and on the Blasket Islands, Co. Kerry in 1992 (*see* Kiely & Myers, 1998).

Grey seals are the more abundant of the two native species in these waters (Bonner, 1990). On the Atlantic seaboard and in the Irish Sea, harbour seals tend to be found in more sheltered waters and closer to human habitation than are grey seals. Grey seals generally require more isolated habitats which provide security from interference by humans and other terrestrial predators. Though such regions are often highly exposed to the elements, grey seals tend to favour specific sites where they may shelter from such conditions, utilising sites such as the rear of sea-caves and beaches on offshore islands or in remote mainland areas. Due to their sensitivity to human disturbance and other conservation concerns, Sites of Special Scientific Interest (SSSIs) and SACs for grey seals have been designated at certain locations in the UK. In Wales, such legally protected SACs include the islands of Grassholm, Skokholm, and Skomer and the Burry Inlet, while Camaes Head is a coastal Site of Special Scientific Interest (SSSI). In eastern Ireland, Rockabill and Lambay Island in Co. Dublin and the Raven Nature Reserve (which is also a Ramsar site) and Saltee Islands in Co. Wexford are legally protected with designations as Special Protection Areas, though this is not due to their seal populations but rather their seabird colonies.

Almost 50% of the world's grey seal population breeds around the British Isles. In the UK, annual surveys have documented a steady increase of up to 7% per annum in the size of the grey seal population to an estimated 108,500 animals in 1994 (Hiby *et al.*, 1996). Against this backdrop, the Irish grey seal population has largely gone uncounted until recently. Data from several sources suggest that the population size is somewhat greater than Summers' (1983) estimate of 2,000-2,500 (*see* Boelens *et al.*, 1999). In addition to providing the first relatively reliable assessment of grey seal population status in Ireland, Summers' work in collaboration with the Wildlife Service between 1979 and 1983 was also important in its view that the largest grey seal colonies occur on the offshore islands of the west and south-west coast with significant grey seal colonies possibly occurring in the western Irish Sea. A recent four-year study of the Irish grey seal population (*see* Kiely, 1998) focused on key sites in western Ireland. While this research showed that there was little evidence of a change in breeding population size at selected sites since surveys conducted in the early 1980's, a large gap in the knowledge existed elsewhere in Ireland, particularly along the eastern and southern coasts which had scarcely received attention. In Wales, a similar gap in knowledge existed until recently, when the West Wales Grey Seal Census (WWGSC) established that west Wales contains the largest concentration of breeding grey seals in southern Britain with an all-age estimate of approximately 5000 animals (Baines *et al.*, 1995). While the population estimates described above may seem to be of lesser consequence in relation to the much larger UK population, the ongoing absence of vital population-based information and a number of environmental factors emerging in recent years demanded a more accurate compilation of information from the Irish Sea region.

1.3 The Irish Sea ecosystem

The Irish Sea, situated close to the north-west European continental shelf, is an open body of shallow water, quite sheltered from the open Atlantic to the west and covering an approximate area of 2,200km^2 (Devoy, 1989). The seabed generally slopes from north-east to south-west, reaching its deepest in St George's channel at depths of over 100m. Closer to the adjacent coastlines much shallower depths of less than or equal to 25m are observed. The main flow of water is from the Celtic Sea, flowing northwards through the Irish Sea to the North Atlantic via the North Channel. The general pattern of salinity in the Irish Sea is a decrease from south to north and an increase with distance from the coast. The currents in the Irish Sea are quite weak, attributable to its partially enclosed nature (Dickson & Boelens, 1988). The central regions of the Irish Sea, the North Channel and St. George's Channel, are all strongly tidal and characterised by a well mixed water column and coarse seabed sediments. The east of the area is affected by a northwards movement through St. George's Channel, subject to considerable oceanic drift. Residual currents bring low salinity and high turbidity water of south Wales (South Gower and the Severn estuary) to the Pembrokeshire coastline with the result that some areas are highly productive.

Because the Irish Sea is enclosed, resonance causes it to have one of the largest tidal ranges in the world. The deep basin to the south west of the Isle of Man is an area of weak tidal current activity and stirring. In spring and summer this area becomes thermally stratified. A muddy substrate present under this stratified region acts as home for a population of Norway lobsters commonly known as the Dublin Bay prawn (Hill et al., 1994). This substrate is particularly evident as a small mud patch present off Cumbria, supporting a fishery for *Nephrops*. The sustainability of this resource relies strongly on the settlement of the larval stage of this species on to the muddy substrate. The productivity of this region may be reflected from the large-scale Irish and Celtic Sea Fronts (Raine *et al.*, 1993), through the food chain to various fish stocks and the nationally- and internationally-important seabird breeding colonies (Nairn *et al.*, 1995; Pollock *et al.*, 1997). The Irish Sea and eastern Celtic Sea contains rich spawning grounds for herring, sprat, sandeel and various flatfish (Nairn *et al.*, 1995; Pollock *et al.*, 1997). While the Solway Firth and Liverpool Bay are important nursery areas for plaice, sole and dab, similarly higher densities of juvenile fish or small species such as sprat and sandeel are found in the western Irish Sea. Further offshore, in the well-mixed, coarse-bed central Irish Sea, the average sizes of fish are significantly larger.

Mammals such as seals, cetaceans and humans are major predators in marine ecosystems and play a key role in determining community structure and balancing the dynamics of the ecosystem, in particular at a local scale. Human activities, such as the harvesting of fish stocks, can have far-reaching consequences for a marine ecosystem. The state of commercially harvested fish stocks in OSPAR Region III (as defined by the OSPAR convention, this includes the Irish and Celtic Seas and Malin Sea) is assessed annually by the International Council for the Exploration of the Seas (ICES) Advisory Committee on Fisheries Management. The seas around Ireland and Britain are divided by ICES into numbered rectangles, with the area covered by this report lying in ICES Division VIIa. In the Irish and eastern Celtic Seas, a variety of species are taken in the region's commercial fisheries. There is an extensive pelagic fishery for herring and demersal fisheries for whitefish (e.g. cod and monkfish in the eastern Celtic Sea. The main target species in the Irish Sea fisheries are cod, whiting, plaice, sole and haddock. However, recent national stock monitoring programmes based on information from landings data and fishery surveys recorded by the Department of the Marine and Natural Resources (DoMNR, Ireland) and the Ministry of Agriculture, Fisheries and Food (MAFF, UK) highlight serious concerns about the decline in stocks of cod, whiting and sole in this area (Connolly, 1999).

The grey seal population of the Irish and Celtic Seas represents an important natural resource and the species' position as a top predator in the marine food chain establishes it as an important indicator both of the area's biodiversity and the state of the marine ecosystem. However, due to the very limited knowledge on the status or dynamics of the grey seal population in these waters, it has been difficult to interpret a wide range of interactions within the ecosystem, particularly where human activities and those of seals appear to collide. A timely reminder of the threats posed to wild animal populations in the Irish Sea which was highlighted by the *Sea Empress* oil spill off Milford Haven in February 1996 when over 72,000 tonnes of crude oil was released into the sea. In addition to pollution, seal populations may also be at risk from other human-induced threats, such as declining fish stocks and habitat degradation.

1.4 Seal - Fisheries interactions in Ireland

Grey seals are known to act negatively upon some commercial fishery operations in Ireland and the UK. This may occur both biologically (i.e. competitively) and operationally. Operational interactions between seals and commercial fisheries may result in substantial economic losses for the fishing and aquaculture industries in some cases (Wickens, 1995). In 1992, an Bord Iascaigh Mhara (BIM), the Irish Sea Fisheries Board, reported that the operational losses in Irish fisheries and aquaculture due to interactions with grey seals could account for up to 5.4% of the total landings. However, this figure was acknowledged to be a poor estimate in the absence of dedicated research on grey seal populations around the Irish coast. As a result of concerns in the fishing industry, the Minister for the Marine assembled a working group made up of representatives from the principal fisheries bodies (Department of the Marine, Fisheries Research Centre, an Bord Iascaigh Mhara, Central Fisheries Board) and the National Parks and Wildlife Service. In its report to the Minister for the Marine in 1993, this Seal - Fisheries Interactions Working Group stated that there was:

> *"sufficient anecdotal evidence to suggest a major problem of interaction" and that "the problem would have to be approached on a national and international basis and in an integrated fashion."*

However, few Irish studies of the interaction between seals and fisheries have occurred to date. Small-scale studies based on fisheries for salmon (*Salmo salar*) (McCarthy, 1985) and monkfish (Collins *et al.*, 1993) suggested that economic losses may be substantial in the case of certain static-net fisheries. Losses of Atlantic salmon to seal predation in Ireland are the cause of considerable concern to the fishing and angling industries. Measures of predation on salmon at sea are not currently available and, while it is known that individual grey seals may feed at salmon nets, the evidence for such interactions has remained largely anecdotal. There is also the suggestion that "rogue" seals (selected individuals which have learned to feed from nets) are responsible for much of the damage to and removal of fish in nets and fish-farming cages. This has never been verified scientifically in the case of grey seals. Such fisheries in Ireland may also be prone to the accidental entanglement and drowning of seals. This interaction has previously been demonstrated in regional studies of tangle-net and gill-net fisheries by Collins *et al.* (1993) and B.I.M. (1997) with unknown consequences for the seal populations in question.

A number of authors (e.g. Gulland, 1987; Wickens *et al.*, 1992) have stated that predation by seals has the potential to reduce the yield of commercially valuable fish species by indirect biological means (including competition). However, others have questioned this view (e.g. Butterworth *et al.*, 1988; Mohn & Bowen, 1996) and the indirect impacts of seals on commercially important fish stocks has led to much debate. In Ireland, a study of one biological interaction between grey seals and fisheries, that of the occurrence of the "codworm" fish parasite *Pseudoterranova decipiens* whose final hosts are seals, suggested that worm infestation levels in whitefish landed in Skerries, Co. Dublin were attributable to an increase in the Irish Sea grey seal population (Coulahan, 1994). However, this view could not be verified since the grey seal population had never been monitored or indeed reliably estimated in this area. Nor could the consequences of declining fish stocks, as is currently the case for several species in the Irish Sea (Connolly, 1999), be assessed in terms of its impact on other components in the ecosystem, including higher predators such as grey seals.

1.5 The health status of seal populations

During the 1980s there were growing concerns about the health status of marine mammal populations in Irish and UK waters. Most significant was the 1987 outbreak of phocine distemper virus (PDV), a morbillivirus which killed approximately 18,000 harbour seals in the North Sea and adjacent waters in an epidemic between 1987 and 1989 (Deitz *et al.*, 1989). A similar morbillivirus outbreak subsequently caused a die-off of striped dolphins in the Mediterranean Sea (Domingo *et al.*, 1990). In the northern Irish Sea, PDV first spread to harbour seal colonies in Northern Ireland, in particular Strangford Lough, in August 1988 (Kennedy *et al.*, 1988). An approximate total of 250 seals died as a result of PDV infection in Northern Ireland (Northridge, 1990). However, in eastern Ireland and Wales, where numbers of harbour seals are significantly lower and the local populations consequently highly vulnerable, it was not clear to what extent these populations were affected by the outbreak. No evidence of effects of the seal virus was recorded on the east coast of the Republic of Ireland (*see* Boelens *et al.*, 1999) where there are at least two small colonies of harbour seals. A quantitative assessment of the impact of PDV on grey seal populations throughout western Europe was more difficult, though mortality was thought to be considerably lower than in harbour seal populations. Grey seal pup production at study sites in the UK dropped considerably as a result of the epizootic and the reproductive output of colonies such as the Orkney Islands and the Isle of May was 20-24% lower than expected for 1988 (Harwood *et al.*, 1991; Hall *et al.*, 1992a). While a number of authors speculate that the lower mortality observed in grey seal populations may have been due to differences in seasonal distribution patterns, little quantitative population-based data have been available to corroborate this view.

Pollution of coastal waters by harmful substances can result in subsequent contamination of seals as many toxins may be passed through the food chain to higher predators. Studies of seal populations in the Baltic suggested that high pollutant burdens may cause pathological changes which could ultimately affect reproductive performance (Olsson *et al.*, 1992). There is evidence that harbour seals feeding on prey from highly polluted waters may suffer detrimental side-effects (Reijnders, 1986; Brouwer et al., 1989). While a number of studies (e.g. Hall *et al.*, 1992) showed that levels of PCBs and DDT were relatively low compared with North Sea levels, seals in the northern Irish Sea have higher concentrations of pollutants such as organochlorines in their bodies than are found elsewhere around Britain. One "hot spot" for mercury pollution was identified in Liverpool Bay and high levels of heavy metal contamination were recorded among grey seals in Wales (Law *et al.*, 1991 & 1992). While there is a possibility that toxic contamination through the food chain may have contributed to the morbillivirus epidemics (Aguilar & Raga, 1993; deSwart *et al.*, 1995), no clear link has yet been established with susceptibility to PDV. Seals are also potentially at risk from oil spills, particularly during the annual moult and breeding seasons when significant numbers of seals are ashore for a period of several weeks. During the oil spill from the *Sea Empress* off Milford Haven in February 1996, over 70,000 tons of crude oil were released at sea, close to some of the most important grey seal haul-out and breeding sites in Wales. Preliminary data collected by Dyfed Wildlife Trust suggested that up to 200 grey seals may have been directly contaminated by oil while hauled out on Skomer Island and other sites. The short- and long-term effects of this and other forms of environmental contamination on seal populations are not fully known and there is no doubt that the absence of reliable seal population data from much of the Irish Sea area has heretofore hindered the development of suitable management strategies.

1.6 Seals as highly mobile predators

One confounding factor during the 1987 PDV epizootic was the rapidity with which seals were contracting the virus across seemingly large geographic distances. However relatively recent studies now show that adult and juvenile grey and harbour seals may travel hundreds of miles and utilise different haul-out sites as they travel (e.g. Stobo *et al.*, 1990; McConnell *et al.*, 1992; Hammond *et al.*, 1993; Lavigueur & Hammill, 1993; Sjöberg *et al.*, 1995; Thompson *et al.*, 1996). A study of seasonal grey seal abundance in Ireland (see Kiely, 1998) noted that a significant influx of "immigrant" seals (i.e. animals which did not breed in the study area) occurred during the moult season in one study area in successive years but this did not occur at other regional sites. Therefore, studies of seal population status in neighbouring countries should, where possible, take factors into account which allow for seasonal changes in distribution and geographic scales that do not adhere to national borders.

The Irish Sea separates Wales from Ireland by a distance of less than 60 miles and is not considered to be an effective barrier to these animals. Indeed, previous tagging of grey seal pups in Wales (e.g Backhouse & Hewer, 1957) suggested that movements of adult seals across the Irish Sea were also highly likely. For this reason, the Coastal Resources Centre (Ireland) and the Wildlife Trust, West Wales (formerly the Dyfed wildlife Trust) formulated a collaborative project which could evaluate the size of the grey seal population in the Irish Sea region as a whole and facilitate the assessment of specific seal-human interactions such as those outlined above. This study, part-funded under the INTERREG II Programme, is expected to provide a secure foundation for the development of sustainable marine resource and coastal zone management strategies for the Irish Sea, extending the information-sharing network already in place by its collaboration with government agencies in Ireland and Wales.

CHAPTER 2. STUDY AREA

The chosen study area (Figure 1) covers the Irish Sea stretching in Ireland from the Boyne estuary (Co. Meath) to Carnsore Point (Co. Wexford) and westward along the Celtic Sea coast to the Blackwater estuary at Youghal (Co. Cork). This takes in the main fishing harbours of Dunmore East, Helvick, Howth and Kilmore Quay, all of which were included in the study of seal - fisheries interactions presented here. The Welsh study area encompassed the south-western coast of Wales (the counties of Pembrokeshire and Ceredigion), an area well known for its concentration and diversity of marine life and consequently an important area for marine eco-tourism. It is also the region in which the *Sea Empress* oil spill occurred in February 1996.

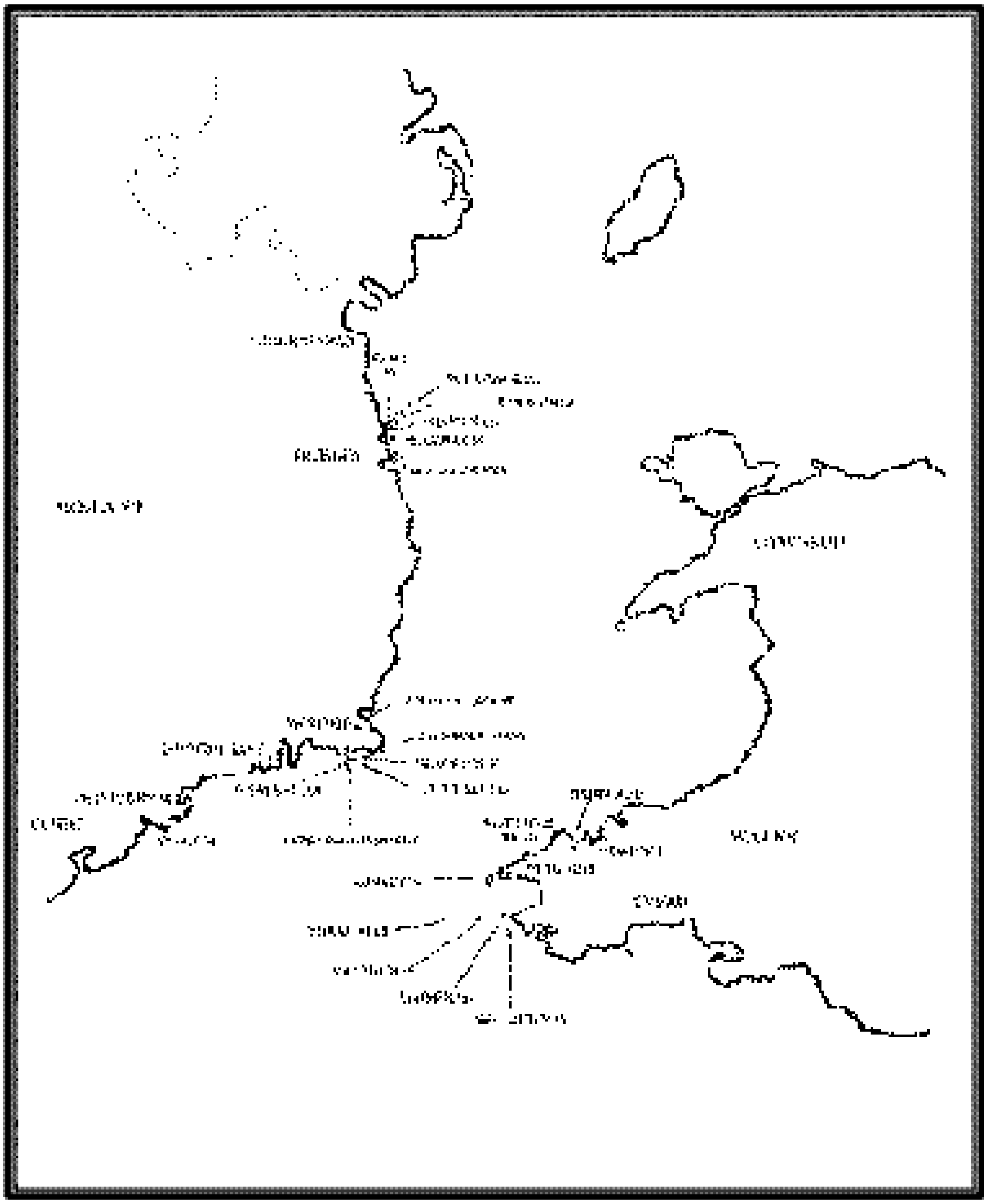

Figure 1. Map of the study area in the Irish and Celtic Seas, including key grey seal sites and fishing ports.

CHAPTER 3. GREY SEAL POPULATIONS IN THE IRISH & CELTIC SEAS

3.1 Methods

3.1.1 General introduction

For the purposes of this study, our hypothesis has been that grey seals in the Irish and Celtic Seas are part of a dynamic system and that the population within the study area has several components:

1. Seals that are resident year-round on either the Irish or Welsh coast;
2. Seals that breed on either the Irish or Welsh coast but move between the two;
3. Seals that breed in Ireland or Wales but leave the study area at other times;
4. Immigrant seals which travel into the study area but breed elsewhere;
5. Juvenile and non-breeding seals that remain faithful to sites in the study area;
6. Juveniles and non-breeders which emigrate from the study area.

Studies by Kiely (1998) at Irish haul-out sites suggest that grey seals in this region may follow an annual cycle of three relatively discrete phases:

1. winter/spring moult (November to April)
2. intermediate phase of alternate haul-out and foraging periods (May to August)
3. autumn/winter breeding (September to December).

From data gathered in previous studies, it appears that the breeding season of grey seals in south-west Britain differs from that in Ireland in that it is earlier and more protracted (Baines, unpubl.). Pups in Wales may be born from July to mid-December, and occasionally as late as March. However, the majority are born between mid-September and mid-October. Pupping may also occur slightly later on the islands in comparison with mainland sites.

The remote locations and rugged nature of sites used by grey seals makes surveying in a systematic manner very difficult. Such sites, in particular those where breeding occurs, are usually on beaches inaccessible to humans and are frequently covered by water at high tide. Preliminary visits were made to the coastlines defined by the INTERREG region. Observations made during these visits, background research and discussions with wildlife rangers, fishermen and local people led to the identification of key haul-out and breeding sites within the Irish and Celtic Sea study area.

Sites of importance for grey seals in Ireland and Wales were visited approximately every two weeks using a fully-equipped Rigid Inflatable Boat (R.I.B.). Each survey comprised 2-3 people. During the breeding season (September to December), beach and beach-cave sites were surveyed close to high tide since seals were usually in the water at high tide; this ensured minimal disturbance by researchers to the site. Cave sites were only accessed at low tide to ensure minimal risks to researchers. During the moult and summer seasons, sites were accessed at low tide when the greatest number of seals were likely to be ashore.

3.1.2 The assessment of pup production and size of the breeding population

Annual pup production was assessed in 1996 at Welsh study sites and in 1997 and 1998 at selected Irish study sites. Total pup production was estimated using the standard technique of through-counting (Boyd & Campbell, 1971) whereby each new pup encountered was classified into one of five age categories and marked with dye (5% Rhodamine B in 95% Ethanol). In this manner, the cumulative number of pups marked gives the total pup production. Dye marks were re-applied to partial- and fully-moulted pups to reduce the error of double counting. Classifying pups into age categories further reduces this error and allows one to estimate the start of the pupping season. Dead pups were also marked and their age, general body condition and external injuries noted. The carcasses were then placed well above the high water mark to prevent double counting. A life history table for the species, developed by Hewer (1964) and later modified by Harwood & Prime (1978), allows an all-age population estimate to be calculated from the total pup production. In this method, multipliers of 3.5 - 4.5 which account for variations in growth rate, juvenile and adult survival, and adult fecundity between populations, were applied to the total pup production estimate. Since many studies use these multipliers, all-age estimates can be compared for different grey seal colonies documented in the literature (*see* Lidgard *et al., in press* for details of methodology).

3.1.3 Seasonal abundance and distribution

Standard survey methods were used to determine grey seal abundance (*see* Lidgard, 1999 for details of methodology). This work involved accessing study sites by boat and conducting visual counts of haul-out groups. The annual cycle was divided into four seasons: male moult (January to April), summer (May to August), breeding (September to October) and female moult (November and December. Individual seals were grouped into three categories: (i) immatures (yearlings and juveniles), (ii) adult females, and (iii) adult males. Immature seals were not sexed because sex-related differences are difficult to judge in the field without observing the genitalia.

3.1.4 Photo-identification

In addition to the above methods a novel technique involving the photographic capture and recapture of individually recognisable seals, i.e. photo-identification (Hiby & Lovell, 1990; Hammond, 1995) was carried out using a standard protocol (Hiby, 1997). This technique relies on the variation in pelage pattern on immature and adult female grey seals which provides a unique fingerprint for each seal (Plate 1). Pelage patterns remain constant over time permitting the identification of individual seals from one year to the next. The head and neck region of each side of a seal is captured on 35mm film. Negatives are developed from each roll of film and resultant images digitised into a desk-top computer. Dedicated image processing and computer software identifies matches for similar images, and generates a sighting history for each seal. Images and their capture histories form an Irish and Celtic Sea Database for grey seals, termed EIRPHOT. This database was already established by previous work undertaken in 1996 (*see* Kiely, 1998). The data generated by photo-identification provide measures of grey seal summer and breeding population size, residency or site fidelity within the study area and movement between study sites. (For more details on image processing and data analysis, *see* Hiby, 1997; Lidgard, 1999).

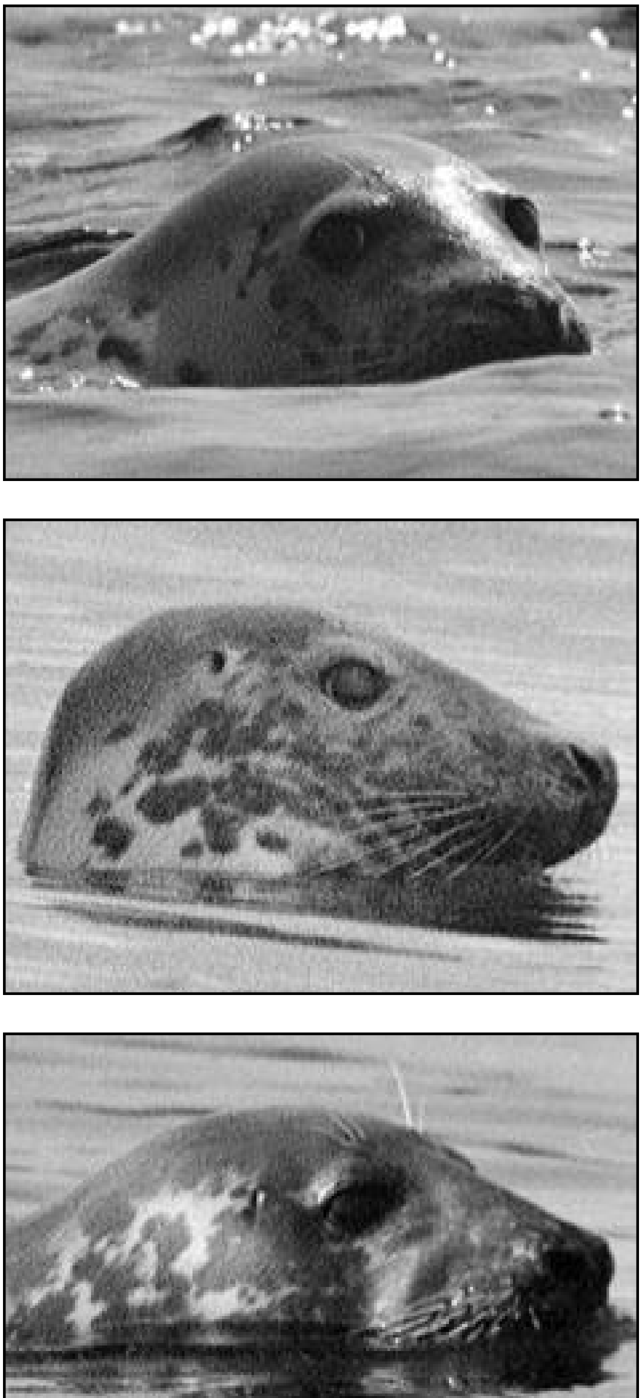

Plate 1. Variation in the pelage patterns of a sample of "well-marked" grey seals in the EIRPHOT database.

3.2 Results

3.2.1 Pup production and breeding population estimates

In 1996 two sea-borne surveys of the Welsh coastline were completed, which spanned Ceredigion, north Pembrokeshire and Ramsey Island (Baines *et al.*, 1996). A total of 744 pups were recorded between the 9th of September and the 17th of October 1996 (Table 1). The relative distribution of pupping sites and pup production for each site encountered during these surveys (Figure 2) identified key pupping areas at Ramsey Island, NW Pembrokeshire (from Fishguard to St. David's), Cardigan Bay and Skomer Island. For comparison with previous years, data from coastal surveys have been grouped into two areas: NW Pembrokeshire and Ramsey Island (Table 2).

Date 1996	Area	Total Pup Count	Number of Dead pups
09 September	DE	10	0
14 September	G	52	2
15 September	F	58	1
16 September	E	34	0
18 September	E	25	0
23 September	F	40	2
24 September	BCD	35	1
02 October	ED	123	3
09 October	FE	88	11
10 October	G	217	16
11 October	C	32	2
17 October	C	30	0
TOTAL		744	38

Table 1. Summary of grey seal pup counts in 1996 among sites in Ceredigion, north Pembrokeshire and on Ramsey Island. Key to sites: **B** = New Quay to Cardigan; **C** = Cardigan to Newport; **D** = Newport to Fishguard; **E** = Fishguard to Porthgain; **F** = Porthgain to St David's Head; **G** = Ramsey Island.

There would appear to be a considerable degree of fluctuation in these annual pup production figures and this is also observed in the data collected both in the present and previous surveys on Skomer Island (Table 3). These data would appear to suggest that annual mortality rates of 10-20% are the general case at sites on this island. However, total mortality recorded for west Wales in 1996 (Table 1) is lower at approximately 5%.

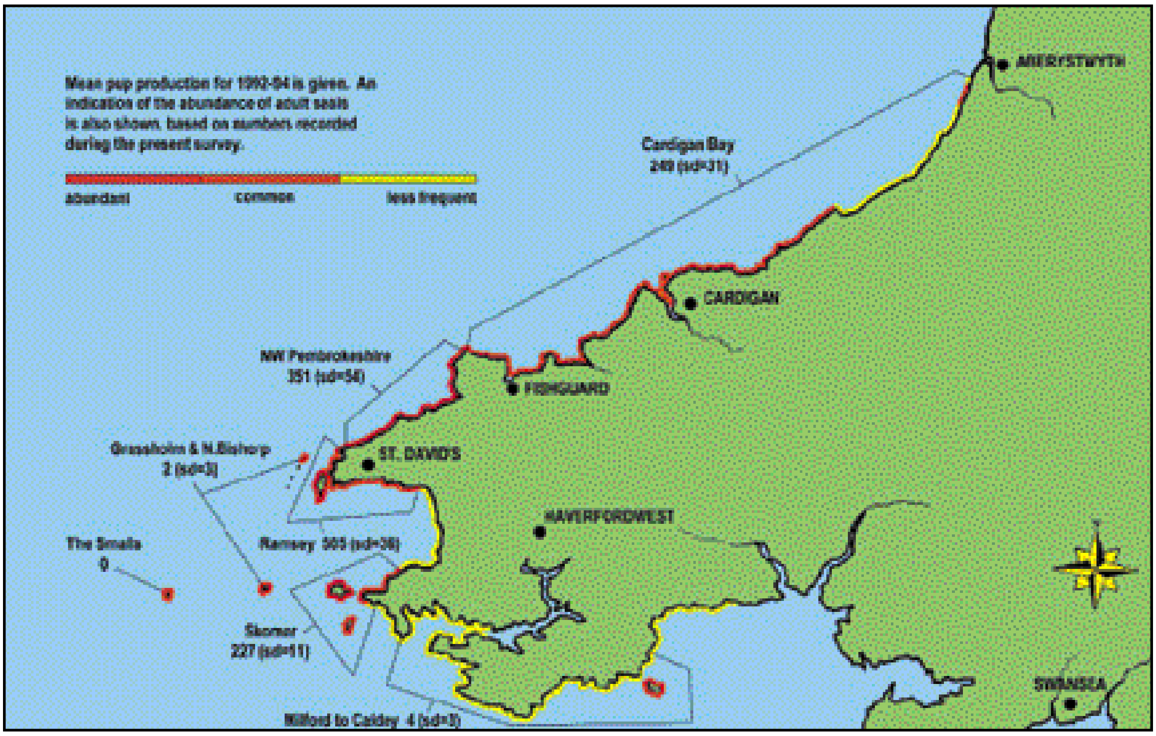

Figure 2. Estimated grey seal abundance and pup production in south-west Wales, 1992 to 1994.

Date of survey	Study site	Year of survey			
1996		1996	1994	1993	1992
14 to 18 September	Ramsey Island	52	87	51	79
	Fishguard - St David's	117	99	89	119
	SUB-TOTAL	169	186	140	198
	% on Ramsey Island	*31%*	*47%*	*36%*	*40%*
	% at Fishguard - St David's	*69%*	*53%*	*64%*	*60%*
02 to 11 October	Ramsey Island	217	202	232	211
	Fishguard – St David's	198	197	186	157
	SUB-TOTAL	415	399	418	368
	% on Ramsey Island	*52%*	*51%*	*56%*	*57%*
	% at Fishguard - St David's	*48%*	*49%*	*44%*	*43%*

Table 2. Comparison of grey seal pup counts between 1996 and 1992-1994 in NW Pembrokeshire and on Ramsey Island, south-west Wales.

	1992	1993	1994	1995	1996	1997	1998
Pup production	150	184	164	163	156	174	178
Mortality	13%	11%	10%	18%	19%	11.5%	15%

Table 3. Grey seal pup production and mortality recorded on Skomer Island, south-west Wales from 1992 to 1998.

In the Irish study area, grey seal breeding centred around four islands (*see* Appendix II; Lidgard, 1999). These were Lambay Island and Ireland's Eye (Co. Dublin) on the east coast and the Little & Great Saltee (Co. Wexford) on the south-east coast (Figure 1). Of these, Lambay Island and the Great Saltee contained the largest numbers of pups in both survey years (Tables 4 & 5). The majority of births took place from the beginning of September to the beginning of December, with a peak in pupping in the first weeks of October. The total grey seal pup production was estimated at 41 and 49 for the east coast islands, and 100 and 128 for the Saltee islands in 1997 and 1998, respectively. Mortality rates were between 2.2% and 12.2% for each island and between 2.0% and 8.6% for each island group.

	1997			1998		
Island Name	**Number of Pups**	**Mortality (%)**	**Number of Visits**	**Number of Pups**	**Mortality (%)**	**Number of Visits**
Lambay Is.	40	7.5	5	46	2.2	5
Ireland's Eye	1*	0	1	3	0	5
Total	**41**	**7.3**	**6**	**49**	**2.0**	**10**

Table 4. Grey seal pup production on islands of the Irish east coast in 1997 and 1998. Figures are based on the number of new pups counted on ground surveys. (* = incomplete surveys)

	1997			1998		
Island Name	**Number of Pups**	**Mortality (%)**	**Number of Visits**	**Number of Pups**	**Mortality (%)**	**Number of Visits**
Great Saltee	99*	3.0	8	122	12.2	7
Little Saltee	1*	0	2	6	16.7	7
Total	**100**	**3.0**	**10**	**128**	**8.6**	**14**

Table 5. Grey seal pup production on islands of the Irish south-east coast in 1997 and 1998. Figures are based on the number of new pups counted on ground surveys. (* = incomplete surveys)

On the basis of these pup production data and data from the WWGSC (Baines *et al.*, 1995), the estimated grey seal population in the INTERREG region of the Irish and Celtic Seas comprises between 5,198 and 6,976 animals of all ages (Table 6). Approximately 90% of this population is associated with breeding sites in west Wales.

Site	Year	Allage estimate (based on pup production)
East coast group, Ireland	1998	172 - 221
South-east coast group, Ireland	1998	448 - 576
South-west coast, Wales	1994 to 1996	4578 – 6179
INTERREG: Irish & Celtic Seas		**5,198 - 6,976**

Table 6. All-age population estimates for grey seals in the INTERREG Irish & Celtic Sea study area. Total estimates are calculated from pup production data using the method of Harwood & Prime (1978).

3.2.2 Seasonal abundance and distribution

Ireland

A total of 91 visits were made to study sites on the Irish east coast from the 13th June 1997 to the 1st December 1998. Six islands were identified as grey seal haul-out or breeding sites. Lambay Island and St. Patrick Island were the most important sites for immature, adult female and adult male grey seals while Colt Island and Shenick Island were the least important (Figure 3).

Five of the six islands were visited regularly throughout the year and were used to describe seasonal variation in abundance in the area (Figure 4). There was no correlation in the total mean monthly count between years (Spearman's rank correlation: r_5=-0.1, p=0.87). Variation in mean monthly counts between years was highest in August, September and October (Figure 4). The number of grey seals recorded was generally low during the months of May and June, increasing in July and reaching a peak in August. In September, at the onset of the breeding season, there was a decrease in abundance and thereafter the number of seals remained relatively static through the female and male moult seasons (i.e. until April). Much of the variation in abundance was attributable to the variation in the number of adult females. The mean monthly count of adult females was strongly correlated with the mean monthly total count (r_{10}=0.92, p<0.01). There was no significant difference between the numbers of immatures, adult females and adult males counted in the east coast study area (Kruskal Wallis: χ^2_2= 4.5, p=0.1). Immature, adult female and adult male grey seals showed an increase in abundance during the months of July and August, a decrease in September, at the start of the breeding season, and an increase during their respective moulting season (November to April).

The distribution of grey seals at study sites was found to vary significantly, depending on the season (male moult: X^2 = 98.34, p<0.01; summer: X^2 = 142.22, p<0.01; breeding: X^2 = 136.41, p<0.01; female moult: X^2 = 102.47, p<0.01). Lambay Island contained the highest numbers of grey seals in each season (Figure 5). All study sites except Rockabill, had the highest count of grey seals during the summer season and showed a decrease during the breeding season. Rockabill had the highest count of grey seals during the male moult and the lowest during the summer season, although this may be an artefact of the low number of visits to this site (Figure 5).

A total of 103 visits were made to study sites on the south-east coast of Ireland from the 24th June 1997 to the 6th December 1998. Six sites were identified as grey seal haul-out or breeding sites (Figure 3). The Great Saltee and The Raven Point were the most important sites for immature, adult female and adult male grey seals while the Little Saltee was the least important. Five of the six sites were surveyed regularly throughout the year and were used to describe seasonal variation in abundance (Figure 6).

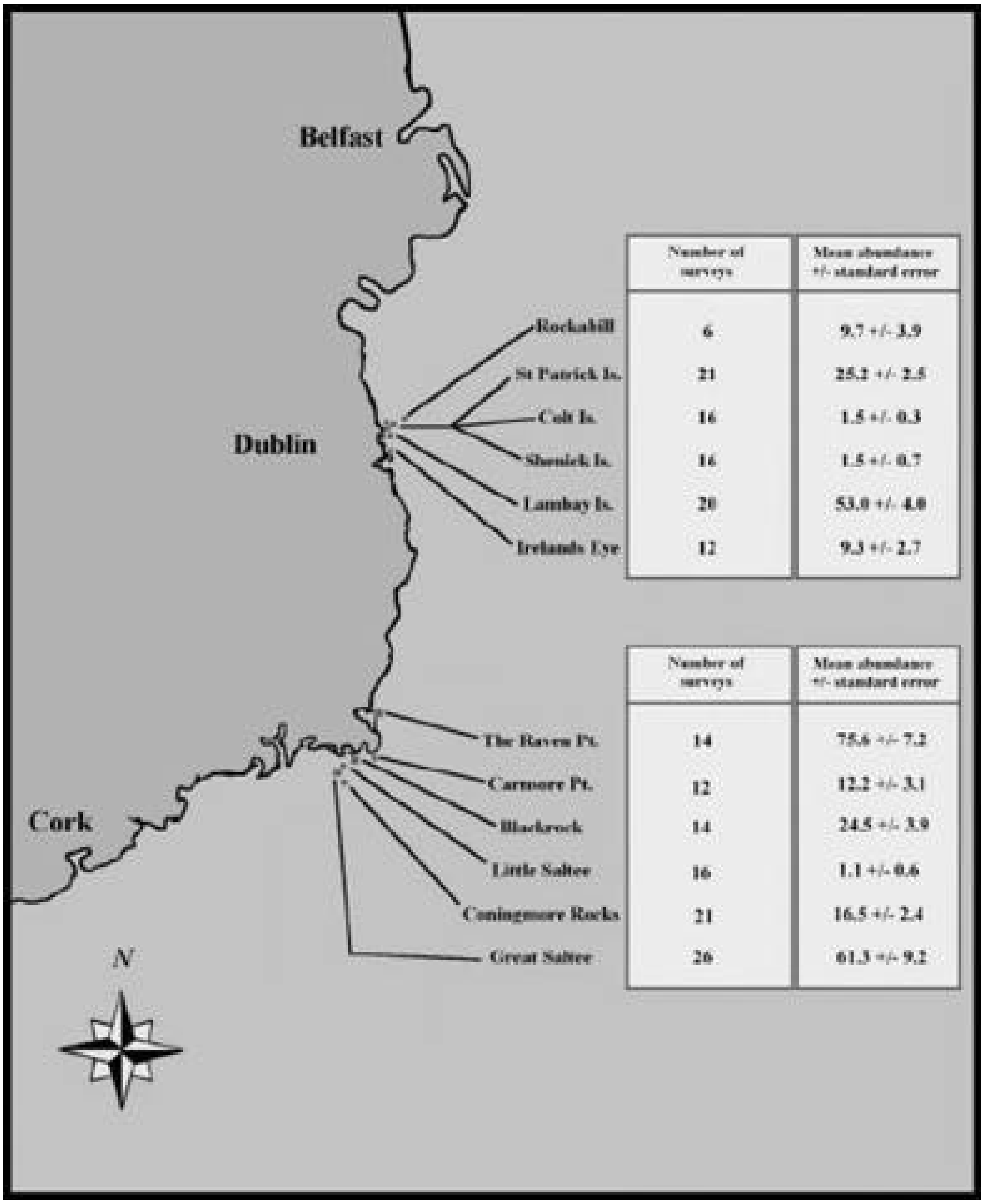

Figure 3. Measures of grey seal abundance at haul-out sites in the western Irish sea.

Much of the seasonal variation in abundance was attributable to the variation in the number of adult females. Immature, adult female and adult male grey seals showed a peak in abundance during the months of May and July and a low during June and August. Adult females and males showed an increase in abundance from the start of the breeding season to the end of the female moult in December, while the number of immature seals decreased during the breeding season and fluctuated during the female moult. Each class of animal showed an increase in abundance during their respective moulting season.

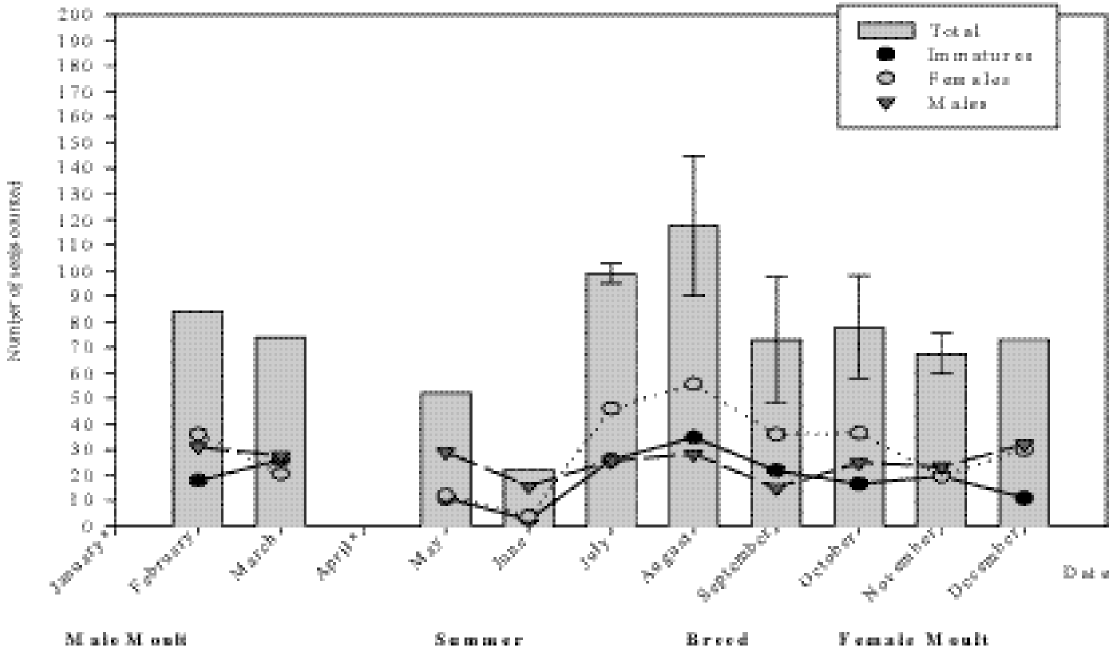

Figure 4. Monthly variation in the number of grey seals counted at sites on the east coast of Ireland. Data represent mean haul - out counts (+/- s.e.) for St. Patrick Island., Shenick Is., Colt Is., Lambay Is. and Ireland's Eye from june 1997 to December 1998.* = no data

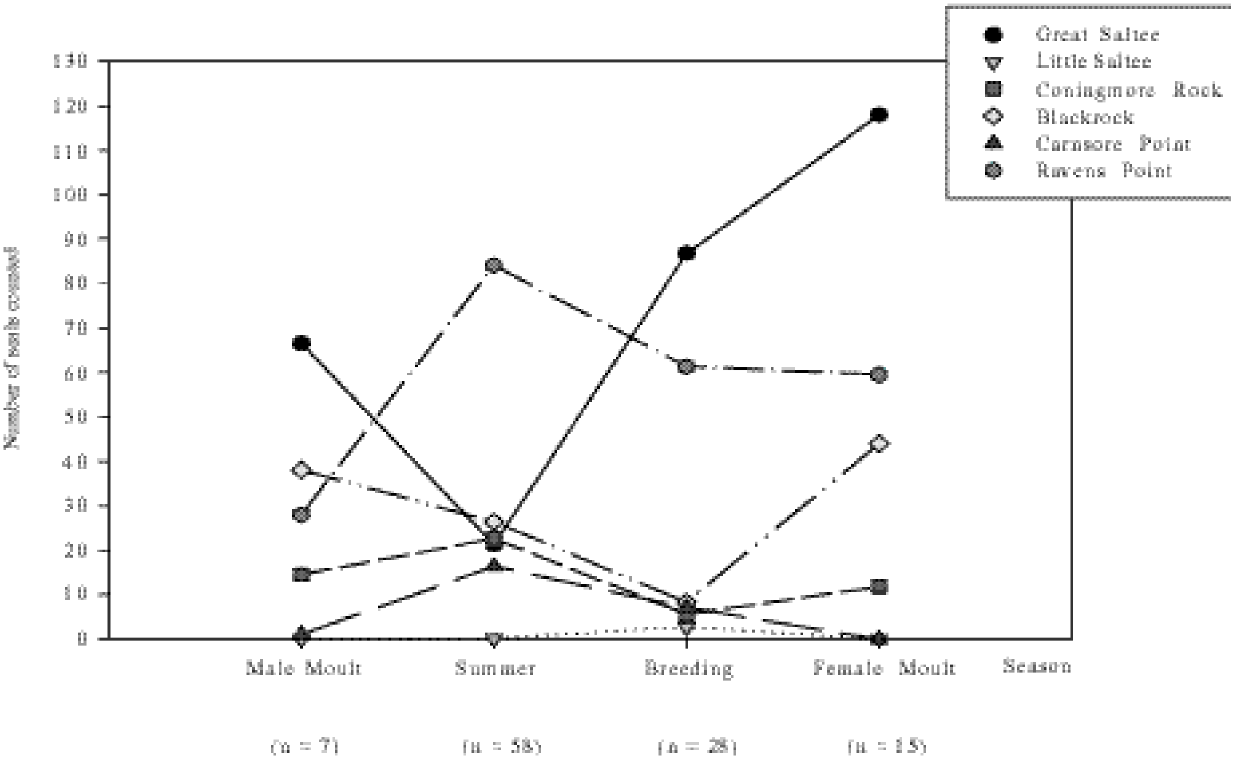

Figure 5. Seasonal variation in the number of grey seals counted at haul-out sites on the east coast of Ireland, 1997-1998. Data rerpresent mean haul-out counts per study site. (n = no. of surveys)

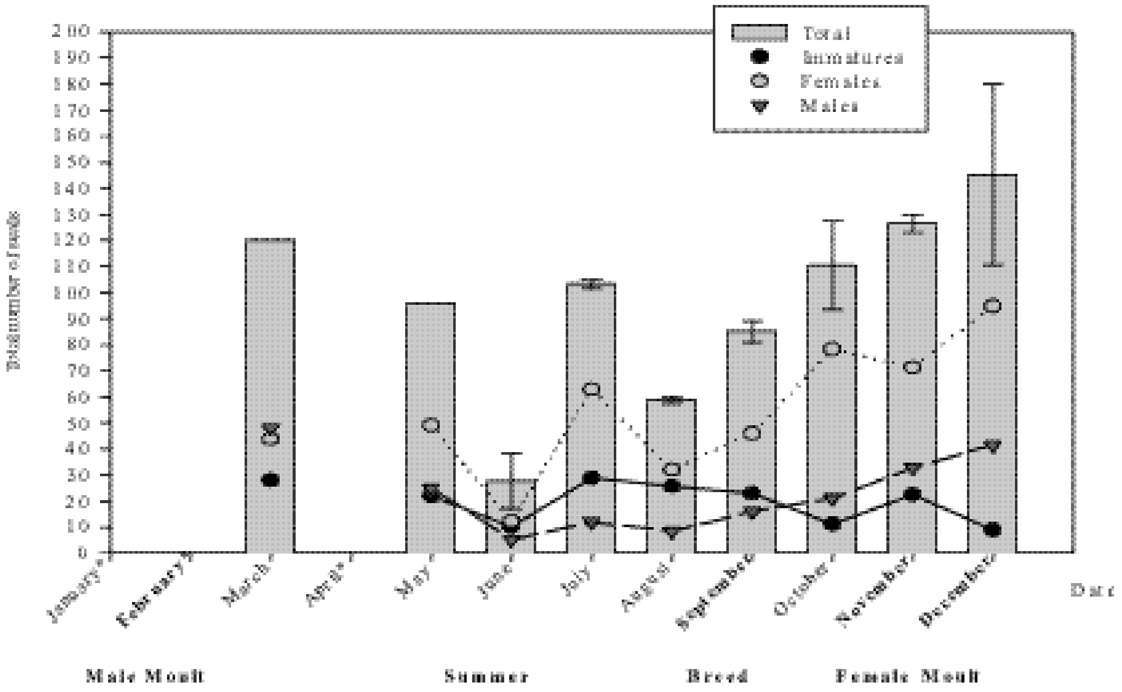

Figure 6. Monthly variation in the number of grey seals counted at sites on the east coast of Ireland. Data represent mean haul - out counts (+/- s.e.) for Little Saltee Is., Great Saltee Is., Coningmore Rocks, Blackrock and Carnsore Point from june 1997 to December 1998.* = no data

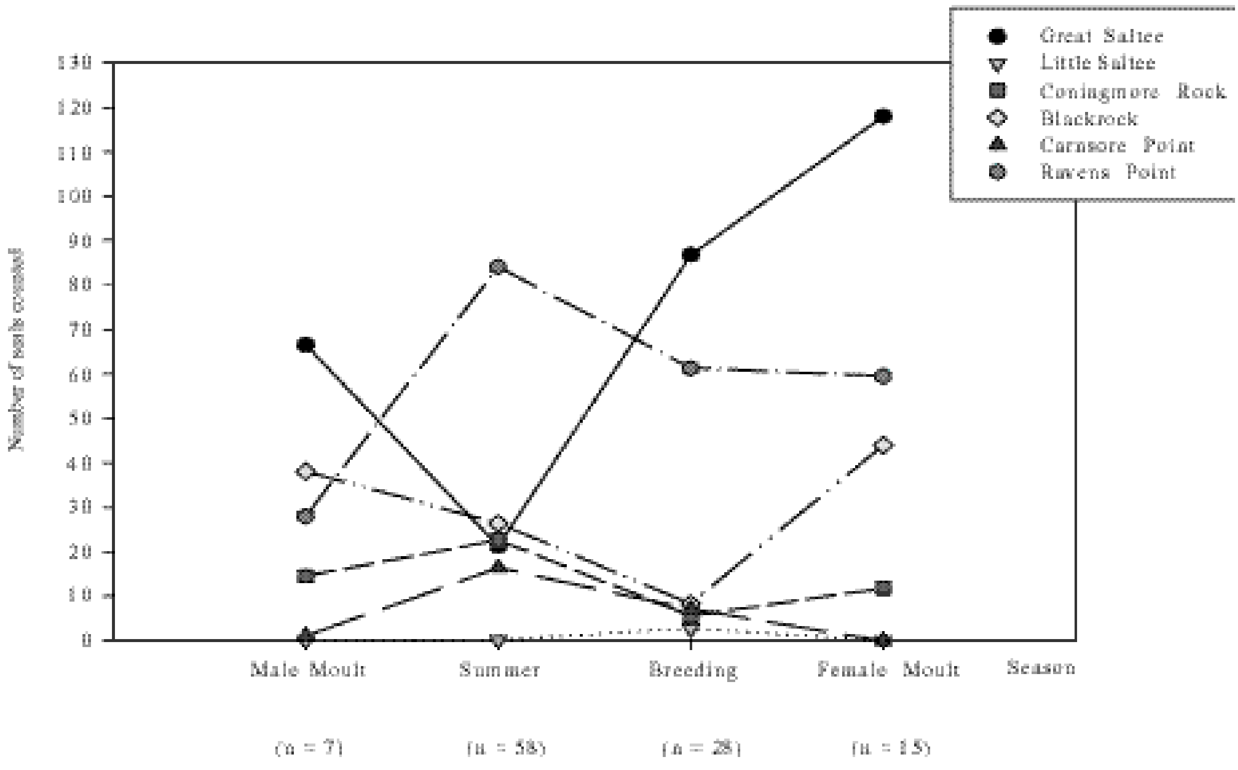

Figure 7. Seasonal variation in the number of grey seals counted at haul-out sites on the south-east coast of Ireland, 1997-1998. Data rerpresent mean haul-out counts per study site. (n = no. of surveys)

Significantly more adult females were counted in the south-east coast study area than immatures (Mann Whitney: U=6.0, $p<0.01$) or adult males (U=11.0, $p<0.01$). Much of the seasonal variation in abundance was attributable to the variation in the number of adult females. The mean monthly total counts were strongly correlated with the monthly count of adult females ($r_9=0.8$, $p<0.01$). Immature, adult female and adult male grey seals showed a peak in abundance during the months of May and July and a low during June and August. Adult females and males showed an increase in abundance from the start of the breeding season to the end of the female moult in December, while the number of immature seals decreased during the breeding season and fluctuated during the female moult. Each class of animal showed an increase in abundance during their respective moulting season.

As seen among sites on the east coast of Ireland, the distribution of grey seals was found to be significantly dependent on the season (male moult: X^2 = 130.15, $p<0.01$; summer: X^2 = 145.20, $p<0.01$; breeding: X^2 = 228.41, $p<0.01$; female moult: X^2 =269.24, $p<0.01$). However, unlike the east coast, there were no common trends between sites. The Great Saltee was the most important site during the moult and breeding seasons but the number of grey seals counted showed a dramatic decrease during the summer season. The Raven Point showed the opposite trend and was the most important haulout site during the summer season. The number of grey seals counted at Blackrock showed a decrease from a peak during the male moult to a low during the breeding season, followed by an increase during the female moult. Counts of grey seals at Carnsore Point and Coningmore Rocks increased from the male moult to the summer season and decreased during the breeding season. There were no grey seals sighted at Carnsore Point during the female moult, while the number recorded at the Coningmore Rocks had increased from the breeding season.

Wales

Figure 8 shows the proportion of adult female and male grey seals at two Skomer haul-out sites from September to November 1997. The data show a predominance of adult females throughout the post-breeding period. Counts were not carried out at North Haven until the beginning of October, and no counts were made at either site from the 6th to the 10th of November.

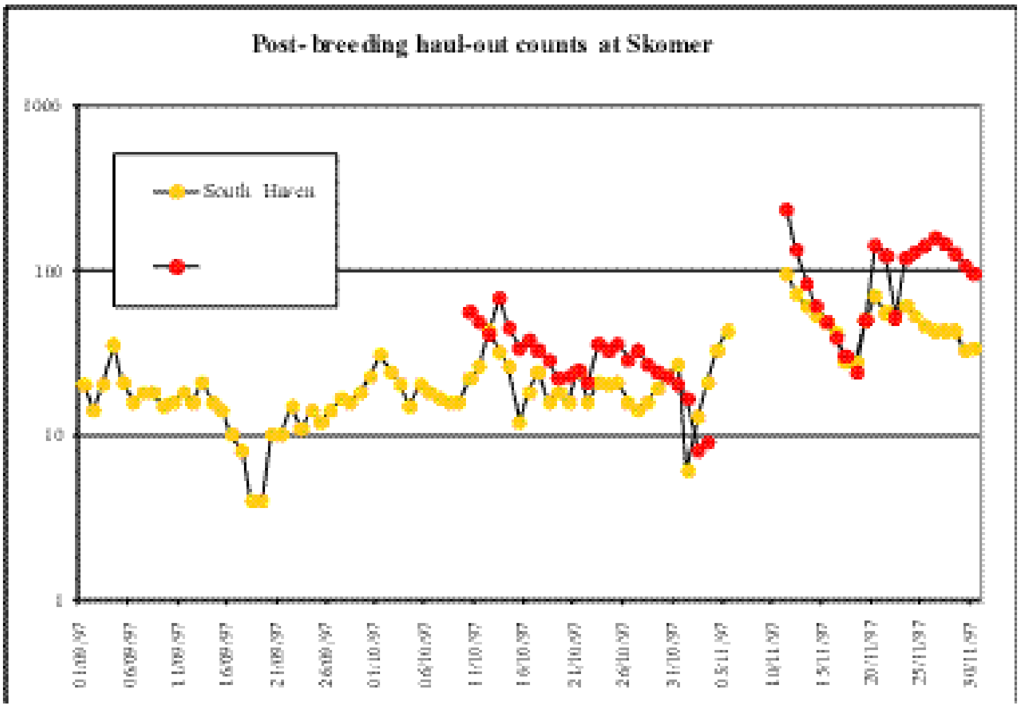

Figure 8. Haul-out counts of grey seals from the breeding and post-breeding period on Skomer Island, west Wales.

Figures 9 and 10 describe the relative abundance of grey seals from Caldey Island, south-west Wales to Penderi, central west Wales for the summer and moult seasons. During the summer season, The Smalls and Grassholm islands were the most important sites but became less so during the breeding and moult seasons. Camaes Head, Newport and Skomer Island were key moult sites. Daily counts of seals present at two haul-out beaches on Skomer Island were conducted throughout the breeding season. Counts continued during the late autumn and included post-breeding aggregations of seals.

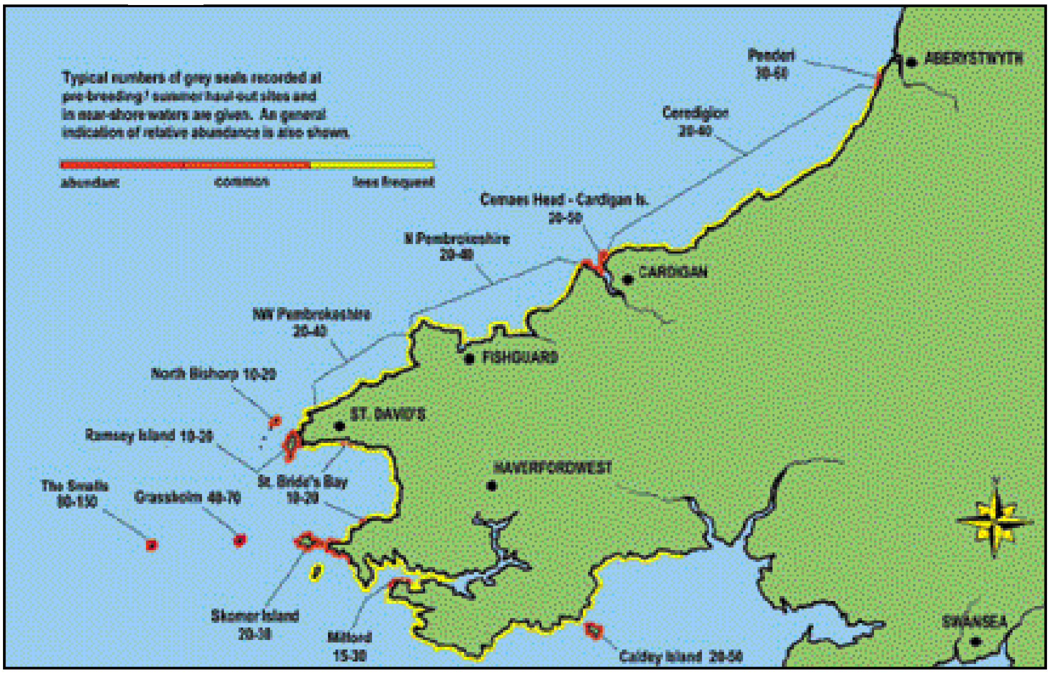

Figure 9. Abundance and distribution of grey seals during the spring on the south-west coast of Wales.

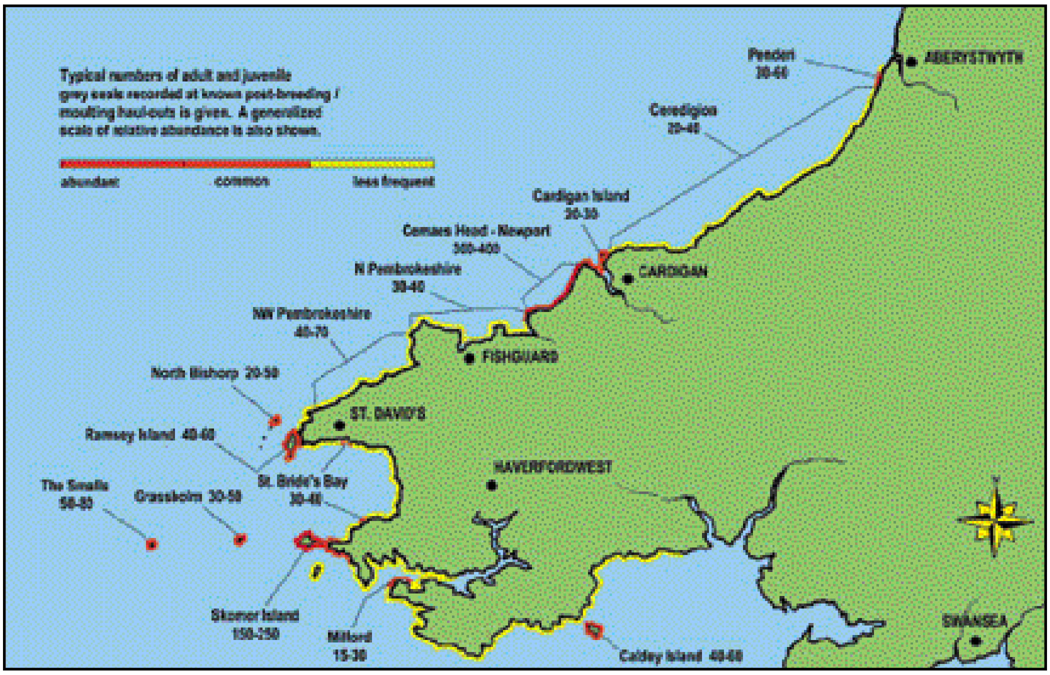

Figure 10 Abundance and distribution of grey seals during the winter on the south-west coast of Wales.

3.2.3 Photo-identification of grey seals

Ireland

A total of 129 photographic sessions were conducted at six of the seven study sites on the east coast of Ireland from the 13th June 1997 to the 19th August 1998 (Table 7). Rockabill had few well-marked individuals present at any one time and was not a suitable site for conducting the photographic surveys. Skerries Harbour was not a haul-out site but was used by grey seals for resting and feeding, as the seals were attracted by the discards from fishing boats. A total of 154 photographic sessions were made at five of the six study sites on the south-east coast from the 23rd June 1996 to the 11th September 1998 (Table 7). Little Saltee Island was not used for photography because there were no suitable individuals present.

Site	Left Only	Right Only	Both	Max	Min
Skerries Harbour	0	0	6	6	6
St Patrick Is.	3	2	21	26	24
Shenick Is.	0	0	2	2	2
Colt Is.	0	0	0	0	0
Rockabill	0	0	0	0	0
Lambay Is.	15	15	52	82	67
Ireland's Eye	0	0	4	4	4
Little Saltee	0	0	0	0	0
Great Saltee	7	14	38	59	52
Coningmore Rocks	4	8	22	34	30
Blackrock	9	15	45	69	60
Carnsore Point	1	1	9	11	10
The Raven Point	1	4	5	10	9

Table 7. The number of immature and adult female grey seals per study site whose images met the stringent criteria required for population analysis. The maximum estimate (Max) assumes that seals photographed from the left or right side only are not of the same individual. The minimum estimate (Min) assumes that seals photographed from the left or right side only are of the same individual.

The majority of seals were photographed at St. Patrick Island and Lambay Island on the east coast, and the Great Saltee, Coningmore Rocks and Blackrock on the south-east coast (see Appendix III for further details). The number of images digitised into the EIRPHOT grey seal database from the east coast study group was 1,237. A further 1,783 images were digitised from the south-east coast study group. The number of immature and adult female grey seals whose images were of a quality suitable for data analysis are given in Table 7. A total of 244 immature and adult female grey seals were identified. Of these, 152 were identified from both sides, 40 were identified from the left side only and 52 from the right side only. Figure 11 shows the frequency distribution of sightings for these individuals for both study groups. The data describe an L-shaped distribution with 127 individuals sighted once during the study period, and 117 individuals sighted on at least two occasions. Of the 127 individuals sighted once, 74 were identified from one side only which partly explains the high number of individuals in this category.

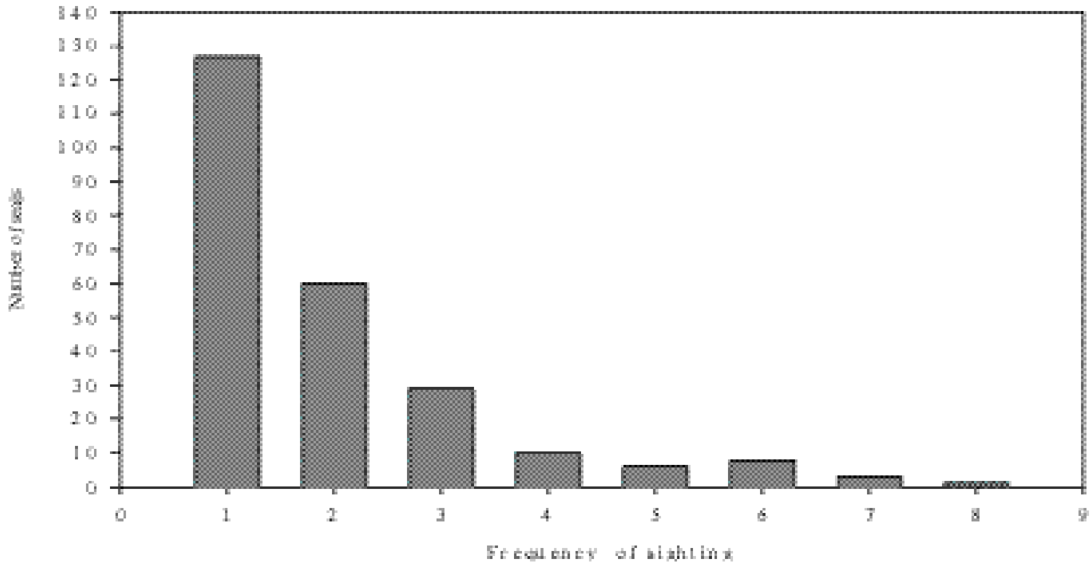

Figure 11. Frequency distribution of sightings of photo-identified grey seals at study sites in the western Irish Sea and eastern Celtic Sea between 1996 and 1998. data are from the EIRPHOT database for grey seals.

Between ▼ / ►		East coast group: SK	SP	SS	LA	IR	South-East coast group: GS	CO	BL	CA	RA
East Coast Group	SK	0									
	SP		0								
	SS			0							
	LA				6						
	IR					0					
South East Coast Group	GS						2				
	CO							7			
	BL								8		
	CA									0	
	RA										0

Table 8. The number of individual grey seals photo-identified on four or more occasions at the same site in the western Irish or eastern Celtic Sea, between 1996 and 1998. Key for abbreviated study site names as follows: **SK** - Skerries Harbour; **SP** - St Patrick Island; **SS** - Shenick Island; **LA** - Lambay Island; **IR** – Ireland's Eye **GS** - Great Saltee; **CO** - Coningmore Rocks; **BL** - Blackrock; **CA** - Carnsore Point; **RA** - The Raven Point.

Individual seals showed a degree of faithfulness to particular sites (i.e. site fidelity) in the western Irish Sea. Table 8 shows the number of immature and adult female grey seals which were sighted at the same site on at least four occasions between 1996 and 1998. Individuals at Blackrock showed the highest level of site fidelity with eight sighted on four or more occasions; individuals at the Great Saltee showed the lowest level of site fidelity with only two sighted on four or more occasions.

Wales

Photo-identification of breeding females at pupping sites in 1996 and 1997 produced 53 matches between the two years (Table 9). In 23 cases, the females had returned to pup on the same site in successive years. In 30 cases, the female pupped on different sites in successive years. The number of recaptures made at the same mainland sites in the two consecutive breeding seasons was approximately equal to the number recaptured at different sites. On Ramsey Island only one recapture was made at the same site and seven females were recaptured at different pupping sites in the second year. All of these individuals had moved to the mainland in 1997.

1996 Pupping site	Mainland Section C	Mainland Section D	Mainland Section E	Mainland Section F	Ramsey Island	Total
At same site in 1997	2	1	13	6	1	23
At different site in 1997	2		14	7	7	30

Table 9. The number of grey seals photo-identified at the same and at different pupping sites in the 1996 and 1997 breeding seasons in the eastern Irish Sea. The coast is divided into: C = Cardigan to Newport; D = Newport to Fishguard; E = Fishguard to Porthgain; F = Porthgain to St David's Head.

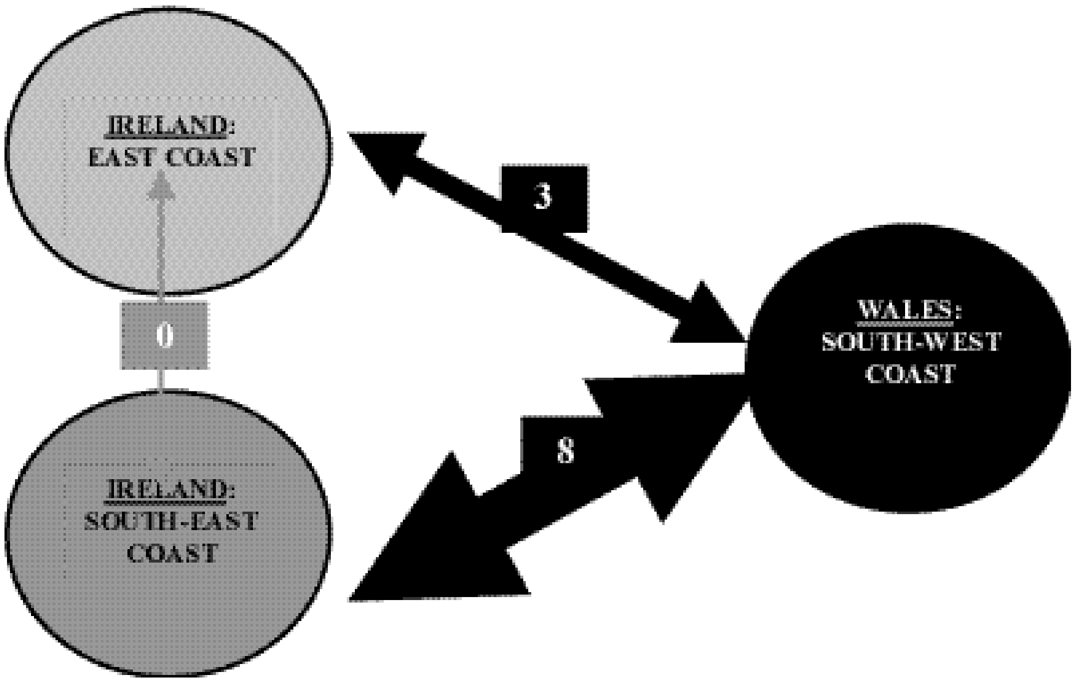

Figure 12. The number of photo-identified grey seals showing movement between study sites in the western and eastern Irish Sea, from 1996 to 1998.

3.2.4 Seal movements in the Irish and Celtic Seas

The greatest movement of grey seals between sites in the Irish Sea occurred across the southern Irish Sea (Figure 12). Seals which travelled between south-east Ireland and south-west Wales were identified from both the left and right sides of the head. Three of the four individuals sighted between eastern Ireland and south-west Wales were identified from both sides. No north-south movement was detected between sites on the east and those on the south-east coast of Ireland. Based on the mark-recapture data generated by this photo-identification study, an Irish Sea grey seal population estimate of 5,613 seals (0.2% CV) was derived using the population model developed by Hiby (1997).

Within the east coast group, the majority of movements occurred between Lambay Island and St. Patrick Island (Table 10) and in the south-east coast group, most movement was between Coningmore Rocks and the Great Saltee, and between Blackrock and the Great Saltee:

BETWEEN ▶ / ▼		East coast group					South-west Wales					South-east group				
		SK	SP	SS	LA	IR	C	E	F	G	SM	GS	CO	BL	CA	RA
East coast group	SK															
	SP	5														
	SS		1													
	LA	2	10	2												
	IR		1		4											
South-west Wales	C		2		1											
	E															
	F															
	G				1											
	SM															
South-east coast group	GS								2	1	2					
	CO									1	1	13				
	BL							1		1		13	3			
	CA											1		7		
	RA								1			1		1	1	

(light shading) indicates movement within a study group

(dark shading) indicates movement between study groups

Table 10. The number of photo-identified grey seals that showed movement between study sites in east and south-east Ireland and those in south-west Wales, 1996 to 1998. Numbers refer to individuals showing movement; Each individual may display more than one movement within or between study groups. Movement of individuals within Wales is not shown. Key for abbreviated study sites: **SK:** Skerries Harbour; **SP:** St Patrick Island; **SS:** Shenick Island; **LA:** Lambay Island; **IR:** Ireland's Eye; **C:** Cemaes & Pwll y Wrach; **E:** Fishguard to Trevine; **F:** Ynys Barry to Morlanod; **G:** Ramsey Island; **SM:** Smalls; **GS:** The Great Saltee; **CO:** Coningmore Rocks; **BL:** Blackrock; **CA:** Carnsore Point; **RA:** The Raven Point.

Of the eastern Irish group, only individual seals from Lambay Island and St. Patrick Island showed movement to south-west Wales and most of this movement was to sites in North Pembrokeshire, although only one individual was recaptured at a site on Ramsey Island. In the south-eastern Irish group, most of the individuals that subsequently travelled to south-west Wales were from the Great Saltee. These animals moved to corresponding Welsh sites further south than those used by individuals from eastern Ireland. This movement was to the area between Ynys Barry and Morlanod (south of the North Pembrokeshire cliffs), Ramsey Island and The Smalls.

No EIRPHOT photo-ID matches were detected to date between animals in the Irish & Celtic Sea area and those in the existing western Irish or Scottish grey seal library.

3.3 Discussion

In comparison with recent Irish all-age population estimates from the Inishkea Group and the Blasket Islands (Kiely & Myers, 1998), the grey seal population based at the Saltee Islands is similar in importance while the east coast population is considerably smaller. However, both the east and south-east coast populations are considerably smaller than those in south-west Wales (Baines *et al.,* 1995) and south-west England (Wescott, unpublished data) and other populations in the UK (Hiby *et al.,* 1996).

Prior to this study there had been no detailed grey seal surveys on the east and south-east coast of Ireland (*see* Lidgard, 1999). On those previous surveys, pup production was estimated from 1-2 visits only and the methods used were not clearly outlined (*see* Lockley, 1966; Summers, 1983; N.P.W.S., unpublished data). Differences in methodology and the determination of the timing of breeding make comparisons between previous surveys and the data collected in the present study invalid (Summers *et al.,* 1975; Haug *et al.,* 1994). Thus the total pup production estimate derived in this study must be regarded as the first reliable minimum estimate for the breeding population at sites in the western Irish Sea and eastern Celtic Sea. It must be remembered that this is representative of the area encompassing the principal known breeding sites and not the entire east and south-east coasts of Ireland, since it was not logistically possible to visit all potential and lesser-known breeding sites using the boat-based survey method.

In contrast, background data for Wales, achieved by the West Wales Grey Seal Census (*see* Baines *et al.,* 1995) allowed for the comparison of pup production figures and population estimates. In this regard, total production figures for selected sites in 1996 were similar to previous years' totals and within one standard deviation of the mean number of pups recorded in 1992-94:

> In 1996, 169 pups were recorded on Ramsey Island and on the mainland between Fishguard and St David's between the 14th and the 18th of September, and 415 pups between the 2nd and the 11th of October. From 1992 to 1994, the mean number of pups recorded from the same sites in mid September was 175 (sd=30.6; CV=17.5%) and in the beginning of October, 395 (sd=25.2; CV=6.4%).

Previous exhaustive surveys conducted during the WWGSC showed that approximately 1,300 pups were born between August and December at over 200 pupping sites (Baines, 1993). Since data collected in 1996 were in close agreement with the WWGSC, it was decided to use the combined data gathered between 1994 and 1996 in deriving population estimates for the INTERREG study area. The resultant minimum all-age population estimate for the Irish Sea of 5,198-6,976 grey seals is the best estimate available at this time since it was supported by the photo-identification mark-recapture estimate (5,613 seals, 0.2% CV) derived in the present study.

All-age population estimates given in this study are based on life-history parameters (see Harwood & Prime, 1978) which are not yet available for Irish and Welsh grey seal populations. In addition, such estimates are based on pup production figures for closed populations and do not account for variations in population size and age structure or mass movement between neighbouring populations, all of which are poorly understood at present and require further investigation. While variation in pup production between years may be attributable to natural variation in the population, grey seal surveys are rarely without logistic difficulties such as gaining access to sites in poor weather conditions. For example, poor weather reduced the number of complete surveys in 1997 to Ireland's Eye and the Saltee Islands and definitive comparisons between years for these islands cannot be made. However, possibility of repeating survey effort in 1998 allowed for more representative data to be gathered and such two-year flexibility should be allowed in conducting surveys of this type.

Pup mortality recorded during the breeding season in the western part of the study area was between 2.0% and 8.6% of the total pup production during the two years of the study. These estimates were similar to those reported for sites in the west coast of Ireland (Kiely & Myers, 1998) and the south-west coast of Wales (Anderson 1979; Anderson *et al.*, 1979; Baines *et al.*, 1995). While the breeding habitat and population density, factors which strongly influence mortality at grey seal pupping sites, would appear to be similar at sites throughout the Irish Sea, care must be taken when interpreting these figures (see Kiely & Myers, 1998). Pups which died in between survey visits may have been washed off beaches by high tides or storm surges (Anderson, 1979; Anderson *et al.*, 1979). During both years, severe weather was documented on numerous occasions, particularly in late October and November. While it is not known what effect such weather may have at a pupping site, since none were continually monitored on a day-to-day basis throughout the breeding season, variation in mortality between years may be attributable in part to survey frequency and interannual variation in the severity of the weather.

Trends in the seasonal abundance of immature, adult female and adult male grey seals showed that sites in the western Irish Sea were more important for grey seals during the months of July and August, while the south-east coast of Ireland was important for grey seals throughout the year, particularly during the breeding and moulting seasons. Variation in the abundance of grey seals after the annual moult and during the summer months may be explained in part by the following (*also see* Lidgard, 1999):

- The pelagic habits of grey seals at this time of year (see Hammond *et al.*, 1993);
- The tendency for adults of both sexes to aggregate closer to the breeding sites toward the end of the summer (Coulson & Hickling, 1964; Cameron, 1970; Stobo *et al.*, 1990);
- The availability of suitable summer haul-out terrain in relative proximity to productive summer foraging areas (Thompson *et al.*, 1991).

The annual moult, in particular, would appear to be an interesting period in terms of population distribution and ecology, as it occurs after breeding and prior to the main foraging period in the annual cycle. Studies by Kiely (1998) indicated that a large site-specific immigration event occurs annually at the Inishkea Group in western Ireland. While the present study indicates that haul-out abundance also increases in the south-east of Ireland during the late breeding and moult seasons, it is currently difficult to assess the importance of these findings and year-round monitoring of abundance patterns and movements or seals would help in understanding the population structure outside the breeding season, as recommended in Boelens *et al.* (1999).

In terms of understanding the movements and association of individual seals with particular sites, the photo-identification aspect of this study proved to be a powerful and cost-effective method, yielding eleven recorded movements across the Irish Sea and numerous inter-site movements within Irish and Welsh study areas. This was also shown in research by Kiely (1998) at haul-out sites in western Ireland. Similar to that work, the present study demonstrated that individual grey seals may show a degree of faithfulness to particular sites. It also went further in the study of population dynamics, by establishing that adult grey seals may also show considerable regional movement. This is a phenomenon which was heretofore shown using methods which are significantly more invasive, costly and logistically demanding (e.g. satellite telemetry; mass flipper tagging). Therefore the correct use of the photo-identification method and EIRPHOT database in seal-related studies in the Irish and Welsh waters should be broadly encouraged in the future.

CHAPTER 4. GREY SEAL - FISHERIES INTERACTIONS IN THE IRISH & CELTIC SEAS

4.1 Methods

4.1.1 General introduction

Detailed reviews of existing seal - fisheries interaction studies are found in Wickens (1995) and, more specifically to the UK, in BIM (1997). The various studies which have been conducted worldwide tend to categorise such interactions into two types:

1. Operational or Physical interactions:
Those in which seals remove fish directly from, or become entangled in fishing gear during its operation. Operational interactions are often immediately detrimental to the fisherman, resulting in damaged catches or gear with consequent economic losses for the individuals and crew, fishing co-operatives and the industry as a whole. Similarly, the accidental entanglement of seals in fisheries operations (known as by-catch) can have immediate effects through the removal of members of the breeding population, directly affecting recruitment and disrupting the population balance.

2. Biological interactions *(see Harwood, 1987):*
Those which operate through various ecological pathways, e.g. competition for food resources, stock depletion, parasite transmission, etc. Biological interactions involve the unseen interactions between seals and fisheries and are usually discussed in terms of the amount of fish taken by seal populations from commercially-exploited stocks. However, fishing activity may affect foraging distribution and diet composition of seals, but, to date, there is limited evidence that this has significantly affected populations.

Background information collected in Wales suggested that interactions between seal populations and fisheries in the area were not as significant as experienced in the western Irish Sea and Celtic Sea. An investigation of interactions between marine wildlife and net fisheries in Wales did not reveal any large-scale problems, although a number of cases of grey seal entanglement in fishing gear were reported (*see* Thomas, 1992). This may be due to the fact that inshore fisheries around the coast of Wales are directed mainly at shellfish with pot-fisheries for lobster and crab most important. Although some tangle-netting for crayfish and demersal species (e.g. rays) takes place and seals are occasionally thought to remove bait from lobster creels, they are generally not perceived to be responsible for economically-significant impacts on Welsh fisheries.

Previous data gathered in Ireland suggested that grey seal interactions with commercial fisheries are most significant in inshore (< 20 nautical miles from shore) static-net (or passive) fisheries (e.g. gill, tangle and drift-nets) (*see* McCarthy, 1985; Collins *et al.*, 1993; BIM, 1997). Initial contacts with the fishing industry and government agencies sought to determine the types, nature and commercial extent of fisheries in the region. The data collected are summarised in Figure 13 and Table 11.

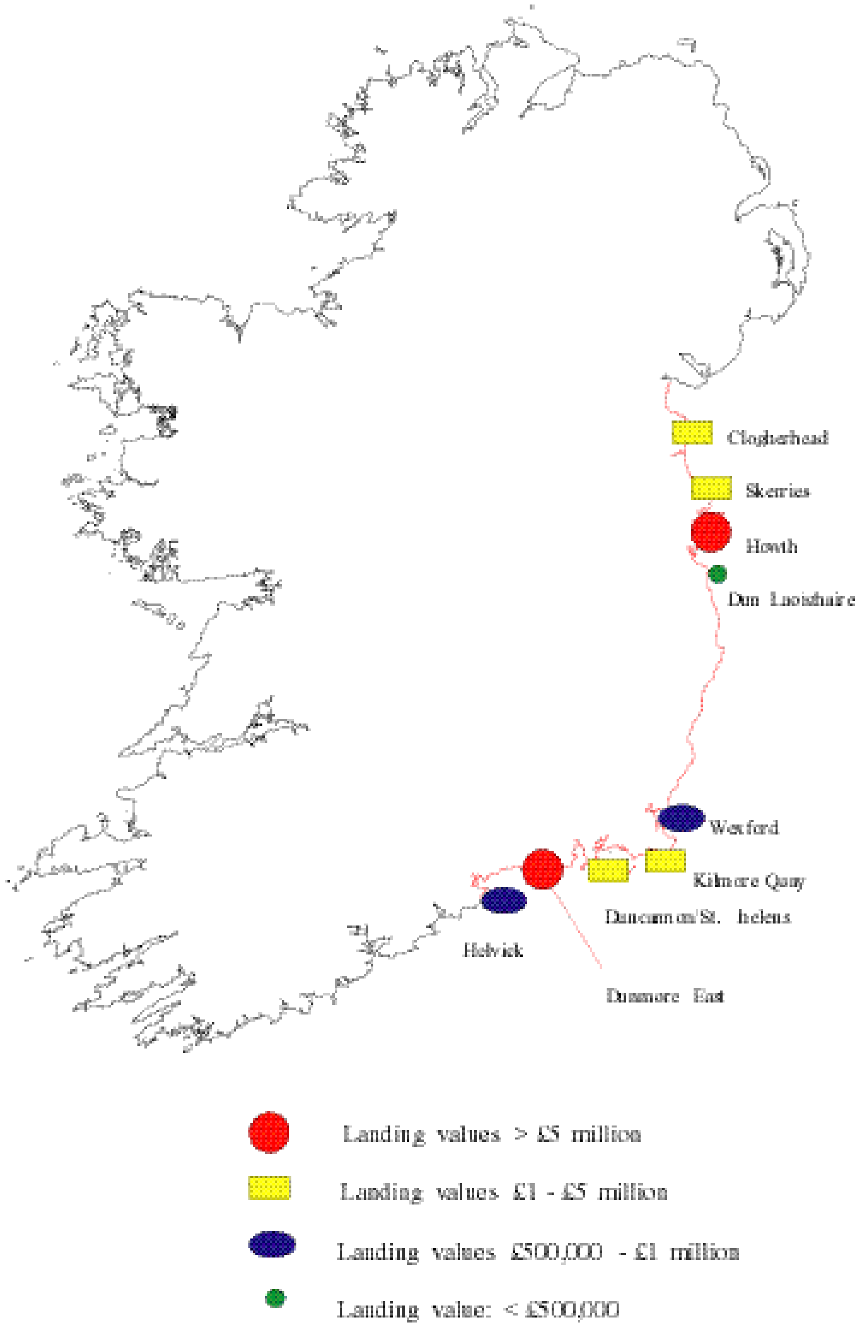

Figure 13. Ports in the Irish INTERREG study area and their corresponding landing values in 1997. Data presented are courtesy of the Dept. of the Marine and Natural Resources.

In order to obtain a more detailed understanding of seal - fisheries interactions and to determine which fisheries might be the focus of detailed study in the present work, interviews were held with co-op personnel and fishermen in Ardmore, Duncannon, Dunmore East and Helvick, Co. Waterford, Kilmore Quay, Co. Wexford and Youghal, Co. Cork. In addition, questionnaires were sent to fishermen in the Irish INTERREG region in the spring of 1997. Of the 700+ questionnaires posted, 72 were returned and of these 24 (33%) were unanswered for a number of reasons (e.g. change of address or retirement). Forty-eight of the returns (66%) were received from fishermen still commercially active. 94% of respondents stated that they commonly observed seals while fishing and 34% said that they experienced damage amounting to >30% of their catch. In general, fishermen and industry representatives in the Irish INTERREG region perceived seal predation to be a serious problem. 89% of respondents felt that this problem had increased in the last decade while 11% said there had been no change. A large majority of respondents (88%) favoured the pro-active management of seal stocks which would include the culling of seal populations, while a number of contributors highlighted the fact that illegal culling had historically and even recently taken place in their areas.

Fishing port	Target species	Fishing method	Season	Approx. no. of vessels	Vessel origin	Typical vessel size
Dunmore East	Herring	Pelagic Trawl	Dec-Feb	40	S, SE, W Local	65-80'
	Flatfish/Whitefish	Bottom Trawl	Jan-Apr	17	Local	50-80'
	Prawns	Prawn trawl	Apr-Oct	17-20	Local, SE, E	50-70'
	Cod, Haddock, Whiting, Pollack	Gill net	Jan-Apr	3-6	Local	40-70
	Salmon	Drift net	June-July	20-30	Local	20-30'
	Monkfish	Tangle net	Mar-Sept	4-6	Local	20-30'
	Crab, Whelk, Shrimp, Lobster	Pots	Mainly Summer	20-30	Local	20-40'
Helvick	Cod, Whiting, Haddock, Pollack	Gill net	Jan-Apr	12	Local Dungar.	32-50'
	White fish	Trawl	Apr-Dec	6	Local	32-50'
	Salmon	Drift net	June-July	11	Local	18-38'
	Monkfish	Tangle net	Mar-Sept	1-2	Local	32-45'
	Crab, Shrimp, Lobster	Pots	Mar-Dec	6	Local	21-32'

Table 11. A summary of the commercial fisheries based at two main ports in the INTERREG region. The information presented is courtesy of the Marine Institute, Dunmore East and Helvick Fishermen's Co-ops.

During the two-year study period, researchers continued to liaise with the relevant government agencies, their employees (e.g. Fleet Assessment Technicians) and local fishermen's organisations. Valuable data were thus gathered first-hand and by indirect collaboration with the fishing industry which recorded significant interaction events.

4.1.2 Operational interactions

The operational interactions of grey seals and fisheries were studied by:

(a) investigating the nature and extent of damage caused by seal predation on commercial catches;

(b) evaluating the levels and nature by-catch of seals in commercial gear.

This research focused on gill and tangle-net fisheries in the INTERREG region, since the preliminary data gathered discounted other fisheries (e.g. those using pot or trawl gear-types) on the basis that their interactions were not significant enough to warrant detailed investigation at this stage. Key gill and tangle-net fisheries within the INTERREG area are carried out from three main ports: Dunmore East and Helvick (Table 11), and Youghal (Figure 1) and it was decided that field research would focus on two problem areas:

1. A tangle-net fishery for monkfish (*a.k.a.* angler fish);
2. A drift-net fishery for salmon, conducted using monofilament gill-nets.

Monkfish Fishery:

The relative importance of monkfish in the study area is detailed in Table 12, by port. This includes monkfish caught by trawling and tangle netting. Dunmore East is the most important port for monkfish in the study area, accounting for 45% (by weight) of all landings, followed by Howth and Kilmore Quay.

Year	Co. Waterford		Co. Wexford		Co. Dublin		Co. Louth	Total
	Helvick	Dunmore East	Duncannon	Kilmore Quay	Skerries	Howth	Clogher Head	
1991	33.3	151.8	9.8	55.9	1.5	31	9.9	293.2
1992	28.2	242.1	17.6	109.4	4.2	217.5	6.3	625.3
1993	19.8	125.3	0.9	33.9	4.8	60.1	19.2	264
1994	35.3	202	32.9	24.4	21.6	68.6	7	391.8
1995	28.2	280.4	21.2		15.1	112.1	6.4	463.4
1996	17.6	237.4	31.6	123.6	10.6	89.4	7.3	517.5
1997	13.2	150.7	41.7	210.5	10.2	124.8	12.1	563.2
Total	*175.6*	*1389.7*	*155.7*	*557.7*	*68*	*703.5*	*68.2*	*3118.4*
Percent	*5.63*	*44.56*	*4.99*	*17.88*	*2.18*	*22.56*	*2.19*	

Table 12. Monkfish landings, in tonnes, by port from 1991 to 1997. Data are courtesy of the Dept. of the Marine and Natural Resources.

The monkfish fishery out of Dunmore East and Helvick, Co. Waterford was chosen for the following reasons:

- The fishery is known to suffer from seal predation and grey seals are known to be entangled in the gear quite easily (see Collins *et al.*, 1993);
- Monkfish have a high individual price and the operators involved generally don't have the financial resources to offset significant economic losses. Thus seal predation at nets may have a significant effect on the economic viability of the fishery;

- Damaged monkfish are left behind in the tangle-nets, unlike salmon in drift-nets which tend to be wholly removed. This allows for more accurate determination of the total economic losses attributable to seal predation;

- The fishery is limited to a small number of boats working close to shore and landing at a home port, facilitating effective monitoring on an observer-led basis.

Salmon Fishery:

Due to their anadromous nature, whereby they congregate annually at estuaries to return to their home rivers to spawn, salmon and the fishermen who target them in this limited season, are particularly vulnerable to predation by seals. To examine this issue, a study was set up in Youghal, Co. Cork for a 10-week period in the summer of 1998. The methods used in this study included information-gathering in addition to remote and shipboard monitoring of the fishery by a research student with the following objectives:

A. To examine the perception of the salmon-fishing industry of south-eastern Ireland concerning seal predation. Fishermen from the Lismore district, which includes Youghal Bay, Co's. Waterford and Wexford were interviewed by questionnaire;

B. To directly observe the salmon drift-net fishery in Youghal Bay;

C. To determine the impact of seals on this fishery both operationally and economically;

D. To investigate whether so-called "rogue" seals are responsible for damage/losses inflicted.

The method used to classify the damage to the commercial catch according to whether it originated from seals or scavengers was based on that used by Collins *et al.*, (1993) as follows:

- **Type I:** characterised by soft-tissue removal - part of or the entire visceral cavity removed with the remainder of the body intact.

- **Type II:** characterised by removal of all or part of the body, soft and hard tissues, as well as part of the visceral cavity and with the backbone frequently broken.

- **Type III:** highly characteristic epidermal and subcutaneous erosive damage caused by the isopod *Natatolana borealis* and/or the amphipod *Orchomene nana*, both of which are known as "skinners".

- **Type IV:** scavenger or point damage, as commonly caused by the common crab (*Cancer pagurus*).

(Types I and II are those among which seal predation is applicable)

Predator and scavenger damage to catches was examined by direct observation on board fishing vessels and through the co-operation of fishermen who landed damaged fish for subsequent examination. Damage was quantified using the wet weight and the number of fish damaged. In the case of monkfish, since the head was always present in the net, head-width was used for estimating the original length and weight of the damaged fish. The extent of damage from crabs and skinners was also examined. A dedicated sample of 100 whole monkfish were provided by the Dunmore East Co-op for measurement by the researcher. This sample was used to determine the relationship between head-width and body length/weight (Figures 14 & 15) so that damage/losses attributable to various causes could be quantified.

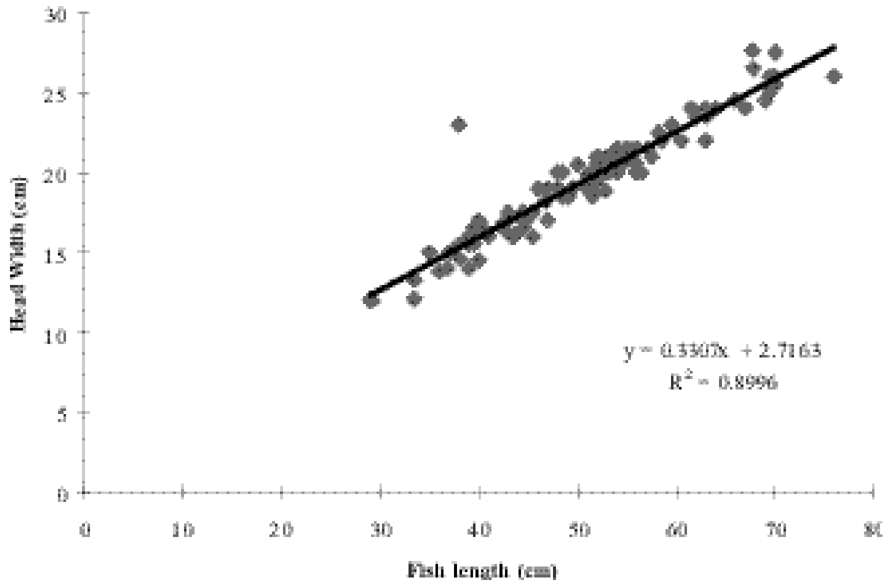

Figure 14. The relationship between head width and fish length from monkfish collected in the Celtic Sea during 1997.

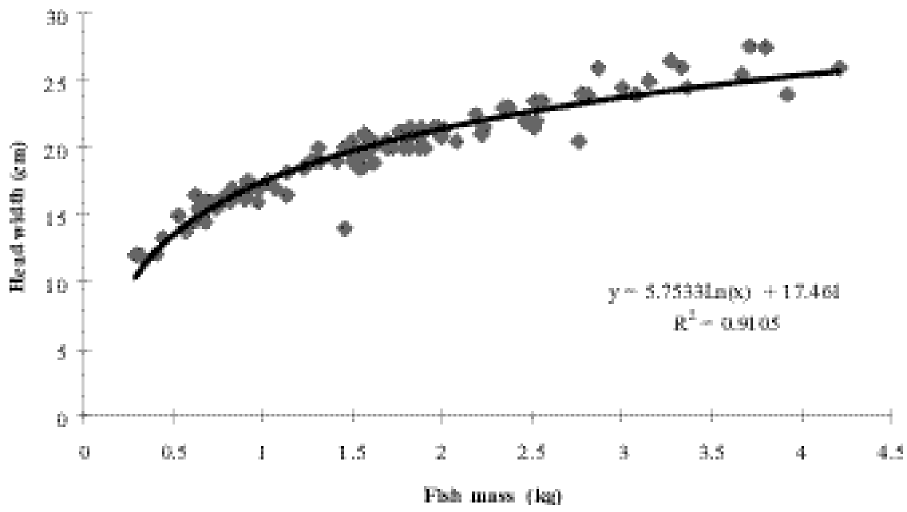

Figure 15. The relationship between head width and body mass from monkfish collected in the Celtic Sea during 1997.

From May to September, 1997 and April to September, 1998, fishermen working on the monkfish fishery were asked to land by-caught seals. The sex, date and location of capture for each seal were noted. Each seal was subjected to a full post-mortem using standard techniques. In addition to the removal of material for analysis in collaboration with the afore-mentioned INTERREG study of marine mammal health status in the Irish Sea, measurements of body length and the digestive tracts of by-caught specimens were removed to assess whether the animals had been feeding from the nets in which they were caught. A single tooth was also removed from each carcass for subsequent ageing of the animal.

4.1.3 Biological interactions

The ecological aspect of this study concentrated on competitive interactions between grey seals and fisheries in the Irish & Celtic Seas, by examining the diet of grey seals known to occupy these waters and comparing the data gathered with existing stock data being gathered by government agencies.

Diet analyses were performed on material collected from a sub-sample of the population. This material was made available from the stomachs of by-caught and stranded seals, in addition to faecal samples collected in the field. Stomachs were removed from by-caught and stranded seals, opened and the contents sorted by sieving through a 350µm sieve. Faecal samples were collected from haul-out sites searched on twice-monthly visits from June 1997 to December 1998. Faecal samples were collected in small polythene bags and stored frozen at -20°C prior to sorting. Samples were sorted by sieving through a 350µm sieve. Care was taken when collecting the samples to ensure that no extraneous material was included.

The identification of prey species from faecal remains and stomach contents relied on the presence of hard skeletal remains to identify the type and number of prey in the diet (see Jobling, 1987). Such information has traditionally been obtained from the identification of fish otoliths (i.e. ear bones) and, in the case of cephalopods (e.g. squid and octopus), by their beaks, which do not degrade in seal digestive tracts. The advantage of using this material is that otoliths and cephalopod beaks are robust, easily sorted from other prey remains and they are species-specific (Härkonen, 1986). Numerous examples of their use in dietary studies exist in the literature (e.g. Rae, 1960; Hauksson, 1984; Lydersen *et al.*, 1989; Pierce *et al.*, 1989; Murie & Lavinge, 1992; Ugland *et al.*, 1993 -- For faecal samples see Hammond & Prime 1990; Pierce *et al.*, 1990; Prime & Hammond, 1990; Thompson *et al.*, 1991; Hammond *et al.*, 1994).

Fish otoliths and bones were removed and stored dry. Cephalopod beaks, fish-eye lenses and decapod (i.e. crustacean) remains were stored in 70% ethanol. Otolith dimensions were measured to the nearest 0.05mm using a binocular microscope fitted with a graticule, or with dial callipers when the size of the otolith was > 10mm. For fish species, body length was the standard morphometric measurement taken, except for herring, for which width is the standard measurement (Härkonen, 1986). Otoliths were identified to the lowest possible taxon using an extensive reference collection held in the Department of Zoology and Animal Ecology, National University of Ireland, Cork and a standard guide-book (i.e. Härkonen, 1986). In order to estimate the original weight and length of the prey species, regression equations based on samples collected in the Celtic Sea were used. For cephalopod species, beaks were identified as either from octopus or from squid. The hood length was taken for octopus and rostral length taken for squid, from which their body weights can be determined using the method of Clarke (1986).

Two dietary indices were used to quantify the diet, following the method of Hyslop (1980). These were as follows:

1. The frequency of occurrence of a particular prey type, expressed as a percentage of the number of samples in which identifiable remains were found (%F). Faecal samples which had no identifiable remains or stomachs that were empty were excluded from the analysis (*see* Hyslop, 1980; Nilssen *et al.*, 1993; Olesiuk, 1993);

2. The contribution of each species to the diet, in terms of the proportion of the total wet weight of fish present in the sample from otolith analysis (%W).

4.2 Results

4.2.1 Operational interactions

The monkfish fishery

Preliminary information was gathered between June and September 1997 from the fishery in Dunmore East. However, significant data were difficult to obtain since the peak period of damage experienced by the industry had apparently passed and there was an initial reluctance by skippers to participate in a shipboard observer-based study. In spite of the best efforts by the researcher, who was highly experienced in this field, to obtain first-hand observational data, members of the industry simply stated that damage to catches and by-catch were too negligible to warrant full participation in the study. These views appeared to be confirmed by detailed data from records for 1996 and 1997 provided by one vessel owner. These data provided general information on the amount of fish landed and the estimated amount of damage incurred by vessels in the fishery, demonstrating that seal-related damage (Type I & Type II) may be highly seasonal in nature with little variation between years (Figure 16) and that the period of greatest catch may coincide with relatively low levels of damage.

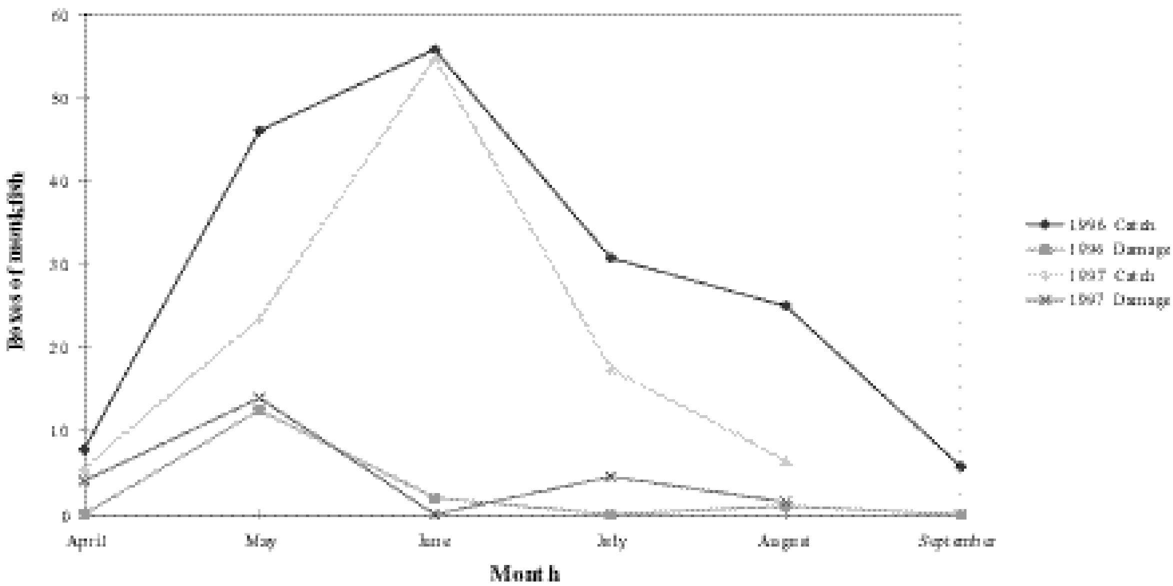

Figure 16. Summary of monkfish landings and the incidence of seal-related damage in 1996 and 1997. Data are taken from the logbook of a Dunmore East fisherman participating in the study.

Damaged fish and by-caught seals were landed for a short period of time in 1997. Two vessels landed damaged fish on four occasions and one observer trip was arranged to verify the industry's statements. On this occasion, just one damaged fish was observed. A total of 176kg of damaged fish was measured. Table 13 details the results gathered in 1997, although it must be stressed that fish were landed only on a few occasions for the reasons outlined above.

Boat	No. of landings of damaged fish	Estimated total catch (kg)[1]	Estimated seal damaged fish (kg)	% damaged	Estimated economic loss £ [2]
A	3	590	104.71		
B	1	320	71.32	22.3	
Total	4	910	176.03	19.3	406.56

Table 13. Data on damage to monkfish catches attributable to seal predation in 1997. The data were recorded in the Dunmore East fishery as proportion of total catch landed. [1]Based on 40kg of fish per box; [2]Based on the average price of monkfish for 1997 = £2.31/kg; 176kg @ £2.31 = £406.56

Field studies in 1998 began as soon as vessels took to sea and two ports were the focus of study. However, vessels based at Helvick, Co. Waterford stopped fishing for monkfish early in the season and thereafter the season focused solely on Dunmore East. Co-operation from the fishermen had improved considerably and the researcher was permitted to conduct shipboard surveys on 20 occasions (Table 14).

Based on the more reliable boat-based observer method in 1998, the total observed damage loss to tangle-net monkfish catches was an estimated 667 kgs, amounting to approximately £1,533 (Table 14). This damage comprised an average loss of approximately 10% of the total catch by weight of the fishery. By simple extrapolation, this would amount to approximately £50 per vessel per month. It must be noted, however, that true landing figures for the fishery were not available, since the tangle-net vessels in question are not subject to mandatory logbook recording due to their size (<10m). Furthermore, unless an observer was present on fishing trips, fishermen tended to land damaged catches ashore only when the level of damage was considered significant by them. This discrepancy was clearly shown in the present study which recorded an average damage by weight of 200 kgs per landing from shore-based monitoring compared with the average of 10.6 kgs per landing from on-board observer monitoring (Table 14).

Total number of fishing trips by Dunmore tangle net boats	207
Total number of observer days at sea	20
Percentage of fishing trips covered	9.7%
Percentage of trips on which damaged fish were observed	60%
Average weight of damaged fish, per landing, from fishermen	200kg
Average weight of damaged fish, per landing, from observer	10.6kg
Total number of damaged fish recorded	308
Estimated total loss by weight due to seal predation	667kg
Average loss of catch by weight due to seal predation	9.9%
Estimated total economic loss due to seal predation	£1,533

Table 14. Summary of data on seal-inflicted damage to the 1998 tangle-nat fishery for monkfish based at Dunmore East. Economic Loss is calculated using an average monkfish price of £2.30 per kg from 1990-1997.

When only the data collected by the onboard observer are used, the level of seal-inflicted damage per vessel per month varied about that derivred by the simple extrapolation above.

Boat	No. Fishing Days	No. of Days Damaged Fish were Recorded	% Frequency Damaged Fish Days
A	62	12	19.4
B	32	11	34.4
C	56	11	19.6
D	48	2	4.2
E	10	0	0
Average %			11.9

Table 15. Summary of fishing activity and the incidence of seal-related damage in 1998 for all boats participating in the study.

Table 15 details the number of fishing days that damaged fish were recorded per vessel. The overall damage frequency ranged from 0-34% of days at sea with a mean of 12%. Details of the gear length and depth for these fishing trips are shown in Appendix III.

Boat	No. of Trips	Weight (kg) of monkfish: No Damage	Damaged	Total	% Damage	Estimated Economic Loss[1] £
A	9	643.37	83.47	726.84	11.48	191.98
B	7	327.25	33.17	360.42	9.20	76.29
C	4	208.44	13.09	221.53	5.91	30.11
Total	20	1179.06	129.73	1308.79		298.38

Table 16. Data on seal-inflicted damage for vessels participating in the monkfish fishery out of Dunmore East in 1998. The data were recorded by a scientific observer on board each vessel. [1]Value of damaged monkfish based on average price per kg from 1990 to 1997 = £2.30/kg.

The level of seal-inflicted damage per boat, recorded first-hand by the researcher on board, ranged from 5.9-11.5% of the catch (by weight) with an associated economic loss ranging from IR£30.11 - IR£191.98 (Table 16). The corresponding recorded damage to the fishery per month ranged from 26.2% of the catch in April to 6.7% in August. This incurred a monthly loss ranging from a minimum IR£26.43 in July to approximately IR£72 in August/September (Table 17). The highest monthly incidence of damage occurred in April and had an associated cost of IR£49.61.

Month	No. of Trips	Weight (kg) of monkfish: No Damage	Damaged	Total	% Damage	Estimated Economic Loss[1] £
April	1	60.74	21.57	82.31	26.21	49.61
May	2	160.49	14.91	175.4	8.50	34.29
June	3	112.25	19.55	131.8	14.83	44.97
July	4	133.51	11.49	145	7.92	26.43
August	7	433.85	31.12	464.97	6.69	71.58
Sept.	3	278.22	31.09	309.31	10.05	71.51
Total	20	1179.06	129.73	1308.79		298.38

Table 17. Data on the monthly seal-inflicted damage to the monkfish fishery out of Dunmore East in 1998. The data were recorded by a scientific observer on board vessels in the fleet. [1]Value of damaged monkfish based on average price per kg from 1990 to 1997 = £2.30/kg.

The data collected in this study showed that the greatest single incidence of seal damage in 1998 was 33.3% in a single haul (Table 18). However, the average incidence of seal damage was 8% and 40% of trips did not experience any seal-inflicted damage to the catch. Further data collected during this period showed that crab and skinner damage accounted for a significantly greater incidence of damage to net-caught monkfish (Table 18). The average incidence of this Type III damage was 15% with a maximum damage level of 46% recorded in a single haul. A total of 30% of trips did not experience any such damage.

The salmon fishery

Research into interactions between grey seals and the drift-net fishery for salmon in Youghal met with similar difficulties to that on the monkfish fishery in that few skippers would agree to taking an observer on board. Nevertheless, the questionnaire survey revealed that the majority of fishermen (89%) reported that they had encountered problems with seals. Damaged fish could nevertheless be sold by 55% of the fishermen depending on the level of damage. Many felt it was difficult to place a value on the amount of damage caused. The majority of fishermen claimed to see 2-5 seals per trip, 29.6% observed 1-2 seals per trip. Such sightings were investigated by the scientific observer who monitored the fishing activities from the shore.

Of the salmon fishermen who also fished outside the salmon season, 94% reported that they also had catch damaged by seals. Although seals often leave behind the heads of larger fish in nets, the questionnaire survey at Youghal also revealed that fishermen believe the whole fish is frequently removed from the gill-net. Remote monitoring of Youghal Bay by telescope showed that grey seals were present in the bay on 20.6% of survey days. Fishing boats were present on 57% of those days. Further scan sampling was carried out on days outside the salmon fishing season. Seals were observed on all boat trips, although never closer than 200m from the boat. Salmon with marks of various kinds were recorded on 75% of boat trips.

		Total	Total	Type of Damage				
Trip no.	Boat	No. of Fish	Saleable/ No Damage	Seal	% Seal	Crab/skinner	% Cr/sk	Rotten
1	A	46	29	3	6.5	14	30.4	0
2	A	28	28	0	0	0	0	0
3	A	29	21	8	27.6	0	0	0
4	B	18	11	6	33.3	0	0	1
5	A	26	21	4	15.4	1	3.8	0
6	B	12	12	0	0	0	0	0
7	C	18	16	1	5.6	1	5.6	0
8	B	13	4	3	23.1	6	46.2	0
9	A	27	27	0	0	0	0	0
10	B	8	8	0	0	0	0	0
11	A	17	13	0	0	4	23.5	0
12	A	44	36	0	0	8	18.2	0
13	B	38	37	0	0	1	2.6	0
14	C	38	27	1	2.6	10	26.3	0
15	A	62	30	8	12.9	24	38.7	0
16	C	22	17	2	9.1	3	13.6	0
17	B	38	29	1	2.6	8	21.1	0
18	A	53	44	5	9.4	4	7.5	0
19	B	83	47	14.5	4.1	23	27.7	1
20	C	38	27	0	0	11	28.9	0
Total	**3**	**658**	**484**	**54**		**118**		**2**
Mean			**24.2**	**2.7**		**5.9**		**0.1**
s.d.			**11.7**	**3.5**		**7.4**		**0.3**

Table 18. The incidence of damage to net-caught monkfish in the 1998 fishery out of Dunmore East. The data, grouped according to damage-type, were recorded by a scientific observer on board the vessels.

By-catch of grey seals

Eight by-caught seals were landed in 1997 and 10 in 1998 from areas between Cork Harbour, Co. Cork and Carnsore Point, Co. Wexford (Tables 19 & 20). Based on their body lengths, which showed that all but two seals caught were between 100 and 140 cm in length, it would appear that the majority of these animals were immature seals. Due to time constraints and problems with the methodology, these seals were not subjected to accurate age determination.

Length (cm)	Sex	Location	Depth of gear (m)
131	M	51 40 26 N, 8 13 47 W	64
116	F	51 40 55 N, 8 19 24 W	46
136	M	51 40 55 N, 8 19 24 W	46
126	M	6nm S of Dunbratten, Co. Waterford	46
124	M	6nm S of Dunbratten, Co. Waterford	46
107	F	11nm S of Dunmore, Co. Waterford	58
122	F	15nm S of Dunmore, Co. Waterford	65
133	M	15nm S of Dunmore, Co. Waterford	65

Table 19. Summary of data gathered from by-caught seals recovered in tangle-net fisheries for monkfish in the eastern Celtic Sea in 1997.

Length (cm)	Sex	Location	Depth of gear (m)
122	M	2.5nm S of Cork Buoy	30-60
124	F	Flathead	30-60
118	F	Newfoundland Bay, Co. Cork	30-60
130	F	Newfoundland Bay, Co. Cork	30-60
132	F	Nohoval, Co. Cork	30-60
131	M	Co. Cork	30-60
160	M	Co. Cork	30-60
139	F	Dunmore East, Co. Waterford	30-60
151	M	Crosshaven, Co. Cork	30-60
123	F	Waterford, Co. Waterford	30-60

Table 20. Summary of data gathered from by-caught seals recovered from tangle-net fisheries for monkfish in the eastern Celtic Sea in 1998.

The sample of 29 grey seals of all ages (including by-caught and stranded seals) which were recovered during the study also showed this significant bias in the age-structure of animals towards juvenile animals (Figure 17). It is noteworthy that no seal pups were by-caught during two years of monitoring in 1997 and 1998. However, on the 2nd February 1999, a young grey seal was caught in tangle-nets for monkfish, 0.5 miles off the east coast of Cork. A post-mortem was carried out and the animal identified as a pup born in 1998 at one of the western Irish Sea pupping sites under study, due to the presence of Rhodamine dye on the pelage. This animal is likely to have been 2-4 months old when it was by-caught.

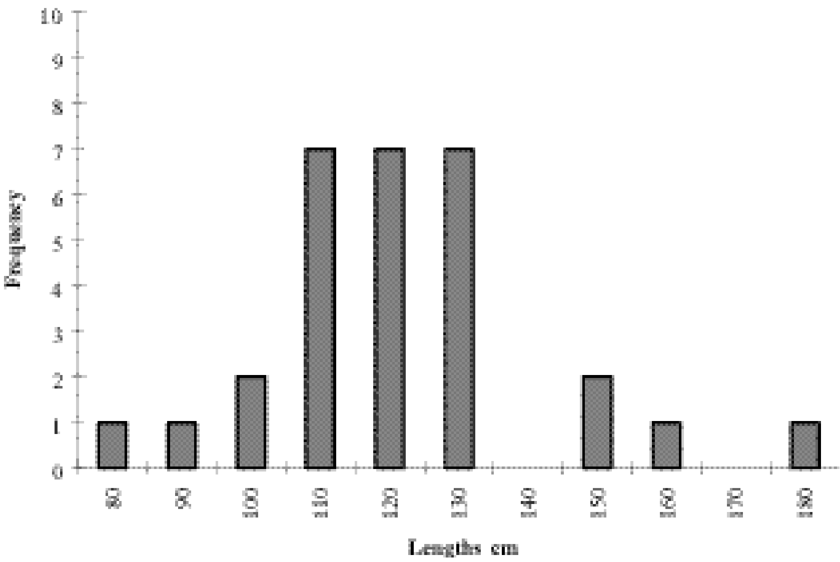

Figure 17. Lengths of all by-caught and stranded seals recovered from the western Irish and eastern Celtic Seas and examined during the INTERREG study in 1997 and 1998.

4.2.2 Biological interactions

Dietary analysis based on faecal samples

In spite of constant effort in recovering faecal samples from study sites, the vast majority were obtained during the late breeding and moulting seasons since samples were scarce during the summer field season. Of the 284 samples examined, 246 (87%) contained prey remains, including fish bones and crustacean remains, while 166 (58%) contained otoliths and cephalopod beaks suitable for measurement. Due to the paucity of samples available from the summer seasons, meaningful dietary analyses could only be based on the samples taken during the breeding-moult seasons. Of 1,171 individual prey remains (i.e. otoliths or cephalopod beaks) examined, 24 prey types were identified (Table 21).

Prey species belonging to the Genus *Trisopterus* (Bib, Norway Pout and Poor Cod), were found most frequently (%F=48.2) in the diet of grey seals followed by whiting (24.7%) and plaice (22.9%). However, when the data were analysed by weight, plaice were the predominant species in the diet (%W=34.5), followed by *Trisopterus* spp. (12.8%) and whiting (9.9%).

For ease of comparison, prey species were divided into four main categories:

1) gadoids - whitefish, including whiting, cod and hake;
2) flatfish - i.e. plaice, sole, dab, brill
3) cephalopods – the squid *Loligo* spp. and lesser octopus
4) others - those not in the categories above, e.g. black goby, herring

Species	N_1	% N	F_1	% F	W_1	% W	L_1
Trisopterus spp.	321	27.41	80	48.19	13185.5	12.78	19.02
Plaice	188	16.05	38	22.89	35621.2	34.53	25.34
Whiting	131	11.19	41	24.70	10276.6	9.96	19.79
Sandeel	117	9.99	10	6.02	2307.5	2.24	17
Dab	72	6.15	29	17.47	3142.5	3.05	15.13
Octopus	55	4.70	21	12.65	9699.6	9.40	9.13
Dragonet	49	4.18	27	16.27	1865.4	1.81	16.64
Long rough dab	37	3.16	21	12.65	1069	1.04	13.97
Haddock	36	3.07	7	4.22	3028.5	2.94	20.69
Cod	33	2.82	27	16.27	7489.6	7.26	24.14
Bull-rout	30	2.56	12	7.23	1217.4	1.18	12.98
Saithe	19	1.62	12	7.23	3180.7	3.08	25.04
Hake	14	1.20	8	4.82	570.4	0.55	18.52
Sole	11	0.94	8	4.82	2092.2	2.03	21.26
Pollack	11	0.94	6	3.61	1638.9	1.59	23.81
Ling	9	0.77	9	5.42	1884.8	1.83	26.41
Squid	8	0.68	7	4.22	2279	2.21	21.54
Ballan wrasse	8	0.68	7	4.22	2072.7	2.01	22.75
Scad	6	0.51	4	2.41	131.1	0.13	14.22
Brill	6	0.51	4	2.41	256.2	0.25	14.1
Blue whiting	4	0.34	4	2.41	111.7	0.11	16.79
Black Goby	3	0.26	3	1.81	11.1	0.01	7.16
Herring	2	0.17	2	1.20	22.2	0.02	11.53
Witch	1	0.09	1	0.60	7.7	0.01	11.07
Total	1171		166		103161.5		

Table 21. A summary of all prey species identified and their relative importance in grey seal diet in the eastern Celtic Sea and western Irish Sea. Data are based on otoliths and cephalopod beaks recovered in faecal samples collected at breeding and moult haul-out sites in 1997 and 1998.

N_1 = Total number of a particular prey item found in the faecal samples; **%N** = Percentage number of a prey item

F_1 = Frequency with which a particular prey item was found in the faecal samples; **%F** = Percentage frequency of occurrence

W_1 = Total weight of a prey item found in the faecal samples; **%W** = Percentage weight;

L_1 = Mean length of prey item found in faecal samples

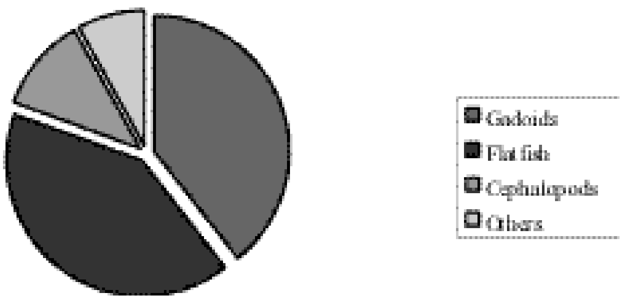

Figure 18. The proportions of different prey-types in the diet of grey seals from faecal samples obtained at sites in the western Irish Sea and eastern Celtic Sea, 1997 and 1998.

The data showed that gadoids and flatfish (both 40% by weight) were co-dominant in the diet of grey seals in the region and that cephalopods (12% by weight) formed a significantly important dietary component (Figure 18).

The investigation of inter-site trends in grey seal diet highlight a degree of geographic variation in diet (Tables 22 & 23). For example, the diet of grey seals from samples recovered at Lambay Island showed that flatfish were dominant both in frequency and weight (%W=68%) and that cephalopods were not significant contributors to the diet.

Site	% Weight of Taxon			
	Flatfish	Gadoids	Cephalopods	Others
Lambay	68	27	3	2
Raven	46	28	17	9
Blackrock	48	19	26	7
Great Saltee	27	57	9	7
All	40	40	12	8

Table 22. The relative importance of different prey types in the diet of grey seals in the western Irish Sea and eastern Celtic Sea. Data presented are the percentage occurrences by weight from faecal samples collected at sites during the breeding and moult seasons in 1997 and 1998.

Site	% Frequency of Taxon			
	Flatfish	Gadoids	Cephalopods	Others
Lambay	47	41	5	7
Raven	44	34	19	3
Blackrock	19	48	13	20
Great Saltee	20	54	6	20
All Sites	26	46	10	18

Table 23. The relative frequency of different prey types in the diet of grey seals in the western Irish Sea and eastern Celtic Sea. Data presented are the percentage occurrences from faecal samples collected at sites during the breeding and moult seasons in 1997 and 1998.

Flatfish were significantly dominant in the diet as recovered from samples at all sites on the east coast of Ireland (Figure 19). However, data from the Great Saltee Island highlighted a pronounced decrease in the frequency of flatfish in the diet and an increasing dominance of gadoids. Cephalopods appeared to be most important in the south-western Irish Sea, as evident in samples from Blackrock and the Raven Point in Co. Wexford while those species grouped as "Others" were markedly frequent in the samples from sites in the eastern Celtic Sea area (i.e. Blackrock and Great Saltee Island) but relatively insignificant from data collected in the western Irish Sea.

Dietary analysis based on stomach contents

Seventeen of the 18 grey seals by-caught in the monkfish fishery between 1997 and 1998 (*see* Section 4.2A) had food remains in their stomachs. In addition, the carcasses of two grey seals stranded in the INTERREG area during this period also had food in their stomachs. Diet analysis, using the same methods as were performed with faecal samples, yielded fewer taxa (n=19 in 1997, n=11 in 1998) than were recorded from the faecal samples (Tables 24 & 25). Most striking in these results was the overall predominance of whitefish in the stomachs of these seals. In 1997 and 1998, both whiting and *Trisopterus* spp. were the most prevalent prey taxa recorded with whiting the most important dietary contributor by weight (%W=45-60%) and *Trisopterus* spp. recorded most frequently in stomach samples (%F=89-90%).

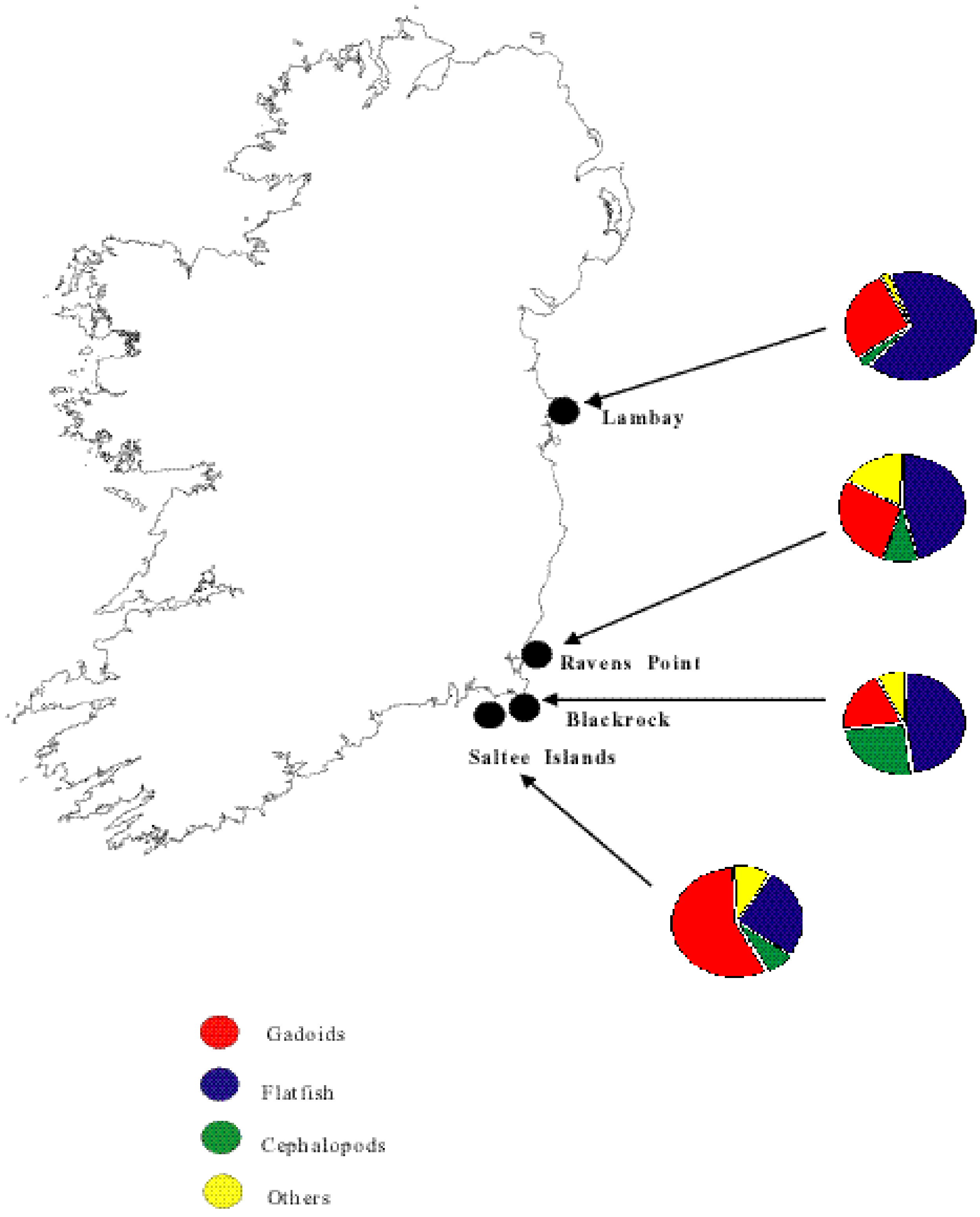

Figure 19. Summary of the relative importance (% occurrence by weight) of various prey types in the diet of grey seals in the western Irish Sea and eastern Celtic Sea. Data are based on faecal samples collected at haul-out sites during the breeding and moult seasons in 1997 and 1998.

Species	N_1	%N	F_1	%F	W_1	%W	L_1
Whiting	117	48.1	9	90	19220.8	59.5	25.5
Trisopterus spp.	86	35.4	9	90	6225.2	19.3	21.8
Hake	7	2.9	4	40	239.0	0.7	18.0
Sandeel	4	1.6	4	40	48.5	0.2	14.4
Ling	4	1.6	3	30	2008.5	6.2	45.9
Herring	5	2.1	1	10	701.5	2.2	24.0
G. Argentine	3	1.2	1	10	399.2	1.2	23.3
Ballan wrasse	3	1.2	1	10	70.8	0.2	12.4
Haddock	2	0.8	1	10	1241.3	3.8	39.1
Pollack	2	0.8	1	10	1019.2	3.2	38.4
Blue Whiting	2	0.8	1	10	155.0	0.5	23.7
Cod	1	0.4	1	10	268.0	0.8	32.3
Saithe	1	0.4	1	10	210.9	0.7	29.5
Octopus	1	0.4	1	10	175.5	0.5	9.4
Dab	1	0.4	1	10	133.6	0.4	24.4
Plaice	1	0.4	1	10	64.9	0.2	19.5
Sole	1	0.4	1	10	59.5	0.2	19.0
Long rough dab	1	0.4	1	10	38.1	0.1	17.9
Sprat	1	0.4	1	10	22.9	0.1	13.9
Total	243		10		32302.5		

Table 24. A summary of all prey species identified and their relative importance in grey seal diet in the eastern Celtic Sea. The data, ranked in order of decreasing frequency, are based on otoliths and cephalopod beaks recovered from the stomachs of by-caught seals and 2 stranded seals recovered in the eastern Celtic Sea area in 1997.

N_1 = Total number of a particular prey item found in the faecal samples; **%N** = Percentage number of a prey item

F_1 = Frequency with which a particular prey item was found in the faecal samples; **%F** = Percentage frequency of occurrence

W_1 = Total weight of a prey item found in the faecal samples; **%W** = Percentage weight;

L_1 = Mean length of prey item found in faecal samples

Species	N_1	%N	F_1	%F	W_1	%W	L_1
Trisopterus spp	100	47.8	8	88.9	4417.0	27.2	20.0
Whiting	72	34.4	6	66.7	7417.0	45.7	21.3
Cod	6	2.9	2	22.2	996.6	6.1	26.4
Octopus	14	6.7	1	11.1	1695.9	10.5	8.1
Dab	5	2.4	1	11.1	243.5	1.5	17.0
Dragonet	3	1.4	1	11.1	127.6	0.8	18.2
Hake	3	1.4	1	11.1	103.9	0.6	18.7
Saithe	2	1.0	1	11.1	564.1	3.5	32.5
Ling	2	1.0	1	11.1	199.3	1.2	20.7
Ballan wrasse	1	0.5	1	11.1	352.9	2.2	26.8
Sole	1	0.5	1	11.1	108.3	0.7	22.9
Total	209				16226.2		

Table 25. A summary of all prey species identified and their relative importance in grey seal diet in the eastern Celtic Sea. The data, ranked in order of decreasing frequency, are based on otoliths and cephalopod beaks recovered from the stomachs of 9 by-caught seals recovered in the eastern Celtic Sea area in 1997.

N_1 = Total number of a particular prey item found in the faecal samples; **%N** = Percentage number of a prey item

F_1 = Frequency with which a particular prey item was found in the faecal samples; **%F** = Percentage frequency of occurrence

W_1 = Total weight of a prey item found in the faecal samples; **%W** = Percentage weight;

L_1 = Mean length of prey item found in faecal samples

The relatively low number of seals sampled and low occurrences of the majority of taxa did not permit pair-wise comparison with the data from faecal samples. However, when the occurrence-by-weight data were pooled and prey divided into four main categories as before, gadoids were the highly significant dietary component in both 1997 and 1998 (Figures 20 & 21) while both flatfish and cephalopods were markedly insignificant.

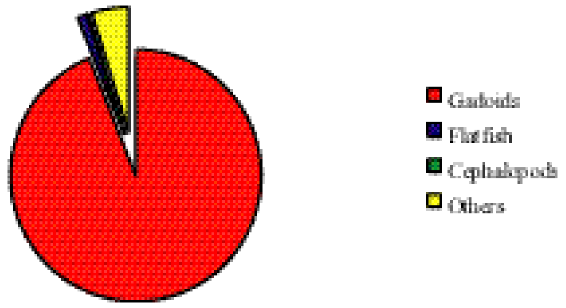

Figure 20. The proportions of different prey-types in the diet of grey seals from stomachs of 8 by-caught and 2 stranded grey seals recovered in the eastern Celtic Sea in 1997.

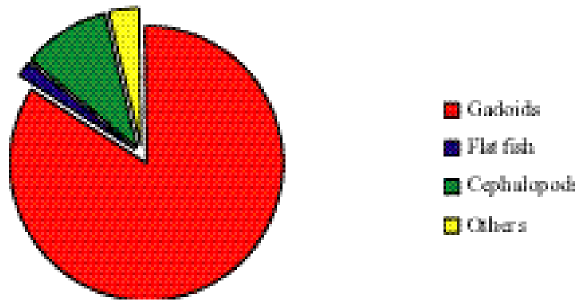

Figure 21. The proportions of different prey-types in the diet of grey seals from stomachs of 9 by-caught grey seals recovered in the eastern Celtic Sea in 1998.

4.3 Discussion

The monkfish fishery in Dunmore East is an economically important fishery with 45% of the catch (by weight) in the Irish INTERREG region landed into this port. However, most of these landings are from trawlers rather than inshore tangle-netters. As a result, that data on seal damage to monkfish catches must be interpreted only in terms of catches in the tangle-net fishery and not extrapolated to monkfish catches as a whole. It must be also be noted that fishermen tended to land damaged fish only when their catch had large amounts of damage and as a result, direct observer-based data could only be relied upon.

As a result, data collected in the 1997 season were not considered representative of seal - fishery interactions because of the few results obtained.

The groundwork done in 1997 allowed for improved data quality in 1998 when 60% of all observer trips recorded seal-damaged fish amounting to an average of approximately 10% of the overall monkfish catch. This contrasts greatly with a study by Collins et al. (1993) which found that 31% of tangle-net caught monkfish in Co. Cork were damaged in a manner consistent with seal predation. However, the latter study was not conducted on an shipboard observer basis and similar questions arise concerning second-hand data, as were encountered in the present study in 1997. Other factors which may influence this discrepancy may be the use of different sampling regimes or simply a lower incidence of damage in the present study. In contrast, the results are similar to damage levels attributed to grey seals in selected gill-net fisheries for hake (7.7%-direct recording) and cod (10%-indirect recording) in western Ireland (*see* BIM 1997). Furthermore, there is a notable similarity between these studies in the level of Type III (crab and skinner) damage reported. BIM (1997) determined that over 20% of the total damage directly observed in gill-net operations was due to scavengers, while in the present study such damage accounted for twice the level of damage to monkfish when compared with seals.

Boat-based monitoring of the monkfish tangle-net fishery out of Dunmore East determined that an average of 10% of the total catch by weight was damaged by seals in 1998 bringing an estimated economic loss to the tangle-net fishery of £1,533 or approximately £50 per vessel per month. These figures should be interpreted cautiously for a number of reasons. Firstly, the scientific evidence pointed to a large discrepancy between data collected first-hand on the vessel and that collected second-hand from fishermen themselves. While monitoring was optimised during the course of the study, boat-based monitoring was conducted on just 9.7% of fishing trips, generally in good weather when fishermen were prepared to take an observer aboard. Therefore care must be taken in relating the results obtained to the fishery as a whole.

Landing figures for the fishery were not available during the study since the tangle-net vessels in question are not subject to mandatory logbook recording due to their size (<10m). Thus the relationship between observed catches and true catches is poorly understood. It is also noteworthy that considerable variation in monkfish catches and the scale of the interaction were observed over the duration of the fishery. This could have important consequences for the tangle-net fishery which is generally operated by small inshore vessels which may not be in a position to bear significant monthly economic losses due to seal-inflicted damage and other such factors.

There were differences in the level of monkfish damage recorded between boats. This difference may be caused, for example, by differences in the distribution of fishing effort, in proximity to local seal haul-outs or in the timing of observer trips. For example, observer trips on boat C began later in the season after the peak period of damage. In an ideal situation observers would be placed on all vessels simultaneously but such effort requires considerably greater investment and effort. In this regard, the somewhat smaller-scale study of seal-interactions with the drift-net fishery for salmon fell short of delivering the quantity and quality of data achieved by the monkfish study. While this may be partially due to the lack of resources to tackle the problem, significant differences exist both in the nature of co-operation from the fishing industry where salmon fishing is concerned and in the nature of the seal - salmon fishery interaction itself which tends to result in the complete removal of salmon by seals and is fraught with other difficulties (e.g. fishermen may shoot at seals while fishing or patrol the nets, thereby affecting the results). McCarthy (1985) estimated that between 7.5% and 25.7% of commercial salmon caught in surface drift-nets off Cos. Sligo and Galway between 1979 and 1982 bore marks attributed to seal predation. In Scotland, grey seal predation on salmon nets may range from 5% to 30% at some netting stations (Rae & Shearer, 1965). Potter & Swain (1979) found that seals physically removed 5% of fish from salmon nets and damaged a further 1.4% while harbour seal predation on seined salmonids in California was estimated to range from 3.1% to 5.5% over a five-year period (Stanley & Shaffer 1995). The present study indicated that grey seals were frequently present in the Youghal Bay area when fishing was taking place and that 75% of trips recorded damage to salmon from a variety of sources. In the light of these findings and the omnipresence of the seal - salmon issue, it would appear that a dedicated well-resourced study of this interaction is necessary. This was previously recommended by the Irish Salmon Management Task Force (Wilkins *et al.*, 1996).

The by-catch of grey seals in inshore fisheries is an unfortunate occurrence for a number of reasons, particularly for fishermen as they do not intend to catch seals in their nets and generally co-operate voluntarily with research into the problem. Nevertheless, it must be stressed that the total number of by-caught seals (i.e. 18 seals) recovered from the tangle-net fishery in Dunmore East between 1997 and 1998 should not be considered representative of the total by-catch in this fishery. Fishermen working this type of gear regularly state that most carcasses fall out of nets before they are hauled aboard the vessels and it appears that the well-trapped seals are those which make it on board. This has not been verified scientifically, as the majority of by-caught seals were brought in voluntarily by fishermen and a dedicated study would be required to observe all hauls and extrapolate to an overall by-catch rate.

A common feature of seal by-catch in Irish waters would appear to be the length/age of the animals caught, which would indicate the vast majority to be immature (juvenile and sub-adult) animals. Examination of 51 seals caught in the Mayo gill-net fishery for cod between 1994 and 1996 showed that 50 animals were immatures with no overall sex-difference in by-catch frequency (BIM, 1997). The authors concluded that, since the Mayo cod fishery occurs during the moult when adult feeding rates would probably be reduced, it was possible that yearlings might be the principal sector of the seal populations feeding on nets. However, the data gathered in this study would indicate that the bias towards the capture of young animals occurs through the summer months when adults too would be feeding intensively. It may also be that adult seals are too heavy to be held in the nets when they are being hauled. Recent dedicated efforts by researchers at the National University of Ireland, Cork, to recover all seals by-caught locally have resulted in larger hauls per vessel than indicated in this study (1999, *unpublished data*). It must be stated, therefore, that the issue is of scientific concern in the case of gill and tangle-net fishing methods in general and that the issue warrants detailed study.

The results of grey seal dietary studies presented here provide the best available indication of seal diet in the western Irish Sea. However, these results must be viewed in light of the discrepancies that arise from the types of analysis used. There are well-documented limitations to the use of otoliths. For example, otolith and cephalod beaks do not pass through the alimentary canals of pinnipeds in equal proportions to the number eaten and both otoliths and beaks are reduced in size (*see* da Silva & Neilson, 1985). The small or fragile otoliths of species such as salmon, herring, and others belonging to the Family Clupeidae, will not appear in faecal samples due to the complete digestion of their remains. Furthermore, the otoliths of larger fish, including monkfish may not appear because the seals do not eat their heads, leaving their ear-bones intact. As a result of such problems, several species may be under-represented in the dietary profile (*see also* BIM, 1997). In addition, while stomach contents are regarded as providing a more accurate picture of seal diet, the reliance on samples from by-caught seals is itself liable to considerable bias and stomachs are often empty in by-caught animals due to pre-mortem regurgitation (*see* Rae, 1960; Harwood & Croxall 1988; Murie & Lavinge 1992; Pierce & Boyle, 1991).

In interpreting the results of this study, it must be remembered that diet may change seasonally according to geographic location and changes in the abundance of prey. Seals are thought to be opportunistic feeders, primarily taking the most abundant suitable prey species available (Hauksson, 1984; Murie & Lavigne 1992; Nilssen *et al.*, 1993). Since the availability of prey species is likely to vary both spatially and temporally (*see* Pierce *et al.*, 1990; Prime & Hammond, 1990; Bowen *et al.*, 1993; Nilssen et al., 1993; Olesiuk, 1993; Hammond *et al.*, 1994), this would be expected to be borne out in research of this kind. It was not possible to detect temporal patterns in diet preferences in this study since faecal samples were predominantly available at sites only between November and March. However, there did appear to be a striking geographic pattern to grey seal diet in the Irish & Celtic Sea region, whereby faecal samples examined according to site showed that flatfish were dominant in diet from samples taken in the western Irish Sea while gadoids were of far greater importance in samples from the eastern Celtic Sea area. While the dominance of gadoids in the diet of seals in south-eastern Ireland in particular, differs from the prey preferences detected in Co. Dublin, it is strikingly similar to findings for grey seals in the eastern region of the Irish Sea (*see* Strong, 1996). Further studies would establish whether this is a reflection of prey availability in the area and to what extent this may be related to the regional habitat characteristics. For example, the seabed of the western Irish Sea is predominantly sedimentary (commonly preferred by flatfish species) while the seabed of the south-western region has a more rocky substrate (common for demersal white-fish species).

The dominance of flatfish in the diet of grey seals at Lambay Island is of interest when compared with the diet of harbour seal populations further north in the Irish Sea. Wilson & Corpe (1996) analysed faecal samples from harbour seals foraging inshore in Dundrum Bay, Co. Down and found that flatfish (mainly flounder and plaice) were a similarly dominant component of the diet in adolescent and adult while gadoids (haddock, pollack, saithe, whiting, and smaller numbers of cod, ling and poor cod) were the next most common prey items in the diet and were the predominant food for pups. The diet of adolescent and adult seals also included clupeoids (mainly herring) and species such as sandeel, eel, dragonets and wrasse. These authors suggested that a diet composed predominantly of gadoids and deficient in oily fish such as herring may be associated with anaemia and increased juvenile mortality, and were concerned that such dietary factors may be implicated in the recent decline in seal populations in Strangford Lough, Co. Down.

In contrast with the results from the faecal samples, analysis of seal stomach contents revealed that gadoids were the most important component. Whiting was the single most important species in stomach samples, accounting for 59.5% of the ingested weight in 1997 and 45.7% in 1998 (average: 52.8%). This should be considered in tandem with the fact that the majority of stomach samples were taken from juveniles and it is likely that they were feeding at least in part on the catch within the nets. It is interesting to note that stomach samples from by-caught grey seals of approximately the same age class but collected on the west coast, showed that whiting was also the most important prey species (BIM, 1997), followed by *Trisopterus* spp.

Both sets of results show that demersal species, principally gadoids and flatfish, and one cephalopod species make up the bulk of the diet. Such findings are consistent with several other studies which indicate that seals usually feed on or near the sea bed (Thompson *et al.*, 1991; Hammond *et al.*, 1993; Thompson & Fedak, 1993). The findings from the present study differ from dietary studies in Scotland, where sandeel was the dominant prey species (Hammond & Prime, 1990; Prime & Hammond, 1990; Hammond *et al.*, 1994; Thompson et al., 1996). In the present study, the majority of fish species identified from faecal remains (and stomach samples) were demersal species, supporting the observation that grey seals are mainly demersal feeders, usually feeding on or near the sea bed (Thompson *et al.*, 1991; Hammond *et al.*, 1993; Thompson & Fedak 1993).

Various studies have estimated the level of food consumption by seal populations. Others have attempted to estimate predation mortality and its impact on fish population dynamics (Overholtz *et al.*, 1991; Ugland *et al.*, 1993; Mohn & Bowen, 1996). Estimates of daily fish consumption by an "average seal" have varied from 5kg to 15kg (*see* Boelens *et al.*, 1999). McConnell et al. (1984) estimated that UK grey seals required on average 5kg of fish per day. The volume of prey in a seal's diet may depend on the type of food consumed, which determines the calorific value of the prey. Fedak & Hiby (1985) estimated that a seal requires 5,530 Kcal/day of energy, equivalent to from 2.5 to 4.5% of the average body mass/day (Prime & Hammond, 1987). Nordoy *et al.*, (1995) estimated that the food intake of captive harp seals varied seasonally from a maximum of 5-6% of body mass/day in August to September, immediately after the breeding and moulting seasons, to a low of 1-2% of body mass per day in April to June, the latter just before the breeding season. It is possible that grey seal food intake would show a similar pattern of seasonal change with the highest consumption in the spring of each year immediately after breeding and moulting. Pierce *et al.* (1990), in their study of faecal samples from harbour seals over a 12-month period observed seasonal changes in diet; they concluded that these changes were consistent with the availability of high energy prey species. Hammond *et al.* (1992, 1994) found that spawning fish of various species were dominant in grey seal diets, suggesting that grey seals take advantage of energy-rich prey, when they are available.

As a consequence of the dietary requirements of seals, there has been much debate on the potential impact of seals on fish stocks. Of the fish species identified from faecal and stomach contents, several are of commercial importance. Stock data and Total Allowable Catch (TAC) rates for various commercial species in the Irish Sea (*after* Connolly, 1999) and their relative occurrence (by weight) in grey seal diet in the region are listed below:

1. Cod - value for 1999 estimated at IR£5.5 million
   Serious concerns about the state of the cod stock.
   TAC for 1999 is 5,500 tonnes - Irish quota is 3,620 tonnes.
   In 1997 Ireland took < 36% of its cod quota for the area

   Occurrence in seal diet: *7.3% in faeces*
   3.4% in stomach

2. Haddock - value for 1999 estimated at IR£4.5 million
   Indications are that healthy stock is increasing in recent years.
   Landings provided a recent financial boost to fisheries in the Irish Sea.

   Occurrence in seal diet: *2.9% in faeces*
   1.9% in stomach

3. Plaice - value for 1999 estimated at IR£2 million
   No serious concerns about the state of the stock.
   TAC for plaice is 2,400 tonnes - Irish quota set is 1,365 tonnes.

   Occurrence in seal diet: *34.5% in faeces*
   0.1% in stomach

4. Whiting- value for 1999 estimated at IR£1.8 million
   Whiting decline due to high levels of fishing mortality during the 1980s.
   In 1997, Ireland took only 14% of its quota for whiting in the area.
   TAC for whiting is 4,400 tonnes - Irish quota is 2,530 tonnes.

   Occurrence in seal diet: *9.96% in faeces*
   52.6% in stomach

5. Sole - value for 1999 estimated at IR£0.75 million
   Serious concerns about the current level of the sole stock.
   TAC for the area for 1999 is 900 tonnes - Irish quota is 110 tonnes.

   Occurrence in seal diet: *2.03% in faeces*
   0.45% in stomach

It is evident that the most valuable fish stocks in the Irish Sea area are not the principal prey species for grey seals. Such results agree with studies by BIM (1997) in western Ireland, which found that whitefish and non-commercial species formed the most significant part of the grey seal diet when prey components were compared in terms of ingested weight and frequency of occurrence. However, the importance of plaice in the diet of grey seals in the western Irish Sea should not be overlooked nor underestimated and may require more detailed investigation in the future.

In spite of the evidence from these findings, the views of fishermen obtained through questionnaire surveys show that the majority of fishermen feel that some form of enforced seal population reduction may be required to reduce the existing seal - fishery interactions. While it may be tempting in some quarters to view seal culling as an effective means of fish stock protection, it is not clear if such measures would actually work in the complex marine ecosystem. The best scientific advice would suggest that this view is too narrow in focus. Research by DeMaster & Sisson (1992) reviewed the advantages and disadvantages of pinniped management to replenish fish stocks. These authors described four accepted ecological relationships that work against the success of culling pinnipeds to enhance fisheries:

1. Prey species almost always have more that one predator;
2. Seals and other pinnipeds are rarely dependent on just one species of prey;
3. The recruitment rate of most fish stocks is highly variable in nature;
4. Predatory fish consume more fish that do other predators.

While the industry's views may be understandable in the light of persistent damage to certain fisheries, the results of this study suggest that this damage is not as great as perceived by the industry. It is considered that several key issues would need to be addressed before any population management strategy is enacted, be it culling or conservation. This study has shown that the grey seal breeding population in the western Irish Sea and eastern Celtic Sea area is comparatively small. However, results from the photo-identification study suggest that grey seals move extensively within the Irish Sea region and that the potential also exists for seasonal movements in and out of neighbouring waters. Thus the population causing damage to particular fisheries is ill-defined. A more effective approach might also be to define the various "seasonal populations" rather than focusing solely on breeding population size. Secondly, the by-catch of seals in static-net fisheries must also be quantified effectively, as there are indications that this may be a significant cause of juvenile seal mortality in Irish waters (*see* Collins *et al.,* 1993; BIM, 1997; UCC, 1999 *unpubl.*) and current co-operation-based methods are not going far enough to obtain accurate measures of the level of this interaction. Thirdly, it is clear that a more refined knowledge of the species' diet and its ecological role in the Irish and Celtic Seas must be obtained. In summary, the development of effective management measures for Irish and Celtic Sea seals must include such concerns and base itself upon a better understanding of their population ecology within the region.

CHAPTER 5. ENVIRONMENTAL DEGRADATION AND GREY SEALS IN THE IRISH & CELTIC SEAS

5.1 The Sea Empress oil spill

5.1.1 Background

On the 15th February, 1996 the Liberian-registered tanker *Sea Empress* (77 356 GRT) ran aground at the entrance to Milford Haven, in south west Wales. On her initial grounding approximately 2,000 tonnes of oil escaped from the damaged hull into the surrounding waters. Although she was refloated, the vessel grounded repeatedly in the persistently bad weather conditions between the 15th and 18th February. On the 21st February, the stricken vessel was successfully brought alongside a jetty and 58,000 tonnes of oil pumped from her storage tanks. On the 27th March, the *Sea Empress* was towed out of Milford Haven, an unknown quantity of oil spilling from the hull during this procedure. In total, an estimated 72,000 tonnes of crude oil and 360 tonnes of heavy fuel oil were discharged into the waters of south west Wales during the incident (White & Baker, 1998), causing a major pollution incident.

Date	Location Source	Oil Type Quantity	Species	Impacts
1949	Ramsay Island, Wales	Fuel oil	Grey seals	Two fouled pups drowned
March 1967	English Channel Torrey Canyon	Crude oil 30 x 10 (6) gal.	Grey seals	Three oiled seals recovered, confirmed deaths
Nov. 1969	N.Dyfed, Wales	Unknown	Grey seals	14 oiled; dead pups
Nov. 1970	Farne Islands	Unknown	Grey seals	Yearling with oiled pelt, crusting around mouth
1973	Dutch coast	Unknown	Harbour seal	Oil on pelt associated with skin lessions
Aug. 1974	France	Fuel oil	Harbour and grey seals	Oil in intestine of harbour seal; three grey seals oiled, one with ingested oil
Sept. 1974	Pembrokeshire, Wales	Unknown	Grey seals	Two heavily oiled pups drowned; 25 pups and 23 adults fouled
Jan. 1975	Ireland African Zodiac	Bunker C; 1.1 x 10 (6) gal	Seals	Reported unaffected
Mar. 1978	France Amoco Cadiz	Crude oil; 60 x 10 (6) gal	Grey seals	Two of four dead seals coated with oil
May 1978	Great Yarmouth UK Eleni V	Heavy fuel 1 x 10 (6) gal	Seals	20 oiled seals were observed
Oct. 1978	South Wales Christos Bitas	Crude oil; 840,000 gal	Seals	Mortality of 16 of 23 oiled seals
Dec 1978	Shetland Islands Esso Bernicia	Bunker C; 370,000 gal	Seals	Oiled seals observed
January 1993	Shetland Island Braer	Crude oil 1,700 tonnes	Seals; mostly grey	31 oiled pups/juveniles; one heavily oiled adult

Table 26. A summary of oil pollution incidents in western European waters and their effects, where known, on neighbouring seal populations. (*After* NOAA, 1999).

Previous oil pollution incidents in western Europe highlighted a range of direct effects on seals from fouling of the pelage and its associated effects to mortality (Table 26). The most significant such event worldwide, the Exxon Valdez spill in Alaska, caused the deaths of an estimated 345 seals.

After the Braer oil spill at the Shetland Island in 1993, seals treated for rehabilitation were recorded as suffering from (a) *local problems*: e.g. conjunctivitis, corneal ulcers, skin ulceration, gastrointestinal tract bleeding and bleeding in the lung, and (b) *systemic problems*: e.g. aggression, lethargy, broncho-pneumonia, diarrhoea and anaemia. In general, oil pollution may affect seals in several ways:

1. Fouling of the fur: which may impair a seal's normal swimming or thermoregulatory capacity or cause the failure of essential mother-pup recognition, resulting in a pup's abandonment;

2. Inhalation: which could seriously impair normal respiratory function and can cause numerous complications;

3. Ingestion: which has been implicated in significant mortality events and may cause organ disease or the transferral of contamination from mother to pup via lactation.

4. Abnormal reproductive stress: whereby contact with oil during the breeding season results in mass premature delivery or spontaneous abortions due to increased stress on the animals. Breeding seals may be particularly susceptible to such failures since they tend to fast completely or eat little during the breeding season and may be more susceptible to environmental perturbation;

5. Disturbance: which occurs as a result of human incursion to breeding areas during clean-up operations. While somewhat unavoidable, this may result in the abandonment of optimal haul-out sites and failure of the mother-pup bond resulting in adandonment.

(*after* NOAA, 1999)

Preliminary investigations of environmental contamination in south-west Wales showed that significant contamination of fish and shellfish had occurred in the area immediately bordering Milford Haven and a fishing exclusion zone was established. In addition 7,000 birds, of which 30%, were seabirds, became casualties of the incident (Haycock *et al.,* 1998) and since the area affected by the spill was also thought to support a grey seal population numbering about 5,000 animals (Baines *et al.,* 1995), concern for the welfare of the population prompted an investigation of the impact of the event on breeding grey seals in the area.

5.1.2 Methods

The provision of accurate baseline data on the status of the grey seal population in the eastern Irish Sea was essential to the determination of both the long- and short-term effects of the *Sea Empress* oil spill on breeding aggregations and the health status of the population. Additional investigation consisted of the examination of grey seal breeding habitat in 1996 and 1997 for evidence of oil pollution and the recording of oil-fouling or other physical symptoms of pollution on seals at breeding colonies in 1996.

5.1.3 Results

The number of pups recorded on Skomer and Ramsey Islands and the north Pembrokeshire coast in 1996 was similar to that recorded during the 1992-94 census (See Tables 2 & 3). The timing of pupping at sites on offshore islands and the mainland in 1996 were also consistent with previous years. While no total pup mortality for south-west Wales was determined in 1996, pup mortality levels at Skomer Island and other sites during the autumn were generally in keeping with previous years' data. Furthermore, there was no visible evidence of breeding habitat degradation by oil pollution, nor was there an increased incidence of pups recorded with oil residue on their coats. No heavily or seriously oiled pups were found.

5.2 Eco-tourism and disturbance

5.2.1 Background

Tourism based on seals is a growing and lucrative industry (Young, 1998). In many instances throughout Britain, in particular in Scotland, tour operators are fishermen who diversify into tourism at particular times of the year, particularly during the summer. While such tourism may promote conservation, its impact on seal populations is poorly understood. The presence of seals at haul-out and pupping sites in south-west Wales attracts considerable local interest and provides a tourist attraction of considerable economic value with many visitors coming to enjoy the coastal scenery and wildlife. Similarly, the Saltee Islands in Co. Wexford and the islands off Co. Dublin are important amenity areas, being sites of historical interest as well as important seabird and seal colonies. These areas are visited throughout the months of April-October by a range of user groups including tourists, naturalists and anglers. The presence of seals is also an attraction to small boat owners and to sub-aqua divers. However, there are potential negative impacts which may be caused by visitor pressure and disturbance to wildlife. While the effects of human disturbance at sites in the Irish and Celtic Seas have not been assessed heretofore, Baines *et al.* (1995) speculated that the development of 'seal-watching' boat trips around Ramsey Island in Wales might have contributed to a reduction in the number of seals breeding there during the early 1990s. It was therefore decided that this study would incorporate a review of current seal eco-tourism operations in south-west Wales and investigate the evidence and potential for human disturbance of local seal populations. Such a study would also benefit the Irish INTERREG region where such tourism is recently emerging with little or no regulation.

5.2.2 Methods

A list of tour-boat operators in west Wales was compiled and information on their operations (e.g. frequency of site visits, types of vessel, etc.) obtained for inventory purposes. Information was gathered on organised seal-watching activities in south-west Wales, differentiating between land-based and boat-based activities, the types of vessel and approximate frequencies of trips in different sections of the coast. Population data gathered in 1996 and 1997 at grey seal haul-out and breeding sites in the eastern Irish Sea were used to compare with previous data in the assessment of human disturbance at grey seal colonies.

5.2.3 Results

Tourism activities which involve a seal-watching aspect are summarised below for each section of the south-west Wales coast:

Ceredigion

A single rigid-hulled inflatable vessel operates from Aberaeron taking passengers on general wildlife tours, although seals are not specifically targeted. Up to five traditional (displacement-hulled) boats carry passengers from New Quay on general interest tours. One boat offers longer distance tours with a greater emphasis on marine wildlife, although seal breeding sites are not included in the itinerary. At Clun yr Ynys, the headland opposite Cardigan Island, the land-owner charges an admission fee to visitors to walk a coastal path which overlooks regularly used seal haul-outs. Seals form one of the main advertised features at this site.

North Pembrokeshire (Cardigan to St David's Head)

No organised boat tours are available in this section of coast. There is a coastal path around the entire coast of Pembrokeshire from which a number of pupping sites are visible. Although there are no organised seal-watching activities, the coastal path is a popular attraction for visitors, especially during the grey seal breeding season.

Mid-Pembrokeshire (St David's Head to Milford Haven)

A considerable industry has developed in recent years, based on seal-watching around Ramsey Island. The island is owned by the Royal Society for the Protection of Birds (RSPB) and managed as a nature reserve. Visitors landing on the island may view seals on breeding beaches from the cliff-tops. Access to pupping beaches from land is prohibited. Two traditional, displacement-hulled boats make regular circuits of Ramsey Island between April and October and seals are a prominent feature of these trips. An additional five rigid-hulled inflatable boats carry visitors around the island between April and October with up to five trips per boat each day during periods of high demand (especially during school holidays). Seals are specifically targeted, in particular during the breeding season when a number of pupping sites are visited by boat, offering views of the seals at close quarters. A voluntary code of conduct has been agreed between the tour operators and the RSPB.

Visitors to Skomer Island, a National Nature Reserve managed by the Wildlife Trust, West Wales, are encouraged to follow a 'Safe Seal Watching' code of conduct when viewing seals from the cliff-tops. A single traditional-type boat offers occasional trips around this island but it does not closely approach seal haul-out sites. The same boat also visits the islands of Skokholm and Grassholm once a week during the summer season. The sea area surrounding Skomer Island has been designated a Marine Nature Reserve and all activities that might affect its diverse wildlife are carefully regulated. Close approach from the sea to pupping beaches on Skomer and the adjacent mainland coast is prohibited during the breeding season.

South Pembrokeshire (Milford Haven to Tenby)

Much of this section of coast lies within a military firing range and access is therefore restricted. Three traditional type boats operating from Tenby carry visitors around Caldey and St Margaret's islands, although seals are not specifically targeted.

5.3 Discussion

Seals are considered to have the ability to detect oil and other petroleum hydrocarbons on the sea surface (see NOAA, 1999). Although no studies have yet been conducted to investigate the detection abilities of the animals, anecdotal observations indicate that seals may actively avoid such spillage. However, there are also numerous instances in the wild where seals have swum directly into an affected area and numerous mortalities have been attributed to direct and indirect exposure to petroleum hydrocarbons.

Breeding population data gathered in the present study in south-west Wales suggest that oil pollution from the *Sea Empress* did not significantly affect breeding in the short term (i.e. in 1996) and did raise breeding site mortality beyond that typically reported. However, the longer-term effects of the incident are unknown and factors such as post-breeding mortality, population health and contamination through the food chain require investigation.

Plate 2. An adult female grey seal with a constrictive neck band thought to have resulted from entanglement in fishing gear.

Grey seals are observed on occasions with spots of oil on the fur or carrying a "necklace" of fishing net around the head (Plate 2), both of which have unknown effects on the animal but are nevertheless of concern. Indeed, before the *Sea Empress* incident, a few pups with signs of minor oil-fouling had been found on surveys between 1992-94. Between 1994-1996 such tainting of the fur was most obvious on white-coat pups in their first two or three weeks of life and may be due to the rather sessile nature of such pups which tend to lie on or above the high water mark, the area in which any oil deposits are also likely to be found. Adult grey seals may also spend significant periods ashore during the breeding season and this terrestrial behaviour is likely to make both grey seal pups and adults extremely vulnerable to such pollution during the peak breeding period (September to November in Ireland and western Britain). However, the *Sea Empress* incident occurred in the month of February, when pups born in the previous breeding season had left breeding sites and haul-out sites in the immediate vicinity were relatively empty. Thus the low impact of the oil spill on grey seals may be attributed to the time of year and to weather conditions at the time which quickly dispersed the oil. Had the accident occurred during the breeding season it is likely that a significant number of pups and adults would have been contaminated with potentially dramatic consequences.

The nature of grey seal breeding also makes the species particularly vulnerable to tourism disturbance. The pupping sites used by grey seals are characterised by their relative inaccessibility to humans and other terrestrial predators with a result that in Wales, 42% of pups are born in caves and nearly all the remainder were born on beaches beneath high cliffs (see Baines *et al.*, 1995). The most important seal breeding areas in Wales, on the north Pembrokeshire coast between Strumble and St David's Heads and the islands of Skomer and Ramsey, are protected from sea-borne human approach by strong tidal currents, high sea swells and numerous rocks and reefs. In south-west Wales, however, grey seals arrive at their coastal breeding sites in August and 95% of pups are born in September and October. The main summer tourism season overlaps the early part of the grey seal's breeding season and this is therefore the most sensitive time of year in terms of potential disturbance to seals.

Eco-tourism has positive benefits beyond its economic value, promoting understanding and awareness of our natural environment and its conservation. Certain grey seal pupping beaches offer good opportunities for seal-watching from cliff-top vantage points and some of these, such as on Skomer Island and Wooltack Point in mid-Pembrokeshire, Pwll Deri and beaches visible from the coast path around Strumble Head in north Pembrokeshire and Clun yr Ynys in Ceredigion, have become very popular and are visited daily. There is no evidence for any reduction in pup production or increase in pup mortality at these sites, which is encouraging.

Traditional displacement-hulled boats used for carrying passengers are limited in their ability to approach the shore-line safely, especially in the rocky, tide-swept habitats favoured by grey seals. However, the development of new types of vessel, especially rigid-hulled inflatable boats, has made it possible to navigate these treacherous inshore areas safely. Tourism operations using these types of vessel to carry passengers close to pupping beaches, possibly including sites located within sea caves, carry the greatest potential risk of disturbance to seals. Ramsey Island is presently the only location in south-west Wales where seal-watching is conducted from such vessels. However, the tour operators here have taken a responsible attitude, co-operating with conservation organisations by adopting a voluntary code of conduct to minimise the environmental impact of their activities. While there is no evidence for any increased mortality or physical harm to individual seals caused by tour boat operations at Ramsey, it is possible that disturbance may cause more subtle effects, such as changes in the fidelity of individual seals to pupping sites or the distribution of pup production. Photo-identification of breeding female grey seals at pupping sites suggests that site fidelity of female seals breeding on Ramsey was lower in 1996-97 than at pupping sites on the relatively undisturbed coast of north Pembrokeshire. However, it is not possible to determine the statistical significance of this result and further study is necessary.

The principal seal haul-out sites in Wales are managed at least partly for their wildlife interest. “Potentially damaging operations”, listed on the SSSI notification, seek to control recreational activities or the use of vehicles or craft which may affect seal behaviour and The Skomer Marine Nature Reserve is managed by the Countryside Council for Wales under bylaws and a voluntary code of conduct. Though no bylaws explicitly relate to seals, a general bylaw provides that either a permit for CCW of a reasonable excuse is required before any animal may be disturbed. While this project contributed to the development of voluntary codes of conduct and tour boat operators are co-operating with the conservation authorities to design methods of approaching colonies, at present there is no enforced regulation of tour-boat activity and this may need to be more formally addressed if the industry is to be sustainable for both people and seals.

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

A good understanding of the status of seal populations is fundamental to understanding the conflicts that have arisen between seals and human populations. For example, the increase in western Atlantic and eastern Atlantic grey seal populations has intensified the conflict between grey seals and fisheries (*see* Summers, 1978; Harwood & Croxall, 1988; Harwood, 1992). More recent conflicts have arisen via tourism (Baines *et al.,* 1995; Young, 1998) and the effects of mankind induced global climate change pose a new and real threat to marine mammal populations and their future conservation.

This study has provided essential baseline data on the status and dynamics of grey seal populations in the INTERREG region of the Irish Sea and their interactions with regional human activities. Our working hypothesis: that "Irish and Celtic Sea grey seals are part of a dynamic system and that the population within the INTERREG region has several components" has been borne out by the data gathered in this study. We have shown that grey seals of all ages may move freely across the Irish Sea and that such movements may have a strongly seasonal component. Thus, for the development of sustainable management strategies and emergency response capabilities we present the following broad recommendations:

1. Further seal population and interaction-based studies should be conducted on a transnational scale and in a similar co-ordinated manner to that employed in this study. Such studies should contain a strong inclusive element to draw on expertise from related fields;

2. Management measures for the Irish Sea grey seal population should be discussed and agreed by relevant agencies on both sides of the Irish Sea and codes of conduct, emergency rocedures, and environmental regulation standardised as much as possible.

3. An ecosystem-based inter-disciplinary approach should be evolved for research in the Irish Sea, drawing from the current data pools and experience in a dedicated manner leading to an overall synthesis of the Irish Sea in its physical and biological states.

6.2 Grey seal populations: Status and monitoring

The data gathered in this study show that the INTERREG region of the Irish & Celtic Seas is home to between 5,198 and 6,976 breeding grey seals, approximately 90% of which are associated with the Welsh breeding population. However, the photo-identification data collected in this research suggest that this association may be somewhat loose and that neither the western nor eastern Irish Sea populations can be considered as closed populations. While this study goes a long way to improving our understanding of the grey seal population in the Irish Sea and yields important deliverables (e.g. minimum population estimate, EIRPHOT database), the data fall short of that necessary for proper management purposes and give little indication of current population trends. This is most notable in Ireland where poor information from other regional populations mean that Ireland's last minimum population estimate of 2,000-2,500 seals (Summers, 1983) still stands; this estimate is almost twenty years old and is probably a poor indication of the true population size. The situation for harbour seals is somewhat similar, since the last Irish census for this species also occurred in the early 1980s; the population shows recent evidence of a decline (Wilson & Corpe, 1996). As a result of such large gaps in scientific knowledge, the effects of, for example, fish stock collapse, environmental degradation or disease outbreak on seals in the Irish Sea, remain unknown. Nevertheless, this study has enabled researchers to use effective monitoring tools and network-based research to eliminate these unknowns in the future. Therefore, we recommend that:

4. An all-Ireland population census for grey and harbour seals should be carried out as soon as possible. This would replace previous outdated estimates and bring Ireland into line with England, Scotland and Wales, all of which have recent population estimates for both species;

5. The use of innovative aerial survey methods for estimating seal populations should be investigated for the Irish Sea area and for Ireland as a whole; it may yield more accurate and cost-effective population data. Surveys during the annual moult season, when a large proportion of the population is ashore for an extended period, should also be explored

6. Studies of seal populations in the Irish Sea should be continued as a case study, with further development of standardised cross-border techniques (such as photo-identification) and integrated management plans; these could then be applied to other cross-border situations.

6.3 Seal - Fisheries interactions in Ireland

The study of interactions between the grey seal and the Dunmore East monkfish fishery showed that the level of damage by grey seals to the catch is comparable with other seal - fishery interactions studies in Ireland (*see* BIM, 1997). The highest level of damage was observed in April. This corresponds to the period when juvenile and adult grey seals have completed their moult and are thought to be highly pelagic. Although no data on the abundance of grey seals in the Celtic Sea was collected in April, data collected in March and the months following April show that there was a fall in the number of grey seals hauled out between March and the summer months. This was also observed in the western Irish Sea and in western Ireland (*see* Kiely, 1998). It is difficult to suggest which age groups are primarily responsible for the damage and which haul-out areas these seals are associated with. Although only immature grey seals were by-caught in the monkfish fishery, it does not imply that only immature seals are responsible for the damage. Indeed, lack of experience may be a factor in the by-catch of juveniles. However, immature seals may be more likely to feed close to coastal haul-out sites during spring and early summer, as suggested by Coulson & Hickling (1964) and Hammond *et al.* (1993).

Clearly, the interactions between seals and fisheries are complex and difficult to interpret. Many previous studies of this nature find their flaws in delivering information on a single variable in what is ultimately a dynamic system. For example, observer-based recording of damaged catches alone does not give an indication of how the interaction occurs operationally, nor does it indicate what proportion of the seal population is actually involved in the interaction. Nor can data gathered on the diet of by-caught animals be meaningful unless compared with dietary information gathered from the population as a whole. This study set out to reduce such problems by simultaneously investigating the seal population and its operational and biological interactions with fisheries in the same geographic region. While the resultant data are substantially more powerful than the singular approach, there are many factors involved which have not been covered and we recommend that:

7. Further studies of seal populations and their interactions with fisheries should include a radio/satellite telemetry component in order to gain an understanding of where seals feed in relation to their haul-out sites;

8. Future studies involving the monitoring of specific fisheries should be adequately resourced in order to achieve total fleet coverage while collaborating closely with the fishing industry;

9. Detailed studies of the damage to static-net fisheries by crabs and skinners by seals should be conducted;

10. The salmon data collected during the present study is very limited and indicates a need for more dedicated work on the topic of salmon/seal interaction considering the impression the fishermen give of high levels of such interaction.

11. Such operational studies should include a gear technology element to test other methods of catching target species with the aim of reducing or eliminating scavenger or seal damage.

6.4 Seals and environmental degradation in the Irish Sea

As the marine environment continues to be exploited to a greater extent into the 21st century, the impacts on the marine ecosystem and its wildlife, which are currently topical, are likely to become even more pertinent issues in the future. The data gathered in this study on grey seal abundance, distribution and movements within the INTERREG region has significantly improved our ability to detect and predict the effects of coastal development, seal - fishery conflicts, eco-tourism and environmental disasters on Irish & Celtic Sea populations both locally and regionally. It has also highlighted particularly sensitive areas and seasons in which seals may suffer greatly from environmental disruption. Since the marine environment being utilised by human activities is constantly changing, we recommend that:

12. Co-ordinated population census programmes should be established to accurately determine current population trends. Censuses should be conducted in two-year blocks to allow for adverse weather conditions and other logistical difficulties. The data gathered by this research effort would greatly facilitate the prediction and management of environmental degradation affecting seals both directly and indirectly;

13. Long term monitoring of key regional breeding sites should be conducted to complement population census data on the ground and investigate the breeding status of the population at these "indicator" sites. A non-invasive in-depth study at one or two such sites throughout a single breeding season would be extremely informative concerning pup mortality and site vulnerability to environmental disruption;

14. The use of techniques such as photo-identification, which have proved extremely valuable and cost-effective to date, should be encouraged in population assessment and monitoring programmes as the information retrieved from such methods is likely to "snowball" with continued implementation.

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ANNEX 1: RESEARCH TEAM

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Mr. Michael Baines	**Project Leader** - Wales
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APPENDIX II: Grey seal population data 1: Ground surveys in Ireland

Island Name	Grid Ref.	Description
Rockabill	53°36'N 06°00'W	Two miles ENE of St Patrick Is. Consists of two steep-sided 9m high rocks, with a shallow passage between. Haul out sites are in the passage and on narrow ledges around base of rocks.
St Patrick Is.	53°35'N 06°04'W	A low-lying, vegetated and uninhabited island. Haul out sites are found on all sides of the island and comprise rocky boundaries, in-shore rocks and an off-shore reef.
Colt Is.	53°35'N 06°05'W	A low-lying, vegetated and uninhabited island almost joined to the mainland beach at Low Water. Haul out sites comprise rocky boundaries and in-shore rocks on the N side.
Shenick Is.	53°34'N 06°05'W	A low lying, vegetated and uninhabited island joined to the mainland beach at Low Water. Haul out sites comprise rocky boundaries and in-shore rocks on the E and NE sides.
Lambay Is.	53°29'N 06°01'W	An inhabited island, 2 miles off-shore, low and rocky on W side, other three sides are bordered by high cliffs. Haul out sites are found on the W, S, E, and NE sides and comprise rocky boundaries, in-shore rocks, beaches, beach-caves and caves.
Ireland's Eye	53°24'N 06°04'W	A rocky uninhabited island, 1 mile off-shore and 97m high at its summit. Haul out sites are found on all sides and comprise rocky boundaries, in-shore rocks, pebble and sandy beaches and a cave.

Table i. Description of islands and associated haul out sites for grey seals on the east coast of Ireland.

Island Name	No. sites	Grid Ref.	Description
Little Saltee	4	52°08'N 06°34'W	An uninhabited island, 1mile NNE of the Gt Saltee, 35m high at its summit and 1.75miles off-shore. Haul out sites are found on the S and E sides and comprise beaches and in-shore rocks.
Great Saltee	39	52°07'N 06°37'W	An uninhabited island, 1 mile in length, 0.3 miles in breadth and 57m high at its summit. Haul out sites are found on the E, N and W sides and comprise in-shore rocks, pebble and sandy beaches, beach-caves and caves.
Coningmore Rocks	4	52°05'N 06°37'W	Three rocks, 1.25 miles south of the Gt. Saltee with the largest rock 4m high. Haul out sites are on top of the rocks or on narrow ledges at the base of the main rock.
Blackrock	3	52°09'N 06°24'W	A group of rocks surrounding a tidal lagoon, 2 miles SW by S of Carnsore Pt, with the largest rock 2m high. Haul out sites are on top of the rocks, on ledges at the periphery of the rocks and on rocks and ledges in the lagoon.
Carnsore Pt.	2	52°11'N 06°20'W	At the most south-eastern point of Ireland, a low clay cliff, 16m high with rocky shelves beneath it. Haul out sites are on the abundant in-shore rocks.
The Raven Pt.	6	52°20'N 06°21'W	Extensive sand-flats in, and at the mouth of, Wexford Harbour. Used as haul out sites at all states of tide.

Table ii. Description of islands and associated haul out sites for grey seals on the south-east coast of Ireland.

Island Name	Site Code	Site Name	No. of pups 1997	No. of pups 1998	Site description
Lambay	48	Carnoon Beach[1]	0	1	Pebble beach backed by low cliff
Island	37	Bishops Bay Beach[1]	4	5	Pebble and boulder beach backed by cliff
	36	Bishops Bay Beach Petite[2]	0	1	Small pebble beach backed by cliff
	35	Dead Mans Bay Cave[2]	0	1	Shallow narrow cave with pebble beach
	34	Dead Mans Bay Beach[1]	15	16	Wide & deep pebble/boulder beach backed by cliff
	32	Sunk Island Cave[1]	7	8	Shallow boulder/pebble beach cave
	31	Sunk Island Beach/Cave[1]	5	6	Shallow pebble beach cave with an open boulder beach through a narrow passage
	24	Seal Hole[1]	8	8	Deep cave with pebble and boulder beach
	23	Boulder Beach[2]	1	0	Steep boulder beach backed by high cliff
Irelands	14	Western Beach[2]	1	0	Pebble and gravel beach backed by low cliff
Eye	2	Seal Cave[2]	-*	3	Deep cave with pebble beach

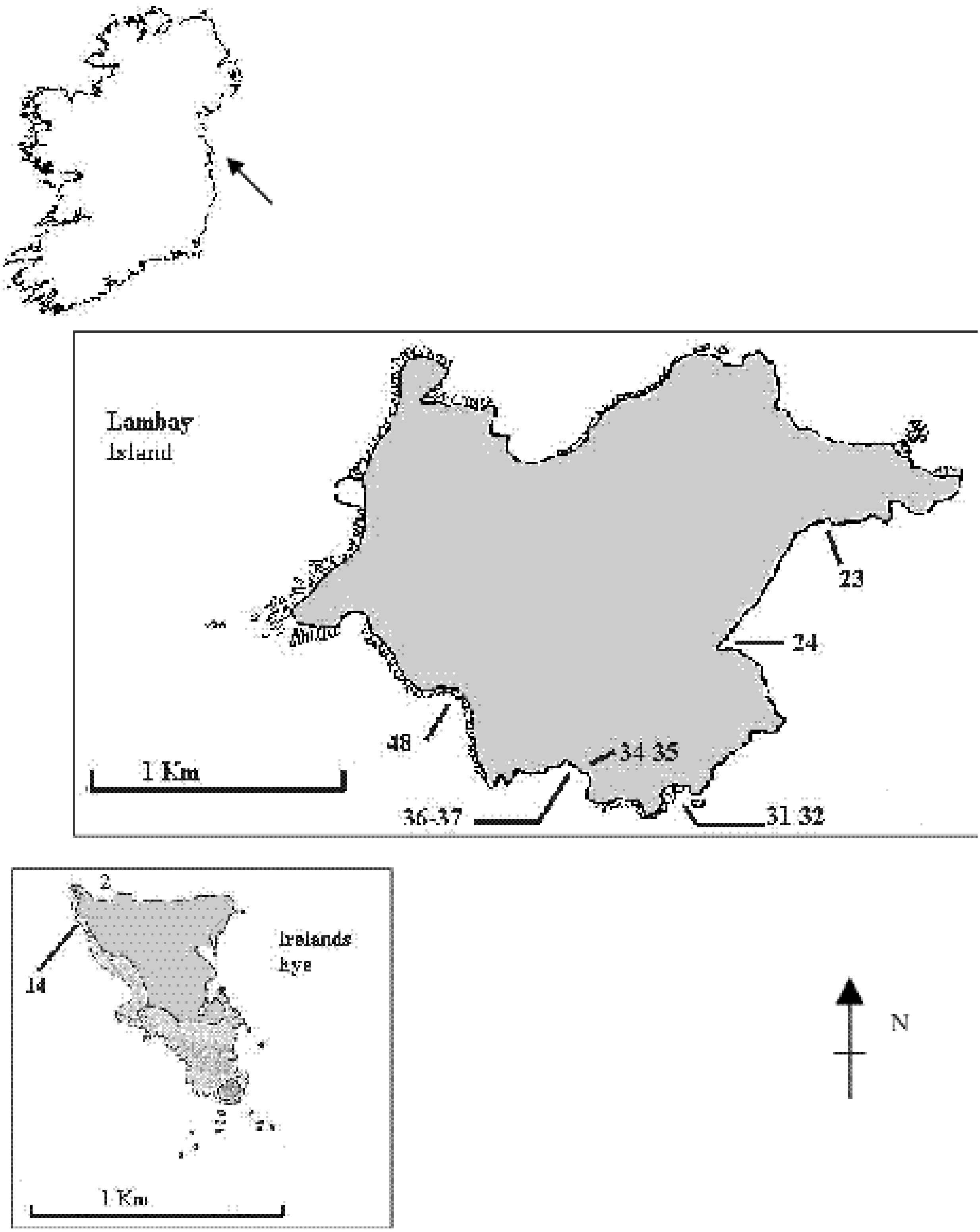
* sites never searched or not searched on every survey.

[1] Site names based on those given by Margaret Kelly, Trust manager for Lambay Island, personal communication.

[2] Site names modified by author.

Table iii. Distribution of newborn grey seal pups counted at Lambay Island and Ireland's Eye, Co. Dublin, 1997 – 1998. Pup production figures based on number of newborn pups recorded during ground surveys.

Fig. I. Lambay Island and Ireland's Eye showing individual grey seal pupping sites
(Descriptions of site codes for each island are given in Table iii).



Island Name	Site Code	Site Name	No. of pups		Site description
			1997	1998	
Great Saltee	1	Sebber Bridge[1]	1	3	Long pebble spit
	4	Lady Walkers U-beach[2]	3	4	Pebble beach backed by low cliff
	7	Big Shag Rock Beach[2]	1	5	Pebble beach backed by low cliff
	9	Fulmar Beach[1]	6	8	Wide pebble and boulder beach backed by cliff
	15	Makestone Cave[1]	*	1	Cave of two entrances, pebble beach and two caves within
	16	Makestone Beach/Cave I[2]	*	4	Pebble/boulder beach cave backed by cliff
	17	Makestone Beach II[2]	*	3	Pebble, boulder and sandy beach backed by cliff
	18	Sunken Rock Cave[1]	4*	3	Shallow cave with two entrances and a pebble beach
	20	Seal Passage[2]	2*	0*	Shallow cave with narrow entrance and sandy beach
	21	Wherry Hole[1]	8*	6	Pebble, boulder and sandy beach backed by cliff
	24	Otters Cave I[1]	*	10	Deep pebble beach cave
	25	Otters Cave II[1]	7*	15	Deep pebble beach cave
	26	Otters Beach[1]	10*	2	Pebble and boulder beach backed by cliff
	29	Happy Hole[1]	3*	4	Shallow cave, wide entrance and narrow sandy beach
	30	Ardheen Beach I[1]	1*	6	Pebble beach backed by cliff
	31	Ardheen Beach II[1]	3*	2	Pebble beach, mostly flooded at high tide backed by cliff
	32	Ardheen Beach III[1]	1*	4	Boulder/pebble beach backed by cliff
	42	Y-Cave[2]	3*	3	Deep cave, narrow entrance with pebble/boulder beach
	45	Dead Man[1]	0	1	Pebble beach backed by earthen bank
	47	The Ring[1]	0	3	Pebble beach surrounding a tidal lagoon
	51	Middle Quay[1]	13	22	Pebble and boulder beach backed by earthen bank
	52	Landing[1]	23	9	Pebble and sandy beach backed by earthen bank
	53	East North Beach[2]	10	4	Pebble and boulder beach backed by earthen bank
Little Saltee	1	West Beach[2]	-*	1	Pebble beach backed by cliff
	3	South-west Beach II[2]	-*	2	Pebble beach backed by cliff
	4	South-west Beach III[2]	1*	2	Pebble and boulder beach backed by low cliff

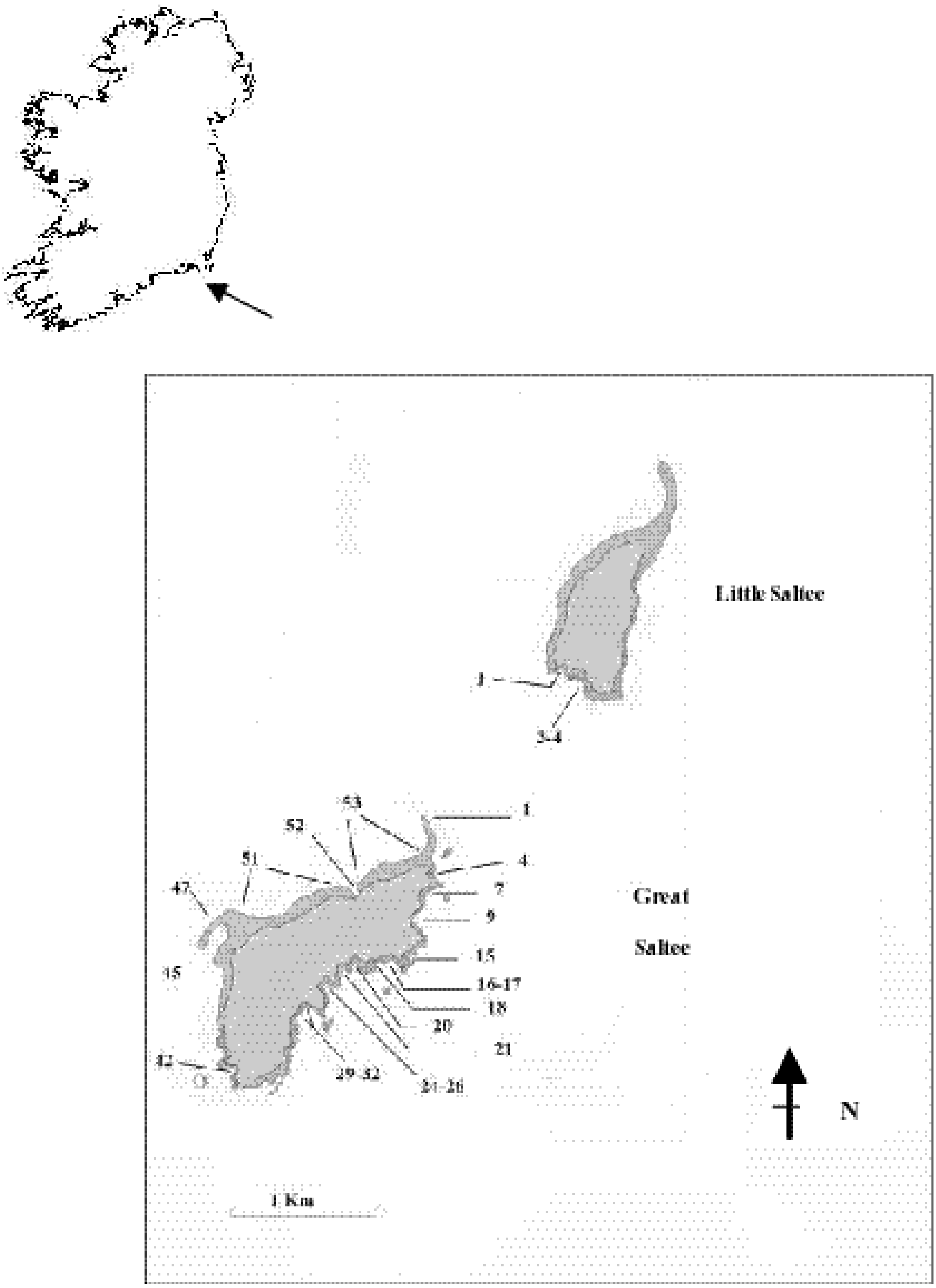
*sites never searched or not searched on every survey

[1] Site names according to Roche & Merne (1977)

[2] Site names created by author

Table iv. Distribution of newborn grey seal pups counted at the Great and Little Saltee, Co. Wexford, 1997 – 1998. Pup production figures based on number of new pups counted during ground surveys.

Fig II. The Little and Great Saltee showing individual grey seal pupping sites
(descriptions of site codes for each island are given in Table iib).



APPENDIX III: Grey seal population data 2: Photo-identification in

Site	Year	No. photo-sessions	Left	Right	Both	Max	Min
Skerries Harbour	1997	0	0	0	0	0	0
	1998	8	10	9	7	26	17
St Patrick Is.	1997	14	10	11	15	36	26
	1998	16	6	9	32	47	41
Shenick Is.	1997	0	0	0	0	0	0
	1998	1	2	0	4	6	6
Colt Is.	1997	1	1	1	1	3	2
	1998	0	0	0	0	0	0
Rockabill	1997	0	0	0	0	0	0
	1998	0	0	0	0	0	0
Lambay Is.	1997	36	39	40	42	121	82
	1998	47	22	30	60	112	90
Ireland's Eye	1997	0	0	0	0	0	0
	1998	6	4	7	6	17	13

Table v. The number of grey seals photographed and 'pelaged' at islands off the east coast from the left side only, right side only and both sides, and estimates of the maximum (Max) and minimum (Min) number of grey seals in the photo database, 1997 to 1998. The maximum estimate assumes that seals photographed from the left or right side only are not the same individuals; the minimum estimate assumes that seals photographed from the left or right side only are the same individuals.

Site	Year	No. photo-sessions	Left	Right	Both	Max	Min
Little Saltee	1997	0	0	0	0	0	0
	1998	0	0	0	0	0	0
Great Saltee	(1996)	(6)	(2)	(6)	(3)	(11)	(9)
	1997	36	39	48	36	123	84
	1998	14	9	13	12	34	25
Coningmore Rocks	(1996)	(7)	(24)	(10)	(13)	(47)	(37)
	1997	6	5	15	7	27	22
	1998	16	23	17	23	63	46
Blackrock	1997	16	18	17	32	67	50
	1998	26	25	49	45	119	94
Carnsore Point	1997	2	1	1	2	4	3
	1998	7	6	4	7	17	13
The Raven Point	1997	4	2	3	1	6	4
	1998	14	18	23	6	47	29

Table vi. The number of grey seals photographed and 'pelaged' at islands off the south-east coast from the left side only, right side only and both sides, and estimates of the maximum (Max) and minimum (Min) number of grey seals in the photo database, 1996 to 1998. The maximum estimate assumes that seals photographed from the left or right side only are not the same individuals; the minimum estimate assumes that seals photographed from the left or right side only are the same individuals. Data in brackets were collected during preliminary surveys conducted in 1996 (see Kiely 1998).

APPENDIX IV: FISHERIES INTERACTIONS IN THE CELTIC SEA: OBSERVER TRIP DATA

Trip No.	Boat	Trip Date	Weight (kg) Of Catch	Damage	Total catch	% damage	Length of string (km)	Length hauled (km)	Depth of gear (m)
1	A	27/04/98	60.74	21.57	82.31	26.21	125	7.41	54.6
2	A	18/05/98	116.41	0	116.41	0.00	175	10.37	54.6
3	A	19/05/98	44.08	14.91	58.99	25.28	105	6.22	54.6
4	B	12/06/98	29.98	6.36	36.34	17.50	50	2.96	43
5	A	16/06/98	57.96	13.19	71.15	18.54	160	9.48	54.6
6	B	20/06/98	24.31	0	24.31	0.00	80	4.74	35
7	C	02/07/98	40.63	4.66	45.29	10.29	90	5.33	40
8	B	18/07/98	8.41	6.83	15.24	44.82	26	1.54	50
9	A	24/07/98	63.11	0	63.11	0.00	175	10.37	54.6
10	B	27/07/98	21.36	0	21.36	0.00	36	2.13	45
11	A	02/08/98	26.68	0	26.68	0.00	66	3.91	60.06
12	A	10/08/98	85.34	0	85.34	0.00	150	8.89	54.6
13	B	13/08/98	72.02	0	72.02	0.00	60	3.56	45
14	C	15/08/98	65.9	2.57	68.47	3.75	100	5.93	45
15	A	22/08/98	70.52	21	91.52	22.95	150	8.89	54.6
16	C	27/08/98	45.52	5.86	51.38	27.87	140	8.30	53
17	B	29/08/98	67.87	1.69	69.56	2.43	110	6.52	45
18	A	01/09/98	118.53	12.8	131.33	9.75	150	8.89	51
19	B	03/09/98	103.3	18.29	121.59	15.04	60	5.93	45
20	C	28/09/98	56.39	0	56.39	0.00	80	4.74	45
Total			1179.06	129.73	1308.79				

Table vii. Details of observer sea trips in 1998 during monitoring of seal interactions with the tangle-net fishery for monkfish out of Dunmore East, Co. Waterford.

APPENDIX V MARITIME INTERREG PROJECTS

The following co-operative projects and networks are supported under Measure 1.3 “Protection of the Marine and Coastal Environment and Marine Emergency Planning”, of the Maritime (Ireland/Wales) INTERREG Programme (1994 – 1999):

Co-operative Projects

1. **Roseate Terns - The Natural Connection - A Conservation and Research Project linking Wales and Ireland.**
   Irish Wildbird Conservancy / North Wales Wildlife Trust.

2. **Marine Mammal Strandings - A Collaborative Study for the Irish Sea.**
   National University of Ireland, Cork / Countryside Council for Wales.

3. **South West Irish Sea Survey (SWISS).**
   Trinity College Dublin / National Museum of Wales, Cardiff.

4. **The Fate of Nutrients in Estuarine Plumes.**
   National University of Ireland, Galway / University of Wales, Bangor.

5. **Water Quality and Circulation in the Southern Irish Sea.**
   National University of Ireland, Galway / University of Wales, Bangor.

6. **Grey Seals: Status and Monitoring in the Irish and Celtic Seas.**
   National University of Ireland, Cork / Dyfed Wildlife Trust.

7. **Sensitivity and Mapping of inshore marine biotopes in the Southern Irish Sea (SensMap).**
   Ecological Consultancy Services (Dublin), Dúchas / Countryside Council for Wales.

8. **Marine Information System: Scoping Study (Phase I).**
   Marine Institute, National Marine Data Centre/ Countryside Council for Wales.

9. **Achieving EU Standards in Recreational Waters.**
   National University of Ireland, Dublin / University of Wales, Aberystwyth.

10. **Irish Sea Southern Boundary Study.**
    Marine Informatics Ltd (Dublin) / University of Wales, Bangor.

11. **Marine Information System: Demonstration (Phase II).**
    Marine Institute, National Marine Data Centre / Countryside Council for Wales.

12. **Emergency Response Information System (ERIS).**
    Enterprise Ireland, Compass Informatics, IMES / University of Wales, Bangor.

13. **Risk Assessment and Collaborative Emergency Response in the Irish Sea (RACER).**
    Nautical Enterprise Centre (Cork), National University of Ireland, Cork, University of Wales, Cardiff.

14. **Critical assessment of human activity for the sustainable management of the coastal zone.**
    National University of Ireland, Cork / University of Wales, Aberystwyth.

15. **SeaScapes – Developing a method of seascape evaluation.**
    Brady Shipman Martin, National University of Ireland, Dublin / University of Wales, Aberystwyth.

16. **Ardfodir Glan – Clean Coasts/Clean Seas.**
    CoastWatch Ireland / Keep Wales Tidy Campaign.

Co-operative Networks

17. **Irish Sea Hydrodynamic Modelling Network.**
    Trinity College Dublin / University of Wales, Bangor.

18. **CoAST - Co-operative Action - Sustainability Network.**
    Dublin Regional Authority / Isle of Anglesey County Council.

19. **ECONET - Erosion Control Network.**
    Enterprise Ireland / Conwyn County Council.

20. **Navigate with Nature.**
    Irish Sailing Association / Centre for Economic and Environmental Development (UK).

21. **"Land Dividing - Sea Uniting" Irish Seas Exhibition.**
    Irish Seal Sanctuary, ENFO / National Assembly for Wales.

22. **From Seawaves to Airwaves.**
    West Dublin Community Radio / Radio Ceredigion CYF.

23. **BENSIS – Benthic Ecology Network.**
    Trinity College Dublin / National Museum of Wales, Cardiff.

24. **Remote Sensing of Suspended Sediment Load in the Coastal Zone.**
    National University of Ireland, Galway / University of Wales, Bangor.

25. **Paving the Information Highway.**
    Ecological Consultancy Services (Dublin) / Irish Sea Forum, University of Wales, Bangor.

26. **Inland, Coastal and Estuarine (ICE) Journal.**
    National University of Ireland, Dublin / Centre for Economic and Environmental Development (UK).

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