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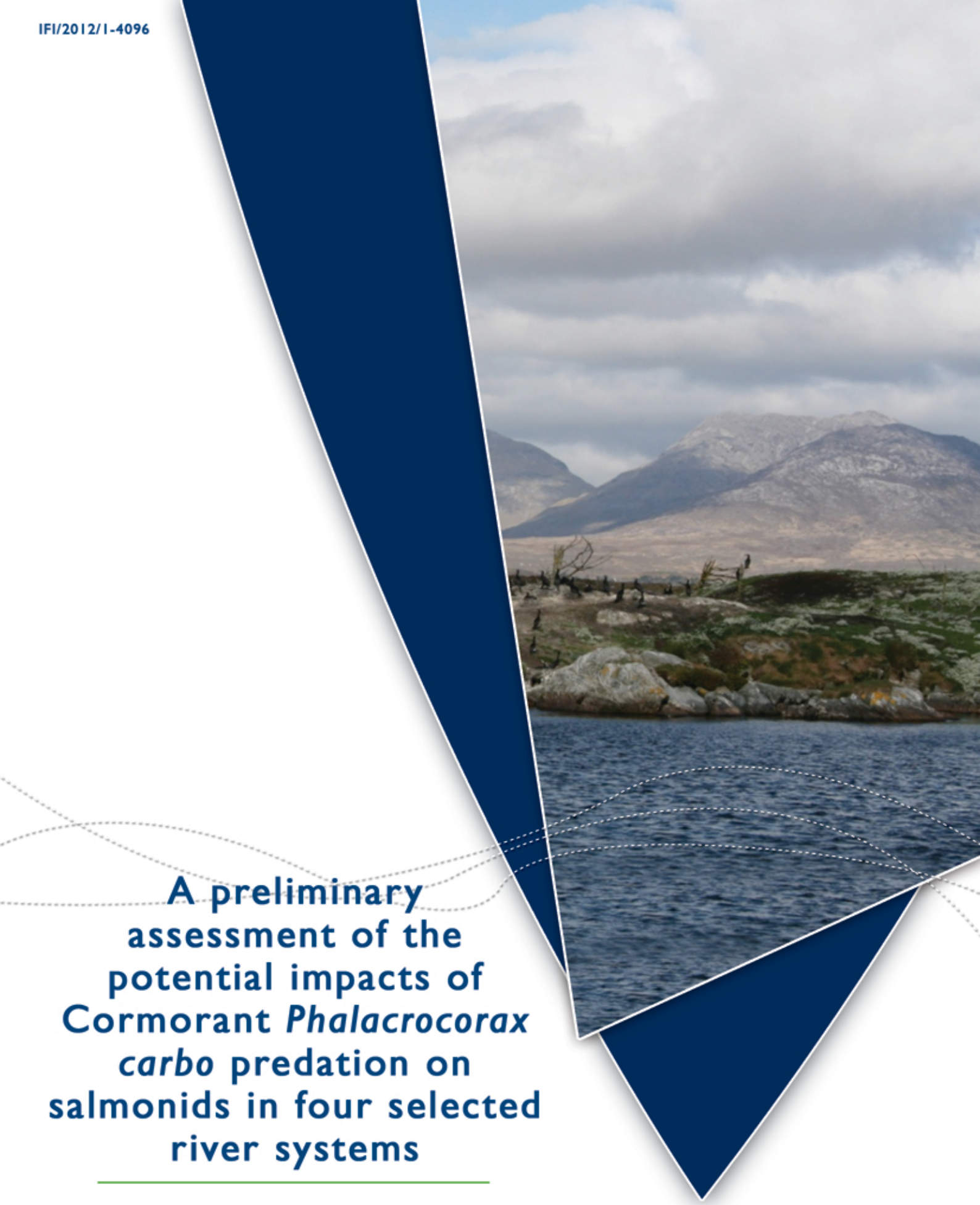

A preliminary assessment of the potential impacts of Cormorant *Phalacrocorax carbo* predation on salmonids in four selected river systems

Iascach Intíre Éireann
Inland Fisheries Ireland

SALMON CONSERVATION FUND
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Report Commissioned by Inland Fisheries Ireland

A preliminary assessment of the potential impacts of Cormorant *Phalacrocorax carbo* predation on salmonids in four selected river systems

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Iascach Intíre Éireann
Inland Fisheries Ireland

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SUMMARY

The objective of this study was to investigate the real and perceived impacts of Great Cormorant *Phalacrocorax carbo* predation on salmonids at defined study sites on four geographically isolated river systems. The four river systems were selected by Inland Fisheries Ireland (IFI) on the basis that they were important rivers for salmonids and were known to be frequented by Cormorants, these were the Owenea, County Donegal, the Slaney, County Wexford, the Ballynahinch, Co. Galway and the Suir, in Counties Kilkenny and Waterford. As few studies have monitored Cormorant numbers and foraging behaviour on a regular basis at specific foraging sites over a prolonged period, the survey element of this project represents the most comprehensive monitoring assessment of spatial and temporal densities of Cormorants at specific feeding areas over one year.

A comprehensive literature review covering Cormorant population status and distribution, population expansion, diet, interactions with fisheries and mitigation measures was conducted. A comprehensive Cormorant survey was undertaken at defined study sites within each survey area between May 2010 and June 2011. A minimum of two counts per month were carried out over this period. In April and May 2011, the survey frequency was increased to two counts per week to coincide with the period of the Atlantic Salmon *Salmo salar* and Sea Trout *Salmo Trutta* smolt seaward migration. A protocol for directly observing foraging Cormorants, in order to determine the broad categories, species and sizes of fish being taken, was trialled in conjunction with the survey. Diet composition was directly assessed by the collection and analysis of pellets and regurgitates from five Cormorant roosts and nesting colonies in proximity to the study areas between 27th January and 1st June, 2011. In order to increase the likelihood of analysing the diet of birds most likely to utilise the survey areas, the closest accessible Cormorant roosting sites and breeding colonies to the survey sites were chosen. A strategic questionnaire was also distributed to IFI staff to interpret their perceptions in relation to the impact of Cormorant predation on salmonids and other fish species.

On average, Cormorant numbers were low across all study areas. The Suir survey area held, on average, one Cormorant per 14.4 hectares and the Slaney supported one bird per 15.3 hectares. The densities for the Ballynahinch and Owenea survey areas were substantially lower at one bird per 242 and 832 hectares respectively. The average number of birds utilising the survey areas decreased during the intensive survey period within all survey areas, which indicates that Cormorant foraging efforts, at a population level, are not targeted towards smolts in the survey areas during their seaward migration.

Attempts to assess Cormorant prey selection by directly observing foraging birds proved to be largely impractical due to a number of limitations; on large water bodies, it was often impossible to adequately monitor the foraging behaviour of focal birds; it was apparent that Cormorants were swallowing prey beneath the surface; and short prey handling times or long distances between the focal bird and the observer meant it was difficult to assign fish to broad categories with any degree of confidence. As the quantity of time devoted to conducting such observations was not balanced by the collection of useful data, it was decided to abandon this aspect and devote more time to visiting roosting and breeding colonies to collect dietary samples for subsequent analysis.

Analysis of 255 diet samples from five coastal and inland roost and nest sites revealed Ballan Wrasse *Labrus bergylta* to be the most important species in the diet in terms of frequency (38.6%), followed by Perch *Perca fluvialtilis* (9.3%) and Roach *Rutilus rutilus* (7.4%). Salmonids and Eel *Anguilla anguilla* represented 6.8% and 1.5% of the diet respectively. Across all sites, 61% of the identifiable prey items were marine species, with the remaining 39% being freshwater species. The diet at the inland breeding colony, which is situated approximately 50 km from the coast, comprised 21.7% salmonids in terms of frequency, which may suggest that Cormorant predation is likely to have a greater impact on salmonids in situations where birds do not have access to coastal foraging areas.

A survey questionnaire was completed by 22 IFI staff members, with the majority (n = 14) ranking Cormorants as the most important predators in their areas. The problem of predation was considered to be increasing by 77.3% (n = 17) of respondents. With regard to mitigation, 72.7% (n = 16) of respondents indicated a necessity for measures to be put in place to mitigate the impact of Cormorants on salmonids.

The survey data shows that foraging Cormorants, at a population level, do not selectively target the salmonid smolt run, on the four selected rivers. The dietary samples collected close to the Ballynahinch and Owenea survey areas provide a reliable approximation of Cormorant diet composition in these areas, as the survey sites are located within the likely foraging ranges of the roosts and breeding colonies. The survey data in conjunction with the dietary analysis in the vicinity of these two survey sites, indicates that the impact of Cormorants on local salmonid populations is limited. As it was not possible to locate accessible roosts or colonies within proximity to the Suir or Slaney survey areas, there is no available diet data to represent these study sites. The breeding colony closest to the Suir survey site is at the Keeragh Islands, which is situated approximately 30km away, and the closest breeding colony to the Slaney survey site is on Great Saltee Island, which is located 28 km away. The dietary samples collected from the breeding

colony on Great Saltee Island, however do show that the diet of breeding birds, at the time of collection, was exclusively marine in origin. Radio telemetry or GPS tagging would be required to accurately determine the movements of individual birds and definitively link birds observed within the survey areas to specific roosts or colonies.

A thorough understanding of the diverse range of factors that affect salmonid populations, robust information on the impact of Cormorants on salmonids, and the site-specific effects of any mitigation actions against Cormorant impacts are all required to ensure that conservation priorities and resources for salmonids can be implemented in the most effective manner. A series of recommendations for future work to comprehensively address these issues is outlined.

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The authors of this report would also like to extend their special thanks to the following people for their assistance with various aspects of the pilot survey;

All IFI staff who assisted with the various aspects of this research, particularly the staff members in the study areas who provided local knowledge beneficial to the survey design. Walter Butler gave specific input in the Ballynahinch survey area, Hugh Mooney and Jim Gallagher also greatly assisted the logistics of fieldwork within the Owenea survey area on numerous occasions. Stephen Byrne, Myles Roban, Morgan Rowsome and Michael Farnan all assisted with boat operations at the Slaney survey area. Robert Cruikshanks facilitated the diet analysis in Swords. Special thanks also to all IFI staff members who participated in the survey questionnaire. The contributions of Simon Ashe, Fisheries Manager at Ballynahinch Estate who has extensive relevant knowledge of this area also proved invaluable.

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There was also significant input from various BWI staff members throughout the project, David Watson conducted the diet analysis and gave much of his free time to ensure this aspect was efficiently completed. Niall Keogh also assisted with this element in the early stages. During the intensive survey period, David Watson and Mike Trewby surveyed the Ballynahinch and Owenea areas respectively. Other staff members who conducted survey work at various stages of this project included; Anita Donaghy, Helen Boland, Olivia Crowe, Peadar O'Connell and Dick Coombes. Many thanks also to Helen Boland and Olivia Crowe for supplying IWeBs data and to Brian Caffrey for providing preliminary Bird Atlas data and maps and for all administration staff at BWI for their help and support.

Finally we would like to extent our gratitude to all the landowners in each of the survey areas who facilitated access to their lands for survey purposes.

Niall Tierney, John Lusby & Alan Lauder

1. INTRODUCTION

1.1 Status and distribution

The Great Cormorant *Phalacrocorax carbo* has a worldwide distribution (Cramp and Simmons 1977), with an estimated 600,000 breeding pairs (Sellers 2004) distributed throughout all continents except South America and Antarctica (BirdLife International 2011). Three subspecies of Great Cormorant (hereafter referred to as "Cormorant") occur in Europe. The "Atlantic" subspecies, *Phalacrocorax carbo carbo* occurs in north-west Europe, inhabiting the North Atlantic, North Sea and White Sea (Cramp and Simmons 1977). Although *Phalacrocorax carbo carbo* does breed in inland situations, it is predominantly a coastal bird, nesting mainly on the cliffs and off shore islands of Iceland, Ireland, Britain, northern France, Norway, Finland and northern Russia (Carss and Ekins 2002). The "Continental" *Phalacrocorax carbo sinensis,* is the more numerous of the subspecies with a range extending across Europe into parts of Asia. The s*inensis* subspecies breeds in both marine and freshwater situations, although inland colonies are most common. In Europe, *sinensis* breeds in southern Norway and Finland and throughout central and southern Europe (Sellers *et al*., 2004). Recent molecular investigations have revealed the existence of a third subspecies, *Phalacrocorax carbo norvegicus* that is found in Norway and along the coasts from Sweden to Brittany (Marion and Le Gentil 2006). The ranges of these three subspecies overlap across large parts of European. The sub-species are difficult to differentiate in the field, with the primary physical diagnostic features of *sinensis* being its slightly smaller size and shape of the "gular pouch" which differs from that of *carbo* (Newson *et al*., 2004), however identification from observations alone are often not possible and DNA analysis is required for confirmation. The situation in Britain has become more complex with individuals of the *sinensis* subspecies having recently established in southeast England where they have potentially hybridised with the *carbo* subspecies (Carss and Ekins, 2002). The presence of *sinensis* has not been confirmed in Ireland, and therefore carbo is the only sub-species of Great Cormorant recorded as a breeding and wintering bird in this country to date.

The European breeding range of the *carbo* subspecies has remained largely unchanged since 1960's, although the population has undergone a moderate increase over this period (Kohl 2010). Debout *et al*., (1995) report a notable upward trend since the 1980s, with moderate increases of a few percent each year, therefore the population is likely to be greater now than it has been for some time. However, due to the fact that *carbo* favours exposed and inaccessible breeding sites, monitoring colonies can pose formidable logistical challenges, and in comparison to *sinensis*, considerably less is known about the population trends of *carbo* across Europe as a whole (Wetlands International 2008). In 2003, the Wetlands International Cormorant Research Group

(WI-CRG) conducted a winter survey, which recorded 134,100 of the *carbo* subspecies in Europe. A comprehensive pan European survey is planned through the WI-CRG for 2012, which will assess densities and investigate trends of breeding and wintering populations of both *carbo* and *sinensis*.

Central and Eastern Europe, from the Czech Republic and Slovakia in the south to southern Sweden in the north is a traditional stronghold for the *sinensis* subspecies (Cramp and Simmons 1977). Due to the perceived impacts of Cormorants on fish stocks (Van Eerden and Gregersen 1995), during the 19th and 20th centuries Cormorants were heavily persecuted throughout Europe. This resulted in substantial population declines, even causing local extinctions of the *sinensis* subspecies in several countries (Herrmann *et al*., 2010). By the 1960s, the European population of *sinensis* was reduced to just 4,000 breeding pairs, approximately half of which occurred in Germany and Poland (Herrmann *et al*., 2010). Over the last 50 years however, the *sinensis* population has undergone a significant expansion from its epicentre in central Europe (Kohl 2010), with the continental population rising to an estimated 150,000 pairs in 1995 (Van Eerden and Gregersen 1995). The WI-CRG recorded 755,300 wintering birds across Europe in 2007, (including juveniles and non-breeders). The Baltic Sea population experienced an increase of 56% between 1959 and 1980 (Herrmann *et al*., 2010). In Finland, since their natural recolonisation in the mid 1990s, Cormorant numbers increased dramatically to almost 3,000 breeding pairs over a period of nine years, despite attempts to control the population (Lehikoinen 2006). In a compilation of data on breeding Cormorants throughout Europe, Kohl (2010) calculated that the *sinensis* population increased by a factor of 23 from 1970 to 2006, and it is now likely that the subspecies is more numerous than ever before (Carss *et al*., 2003). Despite measures adopted in several European countries to control Cormorant numbers, many of which are illegal, the increasing population trend is expected to continue (Sellers 2004). A range of potential factors is likely to have facilitated this population increase including; reduced harassment by humans at breeding colonies (MacDonald 1987; Sellers 2004; Van Eerden and Gregersen 1995), reduced use of harmful toxins (Herrmann *et al*., 2010; Lehikoinen 2006) and improved feeding conditions due to eutrophication and fishery practices (De Nie 1995; Lindell *et al*., 1995; MacDonald 1987). The majority of these factors affect the production of offspring, but have also facilitated the range expansion and the establishment of new breeding colonies (Suter 1995), and it is likely that the same factors increase survival in wintering areas (Carss and Ekins 2002; Cech *et al.*, 2008; Dirksen *et al*., 1995; MacDonald 1987; Suter 1995). Due to the increasing population trend, the Cormorant's current status in the European Union is now described as favourable (BirdLife International 2004). The *sinensis* subspecies has also been removed from Annex I of the Directive on the Protection of Wild Birds 1997 (European Union 1997).

1.1.1 Great Britain

The Cormorant breeding population has been surveyed at a national level in Britain through Operation Seafarer (1969-70), the Seabird Colony Register (SCR) (1985-88) and Seabird 2000 (1999-2002). The population remained stable (+0.5%) between Operation Seafarer (1969-70) and the SCR census (1985-88), but increased by 12% between the SCR census and Seabird 2000 (Sellers 2004). However, such modest changes on a national scale conceal the substantial shifts in abundance that occurred at regional levels over this period. Severe declines were observed in northern Scotland between Operation Seafarer and Seabird 2000, most likely influenced by human activities (Sellers 2004). These declines have however been counter balanced by increases in other parts of Scotland. In Wales, the population grew steadily between Operation Seafarer and the mid 1990's, at which point it levelled off, but subsequently declined by 25% between 1996 and Seabird 2000 (Sellers 2004). There was no recorded change in the number of coastal colonies in England between the SCR census (1985-88) and Seabird 2000; however, the growth of the population in England has been strongly influenced by the increased establishment of inland colonies. This has resulted in the English population growing by 15% since the SCR census (1985-88) (Sellers 2004). DEFRA (2003) report that the breeding population in the UK has experienced an increase of approximately 3% per annum in the period between 1987 and 1994 while the wintering population has increased more rapidly (5-10% per annum) over the same period. Since the 1960's there has been a gradually shift towards increased inland wintering (Kirby *et al*., 1996 Carss and Ekins 2002), prior to which, birds wintered almost exclusively on coasts and estuaries (Sellers 2004).

The recent population and range expansion of Cormorants in Great Britain can be partially explained by the influx of *sinensis. Carbo* is traditionally the only subspecies to occur in Great Britain (Cramp and Simmons 1977), however, DNA analysis has revealed that *sinensis* has become established and now breeds in parts of the southeast and midlands of England (Goostrey *et al*, 1998). The colonisation of *sinensis* in England, its range expansion and the resulting increases in inland colonies (Sellers 2004) is likely to have ramifications on how Cormorants are perceived by fishery interests. Inland breeding first occurred at the Abberton Reservoir in Essex in the southeast in 1981, since this time, the number of Cormorants breeding in inland colonies has increased dramatically (Sellers 2004). Between the SCR census (1985-88) and Seabird 2000, 26 new inland colonies were established, with two existing inland colonies, the Abberton Reservoir and the Paxton Pits each experiencing a substantial increases at an annual rate of 6.7% and 50.1% respectively. In 2000, 1,334 breeding pairs were recorded at 29 inland colonies in England (Sellers 2004). Newson *et al*., (2005) report that inland colonies have better breeding performance compared to their coastal nesting counterparts, suggesting a greater food

availability and a longer breeding period reduces food competition, therefore enhancing survival rates during late chick development.

The continued increase in inland colonies (both establishment of new colonies and increases in numbers at existing colonies) is fuelled by recruitment of *sinensis* from mainland Europe (Carss and Ekins 2002). It is likely that some inland colonies in England were initially established by *sinensis* birds and were subsequently joined by *carbo* birds from other colonies (Sellers 2004). Carss and Ekins (2002) have shown that the two subspecies can co-inhabit the same breeding colony and are likely to be hybridising. Inland breeding colonies occur at sites that have previously been used as winter roost sites (Worden *et al*., 2004), and as there are high numbers of birds wintering in inland areas, further inland colony formation is expected in Britain (Carss and Ekins 2002; Kirby *et al*., 1996; Sellers 2004).

Colony formation and expansion in Britain appears to be fundamentally different to the continent, suggesting that inland breeding birds in south west England may be limited, not by breeding sites, but by the availability of good quality, large water bodies (Carss and Ekins 2002). Worden *et al*. (2004) highlighted a southeastern bias in the distribution of inland winter roost sites in Britain, citing the distribution of gravel pits, which make suitable nest sites, as the main reason for this. Carss and Ekins (2002) reported that maximum colony size on the continent is larger than in Britain, suggesting a less productive foraging environment in Britain and, as a result, the formation of smaller colonies situated close to lowland rivers and lakes. However, in a large colony on an artificial lake in the north east of Italy, Grieco (1999) recorded a colony expansion in a year of markedly poor prey abundance, prompting the author to suggest that the availability of suitable nest sites is a better predictor of colony growth than estimates of potential prey density.

1.2.2 Ireland

Although the range of *Phalacrocorax carbo sinensis* is currently expanding throughout Europe, it has not yet been recorded as far west as Ireland, meaning *Phalacrocorax carbo carbo* is the only subspecies that is known to occur here (Cramp and Simmons 1977). Similar to Great Britain, the breeding Cormorant population in Ireland has been surveyed at a national level through Operation Seafarer (1969-70), the Seabird Colony Register (SCR) (1985-88) and Seabird 2000 (1999-02). In the 2010 breeding season, the National Parks and Wildlife Service (NPWS) conducted a census of known colonies, which included 20 colonies, the majority of which were coastal colonies along the west coast, the unpublished results of which have been provided to BirdWatch Ireland (BWI).

Image 1.1 *Tree nesting colony at Loughahalia*

Seabird 2000 derived a population estimate of 5,211 apparently occupied nests (AON) in Ireland, which accounts for 0.9% of the world population of Great Cormorants and 10% of the *carbo* subspecies' population (Sellers 2004). Of all pairs recorded as part of this survey, 475 were located at five inland colonies (Sellers 2004). Although the nationwide population has experienced a general increase in recent times, trends have varied significantly on a regional basis between the SCR (1985-88) and Seabird 2000 (1999-02), with individual colonies experiencing substantial declines, others remaining constant and other colonies experiencing rapid growth. A traditional colony on the off shore Duvillaun islands, County Mayo experienced declines of 14.5% a year between the SCR Census and Seabird 2000. There were notable declines on the south and west coasts also, particularly in counties Waterford, Wexford, Cork, Galway and Mayo over this period. Lambay Island in County Dublin was the largest recorded colony in Britain and Ireland across both the SCR Census and Seabird 2000, with 1,027 and 675 AONs, respectively. At the time of the SCR Census, Lambay Island supported 98% of all breeding Cormorants on the east coast of Ireland, but by 2011, just 21% of breeding birds known to breed on the east coast were nesting on Lambay Island. As the numbers at this colony declined, two nearby colonies (St. Patrick's Island and Ireland's Eye) expanded, and a new colony (Bray Head) was established (Fig. 1.1).

The four east coast colonies were included in the NPWS census in 2010 and were also surveyed by Cormorant researchers during the chick-rearing period of the 2011 breeding season. The total estimate of AONs for the four colonies was 1,447 in 2010, which increased to 1,649 in 2011. The St. Patrick's Island colony in County Dublin was established in the 1990's, with 558 AONs recorded during Seabird 2000. Ireland's Eye colony in County Dublin has expanded from and 19 to 306 AONs between the SCR census (1985-88) and Seabird 2000. Each of these colonies has experienced further increases since Seabird 2000. St. Patrick's Island had 544 AON in 2010 (as recorded by the NPWS census in 2010) and 819 AON in 2011 (Tom Kealy and Chris Honan, *pers. comm*.). The colony on Ireland's Eye increased to 478 AONs in 2010 (unpublished results from NPWS census 2010) and 417 AON were recorded in 2011 (Oscar J. Merne and Tom Kealy, pers. comm.). Bray head in County Wicklow colony, which was first recorded in 2009, supported 62 AONs in 2010 and 2011 (Oscar J. Merne, *pers. comm*.). Therefore, although the number of breeding Cormorants on Lambay Island has decreased by 66%, the overall number of breeding Cormorants on the east coast of Ireland has increased by 58% between the SCR census (1985-88) and 2011. The 47% increase on the east coast between the SCR census (1985-88) and Seabird 2000 has been followed by a slower increase of 7% over the 1999-2011 period. Figure 1.1 below shows the relative expansions and decreases of these colonies.

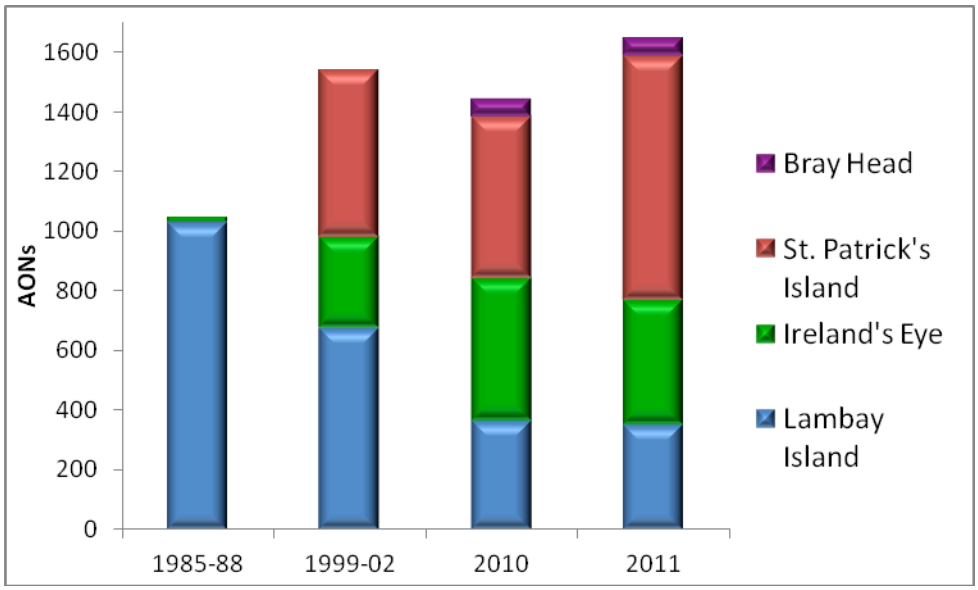


Figure 1.1. *Changes in Cormorant breeding numbers at four colonies on the east coast of Ireland between 1985 and 2011. AON = apparently occupied nests; 1985-88=SCR Census, 1999-02=Seabird 2000, 2010=NPWS Cormorant Colony Census, 2011= data from independent Cormorant researchers.*

Preliminary results from the recent Breeding Bird Atlas (2007-11), shows that breeding Cormorants were recorded in 9.5% of 10km squares in Ireland, with birds recorded in 58.3% of the 10km squares (Fig. 1.2). The number of 10km squares occupied in the breeding season has therefore increased by 92% since the first breeding Atlas (1968-1972) (Sharrock, 1976) and declined by 22% since the second breeding Atlas (1988-1991) (Gibbons *et al*., 1993). The breeding range change map below (Fig. 1.3) shows the changes in breeding distribution throughout Ireland over the past 20 years.

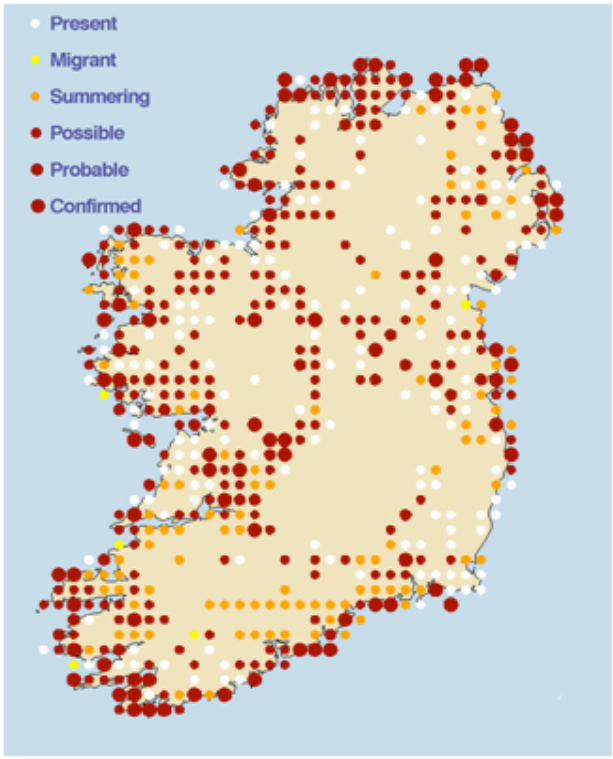


Figure 1.2. *Preliminary Breeding Bird Atlas data showing the Distribution of Cormorants in Ireland during the 2008-2011 breeding seasons (April-July).*

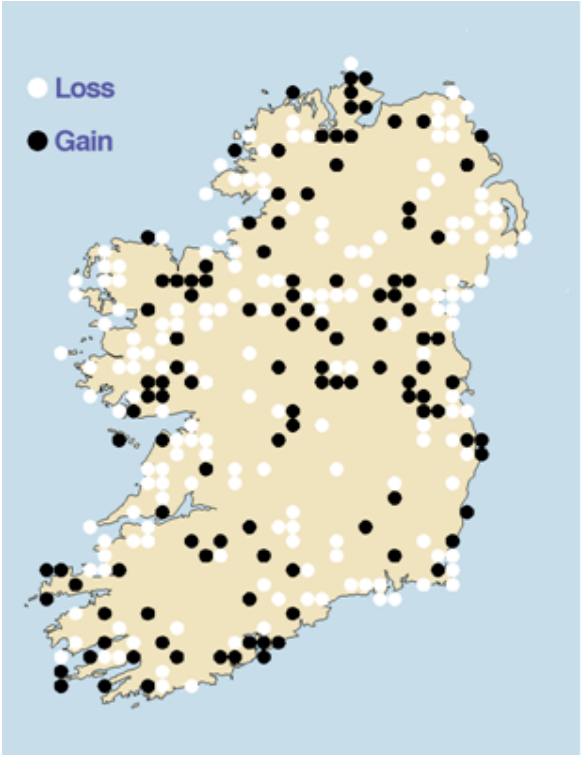


Figure 1.3. *Changes in Cormorant breeding season distribution between the 1988-91 Atlas of Breeding Birds and the 2007-2011 Atlas.*

Historically, Cormorants in Ireland have been regarded as coastal birds, with the preferred nesting habitat being sea cliffs, stacks and rocky offshore islands (Debout *et al*., 1995). However, in the last 50 years, there have been significant changes in Cormorant distribution, with birds dispersing to inland wintering quarters, and in some cases, breeding inland (Sellers 2004). Of 77 breeding colonies surveyed in 1985 by MacDonald (1987), the majority were in marine environments, with 44.5% on maritime islands, 36.5% on mainland coasts and the remaining 19% on islands on freshwater lakes (MacDonald 1987). Ninety percent of the breeding colonies recorded in Seabird 2000 in Ireland were on the coast, and although these colonies are distributed around the country, there was a distinct western bias (Sellers 2004). During Seabird 2000, 8% of the 63 colonies surveyed were inland. Two inland colonies on Lough Derg were surveyed during the SCR census (1985-88) and Seabird 2000, showing their numbers remained relatively stable at a combined 112 AON compared to 125 AON respectively. Another inland colony on Lough Cutra, in Co. Galway, had 166 AON in 1985 however monitoring conducted as part of this project revealed that this colony has been recently abandoned.

The All-Ireland wintering population has risen from 10,500 birds recorded in the 1980's to 14,800 in the 1990's, and this continuing to increase (Crowe 2005). The Irish Wetlands Bird Survey (I-WeBS) records wintering Cormorants on a monthly basis at a large sample of wetlands, and a population index derived from this data shows a 24% increase for the 1996 to 2000 period (Crowe 2005). Wintering Cormorants in Ireland are widely distributed (Fig. 1.4), particularly along the south and east coasts and north midlands, with up to 16% of birds occurring along non-estuarine coastline (Crowe 2005).

Cormorants are highly faithful to their wintering sites (Sellers 2004). The number of Cormorants at coastal sites generally peaks in August and September, as birds arrive from breeding areas, and then numbers decline as they disperse further inland as the winter progresses (Crowe 2005). The numbers inland increase from autumn onwards and are maintained until birds begin to return to breeding colonies in spring (MacDonald 1987). Preliminary results from the latest winter Bird Atlas (2007-10), shows that birds were present in 77.5% of 10km squares during the non-breeding season (Fig. 1.4). The number of 10km squares occupied has therefore increased by 22% since the last Atlas (1981-1984) (Lack, 1986) (Fig 1.5).

Figure 1.4. *Preliminary results from the 2007- 2010 Winter Atlas showing the distribution of wintering Cormorants during (November-February).*

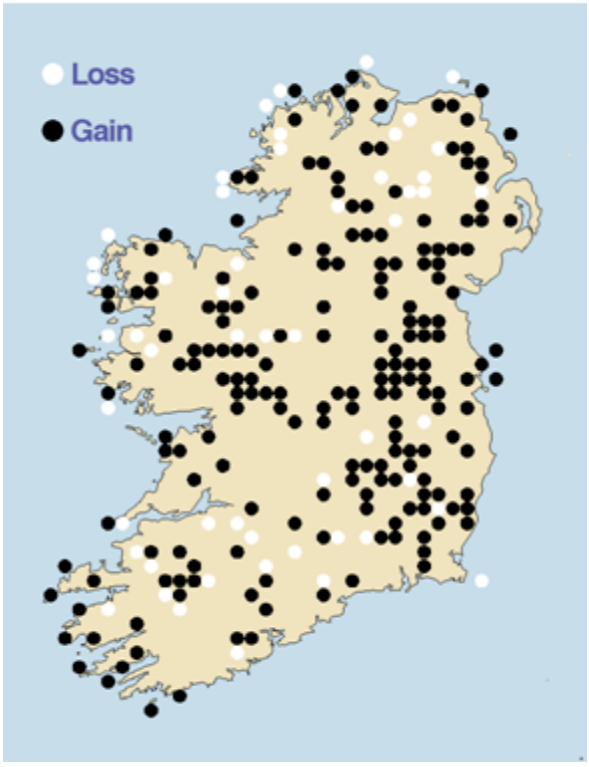


Figure 1.5. *Changes in the distribution of wintering Cormorants between the first Atlas of wintering birds (1981-84) and the 2007-2011 Winter Atlas.*

1.2 Factors influencing the population expansion

There have been a number of factors implicated in the substantial increases in the Cormorant breeding population and expansion in range across Europe over last 40 years.

1.2.1 Increased protection

Reduced persecution is likely to be one of the main driving forces behind the expansion of Cormorant populations in Europe (Carss 2003; MacDonald 1987; Sellers 2004; Wetlands International Cormorant Research Group 2008). The population had been subdued due to intense and widespread persecution in the 19th century and the first two thirds of the last century (Cramp and Simmons 1977; Debout *et al*., 1995). In Ireland, under the government-run bounty scheme, 3,527 Cormorants were shot between 1973 and the implementation of the Wildlife Act in 1976 (MacDonald 1987). The European population has increased and expanded with the implementation of protective measures, which were first introduced in the Netherlands in 1965.

The ensuing recovery coincided with the protection of Cormorants under the EC Bird Directive (1979) (van Eerden and Gregersen 1995). Undoubtedly, this directive along with other legalisation such as the Bern Convention on the Conservation of European Wildlife and Natural Habitats, the Bonn Convention on the Conservation of Migratory Species of Wild Animals and the Ramsar Convention on Wetlands of International Importance have been pivotal in facilitating the population expansion (Carss 2003).

1.2.2 Increased stocking

The greater availability of prey at inland water bodies, through fish stocking, is also likely to be an important factor that has facilitated the Cormorant population increase and expansion (Carss 2003; DEFRA 2003; Kirby *et al*., 1996; MacDonald 1987; Sellers 2004; van Eerden and Gregersen 1995; Warke and Day 1995; Wetlands International Cormorant Research Group 2008). Sellers (2004) speculates that increased stocking on inland waters in Britain and Ireland, and the depletion of stocks in coastal waters are likely to have influenced the behavioural shift to inland wintering from the 1980s onwards.

Large-scale manipulation of predator-prey relationships, such as the removal of Pike *Esox lucius*, or the stocking of lakes with salmonids, or other species, has significant consequences for the fish communities and the predator prey relationships concerned. For instance, Gargan (1986) reports that the removal of Pike from Lough Sheelin, Co. Westmeath, resulted in the Perch *Perca fluviatilis* population exploding in the mid 1970's. Perch is an important component of Cormorant winter diet (Cech *et al*., 2008; Dirksen *et al*., 1995; Suter 1997). MacDonald (1987) showed that Perch were the second most important prey item for Cormorants wintering on the Midland lakes (Lough Sheelin, Lough Ramor, Lough Derravaragh, Lough Owel and Lough Ennell), representing over half of the diet, and becoming the most important prey item in spring.

In Ireland, the spread of Roach *Rutilus rutilus* has been linked to the increased usage of inland waters by Cormorants in winter. MacDonald (1987) noted that the Erne and Shannon catchments, where Roach is abundant, are also the areas with the highest numbers of wintering Cormorants, and predicted that the expansion of the Roach population would be mirrored by the number of Cormorants wintering inland. Roach have been present in the midland lakes since 1979, and in late winter a study has shown this species to represent over 80% of Cormorant diet (Macdonald 1987). This coincides with a time when other potential prey such as Perch and Brown Trout *Salmo trutta* are less active and therefore less available for foraging Cormorants. Roach is an integral part of the winter diet of many European Cormorant populations (Carss and Ekins 2002; Cech *et al*., 2008; Santoul *et al*., 2004; Suter 1997; Veldkamp 1995) and is likely to play an important role in increasing over-winter survival in the Irish context (MacDonald 1987).

Although the ultimate outcome of the gradual shift to inland wintering is not fully understood, it is intuitive that this process, through benefitting overwintering survival, is likely to have influenced the increases in the inland breeding population, and is likely to continue to do so.

1.2.3 Eutrophication

Enrichment with nitrates and phosphates increases primary and secondary production in the aquatic ecosystems, which results in an increase in the abundance of suitable prey species for Cormorants (De Nie 1995). Therefore, the increased eutrophication of coastal and freshwater areas is likely to have been an important factor in the expansion of Cormorant populations (Carss 2003; Engstrom 2001; Herrmann *et al*., 2008; Lehinoinen 2006; van Eerden and Gregersen 1995). Cormorant distribution is, at least in part, determined by the nutrient status of the water body (Carss 2003). Inland breeding Cormorants in Britain exhibit a habitat preference for eutrophic lakes (Carss and Ekins 2002). In Sweden, phosphorous levels in lakes are a reliable predictor of the number of Cormorants that the lake supports (Engstrom 2001). In the Baltic countries, Hermann *et al*. (2008) found that Cormorant populations with the greatest densities occurred around eutrophic estuaries. In Switzerland, Suter (1995) discovered that Cormorant density strongly correlates with the level of eutrophication in the lake and suggests that this is due to the resulting increased biomass of cyprinid and percid fish. Van Eerden and Gregersen (1995) also found a positive correlation between the density of breeding Cormorants and eutrophic freshwater habitats in the Netherlands.

1.2.4 Disuse of toxins

The disuse or decreased use of certain pesticides, which previously reduced Cormorant fecundity, is likely to have had a strong positive effect on Cormorant populations (Carss 2003; WI-CRG 2008). During the 1960's and 1970's, the population development in Baltic countries was stunted by the use of harmful chemicals such as DDT and PCB (Herrmann *et al*., 2010), but since the banning of such chemicals the population has increased and expanded (Lehikoinen 2006). The reduction of heavy industry in central and Eastern Europe has also lead to reductions in aquatic pollution and a recovery of fish populations (Carss 2003) and the decreased use of pesticides have lead to an improvement of foraging conditions, all of which have benefited Cormorants and facilitated population expansion.

1.3 Diet

1.3.1 Methods for assessing diet

A diversity of methods have been employed to assess the diet of Cormorants throughout their range. Pellet analysis, which involves the identification of diagnostic bones of consumed prey is one method that is commonly used (Dirksen *et al*., 1995; Lorentsen *et al*., 2004; Platteeuw and van Eerden 1995; van Eerden and Voslamber 1995; Warke and Day 1995). Cormorants generally regurgitate a single pellet on a daily basis, which can be collected from accessible loafing, roosting and breeding sites for analysis and determination of the prey species within (Carss *et al*., 1997; Duffy and Laurenson 1983; Zijlstra and van Eerden 1995). Visits to breeding colonies to collect nestling regurgitates (which tend to cast recently consumed prey when handled) has also been effectively used to determine diet during the breeding season (Lorentsen *et al*., 2004; Van Dobben 1995; Veldkamp 1995a; Warke and Day 1995).

Analysis of the stomach contents of Cormorant carcasses has facilitated a detailed understanding of aspects of prey consumption and selection (Alexanserson 2006; Carss 1993; Kennedy and Greer 1998; Warke and Day 1995). This method has also been used on live birds via a process known as "water offloading" which involves repeated flushing of the stomach of a trapped Cormorant with warm water, which forces the bird to expel its entire stomach contents (Robertson *et al*., 1994 and Neves *et al*., 2006). Direct visual observations of foraging birds has also allowed researchers to record specific information on Cormorant foraging behaviour and prey selection (Engstrom 2001; Grémillet *et al.*, 2006; MacDonald 1987; Russell *et al*., 2008; Voslamber *et al*., 1995). In recent years measurements of protein stable isotope signatures has provided a means to understand dietary inputs and trophic relationships. Stable isotope ratios in consumers reflect those in their diets, by calculating the isotopic signatures of Cormorant tissues, information on their prey can be deduced (Peterson and Fry 1987). Stable isotope analysis has facilitated robust determination of the proportions of Cormorant diet that originates from freshwater and marine environments (Bearhop *et al*., 1999).

Due to biases associated with different methods of assessing Cormorant diet, comparing dietary studies is not straightforward. Carss *et al*., (1997) provides a comprehensive review of diet assessment methods and discusses the advantages and disadvantages associated with each.

Pellets

Cormorants regurgitate mucous-covered pellets, which contain the indigestible remains of consumed fish on a daily basis. Pellets represent attractive sampling units, which can be collected

in relatively large numbers at roosts and breeding colonies, with little disturbance to the birds (Ziljlstra and van Eerden 1995). Analysis is relatively straightforward, requiring minimal laboratory facilities (Carss *et al*., 1997) and therefore this method has been widely used to determine Cormorant diet throughout the species' range. Analysis techniques require separation of the undigested bones from the mucous and subsequent categorisation of specific bones to family or species level using reference collections and keys. Otoliths, are hard structures situated in the inner ear of the fish, there are considerable differences in otolith dimensions even in closely related species (Hunt 1992), and therefore these are the primary diagnostic bones for identification (Harkonen 1986). By inputting the length of the otolith or pharyngeal bone into a species-specific regression equation, the length and mass of the fish can also be estimated (Doornbos 1980 cited in Veldkamp 1995a). Vertebrae, pharyngeal bones and other skeletal elements are also useful for species identification (Dirksen *et al*., 1995).

Many studies have used pellet analysis to investigate the feeding ecology of Cormorants (Cech 2008; Dirksen *et al*., 1995; Engstrom 2001; Johanson *et al*., 2001; Leopold and Van Damme 2003; Lorentsen *et al*., 2004; Platteeuw and Van Eerden 1995; Santoul *et al*., 2004; Suter 1997; Veldkamp 1995b; Warke and Day 1995) and other seabirds, including Shags *Phalacrocorax aristolelis* (Alverez, 1998; Harris and Wanless, 1993), Imperial Cormorants *Phalocrocorax atriceps* (Punta *et al.*, 1993), Double-crested Cormorants *Phalacrocorax auritus* (Ross and Johnson 1997) and Great Skuas *Stercorarius skua* (Bearhop *et al*., 2001).

However, there are a number of biases associated with this method (Carss *et al*., 1997). While pellet analysis can provide a rough index of the relative importance of prey species over time (Votier *et al*., 2003), it is not suitable for determining quantitative aspects of the diet, such as daily food intake (Carss *et al*., 1997). Research on captive Cape Cormorants *Phalacrocorax capensis* by Duffy and Laurenson (1983) revealed that regurgitated pellets provide little information on the daily intake of fish, as two thirds of otoliths are either completely digested or defecated. Similarly, Ziljlstra and van Eerden (1995) report that, in captive feeding experiments, only 52% of otoliths that were fed to the Cormorants were subsequently recovered from pellets. This shortcoming therefore limits the use of this type of analysis for investigations into the quantitative analyses of diet. Ziljlstra and van Eerden (1995) also indicated that otoliths were recovered from only 15% of pellets when small fish (<10cm) were fed to the Cormorants. This highlights a considerable bias for representation of larger fish species in the diet. However, such biases can be reduced by incorporating the identification of other diagnostic bones in conjunction with otoliths (Dirksen *et al*., 1995).

Otoliths of different sizes and from different species are also know to degrade at varying speeds. This erosion process is determined by a number of factors such as; time in the stomach, acidity of digestive enzymes, the species of fish, the surface area/volume ratio of the bone, the rate of gastric emptying and the ambient temperature (Alexandersson 2006). A study by Duffy and Laurenson (1983) showed that otoliths are reduced in size by at least 25% from the time of ingestion to pellet production, and cautioned that species-specific correction factors for wear must be applied before the size of fish can be accurately estimated. Furthermore, hard parts recovered from pellets may include those from secondary predation, but may be assumed erroneously to be prey which Cormorants have directly consumed (Carss *et al*., 1997).
Cormorants do not produce pellets in their first two months, and they are at least seven months old before they begin to produce pellets at a rate of roughly one per day (Trauttmansdorff and Wassermann 1995). Therefore pellets collected at winter roosts are likely to under represent the diet of first-winter birds. Pellet production is unlikely to be constant throughout the year, Harris and Wanless (1993) found that, in European Shags, pellets are not produced by chick-rearing adults. Therefore, caution is advised when collecting pellets at breeding colonies, as a proportion of the fresh pellets may have been cast by non-breeding birds, which due to variation in dietary requirements, may have a significantly different diet. In Shags, non-breeding and failed breeders consumed a wider spectrum of prey compared to nestlings (Harris and Wanless 1993).

Alexandersson (2006) compared the use of otoliths obtained from regurgitated pellets and stomachs of shot birds as a means of studying Cormorant diet, and concluded that there was a significant difference between the two methods, with the analysis of stomach contents being superior to the analysis of regurgitated pellets. As part of this study, otoliths were divided into three classes of wear; ranging from those with no signs of erosion to those that were highly eroded and lacking diagnostic characteristics. This study showed that the majority of otoliths that were recovered from pellets were those that were highly eroded. Furthermore, the majority of otoliths that were too badly degraded to identify were found in pellets.

Nestling Regurgitates

Nestling regurgitates have been used to assess diet composition of Cormorants in a number of studies (Van Dobben 1995; Veldkamp 1995a; Veldkamp 1995b; Warke and Day 1995), Shags (Harris and Wanless 1993) and Great Skuas (Bearhop *et al*., 2001). In some cases, regurgitated fish are relatively intact, and therefore can simply be indentified to species level by the examination of external features (Warke and Day 1995). Well-digested items can be identified by analysis of diagnostic bones using the same methods as described above for pellet analysis.

One significant drawback with this method is that it can only be undertaken during the chick-rearing period (Veldkamp 1995b) and requires visits to colonies, which can be inaccessible and also require specific licenses. Other factors that are likely to limit the applications of this technique are the differential rate of digestion between fish species, the ease at which different prey are regurgitated (e.g. a Bream *Abramis brama* which has smooth skin is likely to be more easily regurgitated compared with a Perch *Perca fluviatilus* which has spiny scales) (Veldkamp 1995b), and the fact that adults may have different diets to nestlings (Harris and Wanless 1993).

Stomach contents

Recently consumed prey can be assessed by dissecting the stomachs of dead birds, or by flushing the stomachs of live birds using a water off-loading technique (Robertson *et al*., 1994; Neves *et al*., 2006). Some of the biases associated with well-digested items in pellet analysis can be avoided with this method, as the fresh and relatively undigested prey is easily distinguishable from well-digested items (Carss *et al*., 1997). In addition, with this method, information on prey type and size can be linked to the bird's foraging location, provided the bird is shot while foraging. Other information such as the body condition, weight, age, sex and parasite load of the birds can also be obtained (Carss, *et al*., 1997) as well as samples necessary for stable isotope analysis. The analysis of stomach contents of birds which have been shot has been used to investigate the impact of Cormorants (Kennedy and Greer 1988, Warke and Day 1995) and Goosanders *Mergus merganser* (Kalas *et al*., 1993) on salmonids during their seaward migration.

The calculation of daily food intake is, again, not straightforward with this type of analysis, as it is generally not possible to predict if the bird had ceased foraging for the day when the carcass is recovered (Carss *et al*., 1997). Furthermore, maximum values are influenced by the subjective judgement of what amount of prey a "full" stomach would contain. However, the main disadvantage associated with this method is that it relies on shooting birds (or catching birds for stomach flushing), and this means that samples sizes tend to be small. A proportion of birds may have empty stomachs when they are shot (see Kennedy and Greer 1998; Warke and Day 1995), which can reduce the sample size further. Carss *et al*., (1997) also point out that Cormorants foraging in a certain area may be more vulnerable to shooting, which could lead to a biased result. The same issues relating to differential digestion rates between fish species and sizes, as detailed above for pellet analysis, are also present with this method of assessment (Carss *et al*., 1997).

Direct observations

Feeding observations have been used as a means of assessing the diet of seabirds, but this method has not been widely used on Cormorants (Carss *et al*., 1997). Direct observation can yield useful

information, as long as all associated biases are considered. This method is non-destructive, non-invasive and involves minimal disturbance to the birds. In theory, the type and frequency of prey caught can be linked to specific foraging areas, which is not possible with other diet assessment techniques. Supplementary information on diving behaviour can also be collected, which can be used to estimate catch per unit effort to demonstrate foraging efficiency (see Grémillet 1997).
Kalas *et al*., (1993) observed foraging Goosanders using focal animal sampling to record dive frequency and the proportion of successful dives. Voslamber *et al*., (1995) employed this method to investigate the size and species of prey caught by solitary foraging Cormorants in Lake Ijsselmeer in the Netherlands. The proportion of successful dives, along with the dive time and depth, were recorded by focal animal sampling from both the lakeshore and a boat. The authors of both studies acknowledge that since some proportion of prey is likely to be swallowed beneath the surface, any estimates of food intake are likely to be underestimated.

There are a number of other biases associated with this technique. Many Cormorant studies take place on large water bodies, making this approach impractical due to the distance between the observer and the focal bird. Birds foraging closest to the observer make attractive focal birds, as the chances of identifying and sizing prey species is greater in comparison to foraging birds at greater distances from the observer. This is likely to lead to a bias towards prey types that occur in inshore areas (Carss *et al*., 1997).

Regardless of the distance between the observer and the subject, some species are more easily identified than others, and species with longer handling times are more likely to be over represented, while smaller prey are likely to be missed altogether, especially if swallowed beneath the surface (Voslamber *et al*., 1995). Cormorants often surface, apparently without a fish, but still display behaviours such as head shaking, throat fluttering, gaping or drinking (pers. obs.), implying that they have just swallowed a fish. The frequency with which Cormorants swallow fish underwater has not been quantified, therefore observations of prey intake rates are likely to be underestimated. The accuracy at which prey size can be measured, even using the bird's bill as a reference, is questionable, and the potential for inter-observer variability is high (Carss *et al*., 1997). Daily food intake cannot be estimated using this method, as even if a bird could be observed over the course of a day, and every prey item accurately identified and correctly sized, the number of fish swallowed below the surface would remain unknown (Carss *et al*., 1997).

Stable Isotope Analysis

Stable isotope analysis is a valuable tool for understanding trophic relationships and dietary inputs; it also overcomes specific biases associated with other dietary analyses (Bearhop *et al*.,

1999). The isotopic signatures in predator tissues reflect those of its prey, with the signatures of the proteins of animals in marine environments being markedly different to those found in freshwater environments (Bearhop *et al*., 1999). This allows the proportion of a Cormorant's diet derived from marine and freshwater sources to be determined. As the $\delta^{13}C$ and $\delta^{15}N$ signatures of feather keratin reflect that of their prey at the time of feather growth, knowledge of the pattern and timing of the moult therefore facilitates an assessment of the diet over the period of the bird's moult (Thompson and Furness 1995). Bearhop *et al*., (1999) collected feather samples from Cormorants feeding at inland freshwater fisheries in England, and compared carbon and nitrogen levels with piscivorous birds with both marine (captive marine-fed Cormorants, free-ranging Shags) and freshwater diets (Goosanders). The analysis indicated that Cormorants had an exclusively freshwater diet during the winter months. Primary feathers were taken to assess the bird's diet in the days preceding sampling. Recently developed primaries were used to assess diet 2-8 weeks previously (as primary feathers take approximately one month to grow). Lesser coverts were used to derive information on diet over the period from June to November, as body feathers are replaced during this time (Ginn and Melville 2007). Similarly, Mizutani *et al*., (1990) collected naturally shed primary feathers from adult Cormorants for a full year and worked out the proportion of the diet that came from freshwater and marine environments. This analysis has been used to reconstruct the diets of a variety of other seabirds including Great Skuas *(*Bearhop *et al*., 2001) and Yellow-legged Gulls *Larus michahellis (*Moreno *et al., 2010).*The last decade has seen major enhancements in stable isotope analysis, with the development of multi source and Bayesian isotopic mixing models with fewer restrictions and more input variables, which leads to robust quantifications of feeding preferences (Moreno *et al*., 2010). Bearhop *et al*., (2001) advocates the combined use of conventional techniques with stable isotopes to elucidate differences in diet.

1.3.2 Daily food intake

A Cormorant's energetic requirement, and hence their daily food intake, is governed by a number of biotic and abiotic factors, including weather conditions, water temperature, water depth, foraging distances travelled, availability and quality of prey and stage of reproductive cycle (Grémillet *et al*., 2003). This makes it impossible to generalise daily food intake between locations or seasons, and makes predictions of Cormorant impact on fish populations difficult to quantify (Grémillet *et al*., 2003). Initial research on Cormorant daily food intake claimed that birds consumed twice their body weight in fish each day (Robinson 1925; Ward 1919; cited in MacDonald 1987); however, Van Dobben (1952) later proved this to be false, finding that it varied between 425 and 700g/day, which equates to 15-17% of body weight. More recently, many studies have calculated daily food intake using a variety of methods. Johanson *et al*., (2001)

estimated daily food intake by assuming that fish mass per pellet equalled one day's consumption. However, as previously discussed, there are many limitations associated with pellet analysis, which would influence such estimations (Carss *et al*., 1997; Zijlstra and van Eerden 1995). In The Netherlands, Dirksen *et al*., (1995) used mean fish mass per pellet as a proxy for daily food intake and reported a range of 146 to 699g, with consumption being lowest in August and September and highest in October. It is suggested that this is due to the fact that many of the birds are inexperienced and not efficient at foraging which impacts the findings, coupled with the fact that a large proportion of the available fish are also young at this time of year, and therefore small in size. The authors posit that the rise in daily food intake from October occurs as both the birds and the fish are older, the birds having become more efficient at foraging, and the fish having increased in size. Furthermore, the necessity to build reserves for the approaching winter is also likely to influence the biomass of prey ingested per day in October. The biomass of fish per pellet increases steadily from December to March in preparation for the increased energetic demands of the breeding season (Dirksen *et al*., 1995).

Warke *et al*., (1994) speculated that the daily food intake of a breeding adult at a coastal colony in Northern Ireland would be significantly higher than the 560g calculated for the November to March period considering the energetically expensive commuting distance of over 60km to the main feeding site. Grémillet *et al*., (2003) used radio-tracking data, metabolic measurements from captive birds and published data to calculate a daily food intake of 672g (range 441–1095g) for Cormorants wintering at Loch Leven, in Scotland. This value corresponds to 21% of the bird's body mass (range 14–34%), and is in line with values calculated for a wide range of aquatic seabirds. Using an automatic weighing system, which recorded adult weight before and after foraging trips, Grémillet *et al*., (1997) calculated mean daily food intake for breeding Cormorants on the Chausey Islands, France to be 828g, and found this value to be positively correlated to brood biomass.

Grémillet *et al*., (1995) used a time-energy budget model to calculate the food requirements of breeding Cormorants in Germany. The output was a daily food intake of 238g for incubating birds, 316g for birds with small chicks, and 588g for birds rearing downy chicks and the authors concluded that the increase in daily food intake during the breeding season is related to the increased demands of a brood. As a variety of methods have been used to calculate the values listed above, in addition to the fact that studies were carried out in a diversity of conditions which affect factors such as ambient and water temperature, and different prey availability, it is not surprising that a varying range of values have been reported. However, the various findings provide sufficient data to give a reasonably accurate approximation of daily food intake.

1.3.3 Diet in Europe

In Europe Cormorant diet has been extensively studied, showing the species to exploit a broad range of fish, and a tendency to select those species which are locally and temporally abundant (Alexanserson 2006; Bearhop *et al*., 1999; Carss *et al*., 1993; Carss and Ekins 2002; Cech *et al*., 2008; Dirksen *et al*., 1995; Engstrom 2001; Grémillet 1997; Grémillet *et al*., 1995; 2003; 2004; 2006b; Johansen *et al*., 2001; Lehikoinen 2006; Leopold and Van Damme 2003; Lorentsen *et al*., 2004; Platteeuw and van Eerden 1995; Santoul *et al*., 2004; Suter 1995; Suter 1997; Van Dobben 1995; Veldkamp 1995a; 1995b; Voslamber *et al*., 1995). As a result, these studies have shown that Cormorant diet varies considerably, influenced primarily by geographical and seasonal factors. Cyprinids and Percids are prominent in many of the studies (Cech *et al*., 2008; Dirksen *et al*., 1995; Santoul *et al*., 2004; Suter *et al*., 1997; Veldkamp 1995a; 1995b), with Gadoids dominating in others (Johanson *et al*., 2001; Lorentsen *et al*., 2004).

Using over 600 diet samples (62.2% chick regurgitations, 3.6% whole fish, and 34.2% pellets), collected during the chick-rearing stage of the breeding season, Lorensten *et al*. (2004) reconstructed the diet at a Norwegian coastal colony, showing that of the 18 recorded species that comprised the diet, Gadoids (mainly Cod *Gadus morhua* and Saithe *Pollachius virens*) dominated (75% numerically). Similarly, Johanson *et al*., (2001) found, on the Norwegian coast, that the non-breeding season diet was almost exclusively gadoids, predominantly Cod, which made up 86% of the diet by biomass.

On two adjacent freshwater lakes in the Netherlands, Dirksen *et al*., (1995) found that the most important prey items, by biomass, were percids including Ruffe *Gymnocephalus cernua*, Perch and Pikeperch *Sander lucioperca*, in the non-breeding season. At a large winter roost on the Garonne River in France, Santoul *et al*., (2004) discovered that, of the 14 fish species represented in pellets, 90% were cyprinids. Bream dominated the diet, with other important species including Rudd *Scardinius erythrophthalmus*, Silver Bream *Blicca bjoerkna*, Roach *Rutilus rutilus* and Pikeperch. In a summary of all the Cormorant diet work conducted on wintering birds in Switzerland, Suter *et al*., (1997) reported that although 23 fish species were previously recorded, just seven of these account for 95%. Fifty eight percent of all samples contained the remains of Roach, and together with Perch, these two species accounted for 65% numerically.

An analysis of the diet composition at the inland Abberton breeding colony in south west England revealed that the diet is similar to that of breeding Cormorants in Denmark (Carss and Ekins 2002). The authors report that Eel *Anguilla anguilla* was the most prevalent prey item, representing 46.6% of the diet by biomass, and that most Eels taken were >35cm in length. The

other important prey items were flatfish (14.9%) and salmonids (13.6%), which were predominantly Rainbow Trout *Oncorhynchus mykiss*. The relative proportion of freshwater fish in the diet decreased as the breeding season progressed. Carss and Ekins (2002) also reported that birds breeding at inland colonies favour marine species, if they are within suitable commuting distance from the sea. Platteeuw and Van Eerden (1995) consider 20km to be the upper limit on the distance that breeding birds can fly to foraging grounds while maintaining an energetic balance. The two other colonies, Little Paxton (Cambridgeshire) and Besthorpe (Nottinghamshire) investigated by Carss and Ekins (2002), which are both over 60km from the coast had an exclusively freshwater diet, which was dominated by cyprinids, particularly Roach.
Bearhop *et al*., (1999) used feathers from Cormorants shot under licence in England during the winters of 1994-95 and 1995-96 to investigate the birds' diets using stable isotope analysis. It emerged that the diet in June to November comprised of equal proportions of marine and freshwater fish, but at wintering sites, Cormorants fed exclusively on freshwater fish. The authors suggested that this was because Cormorants switch from a fully marine diet during the breeding season to a wholly freshwater diet at wintering quarters. However, in Northern Ireland, Warke *et al*., (1994) found no evidence of a seasonal shift in habitat preference. Suter (1997) also reported minimal seasonal variation in Switzerland in Roach-dominated diets, but recorded a strong seasonal variation in diet at other sites. The $\delta^{13}C$ signatures of six of the twenty-one birds analysed by Bearhop *et al*. (1999) indicated that they had fed exclusively on freshwater fish from June to November, meaning that they may have come from inland breeding sites.

In the Czech Republic, Cech *et al*., (2008) collected pellets from roosts at two freshwater sites over the course of a summer, a warm winter and a cold winter. Eleven fish species made up the summer diet, with Roach, Bream, Bleak and Perch representing 97.4% (in terms of frequency) of the diet. The warm winter diet comprised of 17 fish species, with Roach, Bream, Bleak *Alburnus alburnus* and Perch representing 80.7% of the diet. In the cold winter, the diet was comprised of 13 species and Roach, Bream, Bleak, Perch and Ruffe represented 90.6% of the diet. These results, highlighting a strong dependence on Roach and Perch, typically resemble Cormorant diet on most eutrophic lakes, as defined by Suter (1997). In a year-round study of Cormorant diet on a Dutch lake, using pellets and regurgitates, Veldkamp (1995b) found that the most important prey species, by biomass, were Roach, Bream, Pikeperch, Perch, White Bream *Abramis bjoerkna* and Ruffe. In the breeding season, 86% (by biomass) of all chick regurgitates were cyprinids. Large bream (>300mm in length) were also regularly consumed, with about 70% of the Bream taken being greater than 200mm in length. This is despite the fact that other studies suggest that Bream are seldom preyed upon by Cormorants due to their high, laterally flattened body.

1.3.4 Diet in Ireland

Cormorant diet has been the focus of a number of Irish studies, which have assessed diet through a range of techniques at both coastal and inland colonies and roost sites (MacDonald 1987; Warke *et al*., 1994; Warke and Day 1995; West *et al*., 1975). MacDonald (1987) reports that Eel is an important prey item during the breeding season, representing 54.2% of the diet at a colony in Westport and 26% at a colony in Newport, County Mayo. In autumn, Eel was represented in *c*. 5% of pellets collected at Lough Ramor, County Cavan, and was absent during winter and spring. Other important species were Wrasse (Labridae), Roach and Perch (Kennedy and Greer 1988; MacDonald 1987; Warke *et al*., 1994; Warke and Day 1995; West *et al*., 1975). Salmonids have featured in all Irish studies conducted to date, but their proportion in the diet varies significantly.

West *et al*., (1975) investigated the breeding season diet at seven coastal colonies in Ireland and found that Wrasse comprised 60% of the diet in terms of biomass, with Eel being the second most important prey item (20%) and salmonids representing 2% of the diet. Nestling diet was analysed at two breeding colonies (Westport and Newport) in Clew Bay, County Mayo during May and June 1984, which coincides with the period of the salmonid smolt run. Wrasse and Eel were the most important prey items, together representing 84.1% biomass at the Westport colony and 88.8% at the Newport colony. Salmonids were minor prey items, constituting 8.6% of the diet at the Westport colony and 6.5% at the Newport colony over this period (MacDonald, 1987). Warke *et al*. (1994) used nestling regurgitates collected on three occasions between early June and mid July 1985, to assess fledgling diet at a breeding colony on Sheep Island, which is 1km off the north coast of County Antrim in Northern Ireland. Eel dominated in terms frequency and biomass, with small specimens of Perch almost as common by frequency, but not by biomass. Salmonids (*Salmo solar, Salmo trutta* and *Oncorhynchus mykiss*) were present in the diet throughout the sampling period, and were the second most important prey group by biomass (comprising half the weight of Eel) in early July, and the third most prevalent fish type recorded in the diet by mid July. The biomass of cyprinids, mostly Roach, almost doubled between early and mid July and represented 27% of the total fledgling diet in mid July. The breeding season diet at Sheep Island was once again investigated in 1991 by Warke and Day (1995) through analysis of nestling regurgitates. Eleven prey species were identified. Eels were dominant in terms of biomass (44%), followed by pleuronectids (22%) and salmonids (19%). Flounder *Platichthys flesus* constituted 72% of the biomass of flatfish whereas the most frequent truly marine fish in the diet were Plaice *Pleuronectes platessa*, Herring *Clupea harengus* and Ballan Wrasse *Labrus bergylta*. Roach and Perch formed only a small portion of the regurgitates analysed (*c*. 1%). This is most likely due to the striking declines in the abundance of these species in nearby Lough Neagh prior to this study (Warke and Day 1995). In the same study, the diet of non-breeding birds was investigated by collecting pellets from two roosts close to the Sheep island colony. It was found that the diet of

non-breeding birds was almost exclusively marine, which is in contrast to the nestling diet, which was comprised of just 16% marine fish. Pellets collected from one roost were dominated by Haddock *Melanogrammus aeglefinus* and *Trisopterus* spp., whereas the other roost contained a much wider selection of marine species. During the breeding season Cormorants travel from the Sheep island colony to forage on Lough Neagh, which is located approximately 60 km to the south. This journey requires transit over the River Bush, which is an important river for salmonids and which may also be utilised by these birds for foraging. To assess Cormorant predation on salmonids during the smolt run, a number of birds were shot on the River Bush as part of this study and their stomach contents were analysed. Salmonids represented 67% (by number) of the birds' diet. Four out of the five stomachs analysed contained Salmon and all contained Trout.

Kennedy and Greer (1988) also examined the extent of Cormorant predation in the River Bush, Northern Ireland. Casual observation suggested large numbers of Cormorants were visiting the site in the breeding season, especially during the smolt run. Ten birds were shot during the smolt run, and the analysis of their stomach contents revealed they had been feeding almost exclusively on Salmon smolts and Trout. It was estimated that if the birds had continued to feed to satiation, taking the same proportions of prey, each full stomach would contain an average of 5.1 Salmon smolts and 3.3 Brown Trout (Kennedy and Greer 1988). Furthermore, four birds that were shot downstream of the hatchery-reared salmon smolt release point had predated hatchery-reared smolts exclusively.

The variation in diet recorded across these studies demonstrates the extent to which diet is governed by various natural and artificial factors. For example, the Roach and Perch populations in Lough Neagh suffered huge declines in the late 1980's as a result of interactions with a parasitic tapeworm, and commercial over-fishing (Warke and Day 1995). The affect on Cormorant diet was notable, as shown by comparison of fledgling diets at the nearby Sheep Island colony between 1985 and 1991. Roach and Perch represented 15% and 10% of the diet in terms of biomass in the earlier study, but were practically absent in the later assessment. Flatfish (not identified to species level), Herring and Wrasse didn't occur in the 1985 diet, but were present in the 1991 diet, with flatfish representing 20% of the diet by biomass. Diet within both studies were dominated by Eel (~40%), with salmonids (especially Brown Trout) being the second most important prey item (~16%).

MacDonald (1987) assessed the diet of Cormorants during the winter on lakes in the Midlands of Ireland (Lough Ramor, Sheelin, Derravaragh, Ennel, Owel) by collecting pellets at their principal roost site on an island on Lough Ramor. Despite the fact that these lakes are important Brown Trout fisheries, a high incidence of coarse fish was found in the diet, with a relatively low consumption of salmonids recorded. The diet was almost exclusively Roach and Perch in autumn

and early winter. By late winter, Roach occurred in more than 80% of pellets. Brown Trout and Eel were present in small proportions (appearing in *c*. 5% of pellets) in autumn, and then absent until spring, when Brown Trout reappeared in small numbers (*c*. 2-3% of pellets).

Image 1.2 *Cormorant in flight*

1.4 Salmon and Eel ecology and status

1.4.1 Atlantic Salmon

Atlantic Salmon *Salmo salar* are anadromous, they spend the juvenile phase of their life cycle in rivers, before migrating to sea and once again returning to their native rivers to spawn. The usual life span of Salmon is four to six years, but some individuals can live for up to 10 years (Hendry and Craig-Hine 2003). Spawning occurs in autumn and early winter in the headwaters and tributary streams of rivers that have suitable gravel substrates. The eggs are deposited in a depression on the streambed, called a redd, and covered with gravel. Salmon deposit 1,000 - 2,000 eggs per kilogram of body weight, which hatch the following spring (NASCO, 2011). Newly hatched fish, or alevins, are nourished by a yolk sac attached to their bodies. After three to six

weeks, they emerge from the gravel and enter the free-swimming phase of their life cycle, at which point they are known as fry. At this stage of their life cycle, their survival is strongly influenced by several factors including water temperature, food resources and predation. Fry develop into parr and spend from one to three years in their natal stream. Once they reach approximately 10-24cm in length, they undergo a physiological adaptation for the saltwater environment called smolting. Smolts develop a silvery appearance and begin to migrate downstream in large numbers, in an attempt to reach the sub-arctic regions of the North Atlantic Ocean (NASCO 2011). A number of factors govern the timing of the smolt downstream migration, with movements occurring predominantly at night (Hendry and Craig-Hine, 2003). Water conditions are important in governing the timing of downstream movements, with smolts migrating during the daytime when water levels are high (Dr. Patrick Gargan *pers. comm*.) and during the peak of the smolt run (Ger Rogan *pers. comm*.).

After reaching maturity at sea, the adult Salmon return to their natal streams to spawn, a journey that can be up to 5,000km. Mortality after spawning, due to the demands of the upstream migration, reproduction and predation is significant. However, a small proportion, called kelts, may return to spawn again (NASCO 2011).

Ireland has traditionally been one of the largest producers of wild Salmon in the North Atlantic (Central Fisheries Board 2008). The Salmon fishery in Ireland consists of both commercial and recreational fisheries. The commercial fishery traditionally comprised the drift net fishery in offshore waters and the draft net fishery in estuaries and tidal stretches of rivers. However, in 2006, the Irish government banned all drift netting for Salmon off the Republic of Ireland's coast, and implemented a compensation scheme for affected commercial fishermen (Sea Anglers' Conservation Network 2006). Recreational Salmon angling attracts large numbers of anglers from to Ireland from abroad (Central Fisheries Board 2008). In addition to the commercial importance of Salmon, the species is highly prized and is an indicator of environmental quality. Despite the difficulties in quantifying such value, the iconic status of Salmon with the general public may exceed the values associated with commercial and recreational fisheries (FAO 2010).

Atlantic Salmon are an Annex II species on the EU Habitats Directive (European Union 1992) and the four river systems surveyed are listed as Special Areas of Conservation under the same directive. The North Atlantic Salmon Conservation Organisation (NASCO 2011) report that for some monitored stocks, marine mortality has doubled since the 1970's. Since the early 1960's, the proportion of the adults returning to the UK to spawn as grilse (fish that have spent one winter at sea), rather than as multiple sea winter (MSW) fish, has increased significantly. The decline in MSW Salmon is of concern for overall stock recruitment because MSW fish are larger and produce

significantly greater numbers of eggs (Hendry and Craig-Hine 2003). In 2002, the Central Fisheries Board (now Inland Fisheries Ireland) introduced a quota system for commercial and recreational Salmon fishing, which has been reduced annually. Responding to advice from the International Council for the Exploration of the Sea (ICES) and NASCO, the Irish Government closed mixed stock fisheries in 2007. Since then, only stocks that have a surplus of fish over the conservation limit can be harvested (Central Fisheries Board 2008).

The River Slaney is one of the most important Salmon rivers in Ireland; however, dramatic declines in stocks have been recorded in recent years, similar to a number of other important rivers in Britain and Ireland (Johnston 2010). Extensive electrofishing surveys have been carried on the River Slaney by the Inland Fisheries Ireland (IFI) since 1991.The results indicate an increase in Salmon fry densities in the catchment for the 1995-2007 period. The rod catch on the Slaney has however undergone a significant long-term decline, but has remained stable between 1993 and 2006 (Johnston 2010). The number of Salmon caught in nets has also markedly declined since this study was initiated (Johnston 2010). As juvenile stocks are at a reasonable level, it is surmised that the declines are related to low survival during the marine phase of the life cycle (Johnston 2010; NASCO 2011). Despite rigorous conservation efforts, including the closure of the fishery to both net and rod fishing in 2007, the number of adult fish returning to spawn has not yet increased.

A number of organisations, such as NASCO, the International Atlantic Salmon Research Board (IASRB), and the Atlantic Salmon Trust, have been involved in investigating the factors responsible for the decline in stocks. In Ireland, IFI has implemented a series of conservation measures since the mid 1990s to address these declines, and to facilitate equitable and sustainable Salmon fishing on rivers with favourable conservation status. Research on adult Salmon migration, by IFI and the University of Tomso in Norway, is being undertaken to gain a comprehensive understanding of migration routes and feeding areas for the species. Miniaturised pop-up satellite archival transmitters are being employed to investigate how Salmon stocks are affected by environmental conditions such as climate change (IFI 2011b).

Historically, Atlantic Salmon were present in all western European countries where suitable rivers entered the North Atlantic, however its range has contracted due to anthropogenic effects such as the creation of barriers on rivers and a deterioration in water quality (Hendry and Craig-Hine 2003; ICES 2010). A number of environmental factors in both freshwater and marine environments affect Salmon stocks (ICES 2011). In the freshwater environment, river damming and the deterioration of habitats have detrimental effects on Salmon stocks. Several reasons have

been put forward to explain the recent declines in marine survival at the post-smolt stage. Climatic factors and predators are thought to contribute to the lower productivity (NASCO 2011).The increase in sea lice as a result of fish farming is thought to impact smolts as they migrate from rivers to the open sea (Whelan 1993; Craig-Hine 2003). By-catch from commercial fishing operations or over exploitation of Salmon prey species can affect marine-phase Salmon (Hendry and Craig-Hine 2003).

Obstructions such as dams for hydroelectric power can have significant ecological impacts on Salmon passage, both for smolts on their seaward migration and adults returning to spawn (ICES 2011), and smolts or kelts can be injured or killed by turbines as they migrate downstream. Furthermore, aggregations at such obstacles could increase the incidence of contraction of diseases or parasites, or increase vulnerability to predators. Deterioration of freshwater habitats is also likely to affect certain Salmon populations in their early developmental stages (Hendry and Craig-Hine 2003). Siltation in upstream areas can smother eggs and disrupt feeding behaviour and water pollution from industry and agriculture negatively effects water quality. Genetic fingerprint mapping has been used to chart the areas used by marine-phase Salmon, and it has emerged that ocean warming may result in important elements of Salmon's food chain moving further northwards, which also poses a cause for concern (IFI 2011a).

In addition to these factors, Atlantic Salmon are also predated by a range of species throughout their life cycle, with migrating smolts considered particularly vulnerable (Johnston 2010; Kennedy and Greer 1988). During their seaward migration, smolts are vulnerable to predation from Cormorants, but the impact this has on local Salmon stocks is likely to vary considerably. Kennedy and Greer (1988) estimate that 51-66% of wild smolts and 13-28% of the hatchery-reared smolts were lost to Cormorants on the River Bush, County Antrim in 1986. Cormorant predation on the same river was calculated to be responsible for losses of 47% of smolts in 1991 and 24% in 1992 (Warke and Day 1995). At the Burrishoole fishery in County Mayo, MacDonald (1987) reported that 9% and 13% of the smolts were taken by Cormorants in 1985 and 1986, respectively. The four primary freshwater piscivorous birds in the UK, as listed by Harris *et al*., (2008), are Cormorant, Goosander *Mergus merganser*, Red-breasted Merganser *Mergus serrator* and Grey Heron *Ardea cinerea*. However, in a 1985 survey of Scottish finfish farms, Grey Herons, Cormorants and Shags were the most commonly reported predators (Carss 1994). In the marine environment, Montevecchi and Cairns (2002) report that post-smolt Salmon are predated by Gannets *Morus bassanus*.

In a report to the Slaney River Trust, Johnston (2010) speculated that, although salmonids do not represent an essential feature of Seal diet, Seals have a significant impact on salmonid stocks. Otters also represent a predation threat, especially during the spawning season (Carss *et al*., 1990), and considerable numbers of adult Salmon may be predated at this time.

The Standing Scientific Committee of IFI has provided advice on the status of Irish Salmon rivers for 2012. For the river Slaney, both the one sea winter and two sea winter stocks are predicted to be below the conservation limit. One sea winter stocks for the Suir, Ballynahinch and Owenea are predicted to be above the conservation with a Salmon surplus available.

Table 1.1 *The conservation status of Salmon in the selected rivers in 2012*

River	Age class	Conservation limit	2011	2012	Proportion of conservation limit predicted in 2012
			Deficit/ Surplus	Deficit/ Surplus	
Owenea	1 Sea Winter	2231	744	1322	*1.59*
Slaney	1 Sea Winter	609	-282	-208	*0.66*
Slaney	2 Sea Winter	1827	-1212	-1063	*0.42*
Ballynahinch	1 Sea Winter	1088	1101	1557	*2.43*
Suir	1 Sea Winter	16462	2556	1975	*1.12*

1.4.2 European Eel

The European Eel *Anguilla anguilla* (hereafter Eel) inhabits a wide range of benthic habitats in streams, rivers and lakes that are connected to the Atlantic Ocean, the Mediterranean, North and Baltic seas (Freyhof and Kottelat, 2008). Eels have a complex lifecycle, which involves traversing the Atlantic Ocean on two occasions throughout their lives (Tesch, 2003). Although the life history of Eels at sea is not well known (Eeliad 2008), it is suspected that adult, or Silver Eels, undertake a spawning migration of approximately 5000km from European rivers and lakes to the Sargasso Sea in the west central Atlantic (Moriarty 2010, Tesch 2003). Spawning occurs between March and July, and the adults probably die after spawning (Freyhof and Kottelat 2008; Tesch 2003). Aarestrup *et al*., (2009) attached miniaturised pop-up satellite archival transmitters to adults migrating from Irish waters to their spawning grounds. The Eels were tracked up to 1,300km from the release site. This data provided unique behavioural insights into the speed and depth of their movements on migration. Larval Eels (Leptocephali) migrate along the Gulf Stream from the spawning grounds to European continental shelf waters, where they transform into glass eels, and then migrate to coastal waters, estuaries, rivers and lakes where they mature (Dekker *et al*.,

2006). They generally live for approximately 20 years and grow to 40-60cm in length, but they can live much longer (ICES 2006).

Eels are a commercially important species, with approximately €200 million generated annually and over 25,000 employed in Eel fisheries in Europe (Eeliad, 2008). European Eels are listed as "Critically Endangered" on the IUCN Red List of Threatened Species and are experiencing a decreasing population trend (IUCN 2011). The number of Eels reaching European coasts from spawning grounds has drastically declined since the 1980's. Since 2000, the recruitment of elvers has fallen to just 1-5% of the pre-1980 levels (Eeliad 2008; ICES 2006; IUCN 2007). Recruitment levels reached a historical low in 2001, and have since showed no signs of recovery (Freyhof and Kottelat 2008). Catches of adult Eels have significantly declined over the same period and the Eel population is now judged to be outside safe biological limits (Eeliad 2008).

Following advice from ICES that the Eel stocks were endangered, the European Commission created the Council Regulation 1100/2007 to ensure the recovery of the European Eel stock. The objective of each Member state's Management Plan is to reduce anthropogenic mortalities to permit, with high probability, the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock. Ireland submitted a National Management Plan in January 2009 outlining actions to be undertaken to conserve Irish Eel stocks. There are four main management actions:

- Reduction of fishery to achieve EU target
- Mitigation of hydropower
- Ensure upstream migration at barriers
- Improve water quality
-

In order to reach the EU target of 40% escapement of silver eels the Minister for Communications, Energy and Natural Resources closed the Eel fishery and Eel markets in Ireland in May 2009. The option of re-opening the fishery will be considered in 2012 following a review of the scientific data. Ireland's Management Plan also outlines monitoring objectives to be carried out by IFI and partner organisations. The aim of the monitoring objectives is to evaluate the management actions and monitor the response of the Eel stocks to the actions taken. The monitoring objectives will be reported by the Scientific Eel Group in the 2012 Management Plan review required by the EU. The Eeliad (European Eels in the Atlantic: Assessment of their Decline) project is being undertaken by a consortium of twelve European research institutes to develop a comprehensive understanding of Eel biology in an effort to conserve European stocks. The project aims to

ascertain reasons for the reduced recruitment of elvers and facilitate fishery managers in improving the quality of Eels leaving river catchments on migration. However, as Eels only reproduce once, on average at around 20 years, any restoration of the population will not be achieved in the short term (ICES 2006; IUCN 2007).Comprehensive data on the factors that have caused such catastrophic declines in Eel populations are not fully known. Eels are at risk from a number of threats including physical obstructions to migration, introduced parasites, pollution, eutrophication, predation and chemical contamination (ICES 2006; IUCN 2007). Other factors that are thought to have played a role in the declines are the effects of Gulf Stream shifts, overfishing and habitat loss (Fuentuen 2002). Larsson *et al*. (1991) investigated pollutant levels (PCBs, DDT, DDE and lindane) in an Eel population in Scandinavia and reported that Eels are especially vulnerable to such pollutants, concluding that persistent pollutants may be partly responsible for the decline in the Eel population in recent decades. Eels are also increasingly affected by a nematode worm *Anguillicoloides crassu,* which infiltrates the swim bladder of approximately 90% of European Eels and affects their ability to swim *(*Eeliad 2008; ICES 2006*),* and which is likely to hamper their ability to effectively migrate to spawning grounds. *Anguillicola crassus* was accidentally introduced from Asia in the 1980's, has been progressively expanding its range in inland waters in Europe and has recently become well established in many Eel fisheries in Ireland (Morrissey and McCarty 2007).

1.5 Interactions with fisheries and mitigation

1.5.1 Interactions with fisheries

The expansion of Cormorant populations, coupled with their perceived impacts on certain commercially valuable fish species, has lead to conflicts with commercial and recreational fishery interests (Carss *et al*., 1997; Carss 2003; DEFRA 2003; Worden *et al*., 2004). The REDCAFE project is a pan-European project that was initiated in 2002 to assess and attempt to reduce this conflict. The participants of the REDCAFE project represented commercial and recreational fishermen, aquaculturists, avian ecologists and conservationists, wetland conservationists, fishery scientists and social scientists from 25 countries. Information was collated on a sample of 235 Cormorant conflicts from 24 countries, which revealed that such conflicts occurred across a wide variety of fishery types. These conflicts were reported by stakeholder groups representing recreational, commercial and nature conservation interests (Carss 2003).

Cormorant impacts on fisheries can be economic (causing loss of income), ecological (affecting habitats and ecosystems) or behavioural (affecting fish behaviour and catch rates) (Kirby *et al*., 1996). MacDonald (1987) noted the potential for conflict between Cormorants and fishery

interests and predicted that, with the growth of inland fisheries and intensive stocking programmes, this conflict is likely to intensify. The REDCAFE project revealed that reported cases of Cormorant conflicts across Europe were generally restricted to relatively wide stretches of river systems, and to areas with shallow (less than 50m deep) inshore coastal waters. Overall, the majority of conflicts were reported on eutrophic waters, freshwater aquaculture ponds as well as lakes and coasts (Carss 2003). The fish species associated with reported conflicts at riverine sites were predominantly cyprinids and salmonids, while a wide variety of fish species were reported in relation to coastal conflicts. At freshwater aquaculture ponds, Cyprinids, Perch, and Pike were the main species which were perceived to be negatively impacted by Cormorants, with salmonids were also highlighted, but to a lesser extent.

DEFRA (2003) summarised the primary reasons behind perceived conflicts with Cormorants at recreational fisheries in Great Britain.

1) Direct competition where Cormorants are preying on the same species and sizes that are sought by anglers
2) Damage to future fish stocks caused by Cormorants taking fish at early developmental stages
3) Fish damage, where Cormorants wound individual fish, which can give rise to infection and disease
4) Cormorant presence at a fishery can alter anglers' perceptions of the fishery, leading to reduced income for the fishery
5) The costs associated with implementing mitigation measures

However, rigorous empirical analysis is required to categorise the impact of Cormorants on fish populations at specific sites. Specific and sufficient data on aspects such as local fish abundance, fishery catches, local Cormorant population densities, foraging behaviour and diet is required for robust and effective analysis. Of all studies to date that have assessed Cormorant impact on specific fish populations, few have inclusively addressed each of these elements. As outlined by DEFRA, it must also be noted that the presence of piscivorous birds at a fishery does not necessarily constitute a serious problem (DEFRA 2003).

A number of Cormorant diet studies have assessed the potential for conflict between Cormorants and fishery interests; however, the units used for measuring Cormorant impact are not consistent, making comparisons between studies difficult and often impractical. Some of the aspects studied in this regard include; diet composition (e.g. Alexandersson 2006; Lorentsen *et al*., 2004), the proportion of the fish stock taken by Cormorants (Carss and Ekins 2002; Kennedy and Greer

1988; Veldkamp 1995b; Warke and Day 1995), the total mass of fish lost to Cormorants over time (Cech 2008b; Santoul *et al*., 2004), and the overall impact of Cormorants on a water body based on the biomass of fish taken per hectare (Dirksen, 1995; Engstrom 2001; Veldkamp 1995b).

Europe

Cod and Saithe are important species for coastal fisheries in Norway. In an investigation of Cormorant diet on the central Norwegian coast, Lorentsen *et al*., (2004) reported that during the chick rearing stage it was heavily dominated by these two species, which constituted 86% of the biomass. Although Cormorant diet in this area is dominated by commercially important fish, due to the biases associated with deriving quantitative information using chick regurgitates, whole fish and pellets (Carss *et al*., 1997), no attempt was made to quantify any potential conflict.

Using an average daily fish intake of 600g of fish per Cormorant, Cech (2008b) calculated that Cormorants overwintering on ponds, reservoirs and rivers in the Czech Republic were responsible for taking approximately 5.5 tonnes of fish per day in 2005. By collecting pellets at a roost on the Garonne River in southwest France, and estimating a daily food intake of 500g of fish per Cormorant, Santoul *et al*. (2004) estimated Cormorant consumption of fish to be 450kg per day, when the population was at its highest in October. It was therefore estimated that over the course of the winter (October – March) 65 tonnes of fish would have been eaten. However, information on the ranging distances of the birds within this study was not available, as well as a lack of data on fish densities meant that the impact of Cormorants on local fish stocks could not be accurately predicted. The authors did conclude that the increasing numbers of wintering Cormorants in south-west France are likely to have an increasing impact on the fish populations in the region.

Using pellets and regurgitates collected in a year-round study in the Netherlands, Veldkamp (1995b) estimated the total Cormorant consumption in the area surrounding the Wanneperveen colony in 1991 to be *c*. 40kg of fish per hectare, and concluded that Cormorants were responsible for taking 15-30% of the total fish biomass in the lakes surrounding the colony. On Lake Wolderwjld in the Netherlands, where Eel is commercially fished, Dirksen *et al*., (1995) speculated that conflict between Cormorants and commercial interests in this area are likely to be insignificant, as Eels are only caught by Cormorants employing a solitary hunting strategy, and the majority of the foraging in this area is carried out in large groups. In the winter of 1991/2, the total mass of prey taken from the lake by Cormorants was 12.5 kg/ha, 59% of which was Ruffe, with Cyprinids forming 21% of the diet. The authors concluded that although Roach and Bream are commercially fished in the lake, Cormorants do not take sufficient numbers for this to be classed as a conflict situation.

Engstrom (2001) investigated the impact of predation on fish stocks during Cormorant recolonisation in Lake Ysmen in Sweden. There were no major changes in fish populations for the five most commonly taken prey species (Perch, Pikeperch, Bream, Ruffe and Roach) and there was no significant difference between fish biomass in the lake before and after Cormorant establishment.

Long-term fishery statistics for 15 lakes in south Sweden were used to examine the impact of Cormorant predation on commercial fish species in the late 1990's, coinciding with the period when Cormorants were recolonising the area (Engstrom, 2001). Although Perch and Pike are important species to both Cormorants and commercial fisheries, the author reports that there is no apparent conflict, concluding that there is no evidence for declines in commercial catches related to Cormorant predation. Fish taken per hectare varied considerably between the 15 lakes assessed (0.2 – 15.0 kg/ha). Cormorants removed on average 0.4 - 4.2 times the amount of fish taken by fisheries at the study lakes, which amounts to Cormorants taking 13kg/ha/year compared to *c*. 9kg/ha/year by the commercial fishery. However, the author advises that since fishery catches varied considerably during the study, it is difficult to categorise the overall Importance of Cormorant predation on commercially valuable fish.

A diet assessment at the breeding colony on Lake Ymsen revealed that Eel represented 0.7% of the biomass of Cormorant diet (Engstrom, 2001). However, in some lakes, Eel catches have declined as Cormorant numbers increased, and Cormorant predation is the most likely cause for the decline (Engstrom, 2001). However, the author also states that this decline could be driven by other factors such as a decrease in the productivity of the lake due to decreasing levels of phosphorous.

Great Britain

Carss and Ekins (2002) studied the diet at Abberton, the largest inland Cormorant colony in England, and estimated that Cormorants were responsible for taking 70.3 tonnes of fish during the 1993 breeding season. Flatfish were recorded in Cormorant diet and in commercial landings, with this colony taking 10.5 tonnes of flatfish during the breeding season, which represents 4% of the annual commercial catch of flatfish within 50km of the colony. The flatfish in the Cormorants diet were mainly Flounder, while commercial landings were mostly Plaice. Therefore, the authors report little overlap in Cormorant diet and fishery operations in the vicinity of the Abberton colony. Salmonids (mostly Rainbow Trout *Oncorhynchus mykiss*) made up 13.6% of the breeding season diet. This constitutes 5.1 tonnes and is thought to represent approximately 5% of the likely abundance of stocked Trout in the area. This is the only dietary category that showed no

seasonal variation, and this is thought to reflect the sustained and intensive stocking of Rainbow Trout in the study area. Cormorant predation on Eel during the breeding season at Abberton accounted for 8.9% of the total biomass of Eel caught commercially in England and Wales (369 tonnes) in 1993. Eels were the most important prey item during the breeding season, representing 46.6% of the diet. The authors suggest that such predation could be significant on an international scale, and recommend that it should be incorporated into future investigations of Eel population biology.

Ireland

Kennedy and Greer (1988) studied Cormorant predation on the River Bush, Northern Ireland by comparing stomach samples of birds that were shot while foraging both upstream and downstream from a Salmon hatchery. It was found that birds feeding upstream of the hatchery (n=4) were eating wild smolts and Brown Trout, while those downstream of the hatchery (n=4) were eating only hatchery-released smolts. The overall predation rate on salmonids for the month of May was calculated by extrapolating the number of salmonids recovered from the stomachs of the eight birds that had been shot. The authors conclude that Cormorants would have consumed about 51-66% of the total wild smolt run and 13-28% of the hatchery smolts released in 1986, and state that these estimations should be considered minimum values. In 1991, Warke and Day (1995) analysed the stomach contents of five birds that had been shot on the same river and estimate that Cormorant predation would have accounted for 47% of the smolt run in that year. As the number of Cormorants frequenting the river declined in 1992, the level of expected predation was predicted to be 24% of the smolt run in that year. These estimations are at variance with MacDonald's (1987) finding that 9.2% of the available salmonid smolts were taken by Cormorants in 1985, and 13.1% in the following year on the Burrishoole fishery in County Mayo. Kennedy and Greer (1988) expect that this was due to larger number of birds using the site in Northern Ireland.

Kennedy and Greer (1988) suggest that the predation on Brown Trout may be severe in this small catchment, estimating that 13,000-24,000 yearling and 2+ trout could be predated by Cormorants during the smolt run. Although no information is available on predation outside the smolt migration period, the authors predicted that Trout predation remains high throughout the year, as it is the dominant species in the river (Kennedy and Greer 1988; Warke and Day 1995). It is important to note that these estimates are extrapolated from analysing the stomachs of eight birds, none of which had full stomachs.

1.5.2 Damage to individual fish

Cormorants sometimes catch prey that is too large to ingest, and after handling the fish, it is dropped or escapes (*pers. obs.*). Injuries caused to fish due to unsuccessful predation attempts by Cormorants can take the form of surface grazes or deep wounds (Adamek 2008b). Wounds consistent with Cormorant predation attempts consist of a deep triangular lesion from the upper mandible on one side and lower mandible marks on the other (Carss 2003). Such wounds are a frequent precursor to infection (Adamek 2008b; Carss 2003). Kennedy and Greer (1988) report from observations of smolts migrating through traps on the River Bush, in Northern Ireland, that a number of fish had beak marks on their flanks. The authors surmise that these were the result of attempted predation by Cormorants, however no direct evidence is provided. The frequency of such incidents in Double-crested Cormorants has been quantified by Grémillet *et al*., (2006), finding that only 0.4% of the prey pursued was injured without being ingested.

Carss (2003) removed dead fish from aquaculture cages in Argyll, Scotland on weekly basis between October 1985 and March 1986 and examined each for signs of Cormorant attempted predation. Of the 22,400 fish examined, just 0.4% bore marks consistent with Cormorant attempted predation. However, Carss (2003) notes that fish with even minor wounds are likely to be unmarketable. Kirby *et al*., (1996) indicated that non-lethal injury of fish by Cormorants is likely to financially impact a fishery, as it may reduce the survival, growth or economic value of the stock.

1.5.3 Mitigation

A range of strategies have been employed to reduce the impact of Cormorant predation on fishery stocks. The effectiveness of the various methods is dependent on numerous site-specific factors, with some techniques proving to be successful at certain sites, but ineffective at others (Carss *et al*., 2003). The efficiency of these measures is influenced by the location and size of the site, the type of fishery and the number of Cormorants involved (Carss *et al*., 2003). The REDCAFE Project, which documented the findings of Cormorant mitigation efforts in 16 countries, indicated that while certain measures may be beneficial in the short term, few methods achieve the desired results in the long term.

The two main strategies for mitigation are to reduce the numbers of Cormorants at the fishery or to reduce the attractiveness of a fishery to Cormorants. Fisheries are attractive feeding sites for Cormorants as they contain high densities of fish, so methods to reduce the density or the availability of the fish can serve to reduce Cormorant predation (Kirby *et al*., 1996; MacDonald 1987; Moran Committee 2002). Cormorant numbers at a site can be reduced by shooting or

interfering with breeding attempts at breeding colonies, or using visual or noise-generating deterrents. The availability of fish can be reduced by amending stocking practices, physically excluding Cormorants from water bodies or by providing natural or artificial refuges for fish. Due to the variation in the effectiveness of each technique, further trialling of suitable mitigation measures is required, often on a site-specific basis (Carss 2003).

Lethal measures and breeding interference

As Cormorants are perceived to impact fisheries throughout their range, there have been repeated calls for Cormorant management plans to include culling (Carss *et al*., 1997). The Moran Committee is an advisory and monitoring group that was set up in the late 1990's during the complete review of fishery legislation in England and Wales. It has been suggested that many fisheries are not aware of the various alternative actions which can be implemented to alleviate problems with Cormorants (Moran Committee 2002), or the ineffectiveness of culling in reducing the impacts in certain situations. It is paramount that further rigorous scientific studies are carried out to assess the impact that Cormorants have on fishery interests, and the affect of such control measures on Cormorant populations.

Provisions under Section 42 of the Wildlife Act 1976 enabled fishery owners or managers to apply for licences to kill or otherwise control Cormorants. In Ireland, 27 such licences were granted between 1981 and 1986 (MacDonald 1987). In 1983, the Forest and Wildlife Service moved to restrict the granting of licences to cases where damage was shown to have occurred to fish populations. However, the criteria whereby licences were granted or refused remained unclear. Between 2007 and 2011, 18 licenses have been granted by NPWS to cull Cormorants and 14 licenses to scare birds at specific sites, however the details or rationale of why the licenses were sought or granted are not known. After assessing the number of breeding Cormorants and their diet throughout the year, MacDonald (1987) recommended that the control of Cormorant damage at fish farms should be based on preventative measures, such as enlightened pond design or exclusion wiring or netting. Mac Donald (1987) also suggests that licences to control Cormorants should be granted in cases of persistent harassment of caged fish. However, more recent research has shown that culling of local Cormorant populations does not necessarily reduce Cormorant numbers around attractive feeding sites or significantly affect their impact on fish stocks (Herrmann *et al*., 2010; Moran Committee 2002).To date, there has been no studies which have comprehensively demonstrated that reducing Cormorant numbers prevents damage to fisheries (Carss and Ekins 2002). Cormorants are highly mobile, and culling birds on a local basis can serve to create a vacuum, which can be filled by Cormorants colonising from surrounding areas (Carss and Ekins 2002; Kirby *et al*., 1996). It is estimated that 30,000 – 60,000 Cormorants would have

to be culled on an annual basis in Europe to have a population level affect, which would be impractical, but also likely to be unacceptable from a public view point (Moran Committee 2002).

The Moran Committee (2002) has provided an example on the effects of culling large numbers of Cormorants in Bavaria, Germany where the winter population is approximately 6,000 birds. Although over 6,000 birds were shot in the winter of 1996/97, the average winter population was not reduced, as the cull simply resulted in the replacement of birds from surrounding areas. Engstrom (2001) reported that, in Sweden egg pricking (making a small hole in eggshell that eventually causes the death of the embryo) and shooting have both been carried out, under licence, in an attempt to reduce Cormorant numbers. Egg pricking has been carried out in at least 19 breeding colonies, in addition to 895-3864 birds being shot on an annual basis between 1994 and 2000. These measures demonstrated that when colonies are subjected to such sustained disturbance, the birds are likely to relocate or establish a new colony. As Cormorants are not usually limited by the availability of suitable nesting sites, the measures undertaken had only a marginal effect on the local population (Engstrom 2001). In addition, when the Cormorant foraging and breeding areas which experienced low levels of disturbance, were compared with those which experienced extensive disturbance, it emerged that both populations showed similar growth patterns. This suggests that persecution does not have a significant effect at a population level, and that numbers are regulated by other means (Engstrom 2001). Lehikoinen (2006) described the prevalence of illegal persecution of Cormorants at breeding colonies during the first nine years of their recolonisation in Finland. Although 43% of all colonies experienced egg removal or nest destruction, the Cormorant population was not significantly affected.

Carss and Ekins (2002) ascertained that, in the UK, lethal means of controlling Cormorants is unlikely to affect inland breeding numbers, due to the extensive Cormorant population in the nearby continental countries, which would likely replace any culled birds. The authors also surmise that preventative measures, such as scaring or removal of trees at nest and roost sites, in an effort to deter potential breeders, would be ineffectual due to the number of potential inland roosts in Britain.

Deterrents

Measures to deter Cormorants from foraging at a particular site can involve human disturbance, visual or noise-generating scarers. Kennedy and Greer (1988) noted that most Cormorants restricted their foraging on the River Bush in Northern Ireland to the first hour of light, and suggested that incidental human disturbance and intensive farming in this area discourages foraging throughout the day. On the same river, Warke and Day (1994) reported that deliberate

bank side disturbance by the Northern Ireland Department of Agriculture was responsible, at least in part, for the reduction in the number of Cormorants frequenting the river during the Salmon smolt run in 1987 and 1988. Although continuous human presence has also proved effective at a fish farm in the Netherlands (Moerbeek *et al*., 1987), this is labour intensive and expensive (Kirby *et al*., 1996). "Shooting to scare" has been successfully employed as a method of reducing Cormorant numbers at particular sites, but the effects are generally short term and numbers returned to pre-shooting levels within a few weeks (Moran Committee 2002). Although Cormorants are protected under the EU Birds Directive (79/409/EEC), Lehikoinen (2006) suggests that the hunting of other species during spring may adversely affect breeding Cormorants. Even if not directly targeted by hunters, the associated noise and disturbance caused by hunting activities may dissuade Cormorants from breeding in such areas.

Visual scarers such as scarecrows, bird-scaring kites, reflectors and flashing lights, as well as noise-generating deterrents such as pyrotechnics, screamers and gas-canons can be effective in deterring birds in the short term (Moran Committee 2002). Periodically relocating devices can prolong the effectiveness of such scarers, but due to bird habituation, they are largely ineffective in the long term (Draulans 1987; Kirby *et al*., 1996). The Moran Committee (2002) however, specify numerous negative aspects in relation to the use of such methods. The range of many of the scaring devices is a limiting factor, reducing their effectiveness on large rivers and extensive water bodies. Noise generating scarers also affect all wildlife including domesticated livestock, and are likely to be considered socially unacceptable in areas close to human habitation. Kirby *et al*., (1996) also reviewed the benefits of flying a trained bird of prey in the target areas to scare Cormorants, but notes that it is labour intensive and therefore expensive.

Stocking strategies

The growth of the Cormorant population has been partially driven by fish stocking (Kirby *et al*., 1996). Artificially managed water bodies, with high densities of fish are attractive foraging areas for Cormorants (Kirby *et al*., 1996). The authors note that perceived problems with Cormorants are most frequently reported in artificial situations, and suggest that fish losses to Cormorants should be considered a normal part of fish farming. Mass releases of hatchery-reared Salmon smolts serve to attract predators, and consequently a greater number of smolts are predated than would be the case in a natural situation (Draulans, 1987; Kalas *et al*., 1993; Kennedy & Greer, 1988).

MacDonald (1987) investigated various release strategies of hatchery-reared Salmon smolts at Lough Feeagh, County Mayo, finding that smolts released in large groups (>500 fish) were

predated to a greater extent compared to those released in more discrete quantities (200 fish). Kirby *et al*., (1996) suggested that lower levels of predation would occur if the stocking of "put-and-take" lakes (where lakes are stocked with farmed fish to be caught by anglers) involved frequent small releases rather than a single mass release. Ross and Johnston (1997) investigated the effect of stocking protocol for Lake Trout *Salvelinus namaycush* on Double-crested Cormorant predation in eastern Lake Ontario, Canada. Predation was high on the initial day of stocking, but decreased to a normal, low level by the fifth day after stocking. As half of all Lake Trout predation occurred within one day of the release, the authors suggest altering the stocking strategy to reduce losses. However, Kalas *et al*., (1993) reports that wild Salmon smolts reduce predation pressure by migrating *en masse* over a short time period and suggest that predation can be reduced by shortening the period when smolts are most vulnerable to predation. The authors therefore recommend that smolts are released in large groups and piscivorous birds are deterred from the release site in the period after a mass release. Releasing reared Salmon smolts at night has been shown to increase survival rates (Crozier and Kennedy 2002; Kalas *et al*., 1993) as foraging conditions are sub-optimal for avian piscivores. Delaying the stocking of water bodies until the majority of wintering Cormorants have returned to breeding colonies is another possible measure to reduce predation pressure on commercially important species at certain sites (Kirby *et al*., 1996).

Increasing the minimum size of stocked fish before release is another management strategy that has been adopted to prevent losses to Cormorants (Moran Committee 2002). This approach has been trialled at Rutland Water and Grafham Water, two large Trout reservoirs in England. When releases involved relatively large Trout, which were not vulnerable to Cormorant predation, Cormorants switched their diets to coarse fish or moved to other areas. Furthermore, the numbers using the winter roost and breeding colony near Grafham Water have shown marked declines since the implementation of this management strategy. Although the extended rearing period results in higher costs, however these costs have been covered by better catch return rates (Moran Committee 2002).

Reducing stocking densities of commercially important fish would alleviate predation pressure on specific fish stocks (Grémillet *et al*., 1999; Kirby *et al*., 1996). However, the lower stocking density would have to balance with the economic viability of the fishery operating at the reduced density. Kirby *et al*., (1996) also notes that fish reared at lower density may be healthier and have a higher market value than those reared at higher densities.

Another possible solution to reduce predation pressure on commercially valuable fish stock would be to use a buffer species to provision Cormorants with prey of low economic value (Kirby *et al*., 1996). These artificial feeding areas could be sited away from areas where Cormorants are perceived to cause damage to commercially important fish stocks. However, the high density of the buffer species may result in larger numbers of fish-eating birds being attracted to the area (Draulans 1987; Kallas *et al*., 1993; Kennedy and Greer 1988).

Exclusion

The installation of wires, lines or netting over ponds containing valuable stock at a fishery can be used to prevent or impede foraging Cormorants (Draulans 1987). This technique has been used with varying success (reviewed in Kirby *et al*., 1996). The approach is best suited to small sites, being costly to install on larger water bodies. It is likely not to be suitable if the site is used for angling or other recreational purposes, and will also result in the site being unsuitable for other waterbirds (Moran Committee 2002). Various installations of over-pond wires were trialled at a large fish farm in the Netherlands (Moerbeek *et al*., 1987). Although Cormorants were not entirely excluded, an overall lower intensity of predation was observed. The wires prevented large groups of birds from landing, but it is thought that some individuals may have learned how to land between the wires. The authors recommend that this approach should be complemented by the late stocking of vulnerable fish, and locating such stock in areas close to human activity to reduce the impacts of Cormorant predation.

Fish refuges

Littoral and submerged vegetation provide cover for prey fish species from both avian and fish predators. If there are sufficient natural sheltered areas and refuges available to fish, they can rely on their natural instincts to minimise predation (Moran Committee 2002). As Cormorant numbers are highest inland during winter (Sellers 2004), when natural cover provided by vegetation is at its lowest, the use of artificial refuges may be particularly applicable at this time (Russell *et al*., 2008; Moran Committee 2002). These refuges can be simple (the installation of pipes or bunches of branches) or more elaborate structures. One such design involves a floating raft planted with aquatic vegetation above, and wire-mesh "cages" comprised of coils of sheep wire below (Moran Committee 2002). Fish refuges are anticipated to be most suitable for shoaling species such as Roach, Perch, Rudd and Bream, but other freshwater species should also benefit (Russell *et al*., 2008). The extent of natural refuges (submerged vegetation, reed fringes and off-channel areas) needs to be considered when assessing the requirement for artificial refuges (Moran Committee 2002). Russell *et al*., (2008) suggest that, as artificial refuges are cheap to

construct and deploy, and are long lasting, they are preferable to alternatives such as the continual use of deterrents.

Any measure designed to reduce the availability of fish to predators, will however also result in the fish being less available to anglers, and may cause fish to aggregate unnaturally at such these refuges. It is also likely that, unless the locations of these refuges are indicated to anglers, fishing tackle could become tangled in them. However, the Moran Committee (2002) suggest that these refuges could be deployed in the winter months, when there is less natural cover for fish, and then removed as emergent vegetation provides cover in the summer, coinciding with the most popular angling period. In trials involving two similar and adjacent ponds in Reading in southern England, Russell *et al*., (2008) compared Cormorant activity and foraging success in one pond with artificial fish refuges, and the other pond which was equally stocked but which had no refuges. In the pond with the refuges, there were 77% fewer Cormorant visits on average, and foraging success was consistently lower than in the control pond.

1.6 Objectives

The primary objective of this project was to provide preliminary data to assess the impact of Cormorants on salmonids and other fish species on four selected fisheries. A multifaceted protocol was employed to determine local Cormorant population densities, foraging behaviour and diet in relation to the four selected study areas. Comprehensive Cormorant surveys were conducted to a standardised schedule over a thirteen-month period to determine Cormorant usage of the selected study areas to identify specific areas where birds focus foraging efforts and to identify any evident trends or fluctuations in numbers over the survey period. This aspect represented the most detailed analysis of Cormorant densities and foraging behaviour at specific feeding areas to date in Ireland. Visits to roosting sites and breeding colonies within proximity to the selected fisheries were also be undertaken to investigate densities and breeding parameters and to collect diet samples for subsequent analysis and determination of the prey selection and dietary intake of birds that are likely to utilise the selected fisheries. The resulting data was analysed to provide an effective assessment of the impact of Cormorants on salmonids and other fish species at the specific fisheries. Many studies have previously attempted to identify the effects of Cormorant predation on fish populations across Europe; however, few have adequately addressed each of the outlined objectives, which in combination are necessary for a full, effective and unbiased investigation of the level of impact of Cormorant predation and the existence or otherwise of a potential conflict situation.

In addition this project provides a comprehensive literature review of all relevant data relating to this study in order to; compare the results of this work regarding the impact of Cormorants to that of other European situations; to outline future research avenues; to provide recommendations and best practise protocols for mitigation to reduce, where necessary, the impact of Cormorant predation on salmonids and to provide data on the effectiveness of measures taken to reduce Cormorant populations. To this end, the final objective of this work was to determine the views and perceived impacts of fishery interests in relation to the impacts of Cormorants, which can be compared with the findings of the survey and diet elements of the project to analyse any existing variation regarding the real versus perceived impacts of Cormorants, which is necessary in order to appropriately focus conservation resources for salmonids where they will be most effective in benefitting their populations.

The specific objectives of this study were:

- To determine Cormorant population densities, foraging behaviour and use of four selected fisheries over a defined thirteen month survey period
- To identify the importance of specific habitat types and feeding areas within each selected fishery and to investigate how Cormorant numbers using these sites fluctuate over the survey period
- To comprehensively record Cormorant use of the selected fisheries during the specified salmonid smolt run period to determine any evident peaks in numbers
- To identify Cormorant roosting and breeding colonies within proximity of the selected study areas
- To conduct routine visits (under license from NPWS) to selected roosting and breeding colonies to determine numbers of birds and or active nests, breeding parameters and to collect diet samples to facilitate investigation of prey selection and diet composition
- To analyse diet samples according to best practise methods to determine the Cormorant diet representative of each study area
- To trial the effectiveness of prey selection observations to supplement the diet data via pellet and regurgitate analysis
- To provide a full and comprehensive literature review of all aspects relevant to this study
- To draft and circulate a questionnaire to interpret the views of IFI staff regarding the impacts of Cormorant predation on fish populations
- To analyse the results of each of the above aspects to detail the impacts of Cormorants on salmonids in each of the four selected survey areas

- To provide a series of recommendations for areas of future and beneficial work arising from the findings of this project

2. CORMORANT SURVEY

2.1 Background

The breeding Cormorant population in Ireland has received comprehensive monitoring at a national level since the late 1960's, resulting in detailed information on the trends, status and distribution of the Irish population. Operation Seafarer (1969-70), the Seabird Colony Register (SCR) (1985-88) and Seabird 2000 (1999-2002) assessed the distribution and densities of coastal and marine breeding colonies. In the breeding seasons of 1985 and 1986, MacDonald (1987) conducted a nationwide colony census, which included 77 colonies. In 2010, NPWS conducted a census of 20 known colonies, which predominantly focused on colonies along the west coast, but also included four east coast and two inland colonies. Cormorant population trends have also been assessed through the Breeding Bird Atlases; The Atlas of Breeding Birds (1968-72) (Sharrock, 1976), The New Atlas of Breeding Birds in Britain and Ireland (1988-1991) (Gibbons *et al*., 1994) and the Bird Atlas 2007-2011 have mapped Cormorant distribution and abundance and recorded the locations of breeding colonies which has facilitated data on fluctuations in numbers and distribution patterns. Wintering Cormorants have been monitored through the Atlas of Wintering Birds in Britain and Ireland (1981/82 – 1983/84)(Lack, 1986)and the Bird Atlas 2007 – 2011, which has provided information on how the densities and distribution of Cormorants has changed during the non breeding season in the intervening period between these surveys. Since the winter of 1994/95, the Irish Wetland Bird Survey (I-WeBS) has also recorded Cormorant numbers during the winter months at a large sample of wetland sites throughout the country.

A number of surveys on Cormorants and other piscivores in Ireland and across Europe have also focused on monitoring densities at specific feeding areas to assess their impact on fish populations. Kalas *et al*., (1993) investigated the impact of Goosander predation on salmonids during their seaward migration on the River Halselva in northern Norway in 1988 and 1989. Goosander numbers were surveyed from May to August in 1988 and 1989 and focal animal sampling was used to quantify catching success. In combination with this survey, stomach content analysis was used to determine the importance of salmonids in the diet. It is estimated that the birds predated 1% of the hatchery-reared and 2% of the wild smolts. The authors conclude that since it is likely that it is the least healthy smolts that are being preyed upon, this level of predation has only a minor impact on local salmonid populations. In Ireland, Kennedy and Greer (1988) conducted surveys on the River Bush, on three occasions during the breeding season in 1986, two of which coincided with the period of the Salmon smolt run. Using the estimated number of birds feeding on the river during these two surveys, and the diet composition from analysing the stomach contents of eight shot birds, the authors calculated the overall impact of Cormorant predation on salmonids throughout the Salmon smolt run to be significant, estimating that Cormorant predation would account for 51-66% of the total wild smolt run and 13-28% of the hatchery smolt release. Warke *et al*., (1994) surveyed the same river in 1991 and found that

the number of Cormorants remained quite low throughout the year and were generally lower than those reported by Kennedy and Greer (1988). In a longer-term study on two shallow lakes, Lake Veluwemeer and Lake Wolderwijd in the Netherlands, Dirksen *et al*., (1995) assessed the impact of Cormorants on the commercial fishery. Biweekly counts were conducted at roosts from October 1989 to April 1992 and the flight direction of the birds was used to determine their likely foraging areas. Pellets were also collected and analysed on a monthly basis to investigate feeding ecology. The authors found minimal overlap between Cormorant diet and commercially important fish species.

This survey aims to assess numbers of foraging Cormorants in four separate survey areas over the period of one year, to investigate the numbers of Cormorants utilising these sites, their foraging ecology and how their densities vary on a seasonal basis but particularly in relation to the salmonid smolt seaward migration. There has been no comprehensive, year-round survey of Cormorant abundance at their feeding areas to date in Ireland. Similar studies undertaken elsewhere within the Cormorants range (Dirksen *et al*., 1995; Kennedy and Greer 1988; Warke and Day 1995) have generally focused on a single season and have not investigated trends and fluctuations on such a regular basis or over such an extensive time period as the current study. The survey element of this project therefore represents the most detailed monitoring assessment of spatial and temporal densities of Great Cormorants at specific feeding areas over one year.

2.2 Survey areas and Methods

2.2.1 Survey areas

Four geographically isolated river systems were selected by IFI for the Cormorant survey on the basis that they were important river systems for salmonids and were known to be utilised by foraging Cormorants. These river systems were the Owenea (Donegal), the Slaney (Wexford), the Ballynahinch (Galway) and the Suir (Tipperary, Kilkenny and Waterford), the locations of which are shown below in Figure 2.1. Initial investigations were conducted by BWI with the use of Ordnance Survey maps, aerial photographs and site visits to assess the suitability of these river systems for surveying for Cormorants based on accessibility, and the locations and abundance of suitable vantage points. Specific survey areas within each river system were then selected by BWI so that each survey area contained; a diversity of freshwater and marine foraging habitat types including, where possible, river, lake, estuary and marine habitats; a range of suitable vantage points to allow unrestricted views over the entire survey area during all tide states and so that each survey area could be comprehensively surveyed by a single fieldworker within an estimated four hours. It was possible to define a single and discrete survey area that fulfilled the

above criteria for three of the chosen river systems, however for the remaining system (the Suir survey area) it was necessary to select a series of separate survey blocks.

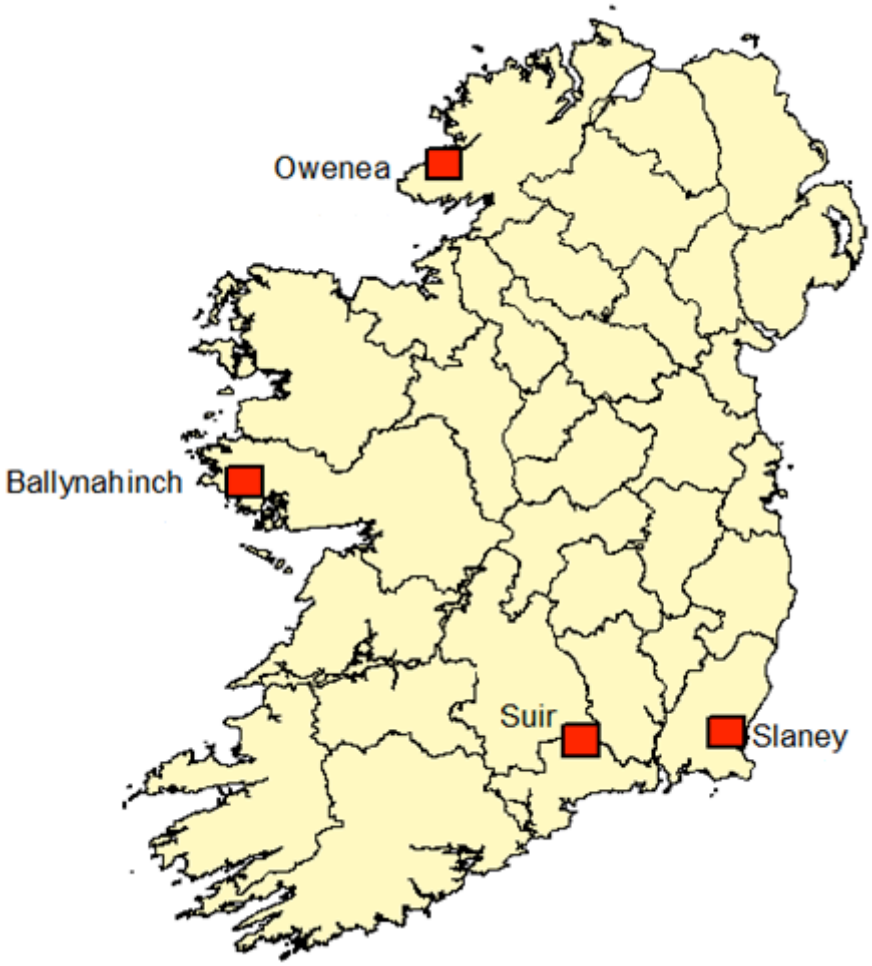


Figure 2.1 *Map showing the locations of the four selected survey sites.*

Owenea

The Owenea survey area is approximately 2,080 ha and incorporates the Owenea River, a shallow freshwater lake and a coastal section surrounding the Loughros peninsula. The survey boundary lies one kilometre from the mouth of the river, and follows the river inland for four kilometres (G748 922 – G782 929). The river is approximately 15-20 metres wide, containing a diversity of slow pools as well as fast flowing sections. It is bordered by a mature conifer plantation and pasture farmland. Lough McHugh is a shallow lake surrounded by a mature conifer plantation, which is connected to the river by a small tributary. The river flows into Loughros More bay, which is north of the Loughros peninsula. The coastal section includes Loughros More and

Loughros Beg Bays, which consist of large expanses of intertidal mudflats and shallow water. Approximately 34.7ha of the survey area is freshwater habitat, with the remaining 2,045.3ha being marine.

Slaney

The Slaney survey area is approximately 1007.8 ha and stretches from the mouth of the Urrin River, just south of Enniscorthy (S972 389) to the end of the North harbour wall in Wexford harbour (T 059 214), a distance of approximately 25km. The river is approximately 50 metres to several hundred metres in width. It is bordered by mature broadleaf woodland and farmland. The river opens into a large shallow estuary at Wexford harbour, with extensive sandbars and intertidal mud flats. The Slaney survey area is entirely estuarine and therefore cannot be divided into marine and freshwater habitats.

Ballynahinch

The Ballynahinch survey site has a surface area of approximately 1886.1 ha, consisting of an interconnected system of Loughs, rivers and bays, including Derryclare Lough, Glendollagh Lough, Athry Lough, Ballynahinch Lake, the Owenmore River and Cloonile and Roundstone Bays. The area is characterised by undulating areas of low intensity agriculture, blanket bog and rocky outcrops. The survey area includes the Owenmore River, which is approximately 4km in length and which is characterised by short streams and deep pools. The river flows from Ballynahinch Lake into Cloonile Bay, a sheltered and rocky bay. Approximately 611.1ha of the survey area is freshwater habitat with the remaining 1,274.9ha consisting of marine habitat.

Suir

The survey area comprises five distinct count sections making up approximately 135.6 ha, all of which are surrounded by intensively farmed land. The principal section between Clonmel and Carrick-on-Suir (S257 232 – S367 222) is non-tidal and is approximately 50m wide and 12km long. Two vantage points are located upstream of the principal section at the village of Newcastle (S130 137) and Knocklofty Bridge (S145 205). The river at these count sections is shallow and approximately 50m wide. The remaining count sections are located downstream of Carrick-on-Suir at Fiddown, (S465 196) and Grannagh Castle (S578 148). This section of the river is tidal and approximately 300m wide. Approximately 63.5 ha of the survey area is freshwater habitat, with the remaining 72.1 ha being marine habitat.

2.2.2 Methods

The Cormorant survey was carried out over a thirteen-month period between May 2010 and June 2011. Within this time frame two separate survey periods were defined, which included the "normal survey period" incorporating May 2010 to March 2011 and June 2011 and the "intensive survey period" which included April and May 2011. Counts were scheduled twice per month during the normal survey period, with a minimum of seven days between surveys at each site. This survey frequency was increased to two surveys per week during the intensive survey period, which coincided with the Salmon smolt run. Counts of the Suir survey area were not initiated until October 2010 but thereafter followed the same frequency as outlined above. Therefore, to achieve a comprehensive dataset on foraging Cormorant densities over the thirteen-month survey period, a total of 129 surveys were scheduled across the four survey areas, which included 74 surveys within the normal survey period and 55 within the intensive period.

Cormorants have a bimodal daily foraging pattern with peaks of foraging activity in the morning and the evening (Johanson *et al*., 2001), therefore the timing of visits were varied across the survey period to determine evident patterns in Cormorant foraging activity or use of specific areas at certain times as a disturbance avoidance strategy, and the influence this may have on the count results. All surveys were carried out between 05:30 and 21:20, with a number of dawn and dusk surveys conducted throughout the survey period in three of the survey areas. It was not possible to conduct dawn or dusk surveys in the Slaney survey area due to the dependence on IFI staff for assistance with boat operations, therefore all counts were conducted between 09:25 and 17:45.

Counts were conducted regardless of the weather conditions, provided visibility was sufficient to ensure complete coverage of the survey area. Initial site investigations confirmed that visits in each of the four survey areas could be completed by one fieldworker, therefore the majority of counts were conducted by a single project fieldworker (n = 126), with two fieldworkers working together to cover the Ballynahinch survey area on two visits.

Specific survey sheets were used to record the date, start and finish times and observers present for each visit. Weather variables were recorded, assessing rain, wind and cloud cover, by assigning each a value of 0-3. The tidal state was defined using local tide tables and sea state. All occurrences of Cormorants were recorded by annotating a field map, noting the precise location, age class (adult/immature), behaviour (fishing/loafing/flying) and habitat type (river, lake, estuary/coast) for each bird. The activity state and behaviour of each bird was recorded as "fishing" if it was in the water, whether it was actively foraging or not, "loafing" if the bird was

perched and inactive and "flying" if observed in flight. The number and location of all other mammalian and avian piscivores was also recorded. After each visit, all data from the survey sheets and maps were stored in an Excel database.

Equipment used for fieldwork included:

- 8 x 42mm binoculars and 20-60 x 65mm telescope
- Handheld GPS (Garmin e-trex)
- Cormorant survey record sheets (and "weather writer" for boat work) & field notebook
- Relevant 1:50,000 OS maps and field maps for annotation.

Due to differences in the topography and accessibility, it was necessary to employ various survey methods to ensure complete coverage of each survey area within an approximate four-hour period. Initial investigations and preliminary counts were used to draft the method for each survey area. The locations of vantage points and the count protocol for each site was then standardised and used throughout the survey period. The methods adopted for each survey area are detailed below.

Owenea

The main river section of the Owenea survey area was covered on foot. Lough MacHugh was surveyed by scanning the lake from two vantage points on the shoreline, which allowed views

over the entire lake. Four elevated vantage points were used to cover Loughros More and Loughros Beg Bays. Nine supplementary vantage points were included during April and May 2011, allowing more comprehensive coverage of Loughros More and Loughros Beg bays.

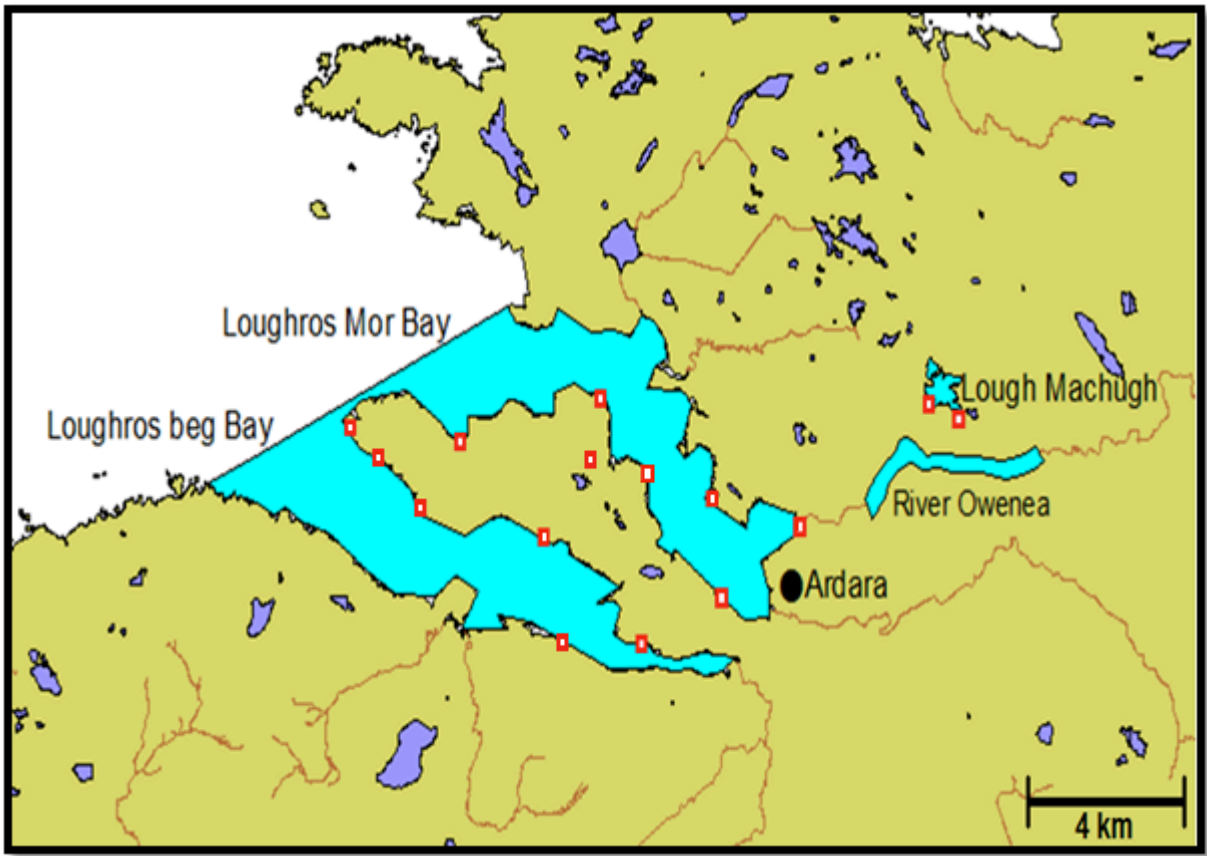


Figure 2.2 *Map of the Owenea survey area showing the locations of vantage points.* ▫ *= vantage points used.*

Slaney

The entire survey area was covered by boat, manned by IFI staff. This facilitated a larger survey area than would have been otherwise possible. A BWI fieldworker recorded all birds encountered, and the boat was frequently stopped to allow for comprehensive scanning. Although the survey route was consistent each time, it was conducted in both directions. This depended on tidal conditions, as certain sections in the upstream portion of the site are not navigable at low tide. On one occasion, this survey method was compared to a bankside vantage point approach. One observer conducted the survey by boat while another simultaneously covered the site by scanning from ten suitable vantage points at the shore. The comparison between the two survey

methods indicated that the boat survey was significantly more efficient compared with the land based vantage point watches. The vantage point survey took over twice as long to complete, and recorded only 69% of the Cormorants recorded by the fieldworker in the boat over the same period. This trial therefore informed the best methods to ensure the most complete coverage, which was standardised and employed thereafter.

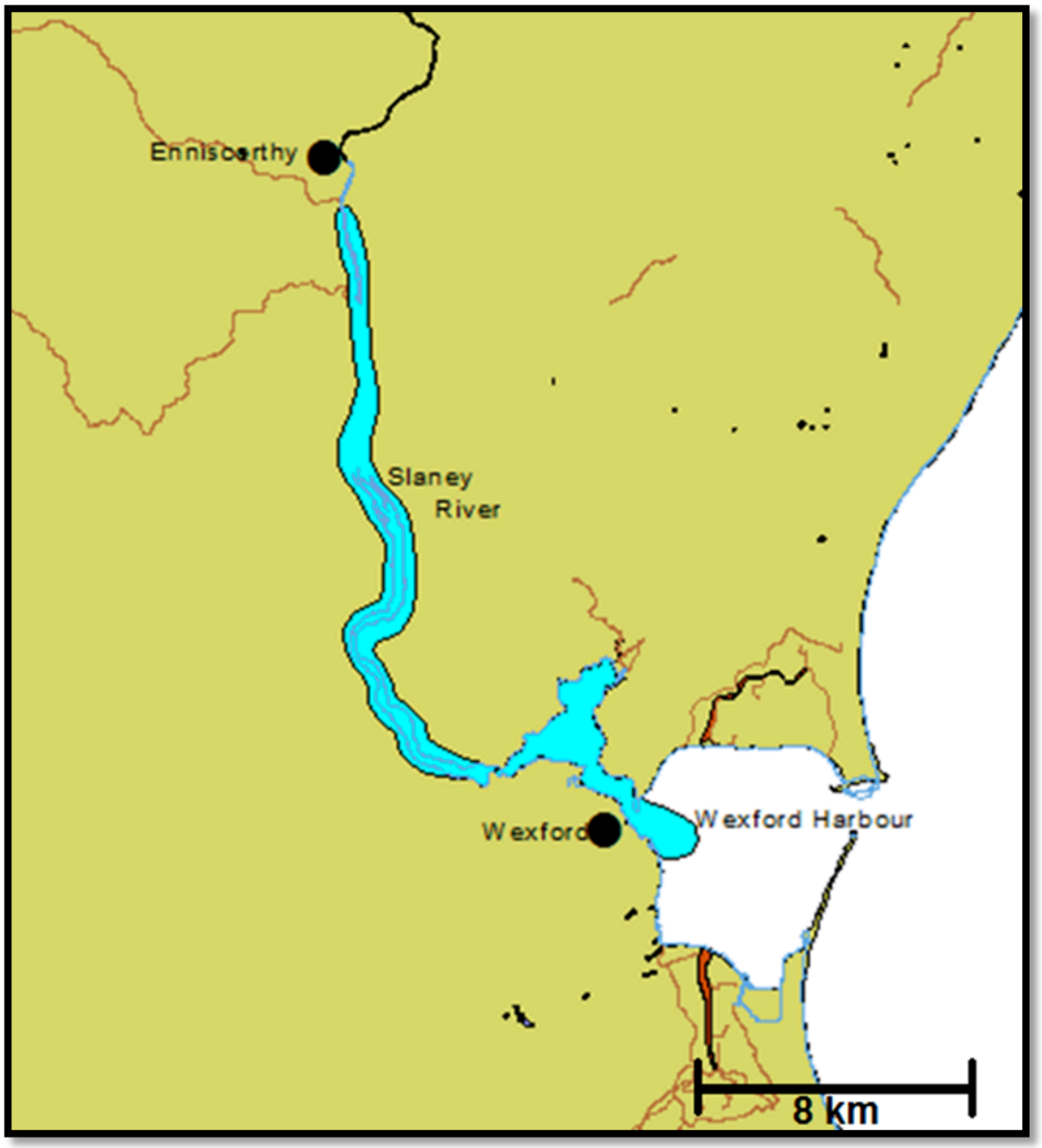


Figure 2.3 *Map showing the Slaney survey area.*

Ballynahinch

The survey area was covered by scanning from 24 vantage points accessed by vehicle. Multiple vantage points were used on the larger lakes and estuarine sections to ensure comprehensive coverage.

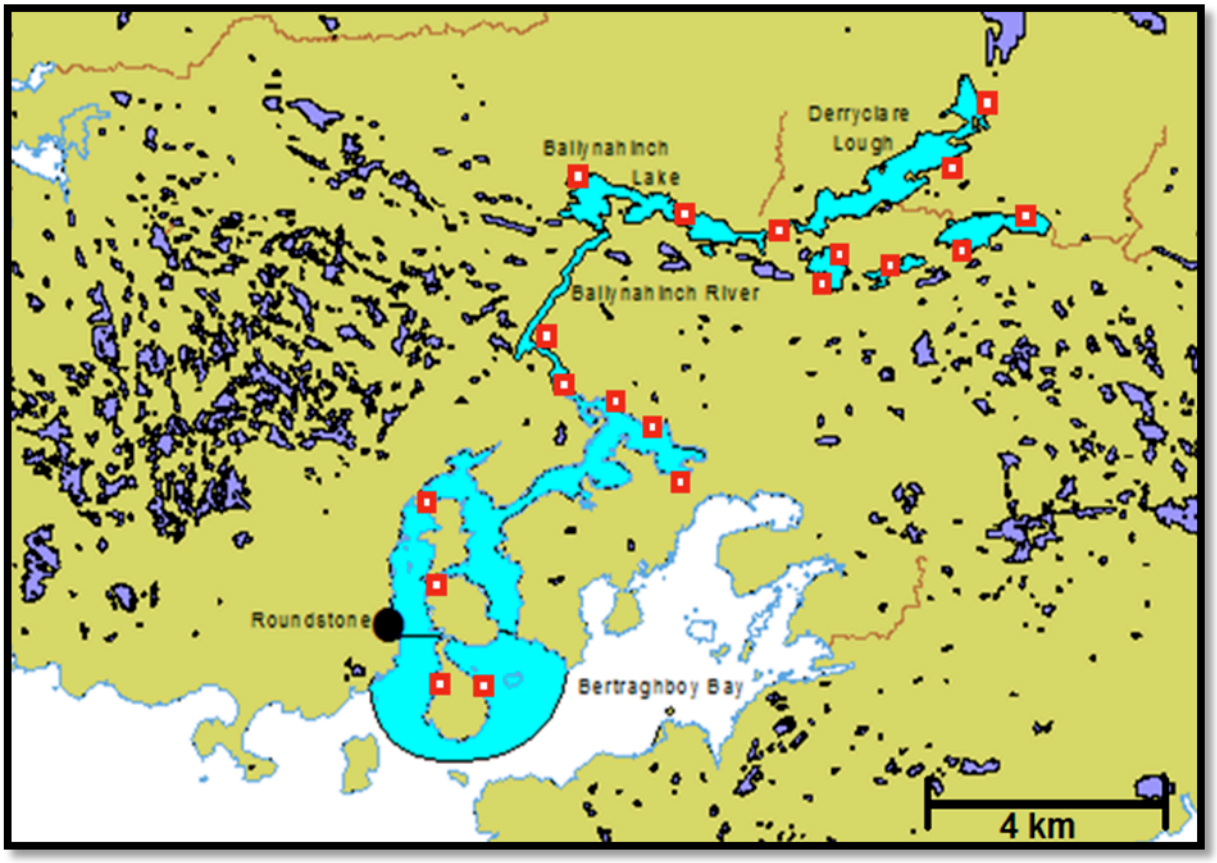


Figure 2.4 *Map of the Ballynahinch survey area showing locations of vantage points.* = *vantage points used.*

Suir

The Suir survey area was covered by a combination of vantage point scanning accessed by vehicle and one section that was covered on foot. The 12km section between Clonmel and Carrick-on-Suir was covered on foot. Four additional vantage points, two upstream and two downstream of the main section, were accessed using a vehicle.

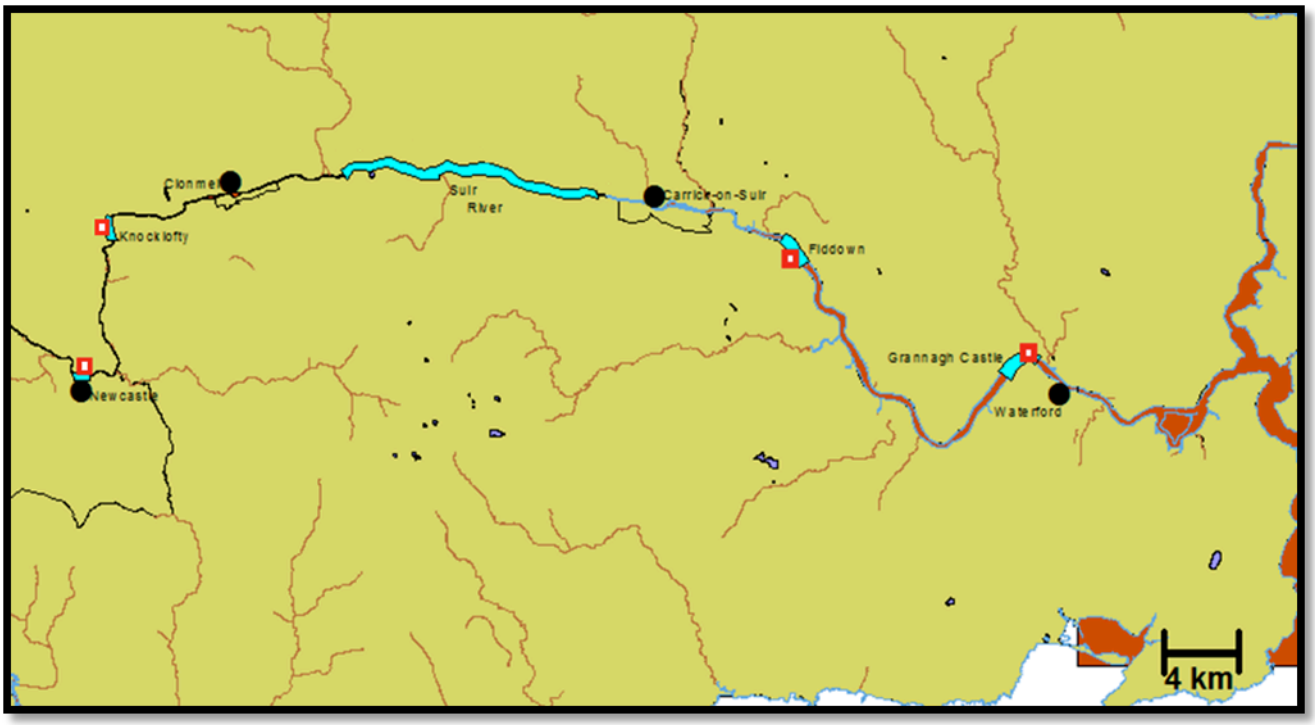


Figure 2.5 *Map showing the Suir survey area showing the locations of vantage points* ▫ *= vantage points used.*

Health and safety

Due to the characteristics of the fieldwork, several health and safety considerations were taken into account. Health and safety related equipment carried into the field included:

- Fully charged mobile phone
- First aid kit
- Lifejacket (for boat work)
- Other essentials (sun screen, water, food, etc.)

A buddy system was also operated for the duration of the field season. Fieldworkers contacted the Project Manager prior to starting fieldwork each day to inform of the times and specific area they were working in and then made contact again once they finished fieldwork for the day.

2.3 Results

2.3.1 Survey effort

A total of 129 surveys were carried out over the thirteen-month period between May 2010 and June 2011. It was not possible to complete nine surveys (from the original survey schedule of 135 visits) due to logistical reasons (n = 2) and adverse weather conditions (n = 7). Three additional surveys were carried out during the course normal survey period (two on the Slaney and one at Ballynahinch). In total 74 visits were conducted during the normal survey period and 55 were undertaken within the intensive survey period. Table 2.1 and Figure 2.6 below show the number of visits to each survey area throughout the survey period.

Table 2.1 *The number of surveys conducted in each survey area*

	Owenea	Slaney	Ballynahinch	Suir	Total
Normal survey period	19	23	21	11	74
Intensive survey period[1]	14	14	13	14	55
Planned surveys missed	3	1	3	2	9
Extra surveys	0	2	1	0	3
Total number of surveys	33	37	34	25	129

[1] 6th April – 29th May

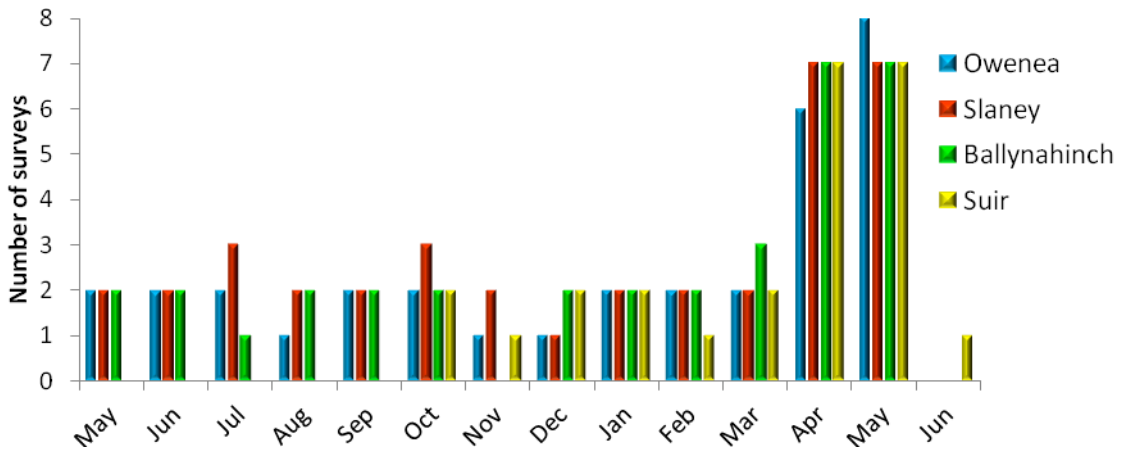


Figure 2.6 *The number of surveys conducted per month at each site from May 2010 – June 2011.*

The total time required to complete all 129 visits to each of the four survey areas was 472.7 hours. The average length of visit was 3.8 hours and ranged from 1.3 to a maximum visit length of 7.9 hours. In total 150.7 hours were spent surveying the Owenea survey area, which included 65.1 hours within the normal survey period and 85.6 in the intensive period. The average visit length was 4.6 hours, which ranged from 1.5 hours to 7.9 hours. A total of 61.4 hours were required to complete all visits to the Slaney survey, which included 39.6 hours within the normal survey period and 21.8 hours within the intensive survey period. The average visit length for the Slaney was 1.7 hours, ranging from 1.3 hours to 2.3 hours. A total of 132.6 hours were spent surveying the Ballynahinch survey area, which included 83.0 hours within the normal survey period and 49.6 in the intensive survey period. The average visit length for this survey area was 3.9 hours, and ranged from 2.0 hours to 7.3 hours. The Suir required 128.0 hours to complete all visits, which included 48.8 hours within the normal survey period and 79.2 within the intensive period. The average visit length for the Suir was 4.9 hours, which ranged from 3.0 hours to 6.9 hours.

2.3.2 Weather

Meteorological conditions were generally favourable for survey work, however it was not possible to conduct counts on 7 days for which they were scheduled due to adverse weather. Of the 129 counts that were successfully completed, weather parameters recorded show that, across all sites, 84% of surveys experienced light rain, or no rain, and 16% had persistent rain or heavy showers. Similarly, 34% of survey days were sunny, 20% were intermittently cloudy and the remaining 46% were overcast. Calm or breezy conditions were recorded on 57% of survey days, 26% were breezy, with strong winds on the remaining 17%. The weather was not considered a limiting factor for three of the survey sites, however strong winds and heavy showers, coupled with choppy or rough waters made counting difficult in certain sections of the Slaney on eight days.

2.3.3 Cormorant densities

A total of 2,970 individual Cormorants were recorded across all surveys between May 2010 and June 2011, 2,155 encounters were recorded within the normal survey period and 815 encounters within the intensive survey period. Cormorants were encountered in 92% of surveys conducted (n = 129), with the Owenea survey area being the only site where no birds were recorded on 10 visits. Table 2.2 below shows a breakdown of the Cormorant numbers recorded at each survey site.

Table 2.2 *Summary of Cormorant numbers recorded at all survey sites*

Site	Total number of visits	% of visits with Cormorants	Mean number per visit		Range
			Normal survey period	Intensive survey period[1]	
Owenea	33	69.7	3.8	0.7	0-10
Slaney	37	100	78.8	44.9	20-187
Ballynahinch	34	100	8.3	6.5	1-19
Suir	25	100	13.0	6.6	1-38

[1] 6th April – 29th May 2011

Of all Cormorant encounters where behaviour was recorded (n = 2,801), 18.56% (n = 520) were classed as fishing, 62.87% (n = 1761) of individuals were observed loafing and 18.56% (n = 502) were recorded as in flight. Of the foraging habitat available to Cormorants within the combined survey areas 90.1ha (1.8%) was classed as river, 572.1ha (11.3%) was lake and 4400.2ha (86.9%) was estuary or marine.

Of the birds which were recorded either fishing or loafing (n = 2,281), 4.8% were present in river habitat, 1.2% on lakes, and 94.0% in estuary or marine habitat. From the 520 birds recorded fishing the majority used the estuary or marine sections of the survey area (93.7%), followed by riverine sections (5.0%), with the remainder observed fishing on lakes (1.3%). Therefore an average density of one foraging bird per 20.1 ha were recorded using freshwater habitats compared with one birds per 9.0 ha feeding in estuarine or marine areas.

A comprehensive description of Cormorant usage throughout the survey period for each survey area is detailed below.

Owenea

A total of 82 Cormorant encounters were recorded from 33 complete counts of the Owenea survey area. The average number of birds observed was 2.5 per visit, with a maximum of 10 birds observed on any one visit and also 10 visits conducted on which there were no Cormorant encounters. Figure 2.3 shows the variation in Cormorant densities recorded throughout the survey period.

The average density of Cormorants per visit within the normal survey period (n = 19 visits) was 3.8, compared with an average observed density of 0.7 birds during the intensive survey period (n = 14 visits).

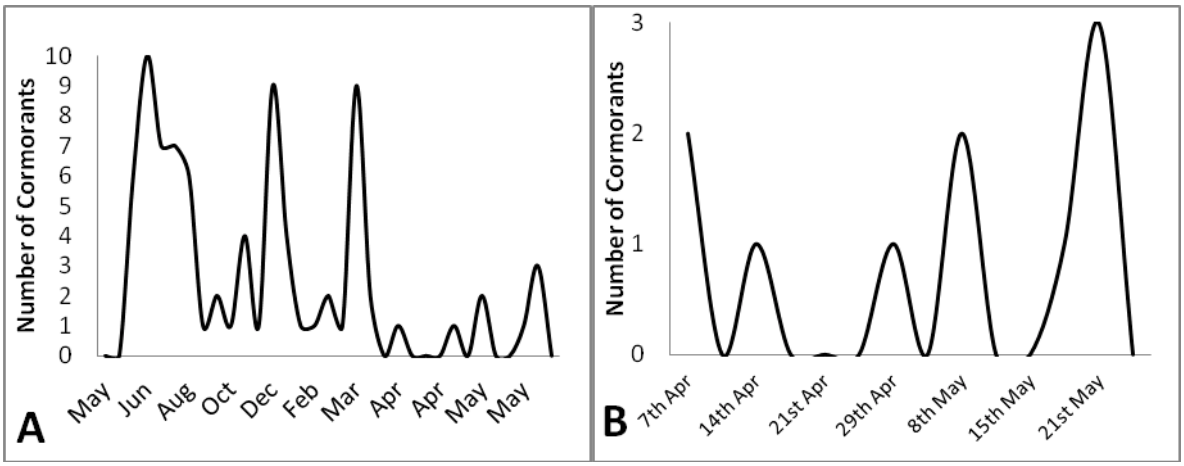


Figure 2.7 *Numbers of Cormorants recorded in the Owenea survey throughout the normal and intensive survey periods.*

(A) Throughout the entire survey period (May 2010-May 2011); (B) during the intensive survey period (7th April – 29th May)

The majority of cormorant encounters were in the estuarine section of the survey area (86.6%). A single Cormorant was observed at Lough Machugh on seven occasions. No birds were observed foraging on the river. Figure 2.8 below shows Cormorant usage and behaviour within the separate habitat types in the Owenea survey area.

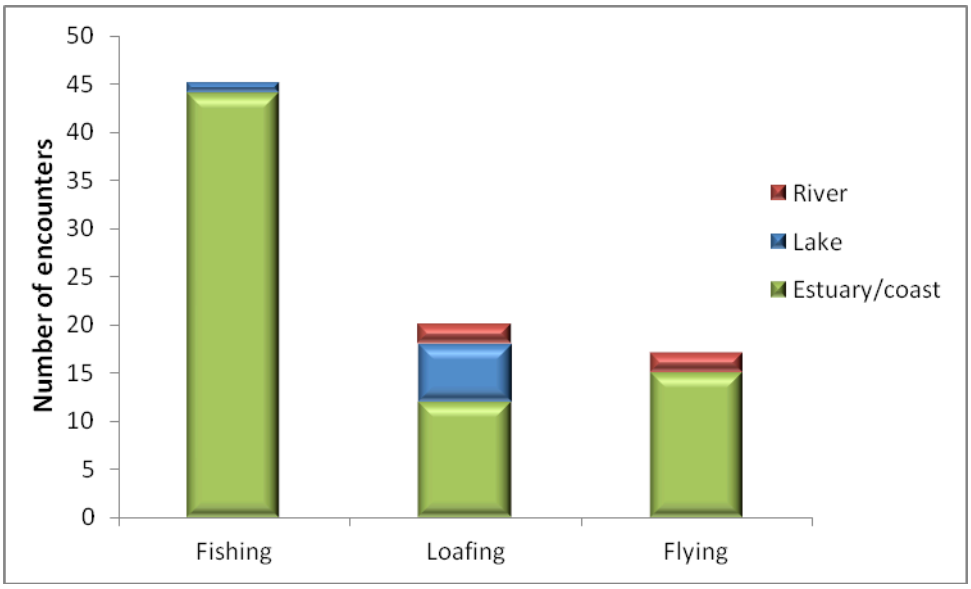


Figure 2.8 *Cormorant habitat use in the Owenea survey area.*

Of the 82 confirmed observations, 54.9% were of birds fishing, 24.4% were of birds loafing and 20.7% were birds in transit. Of the foraging birds, 97.8% were recorded in the estuary with the remaining 2.2% on Lough McHugh. Based on the available habitat types within the survey area, an average density of one bird per 27.7 ha used the freshwater areas for foraging compared with a density of one bird per 46.5 ha using the estuarine or marine sections. The map below displays Cormorant behaviour and habitat use during the intensive survey period (Fig 2.9).

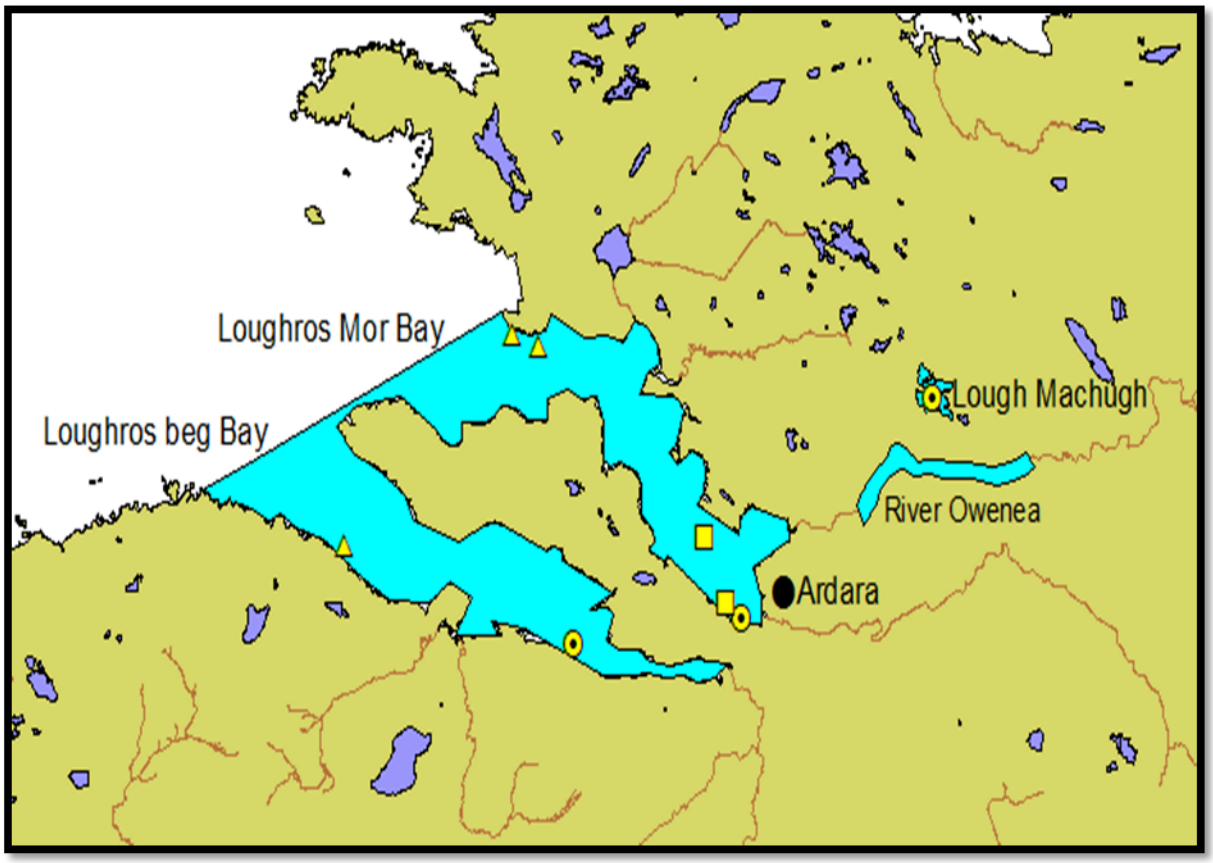


Figure 2.9 *Map showing all Cormorant encounters in the Owenea survey area during the intensive survey period (7th April – 29th May 2011).*

= flying, = loafing, = fishing.

Of all Cormorant encounters where birds could be aged (n= 32), 46.9% were classed as immature and 53.1% were adults.

Slaney

A total of 2,393 Cormorant encounters were recorded from 37 complete counts of the Slaney survey area. An average of 66 birds were observed per visit. The average density of Cormorants per visit within the normal survey period (n = 23 visits) was 78.8, compared with an average observed density of 44.9 birds during the intensive survey period (n = 14 visits). Figure 2.10 shows the variation in Cormorant densities recorded throughout the survey period.

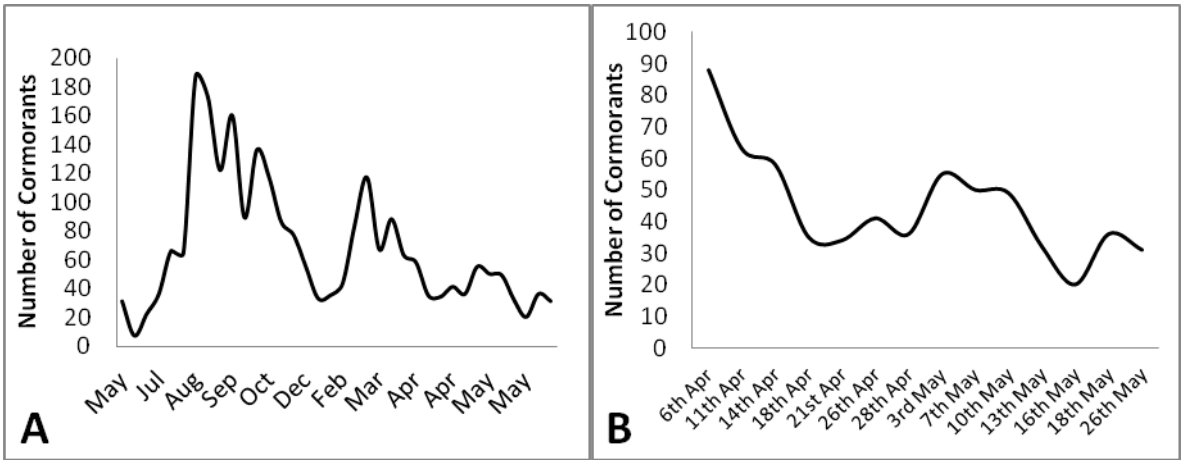


Figure 2.10 *Numbers of Cormorants recorded in the Slaney survey area throughout the normal and intensive survey periods.*

(A) Throughout the entire survey period (May 2010-May 2011) and (B) during the intensive survey period (6th April – 26th May).

As the entire Slaney survey area is estuarine, and could not be divided based on broad habitat type, it was dived into a north and a south count section with the division being where the river widens into the inner harbour at Wexford. The two count sections were roughly similar in length. The majority of all Cormorant encounters (62.86%) occurred in the South section of the survey area, however foraging birds were equally distributed in both sections of the site (Fig. 2.11).

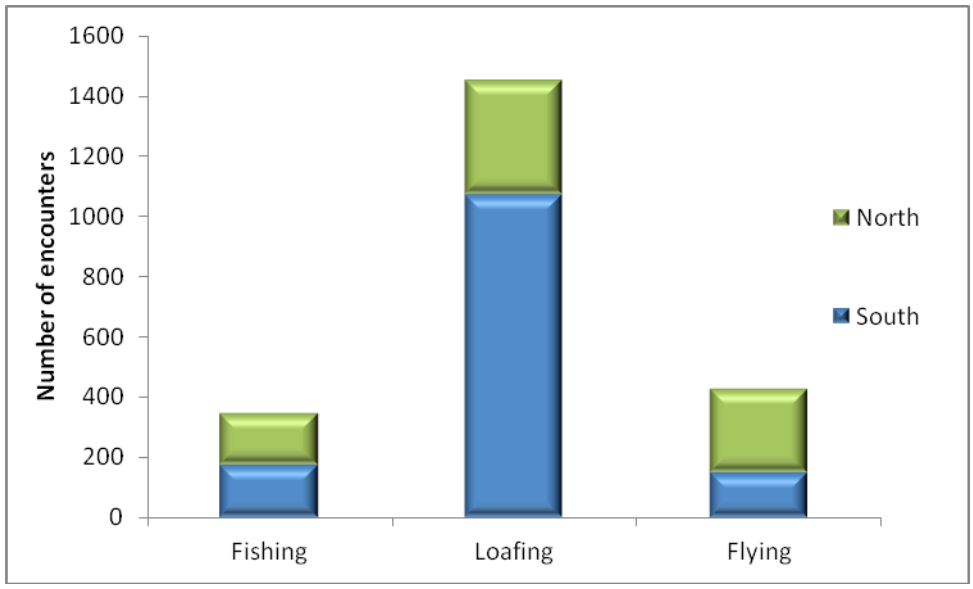


Figure 2.11 *Cormorant habitat use in the Slaney survey area.*

Of the 2,224 confirmed observations where behaviour was recorded, 15.6% were of birds fishing, 65.3% were of birds were observed loafing and 19.1% were flying. The map below displays Cormorant behaviour and use during the intensive survey period (Fig 2.12).

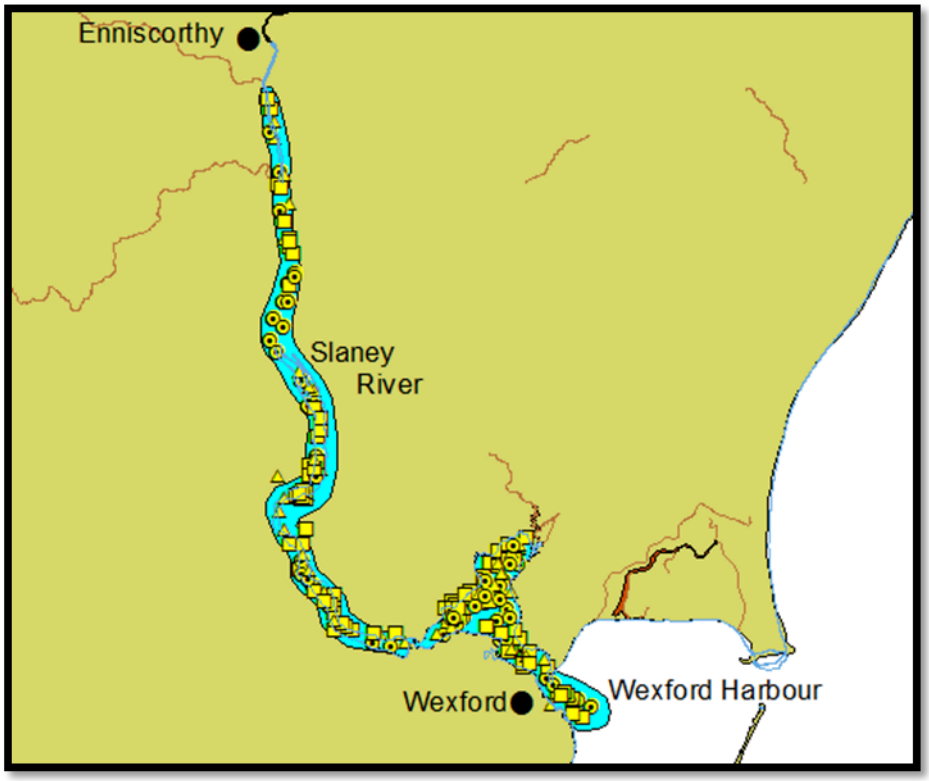


Figure 2.12 *Map showing all Cormorant encounters in the Slaney survey area during the intensive survey period (6th April – 26th May).*

= flying, = loafing, = fishing.

Of all Cormorant encounters where birds could be accurately aged (n= 711), 47.8% were classed as immature and 52.2% identified as adults.

Ballynahinch

A total of 260 Cormorant encounters were recorded from 34 complete counts of the Owenea survey area. The average number of birds observed was 7.6 per visit, with a maximum of 19 birds. Figure 2.13 shows the variation in Cormorant densities recorded throughout the survey period. The average density of Cormorants per visit within the normal survey period (n = 21 visits) was 8.3, compared with an average observed density of 6.5 birds during the intensive survey period (n = 13 visits).

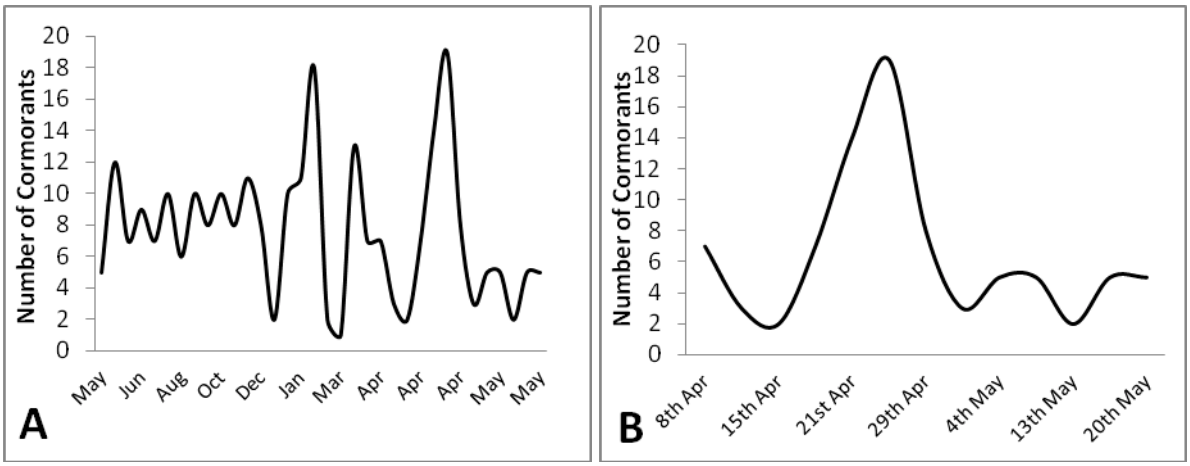


Figure 2.13 *Numbers of Cormorants recorded in the Ballynahinch survey area throughout the normal and intensive survey periods.*

(A) The entire survey period (May 2010-May 2011); (B) during the intensive survey period (8th April – 20th May).

The majority of Cormorant encounters occurred in the estuarine section of the survey area (90.4%), with 8.8% on lakes and 0.8% on the river. Figure 2.14 below shows Cormorant usage and behaviour within the separate habitat types in the Ballynahinch survey area.

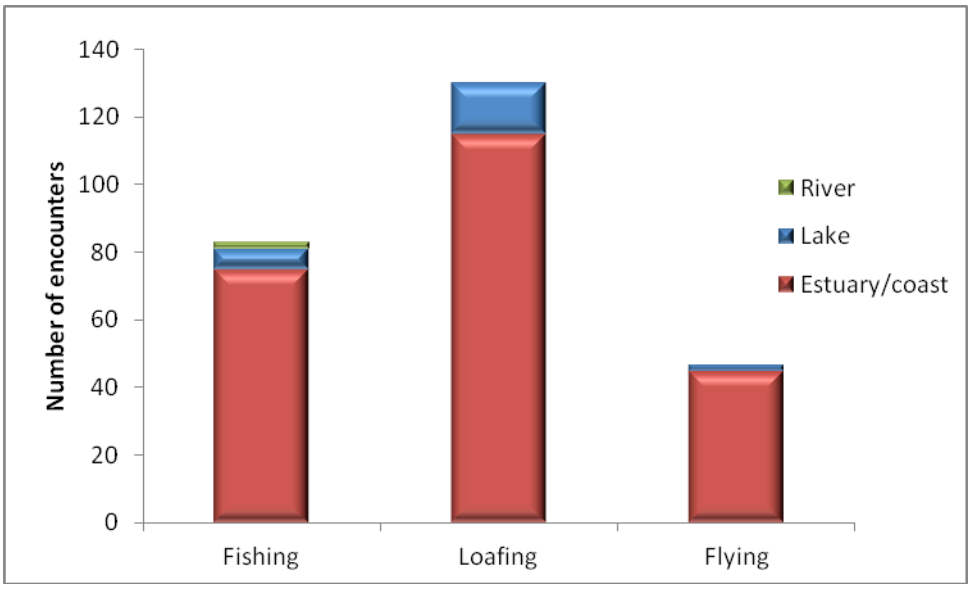


Figure 2.14 *Cormorant habitat use in the Ballynahinch survey area.*

Of the 260 confirmed observations, 31.9% were of birds fishing, 50.0% were of birds loafing and 18.1% were birds in transit. Of all foraging birds encountered 90.4% were in the estuarine section of the survey area, with 7.2% on the lakes and 2.4% on the river. Based on the available habitat types within the survey area, an average density of one foraging bird per 70.5 ha used the freshwater areas compared with a density of one bird per 17 ha which used the estuarine or marine sections. The map below displays Cormorant behaviour and habitat use during the intensive survey period (Fig 2.15).

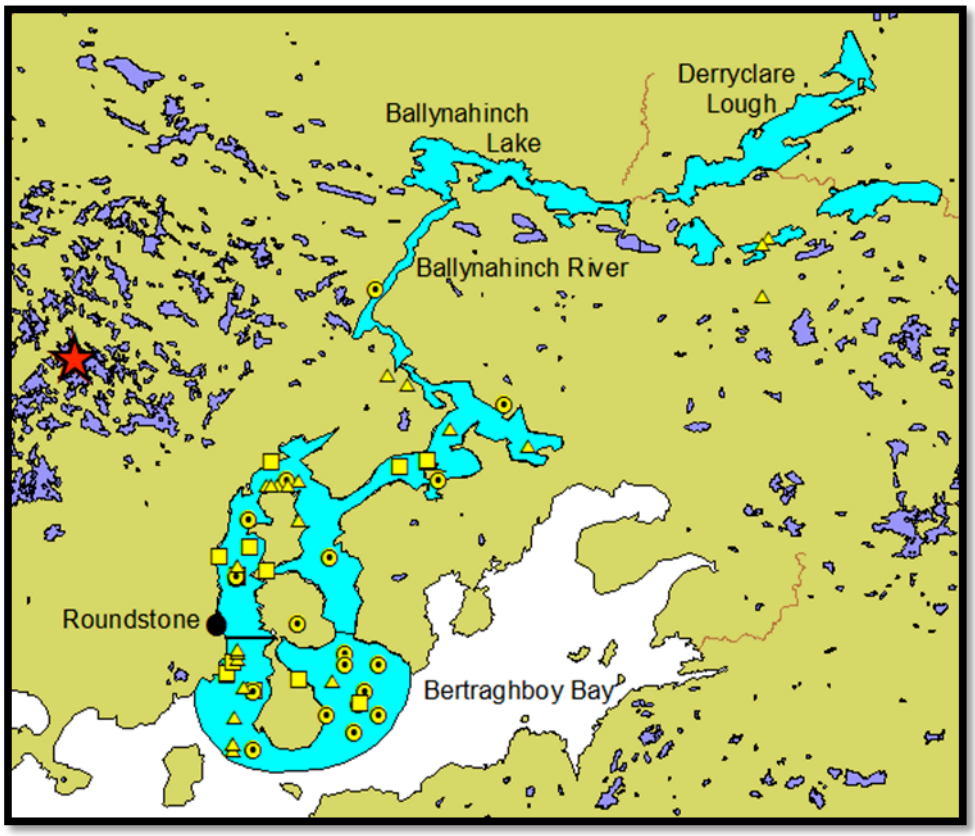


Figure 2.15 *Map showing all Cormorant encounters in the Ballynahinch survey area during the period of the intensive survey period (8th April – 20th May 2011).*

= flying, = loafing, = fishing, = Breeding colony

Of all Cormorant encounters where birds could be aged (n= 180), 17.2% were classed as immature and 82.8% were adults.

Suir

The Suir survey area was surveyed from October 2010 to June 2011. A total of 235 Cormorant encounters were recorded from 25 complete counts of the survey area. The average number of birds observed was 9.4 per visit, with a maximum of 38 birds. Figure 2.16 shows the variation in Cormorant densities recorded throughout the survey period. The average density of Cormorants per visit within the normal survey period (n = 11 visits) was 13, compared with an average observed density of 6.6 birds during the intensive survey period (n = 14 visits).

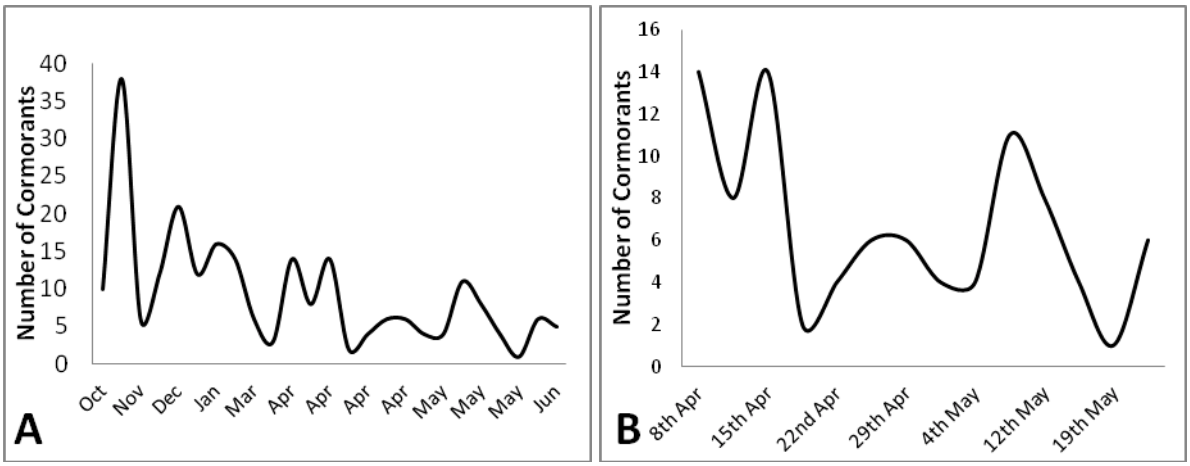


Figure 2.16 *Numbers of Cormorants recorded in the Suir survey area throughout the normal and intensive survey periods.*

(A) The entire survey period (Oct 2010-June 2011) and (B) during the intensive survey period (8th April – 24th May).

The birds were spread equally between the freshwater and estuarine sections of the survey area. Figure 2.17 below shows Cormorant usage and behaviour within the separate habitat types in the Suir survey area. Of the 235 confirmed observations, 19.1% were of birds fishing, 67.7% were of birds loafing and 13.2% were in flight. Based on the available habitat types within the survey area, an average density of one foraging bird per 2.6 ha used the freshwater areas compared with a density of one bird per 3.4 ha which used the estuarine or marine sections. The map below displays Cormorant behaviour and habitat use during the intensive survey period (Fig 2.18).

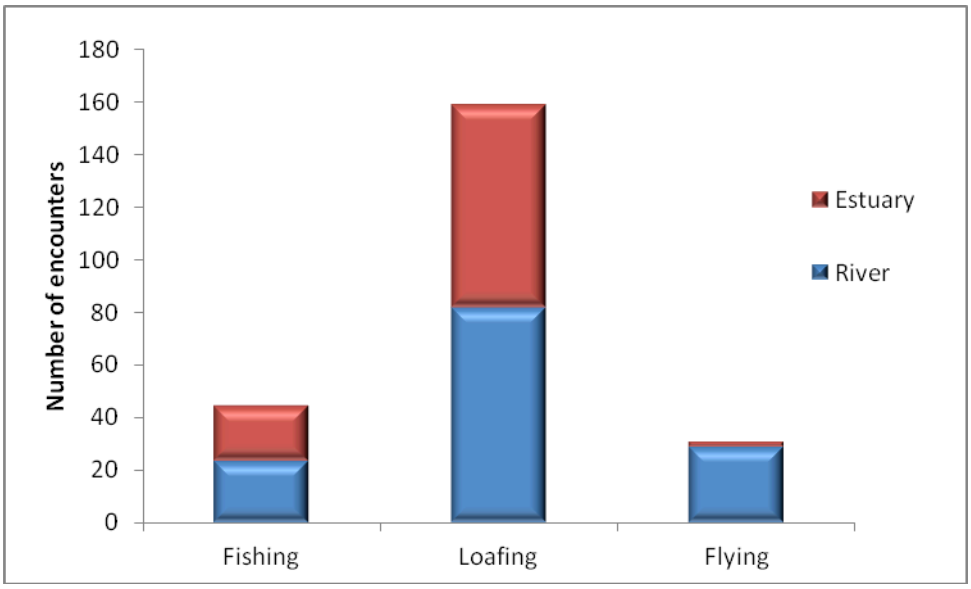


Figure 2.17 *Cormorant habitat use in the Suir survey area.*

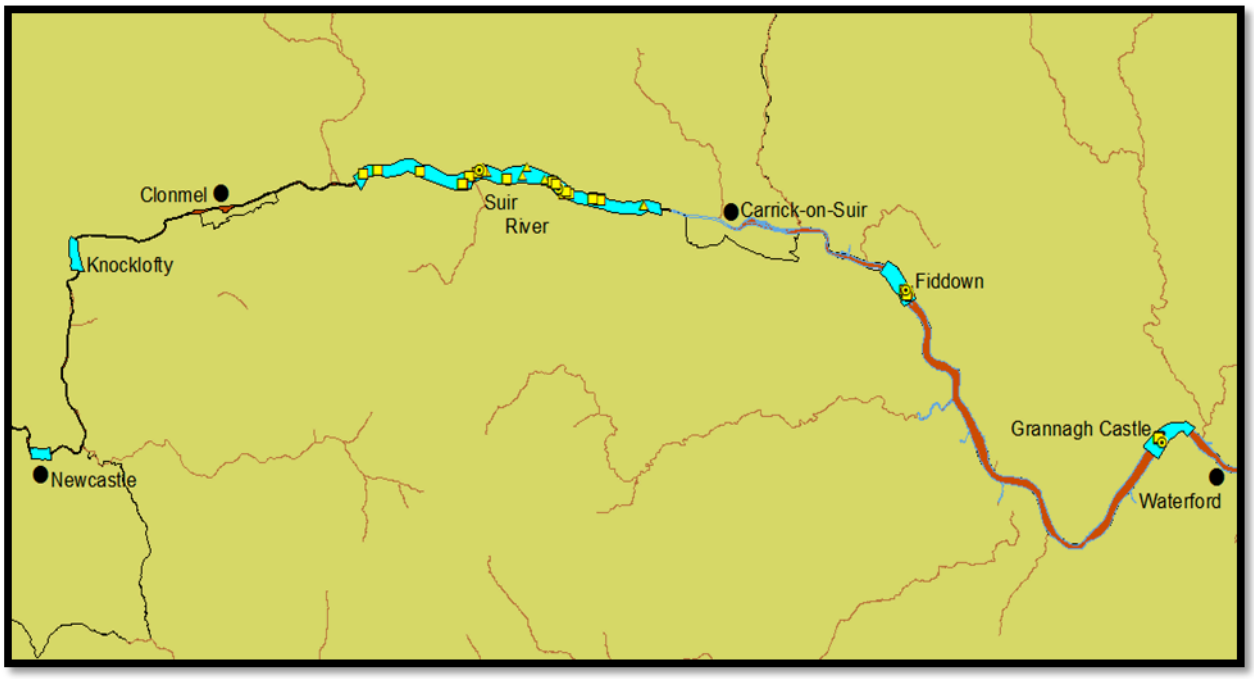


Figure 2.18 *Map showing all Cormorant encounters in the Suir survey area during the intensive survey period (8th April – 24th May).*

= flying, = loafing, = fishing

Of all Cormorant encounters where birds could be aged (n= 151), 64.2% were classed as immature and 35.8% were adults.

2.3.4 Other Piscivores

In addition to Cormorant, nineteen avian fish-eating predators and four mammalian piscivores were recorded over the survey period in each of the four survey areas. A list of all species recorded is shown in Table 2.3.

Table 2.3 *All piscivorous animals encountered throughout the survey period (May 2010 – June 2011).*

Species	Owenea	Slaney	Ballynahinch	Suir
Avian				
Black Guillemot *Cepphus grille*	•		•	
Common Gull *Larus canus*	•	•	•	
Common Tern *Sterna hirundo*		•		
Cormorant *Phalacrocorax carbo*	•	•	•	•
Gannet *Morus bassanus*	•			
Great Black-backed Gull *Larus marinus*	•	•	•	
Great Crested Grebe *Podiceps cristatus*	•	•	•	
Great Northern Diver *Gavia immer*	•		•	
Grey Heron *Ardea cinerea*	•	•	•	•
Guillemot *Uria aalge*	•			
Herring Gull *Larus argentatus*	•	•	•	•
Kingfisher *Alcedo atthis*	•		•	•
Lesser Black-backed Gull *Larus fuscus*	•		•	
Little Egret *Egretta garzetta*		•	•	•
Little Grebe *Tachybaptus ruficollis*	•	•	•	
Razorbill *Alca torda*	•			
Red-breasted Merganser *Mergus serrator*	•	•	•	
Red-throated Diver *Gavia stellata*	•			
Sandwich tern *Sterna sandvicensis*	•			
Shag *Phalacrocorax aristotelis*	•		•	
unidentified Auk species	•			
Mammalian				
Common Dolphin *Delphinus delphis*	•			
Grey Seal *Halichoerus grypus*	•	•	•	
Harbour Porpoise *Phocoena phocoena*	•			
Otter *Lutra lutra*	•	•	•	•

Three species, Cormorant, Grey Heron and Herring Gull were recorded in all four survey areas, with a further seven species; Common Gull, Great Black-backed Gull, Great Crested Grebe, Kingfisher, Little Egret, Little Grebe and Red-breasted Merganser encountered in three individual

survey areas. Within the intensive survey period the most frequently recorded avian fish-eating predator was Cormorant, followed by Grey Heron, Shag and Red-breasted Merganser.

Grey Seal was recorded in three survey areas and was the most abundant mammal observed across all survey areas over the thirteen month count period with a total of 69 seal encounters, followed by Otter (30 encounters) (Fig. 2.19). Otter was the only mammal observed in all four survey areas. Within the intensive survey period, Grey Seals were the most abundant piscivorous mammal and were encountered on 46 occasions with Otters being encountered four times.

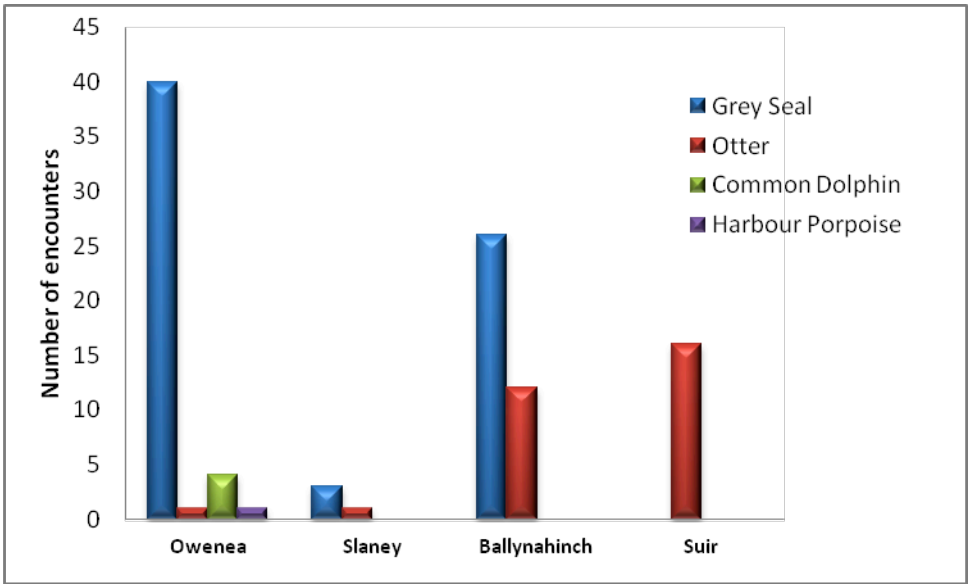


Figure 2.19 *The number of mammalian predators encountered at each site over the course of the survey.*

Owenea

A total of 19 fish-eating birds were recorded in the Owenea survey area, making it the most diverse survey area for avian piscivores. Within the intensive survey period Shag (n = 176) was the most numerous, followed by Sandwich Tern (n = 144) and Red-breasted Merganser (n = 143). Trends in densities of these species using the survey area during the intensive period show that the number of Shags, Red-breasted Mergansers and Great Northern Divers peaked towards the end of April, while no such trend was observed in Cormorant numbers (see Figure 2.19 below). There was a smaller, and less sustained rise in the numbers of Red-breasted Mergansers in mid-May. The number of Shags recorded also increased and continued to grow. Cormorant numbers increased too, albeit at a lesser extent. Cormorants were recorded at a rate of 3.9 encounters per visit during this period, compared to 13.5 Shags, 11.0 Red-breasted Mergansers and 3.6 Great Northern Divers.

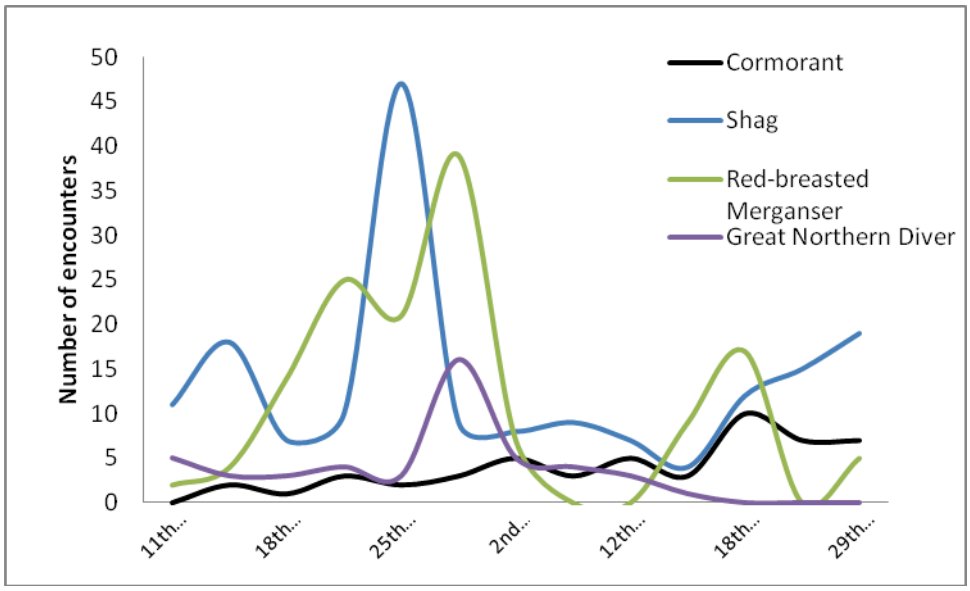


Figure 2.20 *Numbers of Cormorants and other avian piscivores at the Owenea survey site during the intensive survey period (7th April - 29th May).*

A total of four fish-eating mammals were recorded in the Owenea survey area over the entire survey period. Within the intensive survey period, Grey Seals were observed at an average of 3.2 seals per visit (n=42 encounters). Three Common Dolphins and one Harbour Porpoise were also encountered (Fig. 2.18) during this period.

Slaney

A total of 10 fish-eating birds were recorded in the Slaney survey area during the 13-month survey period. During the intensive survey period Cormorants (n = 628) were the most numerous, followed by Grey Heron (n = 88) and Little Egret (n = 70). There was an increase in the numbers of Grey Herons and Little Egrets using the survey area in mid-May (Fig. 2.20). This trend coincided with Cormorant numbers being at their lowest for the entire survey period. Cormorants were recorded at a rate of 44.9 birds per visit, compared to 6.3 Grey Herons and 5.0 Little Egrets per visit.

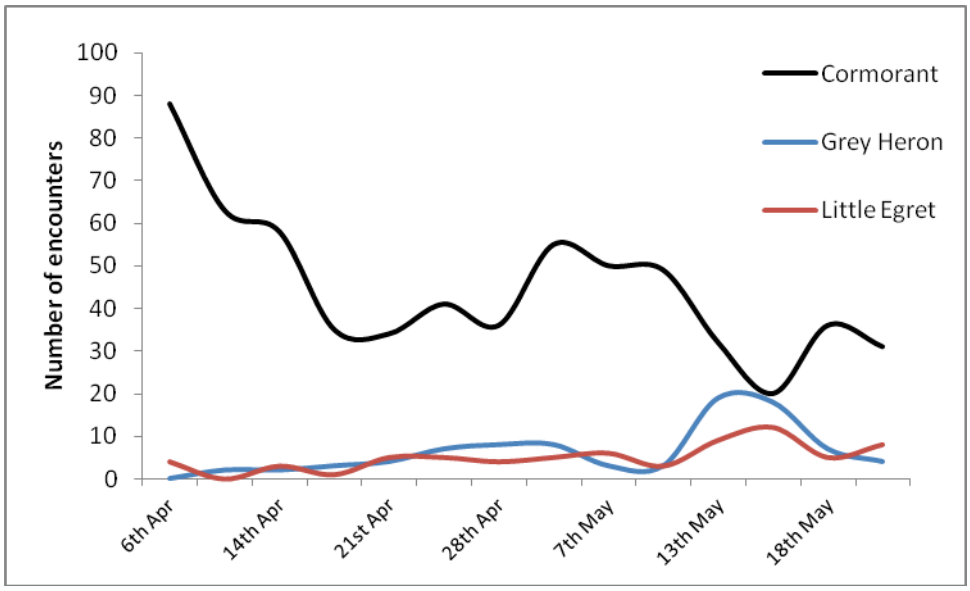


Figure 2.21 *Numbers of Cormorants and other avian piscivores the Slaney survey area during the intensive survey period (6th April - 26th May).*

Two fish-eating mammals (Grey Seal and Otter) were recorded in the Slaney survey area over the survey period. Within the intensive survey period, a single Grey Seal were observed (Fig. 2.18).

Ballynahinch

A total of 14 fish-eating birds were recorded in the Ballynahinch survey area, making it the second most diverse survey area for avian piscivores. Within the intensive survey period Cormorants (n = 85) were the most numerous, followed by Grey Heron (n = 21) and Red-breasted Merganser (n = 9). Trends in the numbers of these species using the survey area show that the peak in Cormorant numbers (n=19) in the second half of April was not accompanied by any perceptible rise in the number of Grey Herons of Red-breasted Mergansers (Fig. 2.21). An average of 1.6 and 0.7 birds per visit was recorded for Grey herons and Red-breasted Mergansers, respectively, compared to 6.5 Cormorants per visit. The relatively low numbers of Grey Herons and Red-breasted Mergansers remained stable over the course of the intensive survey period.

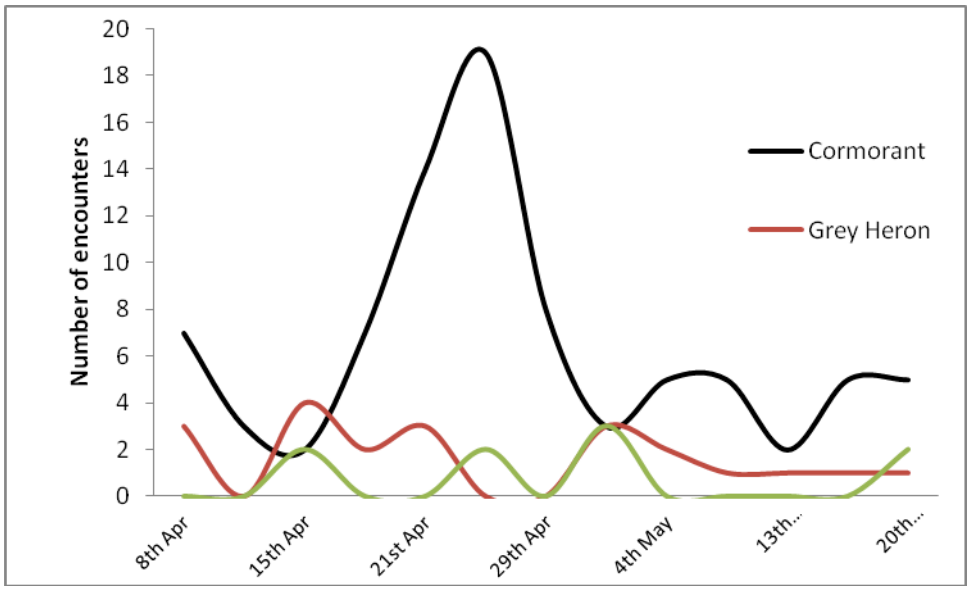


Figure 2.22 *Numbers of Cormorants and other avian piscivores at the Ballynahinch survey area during the intensive survey period (8th April - 20th May).*

The two fish-eating mammals that were recorded in the Ballynahinch survey area (Fig. 2.18), over the survey period, were Grey Seal and Otter, with 26 and 12 encounters, respectively. Within the intensive survey period, Grey Seals were observed at an average of 1.0 seal per visit (n=13 encounters) and Otters (n=2 encounters) were observed at an average of 0.2 Otters per visit.

Suir

Five fish-eating birds were recorded in the Suir survey area. The most abundant species was Cormorant (n=235) followed by Grey Heron (n=149) and Little Egret (n=11). Within the intensive survey period Grey Heron (n = 93) was the most numerous, followed by Cormorant (n = 92) and Little Egret (n = 6). Cormorants and Grey Herons were both encountered at a rate of 6.6 birds per visit.

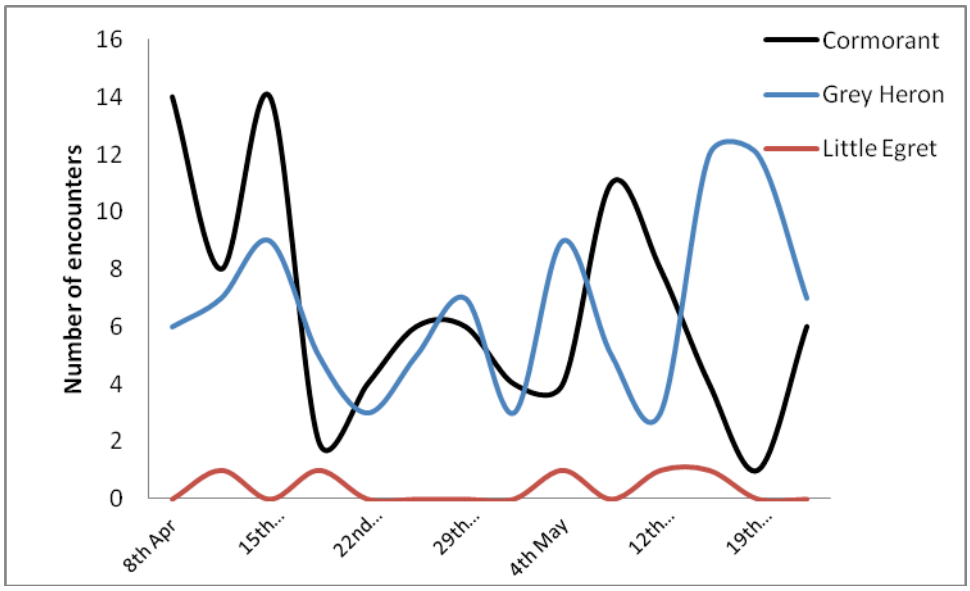


Figure 2.23 *Numbers of Cormorants and important avian piscivores in the Suir survey during the intensive survey period (8th April - 24th May).*

Otter was the only mammalian predator recorded in the Suir survey area (n=16), being encountered at a rate of 1.3 Otters per visit during the normal survey period, and 0.1 Otter per visit during the intensive survey period.

3. DIRECT OBSERVATIONS OF FORAGING BIRDS

3.1 Background

Direct observations of foraging Cormorants can be used to determine prey selection and consumption (Carss *et al*., 1997). This method has several advantages over other diet analysis techniques, as it is non invasive and facilitates data on the spatial and temporal variation in numbers of foraging birds and the type and frequency of prey consumed can be linked to specific foraging areas, which is not possible with other diet analysis methods. Supplementary information on diving behaviour can also be collected, which can be used to estimate catch per unit effort to demonstrate foraging efficiency (see Grémillet 1997).

Although this method can yield valuable information, its effectiveness is influenced by numerous factors, such as the ability of the observer to get within sufficient proximity to birds to adequately observe foraging behaviour and success. As many Cormorant studies are conducted on large water bodies, this approach is therefore often impractical due to the distance between the observer and the focal bird. Birds foraging closest to the observer make attractive focal birds, as the potential for identifying prey species is increased compared with birds foraging at greater distance, which can introduce bias towards prey types that occur in inshore areas (Carss *et al*., 1997). Regardless of the distance between the observer and the subject, certain species are more easily identified than others. Species with longer handling times are more likely to be overrepresented, while smaller prey are likely to be missed altogether, especially if swallowed beneath the surface (Voslamber *et al*., 1995). Cormorants often surface, apparently without a fish, but still display behaviours such as head shaking, throat fluttering, gaping or drinking (pers. obs.), implying that they may have consumed prey before surfacing. The frequency with which Cormorants swallow fish underwater has not been quantified, therefore observations of prey intake rates are likely to be underestimated. The accuracy at which prey size can be measured, even using the bird's bill as a reference, is questionable, and the potential for inter-observer variability is high (Carss *et al*., 1997). Daily food intake cannot be estimated using this method, as even if a bird could be over the course of a day, and every prey item was accurately identified and correctly sized, the number of fish swallowed below the surface would remain unknown (Carss *et al*., 1997).

As a consequence of the factors listed above, direct observations to determine prey selection of Cormorants has not been widely employed. Voslamber *et al*., (1995) did use this method to investigate the size and species of prey caught by solitary foraging Cormorants in Lake Ijsselmeer in The Netherlands. The proportion of successful dives, along with the dive time and depth, were

recorded by focal animal sampling from both the lakeshore and a boat. Kalas *et al*. (1993) observed foraging Goosanders using focal animal sampling to record dive frequency and the proportion of successful dives. The authors of both studies acknowledge that since some proportion of prey is likely to be swallowed beneath the surface, any estimates of food intake are likely to be underestimated.

An objective of this project was determination of the abundance and distribution of Cormorants in each of the four study areas, which was achieved through standardised counts. A trial of direct observations of foraging Cormorants was also incorporated into the survey element to assess the merits of this technique in providing data to compliment the dietary analysis via the more standard pellet and regurgitate identification methods.

3.2 Methods

A protocol for recording predation events was initiated in September 2010 and trialled at all study sites between 9th September 2010 and 21st May 2011. Individual foraging Cormorants located 80 to 500 meters from the observer and in suitable areas which offered unrestricted views of the birds behaviour, were selected for fifteen minute focal animal samples (Altmann, 1974).The selected focal bird was observed for as long as possible up to a maximum of fifteen minutes. For each focal sample, the following information was recorded on standard recording forms; the date, start time and finish time, weather variables (using the same parameters described in section 2.2), tidal state and sea state where appropriate (using same parameters described in section 2.2), location of the observer (six figure grid reference), location of the focal bird (six figure grid reference), distance between observer and focal bird in meters, length of focal sample, age class of focal bird, total number of dives, number of head shakes and dips, total number of prey caught and size class and type of each prey caught. A successful predation event was inferred if head shaking, throat fluttering, gaping or drinking was observed after a dive. Prey items were categorised as either salmonid, coarse fish, flatfish or Eel.

In total 59 focal samples were attempted, which accounted for approximately fifty hours of fieldwork, these included 10 focal samples in the Owenea survey area, 38 in the Slaney, seven in the Ballynahinch survey area and four in the Suir. The fifty hours of fieldwork includes the actual observation time and the intervening period between focal samples when the observer was scanning to locate foraging birds within suitable range. All observations were conducted from suitable vantage points along riverbanks or headlands except for the Slaney survey area, where observations were also carried out from a boat.

Equipment used included:

- 8 x 42mm binoculars and/or 20-60 x 65mm telescope
- Handheld GPS
- Standard record sheets (and "weather writer" for boat work)
- Relevant 1:50,000 OS maps and field maps for annotation.
- Dictaphone

3.3 Results

Of the 59 focal samples attempted, eight were 15 minutes in length and 18 lasted longer than 10 minutes. The average length of focal samples was 6.6 minutes. The total length of all focal samples was 390.0 minutes.

Observations were prematurely ended (n = 51) for a number of reasons;

- The focal bird was lost from view (n = 28) (54.9%).
- The focal bird ceased foraging (n = 11) (21.6%).
- The focal bird was joined by another foraging bird, meaning differentiating between birds was not possible (n = 9) (17.6%).
- The focal bird was disturbed by the observer and took flight (n = 3) (5.9%).

Predation events were observed or inferred on 188 occasions from all focal sample attempts (n = 59). In the majority of cases (n = 182), it was not possible to identify the prey species. Six fish were successfully identified, which included three flatfish, two salmonids and one Eel.
Attempts to record focal samples by boat on the Slaney were unsuccessful as it was not possible to get within suitable observation range of a bird without scaring it.

4. DIETARY ANALYSIS USING REGURGITATED SAMPLES

4.1 Methods

4.1.1 Selection of study sites

In order to determine Cormorant diet composition in the survey regions, available data on the locations of breeding colonies previously recorded as part of the Breeding Birds Atlas (2007 – 2011), Seabird 2000 and the NPWS 2010 colony census were assessed, in addition to liaising with local IFI and NPWS staff to draw on local knowledge in each of the four survey areas. All colonies within a 30 km radius of the survey areas were identified and subsequently investigated to determine their accessibility and suitability for collecting diet samples. In total four breeding colonies were selected in three of the survey areas. It was not possible to locate any breeding colonies within the specified distance from the Suir survey area. Two colonies (Lough Scannive and Loughahalia) were classed as coastal under the criteria applied to Seabird 2000, whereby a colony is defined as coastal if it is situated within 5km of the mean high water mark. Two colonies (Great Saltee Island and Roaninish) were classed as marine as they are situated 6.9 and 3.7 km from the shore, respectively. In order to compare the diet at marine and coastal colonies to the diet of inland breeding birds over the same time period, a fifth inland breeding colony was also selected even though it was not associated with any of the four survey areas. A description including the relevant details of each breeding colony is given below, as well as a map showing their locations (Figure 4.1).

Owenea survey area

Roaninish island group (B 662 029) is a cluster of small, low-lying rocky islets in Gweebarra Bay, approximately 3.7 km north-west of Dunmore head in Co. Donegal. This marine colony is situated on an unvegetated islet, which is 8.3 km from the Owenea survey area. The NPWS 2010 colony census recorded 17 AONs.

Slaney survey area

Great Saltee Island *(X 946 964)* lies approximately 6 km off the south Wexford coast and is served by a boat in the summer, which ferries hikers and birdwatchers to and from the island. The colony is situated on grassy cliffs on the south side of the island. This colony is located 28 km from the Slaney survey area. The most recent available data indicates 145 AONs in 2011 (Niall Keogh, *pres. comm*.).

Ballynahinch survey area

Loughahalia *(L 971 400)* is a freshwater lake, which forms part of the River Screebe catchment in west Galway. It has an approximate surface area of 40ha and a mean depth of 1.7m (Harrod *et al*.,

2005). The Cormorant breeding colony, which is exclusively tree nesting, is located on a small vegetated island 450m from the lake shore. The colony is situated 14.1 km from the Ballynahinch survey area and is located 2.0 km from the coast, thereby defining the colony as "coastal". Most recent census data for this colony was from the NPWS 2010 colony census, which recorded 33 AONs.

Lough Scannive *(L 699 446)* is a small freshwater lake with a surface area of approximately 50ha, located amid a myriad of small lakes and ponds in the centre of Roundstone bog, west Galway. The breeding colony is a ground-nesting colony located on a small unvegetated island on the lake, and is known to have existed pre- 1968 (NPWS, 2005). The colony is located 3.9 km from the Ballynahinch survey area and is classified as coastal due to its proximity to the coast. The NPWS 2010 colony census recorded 136 AONs.

Suir survey area

It was not possible to locate a Cormorant breeding colony within 30 km of the Suir survey area despite investigation of all available and relevant data sources and liaison with IFI staff and NPWS conservation rangers.

Silver Island (M 844 024)

The Silver Island colony is situated on the northern edge of Lough Derg on the river Shannon, close to Portumna on the Galway and Tipperary border. It is a tree nesting colony with approximately 95 AONs (NPWS 2010 colony census), and is classed as an inland colony as it is located approximately 50 km from the coast.

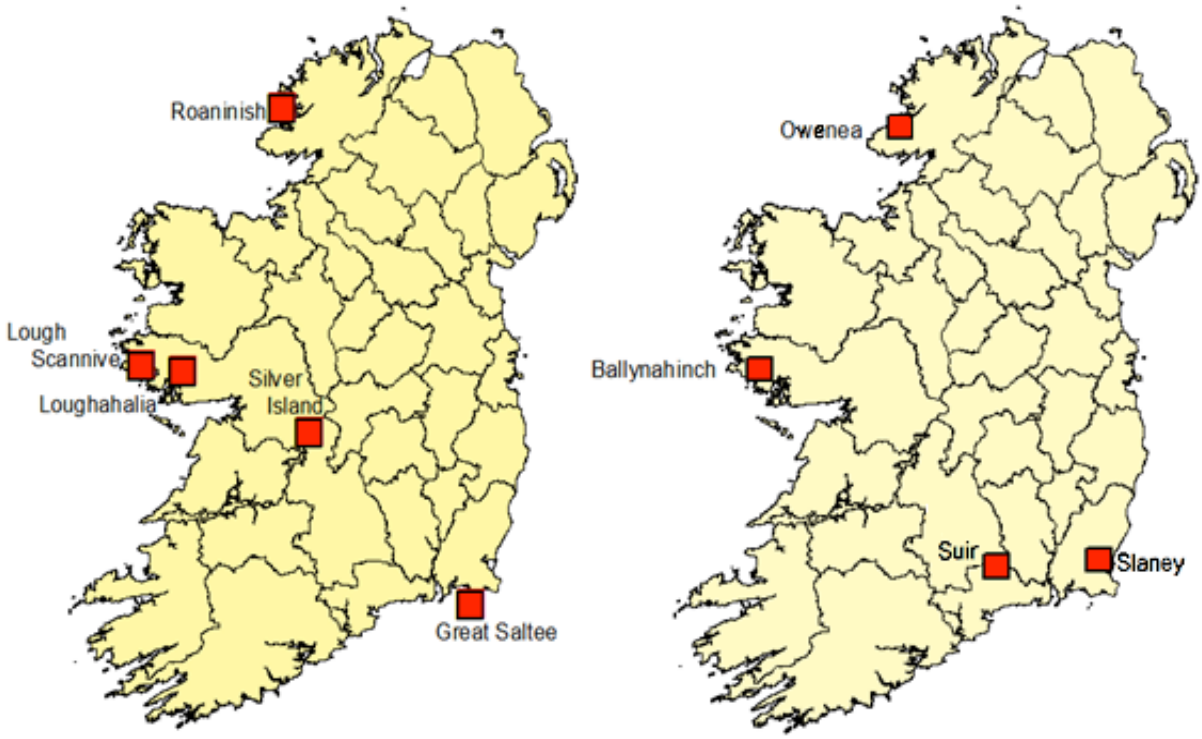


Figure 4.1 *The locations of sites used for dietary collection and analysis (left) in comparison to the locations of the survey areas (right)*

4.1.2 Dietary sample collection methods

A total of 14 diet sample collections were carried out at five Cormorant roosting and breeding colonies between the 27th January and the 1st June 2011. To assess seasonal shifts in prey choice diet samples were collected from Lough Scannive, Loughahalia and Silver Island in the winter and pre-breeding season, as these sites are used for roosting outside the breeding season. Collections at Roaninish and Great Saltee were confined to the breeding season. Given the diversity of colony types, the variation in terms of accessibility and the remote nature of specific colonies, a range of access methods were employed which included use of a canoe (n = 8), swimming (n = 2), use of a dingy (n = 1), chartering a private boat (n = 1) and use of a passenger ferry (n = 1).

Table 4.1 *Sites selected for diet composition study*

Site	Site type	County	Grid Reference	Number of visits	Access method	Dates visited (2011)
Loughahalia	Coastal	Galway	L971 400	5	Canoe	27th Jan, 23rd Mar, 15th Apr, 1st Jun
Lough Scannive	Coastal	Galway	L699 446	3	Swim & dingy	15th Apr, 1st Jun
Silver Island	Inland	Galway	M844 024	3	Canoe	8th Feb, 1st Jun
Great Saltee	Marine	Wexford	X946 946	2	Ferry	17th Apr
Roaninish	Marine	Donegal	B662 029	1	Charter	6th May

To ensure an effective health and safety protocol, a buddy system was operated for the duration of the field season, with particular emphasis on diet sample collections. All colony visits were carried out in pairs, and a specific office based BWI staff member was informed by Cormorant project staff prior to a colony visit of the following details; fieldworkers conducting the work, specific task, precise location details including a six figure grid reference of the colony and start time and estimated finish time. Contact was once again made by Cormorant project staff once the specific task had been completed. Health and safety related equipment carried by all fieldworkers included:

- Fully charged mobile phone
- First aid kit
- Lifejacket/wetsuit (for boat work)
- Map, GPS & compass
- Other essentials (sun screen, water, food, etc.)

As Cormorants are a Schedule II species, all visits to breeding colonies during the nesting period required a site specific Schedule II license from NPWS. All necessary licenses were acquired prior to the breeding season. In accordance with the license specifications, it was necessary to record any negative effects (such as increased predation by gulls or keeping incubating females away from eggs for prolonged periods) to the colony arising from visits by project staff during the sensitive breeding period. To this effect, all efforts were taken to reduce disturbance and visits were only conducted in suitable weather conditions (cold and wet days were avoided). The duration of time spent at a colony was kept to a minimum (dependent on the stage of breeding, weather conditions and the presence of predators) and always below 40 minutes. In order to

assess any potential negative effects the following aspects were recorded for each colony visit; the time at which adult Cormorants attending nests were flushed; the time of arrival of project staff at the colony; the presence, species and numbers of potential predators e.g. gull species; any successful or attempted predation attempts on Cormorant eggs or young; the time of departure of project staff from the colony and the time of settling of adult birds back at the nest sites. In addition, colony visits were also used to record specific breeding parameters where possible, including; the number of active nests; the stage of breeding; clutch counts and brood counts where appropriate and any relevant mortality data.

Image 4.1 *Chick regurgitates at the Lough Scannive colony*

On the initial visits to each colony an attempt was made to remove all pellets, and only pellets which were considered to be fresh (estimated to have been cast within the previous month) were later included within the identification and analysis. On subsequent visits to these colonies, all new pellets collected were then assumed to have been cast within the intervening period since the last visit, thus allowing diet data to be assigned to a specific time periods or season. All pellets collected were placed in individual zip loc plastic bags, which were then placed in a larger sealable bag and labelled with the site name and date. Regurgitates were collected at ground

nesting colonies (Lough Scannive, Roaninish and Great Saltee) by gathering fresh prey remains in proximity to nest sites or by collecting those discarded by nestlings. Nestlings spontaneously regurgitate some or all of their stomach contents, either to distract the predator, allowing the bird to escape to safety (kleptoparasitism is common among seabirds), or as a result of an adrenaline "fight or flight" response, which leaves the bird lighter and capable of a more rapid escape. Regurgitates were collected in a similar manner to pellets, each was placed in an individual sealable bag which was then placed in a larger sealable bag which was labelled with the site and date. All diet samples were then placed in a freezer at – 20^0c, where they were stored until analysis.

4.1.3 Diet analysis methods

Diet analysis methods involved identification of prey items within pellets and identification of partially consumed fish species from regurgitates. The pellet analysis protocol was informed by best practise methods as described in (Cech *et al*., 2008a; Dirksen *et al*., 1995; Leopold and van Damme 2003; Ross and Johnson 1997; Veldkamp 1995b). Pellets batches were removed from the freezer and allowed to thaw prior to analysis. For each pellet, the mass (g) was calculated with the use of an electronic balance, and the pellet length and width (mm) was also measured.

Individual pellets were soaked in a mild detergent solution for 24 hours. Pellets were then placed in a sieve with a 0.5mm mesh under running water and agitated with a soft brush. The contents of the sieve were transferred to a sorting tray, and non-soluble mucous was manipulated by hand to identify remaining prey items and all other non-diagnostic material (non-soluble mucous and organic material such as algae, stones, vegetation etc.) was removed. All diagnostic material for use in the prey identification analysis was labelled and left to dry for 24hours.

Identification of prey species was conducted using all readily identifiable items occurring in the pellet. The material was first separated into different categories, which included vertebrae, otoliths, skull bones and non-piscean items (shrimp, molluscs). Primary diagnostic bones used in the analysis were otoliths, vertebrae, maxillary, premaxillary and parashenoid bones. Otoliths and small vertebrae were examined under a 10x magnification binocular microscope. Larger bones were examined by magnification hand lens. The number of prey items within each pellet was determined by calculating the number of unpaired items plus half the number of paired items. Identification to species level was achieved by comparison of diagnostic bones to Harkonen (1986), and Conroy *et al.,* (2005), the digital reference collection of diagnostic fish bones from the University of Nottingham (http://fishbone.nottingham.ac.uk) and a reference collection of fish bones from Otter spraints previously collected and identified by NPWS.

Otoliths were the main bones used for species identification. As otoliths change considerably throughout the development of fish, accurate identification was not possible if reference material for a specific otolith type size was not available. Where additional diagnostic material was available, prey items were identified in this manner. Otoliths and vertebrae of salmonids are distinct from other species, however are similar between salmonid species, therefore it was often not possible to identify to species level within this category.

Regurgitates were removed from the freezer and allowed to thaw. Where possible prey items were identified based on physical characteristics and by comparison with Miller *et al.,* (1997). For prey items which were too decomposed, incomplete or which were not possible to identify to a species level in this manner further preparation and analysis was undertaken. The regurgitate was agitated under running water within a 1mm meshed sieve over a pair of stacked, inclined black sorting trays and the flesh was stripped by hand. Key diagnostic bones were removed and compared to the reference material described above for pellet analysis.

Equipment used for the diet analysis included:

- Sorting try
- Dissection Kit
- Lab microscope with light source
- Petri dishes
- Sample tubes & caps
- Labels
- Detergent
- 500 micron (= 0.5mm) mesh sieve
- Ruler
- Electronic Balance
- Beaker
- Plastic sample bags

4.2 Results

A total of 255 dietary samples were collected from all sites between the 27th January and the 1st June 2011, from which a total of 269 individual prey items were identified. It was not possible to identify 55 prey items. A total of 156 samples (138 pellets and 18 regurgitates) were collected from coastal sites, 36 samples (35 pellets and 1 regurgitate) from the single inland site and 63 samples (37 pellets and 26 regurgitates) from marine sites. Table 4.2 shows the number of pellets and regurgitates collected and the total number of prey species recorded at each site.

Table 4.2 *Total number of dietary samples collected per roost/colony*

Site	Number of Pellets	Number of regurgitates	Total sample	Number of prey species*
Loughahalia	105	0	105	10
Lough Scannive	33	18	51	7
Silver Island	35	1	36	5
Great Saltee	0	15	15	5
Roaninish	37	11	48	6
Totals	**210**	**45**	**255**	

**Salmonids were counted as a species for the purposes of this table*

In total thirteen species were recorded across all sites, seven of which are typically marine species and seven of which are freshwater species. The most important prey item overall (in terms of frequency) was Ballan Wrasse (38.6%), followed by Perch (9.3%) and Roach (7.4%). However, the diet varied considerably between sites and particularly between inland, coastal and marine sites. The two coastal and two marine sites had diets dominated by Ballan Wrasse (range: 29.4-60.0%), while this species was absent from the diet at the inland site. Perch (32.6%) and Roach (21.7%) dominated the diet at the inland site.

Table 4.3 *Importance of each prey item recorded from all diet samples analysed.*

Species		**Number of prey**	**% of diet**
Ballan Wrasse	*Labrus bergylta*	125	38.6
Perch	*Perca fluviatilis*	30	9.3
Roach	*Rutillus rutillus*	24	7.4
Haddock	*Melanogrammus aeglefinus*	13	4.0
Tench	*Tinca tinca*	12	3.7
Trout	*Salmo Trutta*	11	3.4
Salmonid*		11	3.4
Ling	*Molva molva*	10	3.1
Pike	*Exos lucius*	8	2.5
Eel	*Anguilla anguilla*	5	1.5
Halibut	*Hippoglossus hippoglossus*	4	1.2
Mackerel	*Scromber scrombus*	4	1.2
Whiting	*Merlanguis merlangus*	1	0.3
Goby	Gobiidae	1	0.3
No ID possible		34	10.5
No ID possible, but not salmonid		21	6.5

**Not identified to species level*

Of the 269 individual prey items identified, marine species comprised 62.5% of the diet in numbers and freshwater species represented 37.5% (Fig. 4.2). The diet of the Great Saltee colony was exclusively marine, while the diet at Roaninish was compromised predominantly of marine species (78.5%). Marine species also constituted a greater portion of the diet at the two coastal colonies, whereas diet samples analysed from Silver Island contained only freshwater fish species.

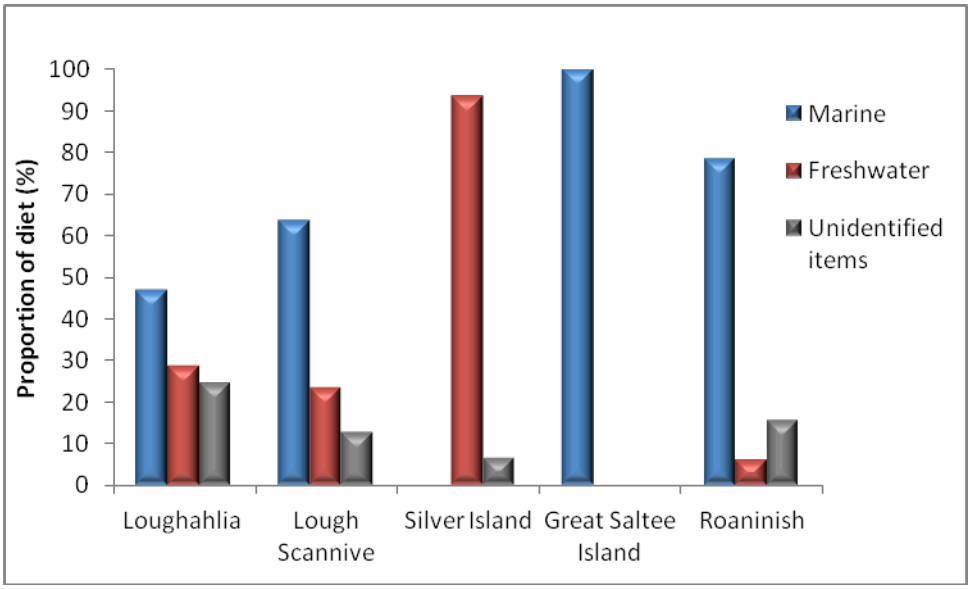


Figure 4.2 *The proportion of marine and freshwater species recorded at each site (n=269 prey items). * Salmonids and Eel are included within "Freshwater".*

The diet at the Loughahalia colony (Fig. 4.3) contained 10 species, and was dominated by Ballan Wrasse (29.37%). It was not possible to identify 24.48% of the prey items collected at this site. At Lough Scannive (Fig. 4.4), the diet was also dominated by Ballan Wrasse (54.55%) with six other species also confirmed. It was not possible to identify 12.73% of prey items collected. Five species were confirmed from Silver island (Fig. 4.5), and this was the only colony which recorded Pike (17.39%). This site also had the largest proportion of salmonids (21.74%) of all of the sites assessed. The recorded diet of the Great Saltee colony (Fig. 4.6) was dominated by Ballan Wrasse (60.00%) and was the least diverse, containing only four other species. All prey remains collected were successfully identified. The diet at the Roaninish colony (Fig. 4.7) was composed of six prey species and was also dominated by Ballan Wrasse (67.69%). It was not possible to identify 15.38% of prey items.

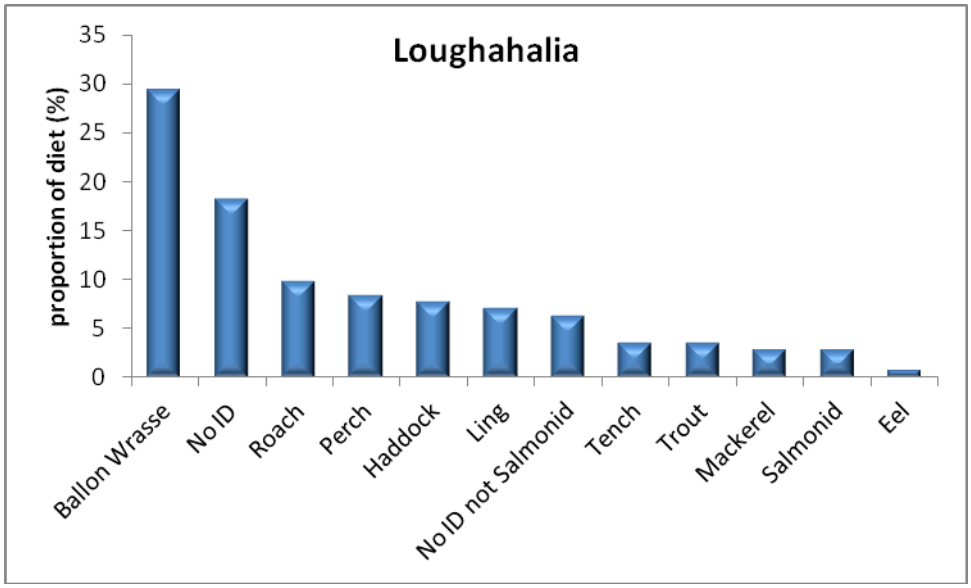


Figure 4.3 *Diet composition of the Loughahalia colony (n = 105 samples analysed).*

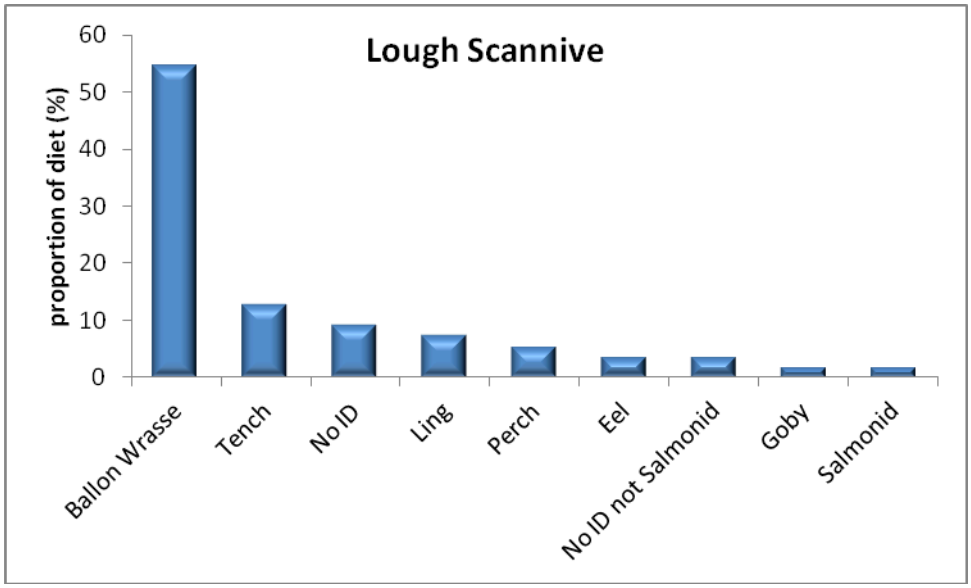


Figure 4.4 *Diet composition of the Lough Scannive colony (n = 51 samples analysed).*

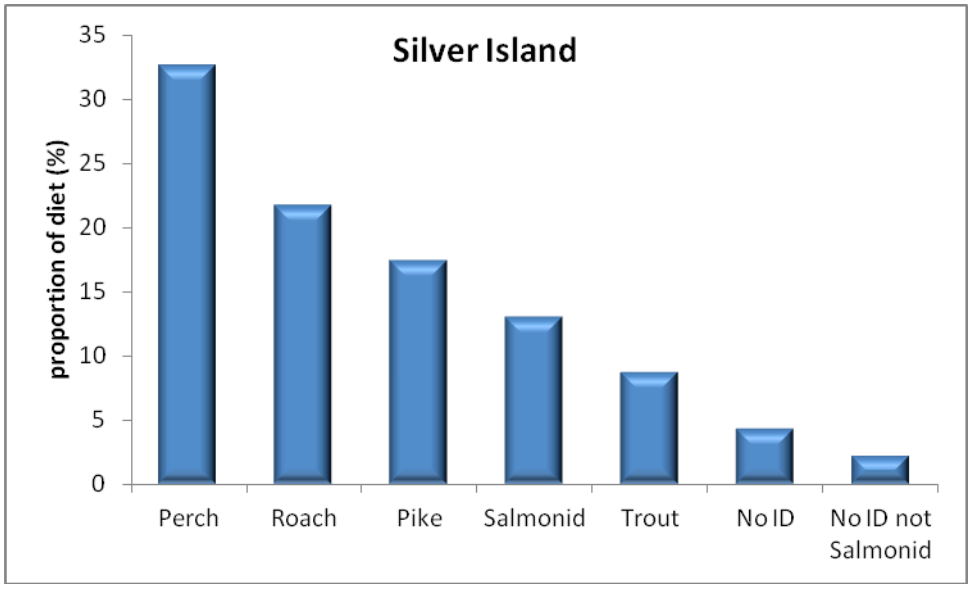


Figure 4.5 *Diet composition of the Silver island colony (n = 36 samples analysed). "No ID" refers to samples that could not be identified. "No ID not salmonid" refers to samples that could not be identified, but were not salmonids.*

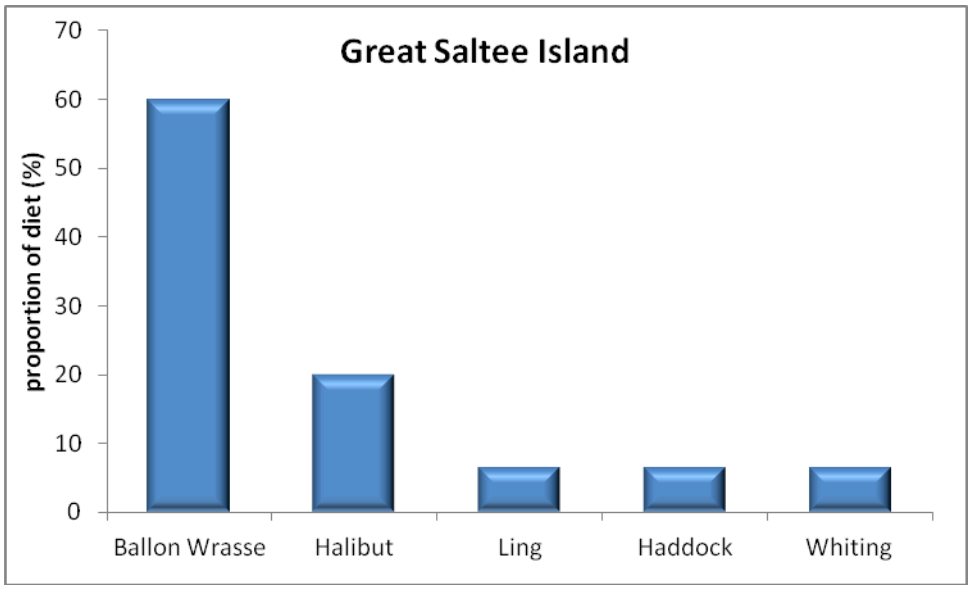


Figure 4.6 *Diet composition of the Great Saltee colony (n = 15 samples analysed).*

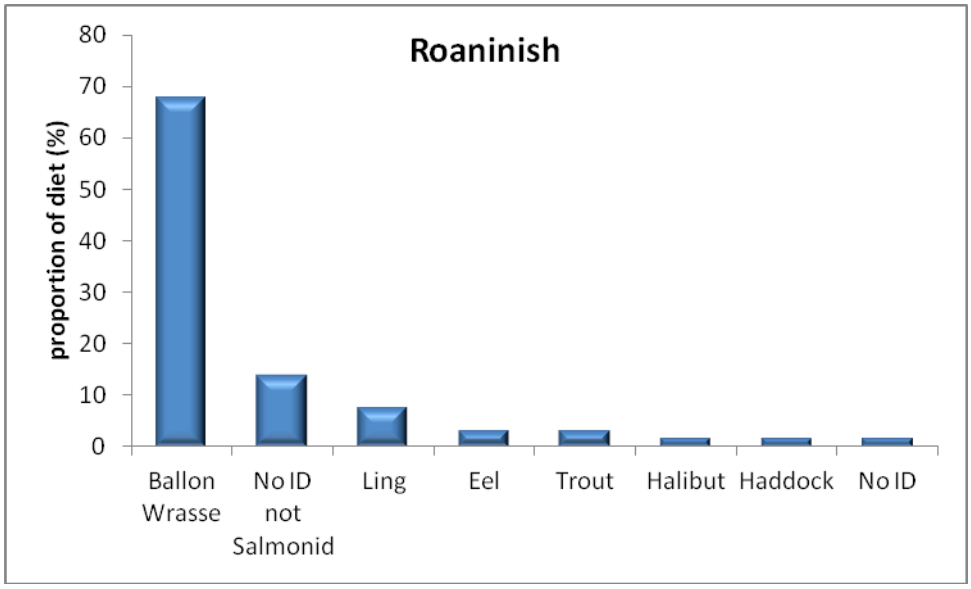


Figure 4.7 *Diet composition of the Roaninish colony (n = 48 samples analysed). "No ID" refers to samples that could not be identified.*

The proportion of salmonids in diets varied between the inland sites and those that were in, or closer to, a marine environment. The diet at the inland colony was composed of 21.74% salmonids (n=36) (either Trout or unidentified salmonids). Conversely, salmonids were absent from the samples analysed from the Great Saltee colony (n= 15). The diets at the three other colonies contained between 1.82 and 6.29% salmonids.

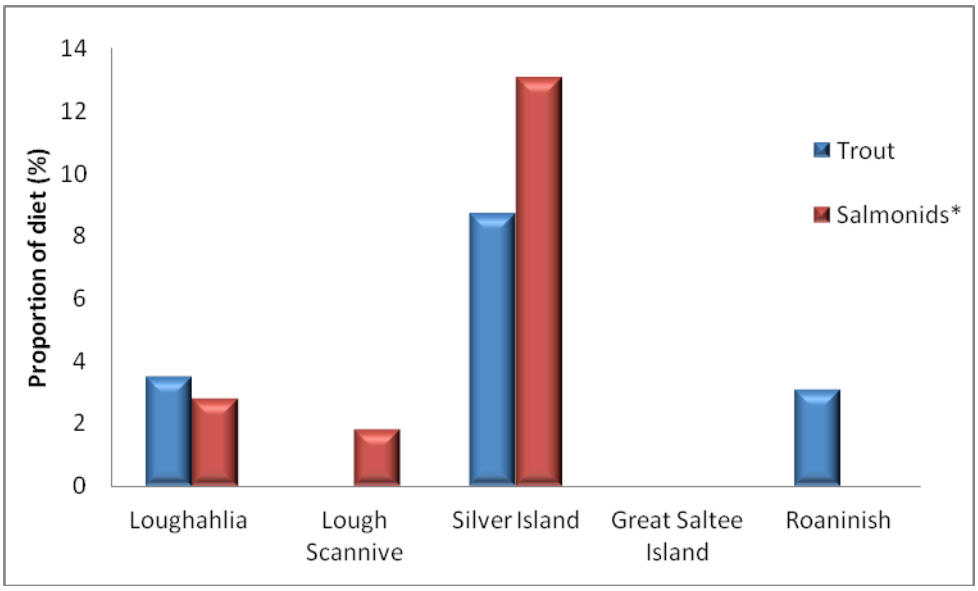


Figure 4.8 *Proportion of Trout and other salmonids recorded in the diet from all sites assessed (n = 255 samples analysed).* * Salmonids represent prey items that could not be analysed to species level, but that are either Salmon or Trout.

5. PERCEPTIONS OF FISHERY STAFF

5.1 Background

The expansion of Cormorant populations, coupled with their perceived impacts on certain commercially valuable fish species, has lead to conflicts with commercial and recreational fishery interests across Europe (Carss *et al*., 1997; Carss 2003; DEFRA 2003; Worden *et al*., 2004). The breeding and wintering Cormorant population in Ireland is experiencing a steady and continual increase, with an additional trend towards increases in inland wintering and breeding over recent years (BTO Breeding Bird Atlas (2007-11)). MacDonald (1987) previously noted the potential for conflict between Cormorants and fishery interests in Ireland, predicting that, with the growth of inland fisheries and intensive stocking programmes, this conflict is likely to intensify. Cormorants are particularly visible in comparison to other piscivores, which is in part due to their large size, the fact that they tend to spend long periods on the surface of the water or loafing close to their foraging areas and also frequently gather in small groups. Therefore, although fish populations are affected by a wide range of ecological factors, declines in specific fish stocks may often be directly linked to the presence of Cormorants. However, comprehensive data is required to determine the actual impact of Cormorants on fish populations at specific sites, and the presence of Cormorants should not automatically be identified as a conflict (DEFRA 2003). Since 2007, 18 licenses to kill Cormorants and 14 licenses to scare birds have been issued by NPWS.

It is essential to interpret the views of fishery staff regarding the perceived impacts of Cormorants and to use this data within a robust analysis of the documented impacts at specific sites. This is important in order to determine the most effective conservation objectives to benefit specific stocks, to utilise available resources in the most effective manner to achieve these objectives and to limit any unnecessary and ineffective culling or illegal persecution of Cormorant populations.

A survey questionnaire has been previously used by the Centre of Ecology and Hydrology (CEH) to interpret the views of fishery interests in relation to Cormorant predation and their impacts on fish stocks in Scotland (Dave Carss *pers comm*.). A similar survey was adopted for this project, the main objectives of which were to gauge the opinion of fishery staff on specific aspects in relation to the perceived impact of Cormorants and other fish-eating predators and the potential reasons for declines in certain fish stocks in Ireland and to then compare this information to data from the Cormorant survey (Chapter 2) and dietary analysis (Chapter 4) aspects of this project.

5.2 Methods

The drafting of the questionnaire was informed by a template of a previous questionnaire used by CEH in Scotland, but modified and expanded to meet the specific requirements of the current study. The draft questionnaire was sent to IFI to incorporate additional aspects that were deemed beneficial. The finalised questionnaire contained 32 questions in total, the majority of which were multiple choice (n = 17). Four of these allowed the participant to select more than one option. Some questions required respondents to rank answers in order of preference (n = 6), and the remaining nine requested respondents to input specific information or opinions. The questionnaire was designed to solely gauge the opinions of IFI staff, as due to the limitation of relevant research based data it would not be possible to answer the majority of questions with factual data.

The survey questionnaire was uploaded onto "Survey Monkey," a website that facilitates the creation of questionnaires and subsequent analysis of responses. A link to the online survey was then sent to IFI on the 23rd August 2011 for distribution to relevant IFI staff nationwide, with particular emphasis on staff whose jurisdiction incorporated each of the four survey areas. The survey questionnaire was only distributed to IFI staff and was not circulated to private fishery interests.

The deadline for submitting responses was 1st November. After this time the data was compiled and analysed. A summary of the results of the questionnaire is shown below followed by a detailed list of all questions and the answers provided.

5. 3 Results

5.3.1 Summary of results

A total of 21 IFI staff submitted responses to the questionnaire online, with an additional staff member completing the questionnaire over the phone. All participants provided answers to each question unless otherwise stated. The work areas of the 22 respondents were in different counties, which included Carlow, Cavan, Clare, Dublin, Galway, Kerry, Kildare, Kilkenny, Laois, Leitrim, Limerick, Longford, Louth, Mayo, Meath, Monaghan, Offaly, Roscommon, Tipperary, Waterford, Westmeath, Wexford and Wicklow. Of the 22 participants, 14 were based in areas that incorporated both coastal and inland habitats, while the remaining eight had work areas that were entirely inland.

Regarding the perceived impacts of IFI staff in relation to Cormorants and other fish-eating predators, the majority of respondents (n = 17) viewed predators to be a problem in their area, three IFI staff did not see predators as an issue and the remaining two participants did not know or did not have an opinion. Six (27.3%) participants ranked pollution as the main issue affecting fish stocks in their areas. Loss of habitat and predation were each selected by five participants representing 22.7% respectively. The remaining respondents considered poaching (13.6%), fishing at sea (9.1%) and fish farms (4.5%) to be the main issue affecting stocks. From a list of eight avian and mammalian piscivores, Cormorants were ranked as presenting the greatest problem by 14 (63.6%) participants, followed by Seal, Grey Heron and Mink. Kingfisher, Little Egret and Otter were not identified as problem species by any of the 22 respondents and one of the participants choose the option for "none of these predators".

From twenty IFI staff responses, Salmon most commonly listed as the fish species most affected by the factors outlined above (85%), followed by Trout (75%) and Eel (25%), with cyprinids, coarse fish, Bass and "all fish" all ranking at 5% (participants listed multiple species). Rivers were considered by 14 participants, to be the habitat type where fish are impacted to the greatest extent. Ten participants listed lakes, four listed tidal areas, and coastal areas were considered by one participant to be the location where fish are most severely impacted. Hatcheries, fish farms and "none of these" were provided as options but were not selected as areas where predation or other issues affect fish species. Regarding the specific problems caused by predators, 20 of the participants perceived that it was a result of predators consuming fish, ten believed it was due to predators damaging fish, three cited the main problem was the fact that predators were changing the behaviour of fish and one respondent indicated "other" problems. Participants were asked to select the resulting affects of predation from a list of five options. "Predation at early developmental stages" was judged by 18 participants to affect fish populations. The option for "predation of adult fish" was deemed important by 13, "fewer fish making it to sea" by 12, "fewer fish returning to spawn" by nine and "reduced recruitment" by six.

Of all participants, 40.9% were of the opinion that predation resulted in significant financial losses, 22.7% did not think this was the case and the remaining 36.4% answered that they "did not know" if predation caused significant economic losses. Nine IFI staff indicated the approximate extent of such financial losses, of these one (11.1%) perceived the loss to be in the region of €1,000 to €5,000, 22.2% believed it was €20,000 – €50,000, 22.2% indicated €50,000 – €100,000 and 22.2% thought predation of fish stocks resulted by the predators previously mentioned resulted in losses in excess of €100,000 on an annual basis. Two participants (22.2%) viewed predation as having no financial impact. From 21 respondents, 95.2% considered financial

losses to be predominantly affecting fishing tourism, 4.8% viewed fish farms as the area negatively affected by predation to the greatest extent, while none of the IFI staff who addressed this question considered the economic losses at hatcheries to be the most significant impact of predation.

In total 45.5% of IFI staff considered the problem of predation to be increasing a little, 31.8% viewed predation of fish to be increasing a lot, 13.6% were of the opinion that the problem has remained the same and 9.1% responded that they "did not know". None of the 22 respondents considered predation to have decreased. Those IFI staff that thought that predation was increasing were then asked to put forward their reasoning. The 16 responses were grouped into eight categories, with some answers spanning more than one category. The increase in Cormorant numbers was listed as the main factor by seven participants, an increase in Seal numbers was specified by five, an increase in Grey Heron numbers by three, an increase in general predator numbers by two and the Cormorants' inland range expansion by two. An increase in Red-breasted Mergansers, an increase in Mink and an increase in predators at inland sites were also listed.

Of all responses, 17 (77.3%) IFI staff believed that densities of Cormorants have increased in their areas of work in recent years; one (4.5%) was of the opinion that Cormorant numbers have remained more or less the same and four (18.2) did not know. None of the respondents believed local Cormorant populations in their area had declined in recent years. Of the 17 IFI staff that believed Cormorants to be increasing, 13 expressed their opinions as to why this was the case, with some listing more than one cause; six cited the lack of culling activities as the main driving factor influencing the increasing densities, four reported an abundant food supply as the primary reason, two thought it was due to a lack of predators and the remaining one believed it to be as a result of a diminished food supply at sea.

In terms of perceived densities of Cormorants within individual areas of work, 31.8% of IFI staff estimated that there were 501 – 1,000 birds present in their area, 22.7% thought there were 101 – 200, 13.6% thought that over 2,001 birds used their area, 13.6% indicated 201 – 500 birds, 4.5% 101 – 200, 4.5% 51 – 100, 4.5% 11 – 50 and 4.5% 1 – 10. April (27.3%) was considered the month at which Cormorant densities were at their highest in each of the participants study areas, followed by August (22.7%), May (22.7%), and March (18.2%). Less than 13.6% of participants ranked the remaining months as a time when Cormorant numbers were at their maximum. 54.5% of staff were aware of one or more Cormorant breeding colonies within their area of work.

A total of 59.1 % of participants believed that Cormorants in Ireland in general feed to a greater extent on freshwater fish species in comparison to marine prey. Regarding the prevalence of freshwater fish species in the Cormorant diet, seven IFI staff (31.8%) perceived Salmon to be the most important prey item, followed by Trout (22.7%), Eel (27.7%), and Roach (9.1%), 3 (13.6%) answered that they didn't know and no IFI staff member selected Perch, Pike, Bream, Rudd, Tench or other fish species as constituting the most important freshwater component of Cormorant diet. Specifically regarding the importance of salmonids in the diet, 27.3% of staff considered salmonids to constitute between 26 – 50%, 13.6% of IFI staff believed salmonids comprise 1 – 25% of Cormorant diet, 13.6% thought this figure was 51 – 75%, 4.5% answered 76 – 100% and 40.9% replied that they did not know. The majority (45.5%) believed that Cormorants were mainly feeding on salmonids at the smolt stage, followed by parr (31.8%) and adult salmonids (4.5%). One (4.5%) respondent indicated that they did not believe Cormorants were feeding on salmonids and three (13.6%) did not know. April and May (n = 6 participants each), followed by March (3 = participants) were considered the months during which Cormorants feed to the greatest extent on salmonids.

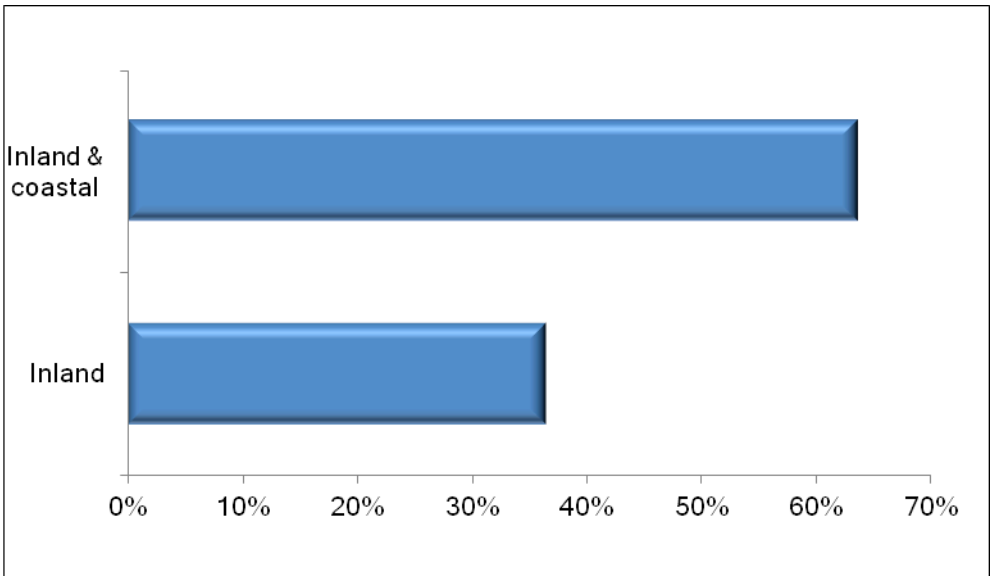
In relation to IFI staff knowledge of illegal persecution of Cormorants in the individual work areas, 20 (90.9%) had no knowledge of such activity occurring, one (4.5%) reported that illegal persecution does occur and one (4.5%) declined to answer. With regard to mitigation, 16 (72.7%) respondents indicated a necessity for measures to be put in place to mitigate the impact of Cormorants on salmonids. The suggested mitigation measures were grouped into categories with some answers spanning more than one category. Culling was recommended by 14, a scientific approach was called for by two, relocation away from spawning beds was proposed by one and scaring during the smolt run was suggested by one. In relation to the specific benefits of such mitigation 63.6% believed it would result in increased fish for anglers, 9.1% were of the opinion it would reduce hatchery losses, 4.5% suggested reduced fish farm losses and 50% listed "other" potential benefits.

5.3.2 Draft of questionnaire and responses

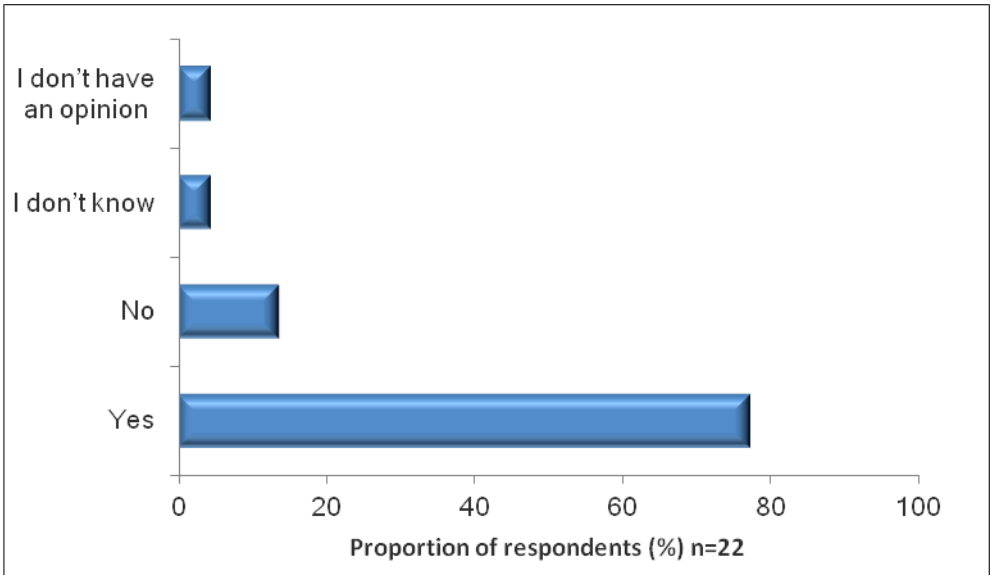
Q. 1 Please enter your name, position, contact address, telephone number and email address.

Q.2 Please specify the area where you work (listing main rivers, lakes, and coastal areas).

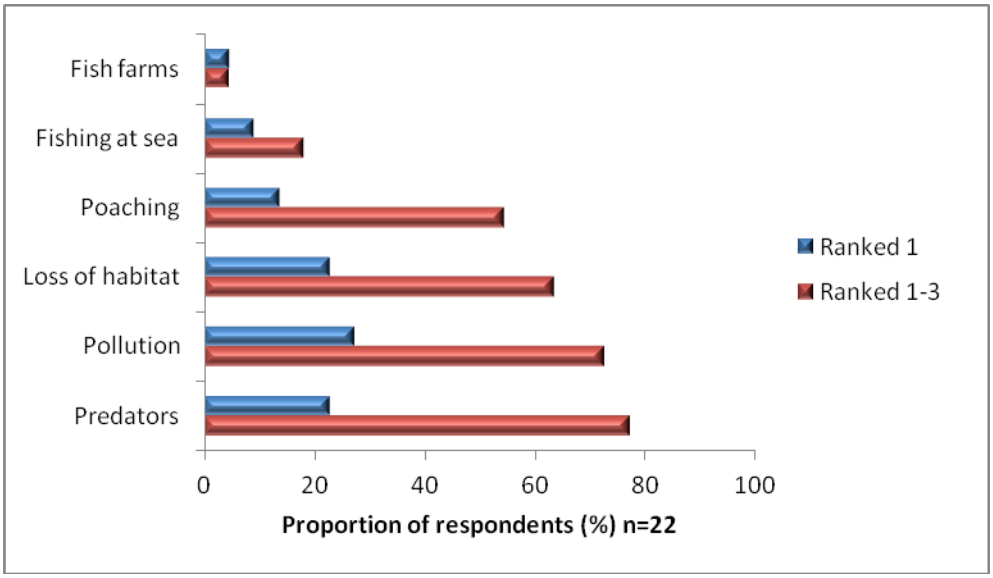
Q. 3 Is your area entirely inland or does it also contain coastal areas?



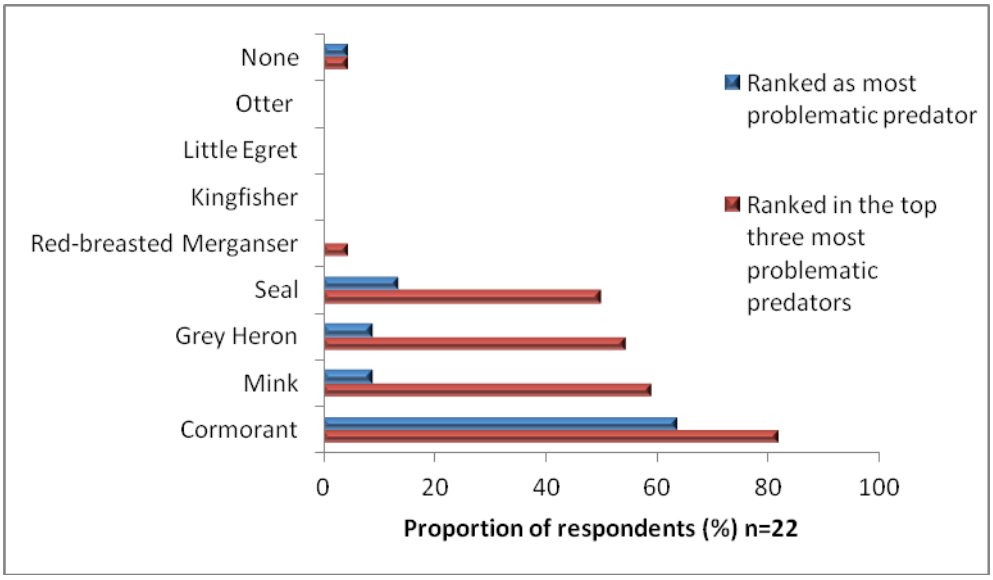
Q. 4 Do you view fish-eating predators as a problem in your work area?



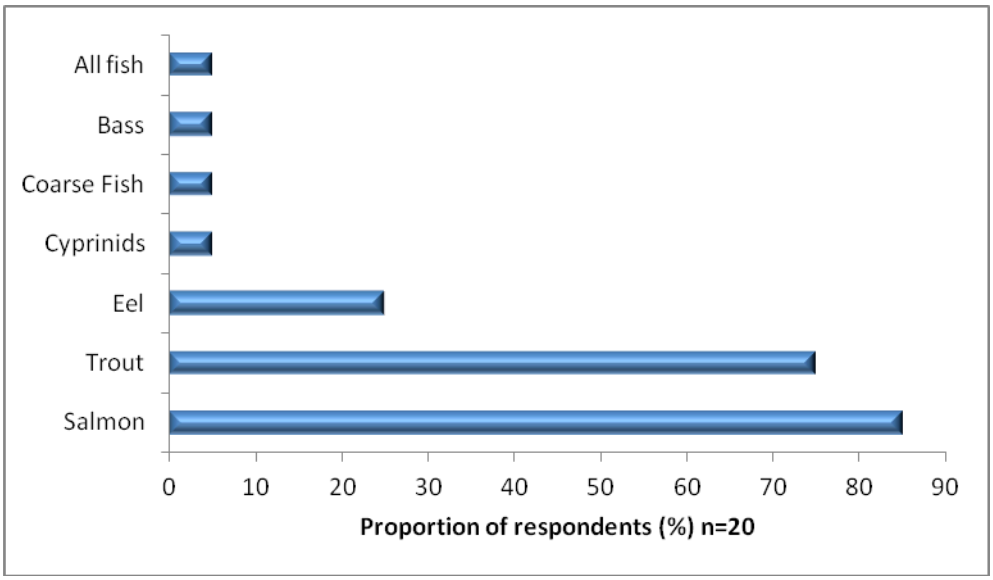
Q. 5 What issues do you think are affecting fish stocks the most in your area? Please rank the top three.



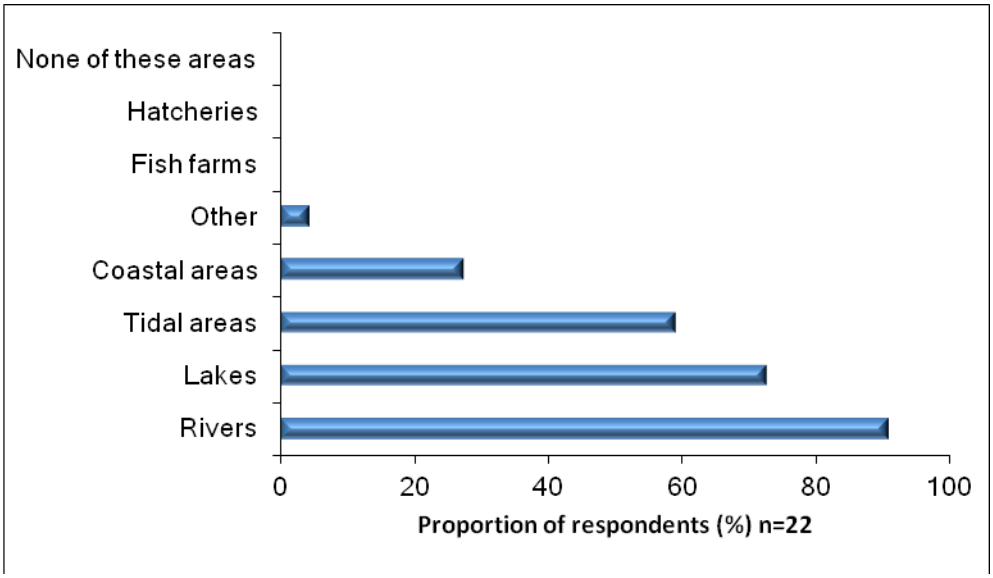
Q. 6 For your area, please rank the predatory species in order, with 1 representing the species that you think causes the greatest problems for your fishery (if you don't view a certain species to be a problem, please leave a blank beside them).



Q. 7 In your view, which fish species are most affected?



Q. 8 In what type of locations in your area do you believe the problems are occurring?



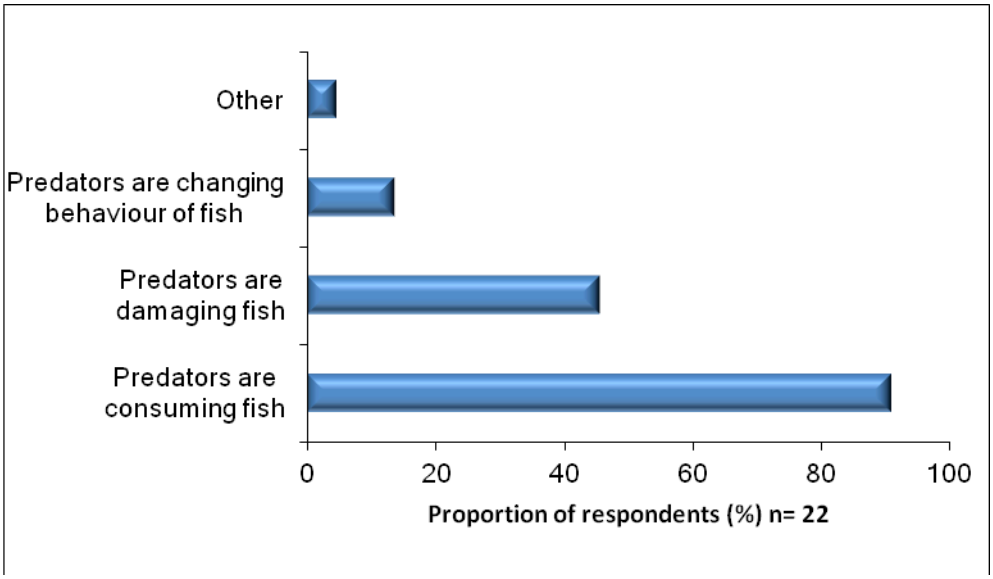
Q. 9 Please name the specific locations in your area where you think the problems occur.

Eighteen respondents answered this question:

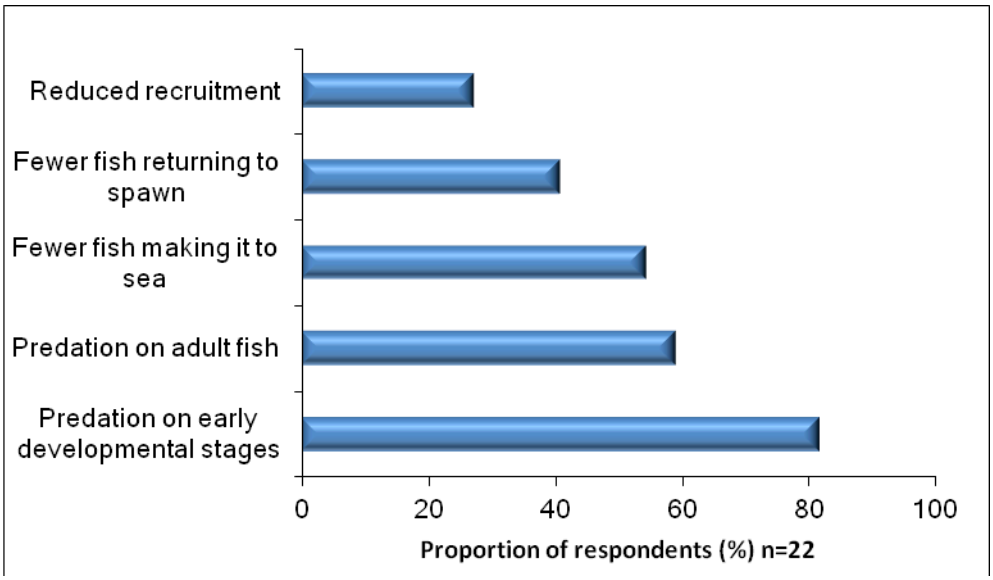
1. *"All salmonid rivers during smolt runs and spawning times"*
2. *"Lakes and tidal areas"*
3. *"The problem is widespread"*
4. *"They turn up everywhere"*
5. *"Too widespread to be specific"*
6. *"Predators are populating all areas"*
7. *"All rivers and lakes"*

8. *"Estuaries of the Cashla, Ballynahinch and Screebe Rivers, Connemara, Co. Galway"*
9. *"Lough Ramor, the Boyne estuary and the river Boyne"*
10. *"Great Island, Waterford Harbour, Lower Barrow and the tidal section of the River Nore"*
11. *"River estuaries flowing into Lough Mask and Lough Carra"*
12. *"Mouth of rivers and holding pools on rivers. Shallows areas of the lake where Cormorants can perch"*
13. *"Dublin Bay , the entire River Liffey and its tributaries, the Dodder River, Balsbridge, the Dargle, Peoples' Park in Bray, Vartry at Broadlough"*
14. *"Lower Lough Corrib, Upper Dunkellin, Clare river"*
15. *"Lower stretches of all rivers especially Feale, Maigue, Fergus, Inagh. Shannon estuary at various locations and especially where salmon and other fish seem to congregate. Most inland lakes have high numbers of Cormorants roosting in the water, above the dam at Ardnacrusha in head race, below dam at Ardnacrusha in tail race"*
16. *"In the main river Corrib and at the mouth of Galway Bay! "*
17. *"The entire Feale, Brick, Galey and Cashen catchments, from spawning grounds to tidal areas"*
18. *"River Moy, numerous Lakes and the Moy Estuary"*

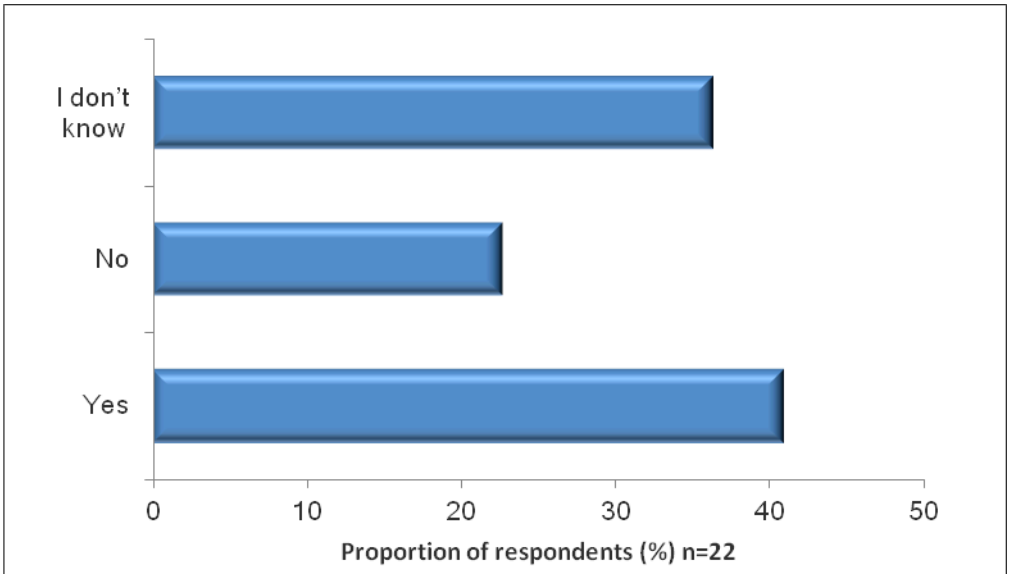
Q. 10 In your view what is the nature of the problem?



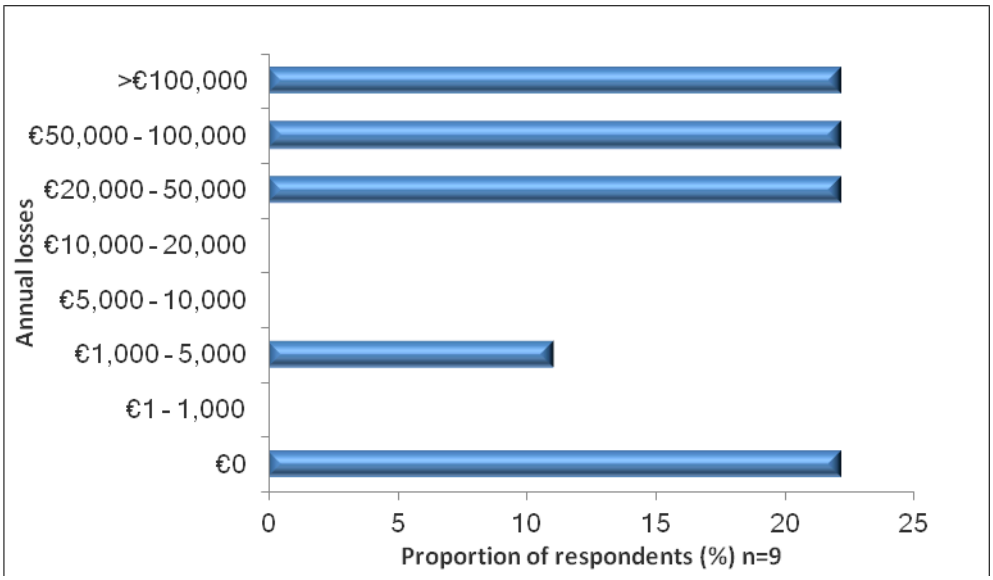
Q. 11 How is this affecting the fish populations?



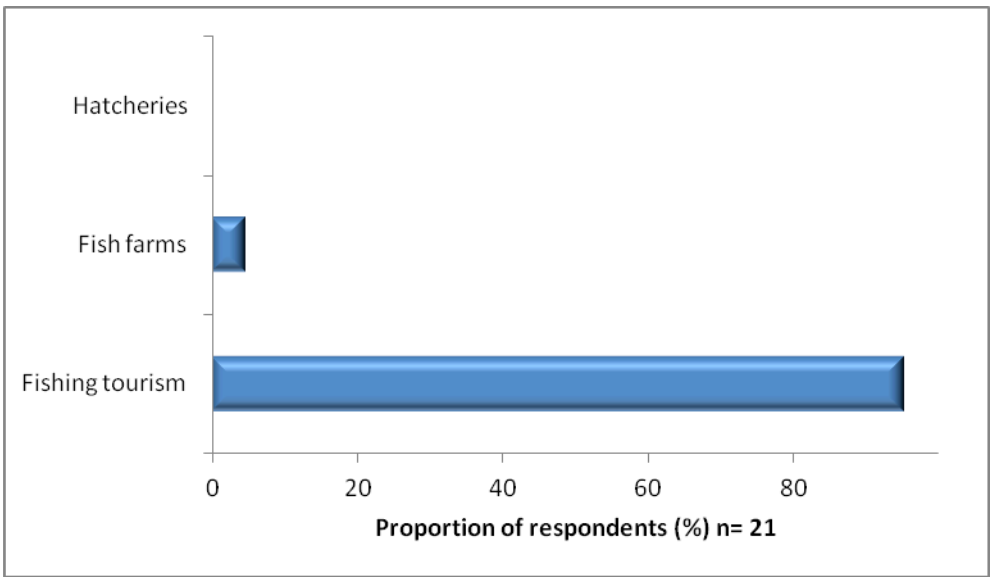
Q. 12 Is predation resulting in financial losses?



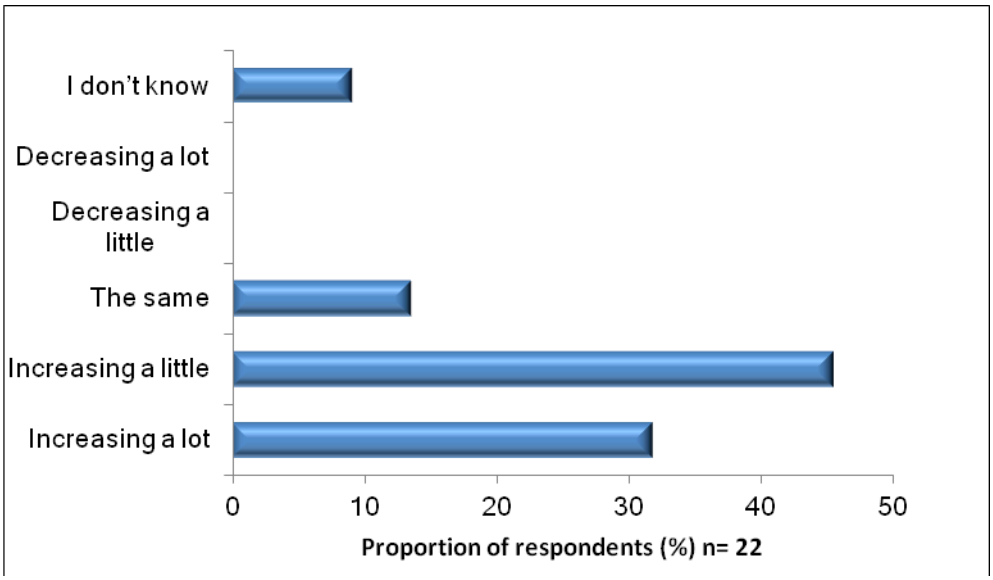
Q. 13 If yes, please indicate the approximate losses caused by predation on an annual basis for your area.



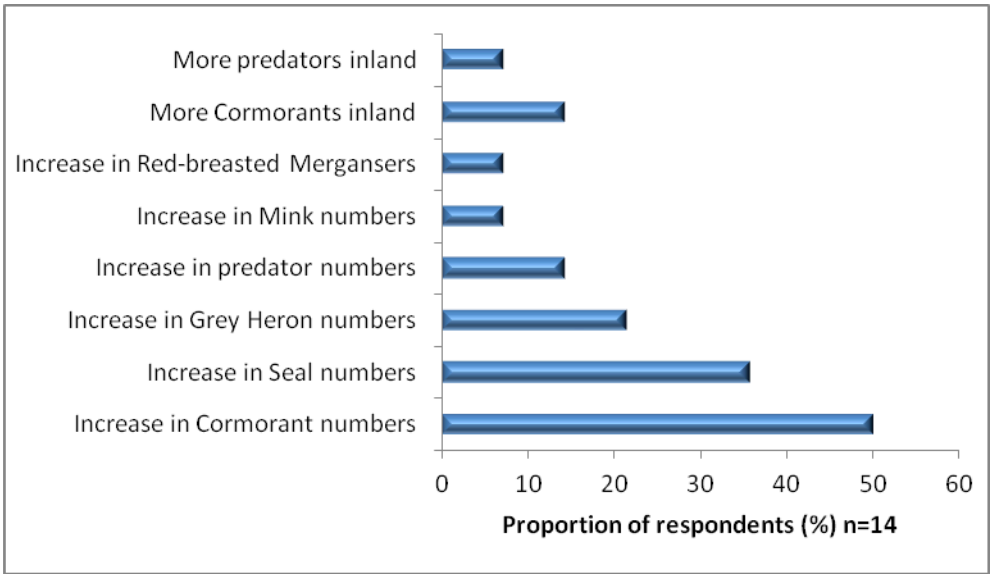
Q. 14 How are these financial losses mainly occurring? Please rank them.



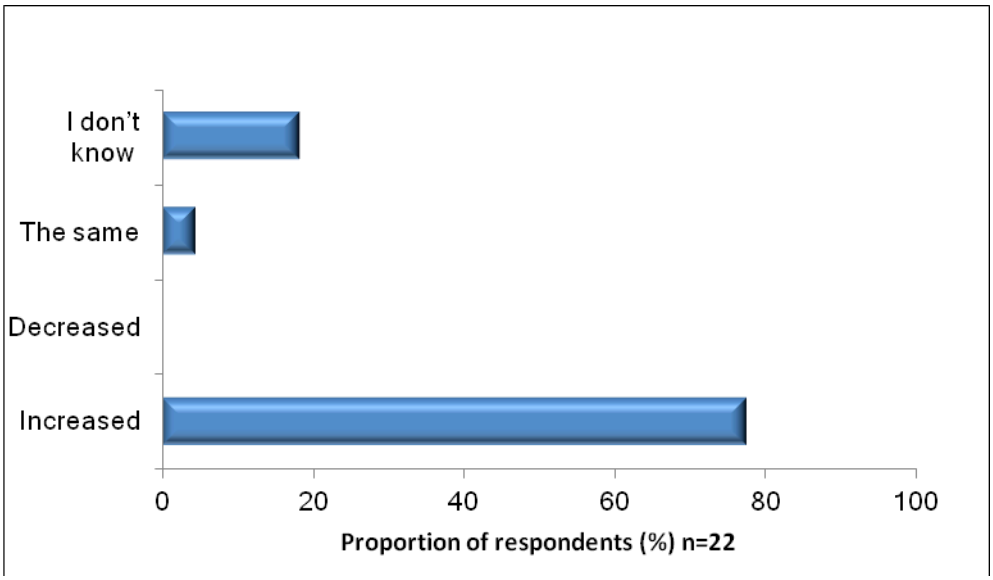
Q. 15 Do you think the problem of predation is increasing, decreasing or has remained the same in your area in recent years?



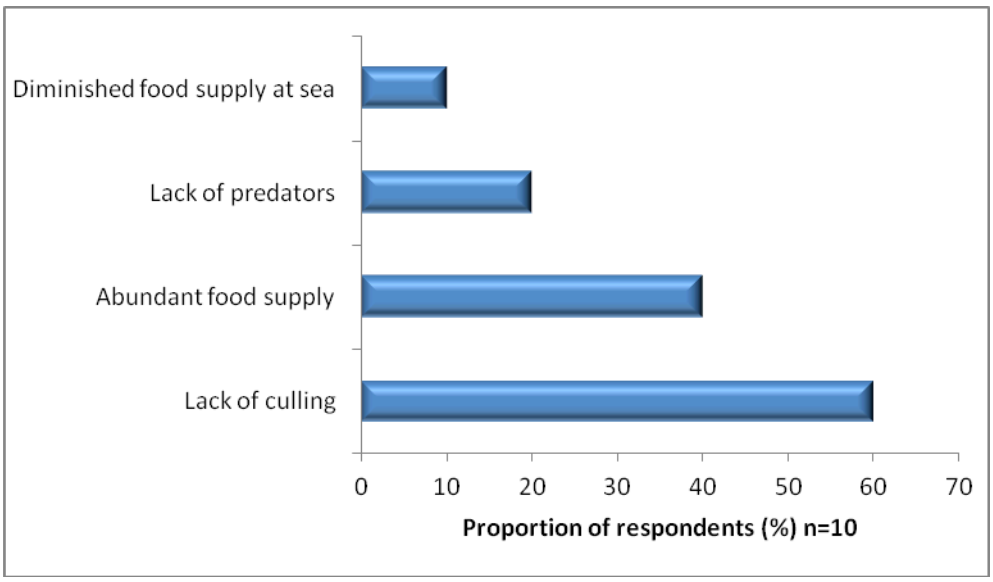
Q. 16 If your answer was "increasing a lot or a little" to number 15, please explain why you think this is the case.



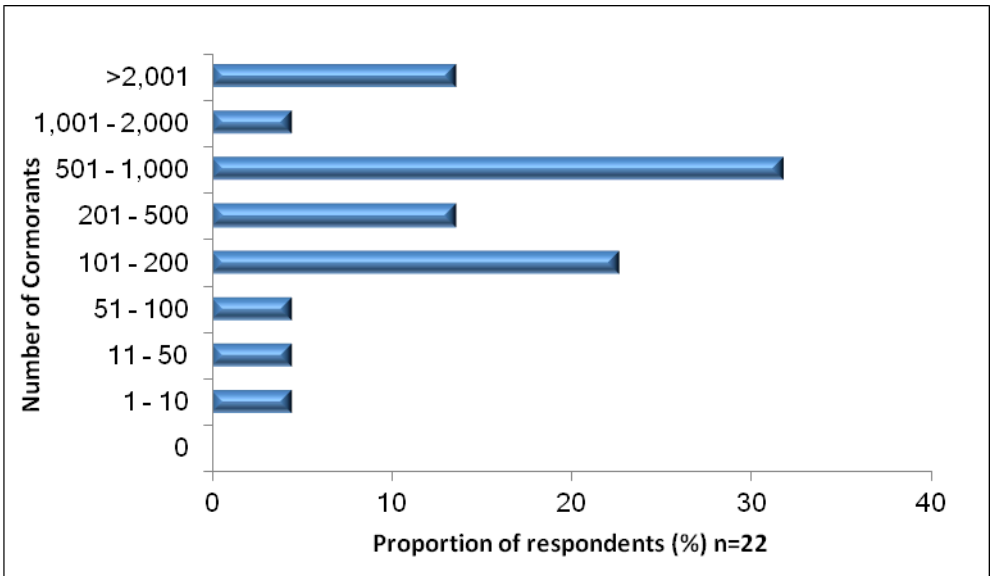
Q. 17 Do you think the number of Cormorants has increased, decreased or remained the same in your area in recent years?



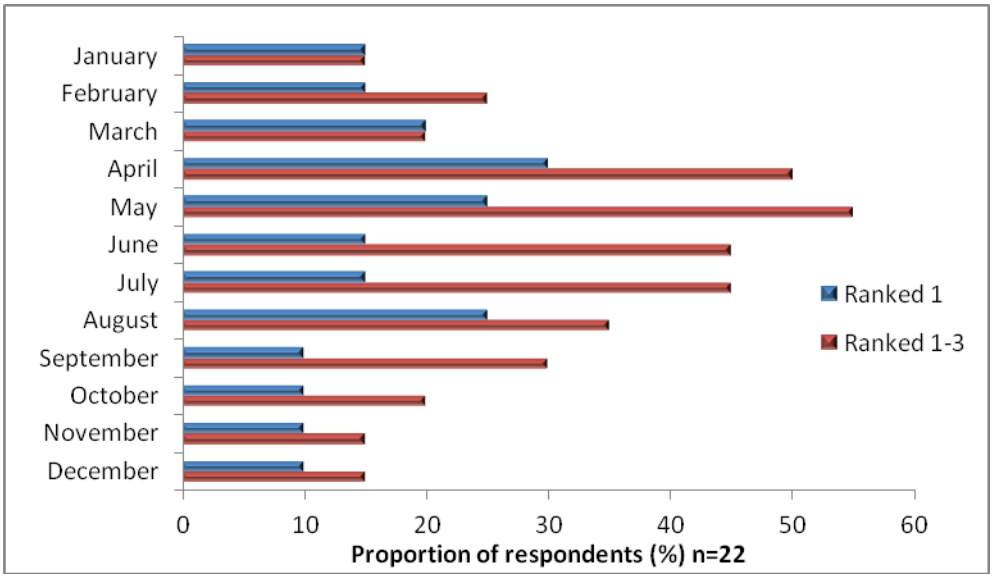
Q. 18 If you answered "increasing" to question 17, please explain why you think this is the case.



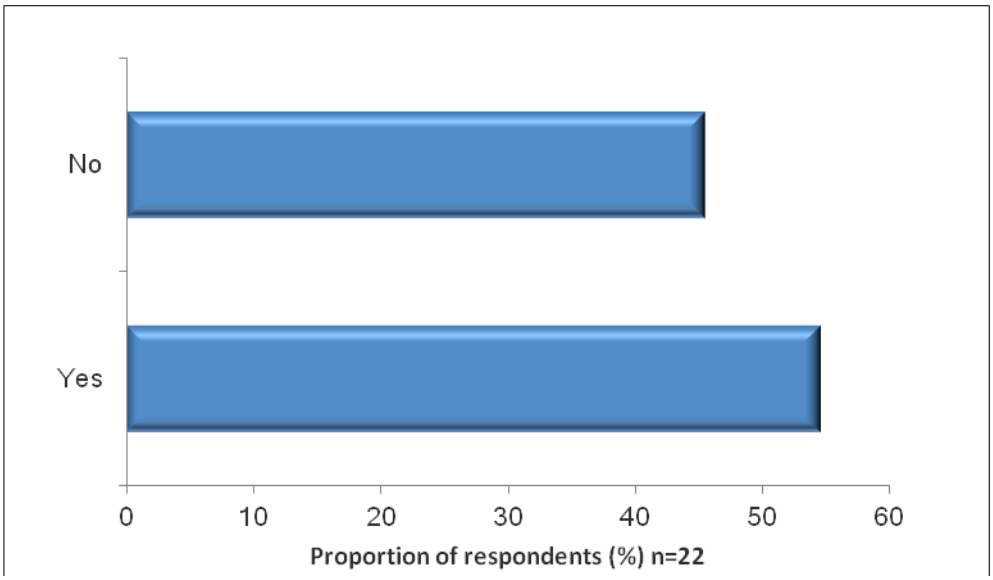
Q. 19 Approximately how many Cormorants do you think are present in your area?



Q. 20 Which month/s of the year do you think Cormorants reach their highest numbers in your area, please rate appropriate months with 1 representing the month with most birds (any months with no birds please leave blank).



Q. 21 Are you aware of a Cormorant breeding colony/colonies in your area?

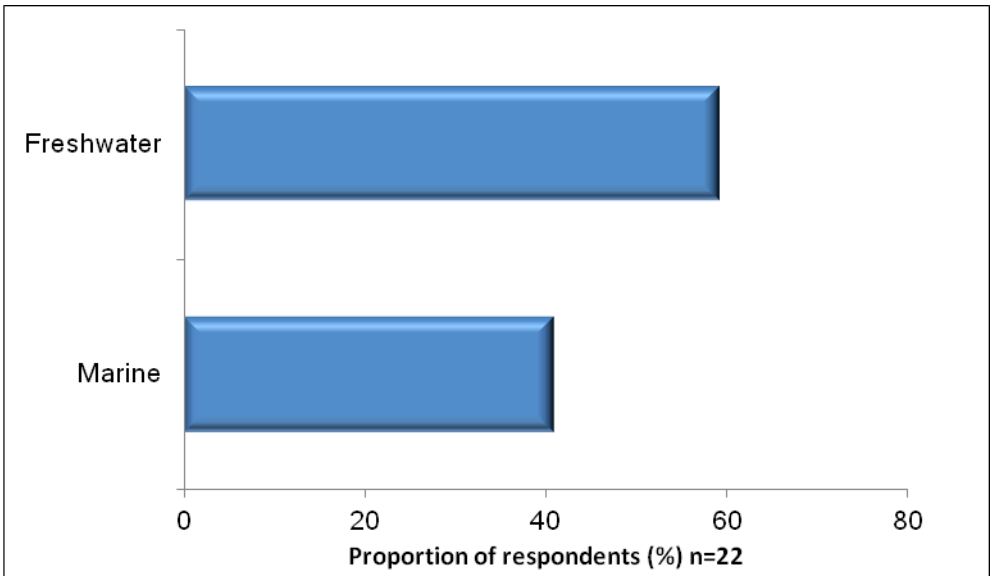


Q. 22 If so, please give a brief description of where the colony/colonies are?

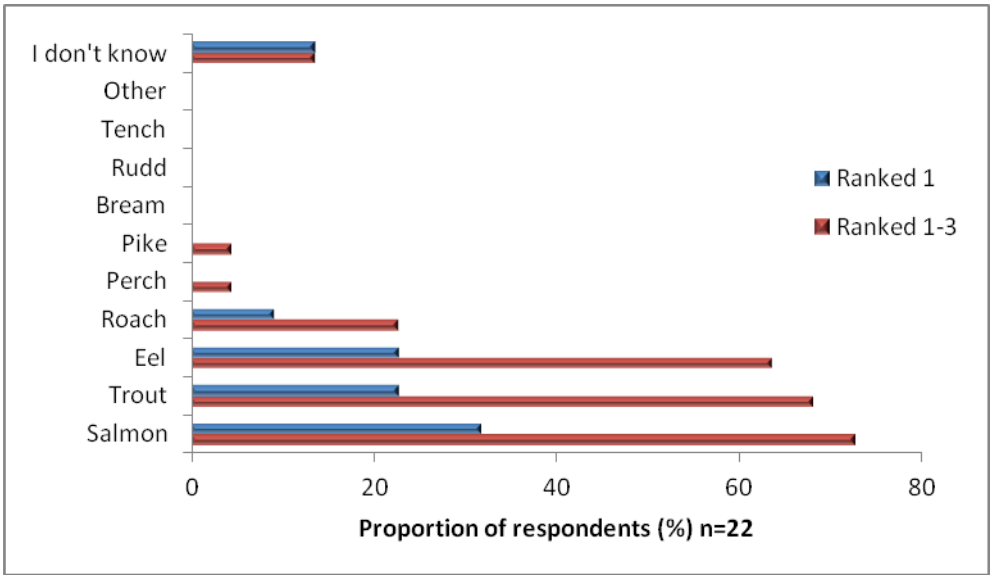
Nine respondents gave specific details of the locations of breeding colonies. Two listed the habitats where colonies are generally located without specific information on the locations. One respondent stated that they were aware of a number of roosting sites, but not breeding colonies. The locations of the colonies are as follows:

- Clew bay, Co. Mayo.
- Lough Ramor, Co. Cavan.
- Waterford Harbour, Co. Waterford.
- The Upper Liffey downstream of Ballymore Eustace, Co. Kildare (noted by two respondents).
- Lickeen Lake, Co. Clare and Dock Road, Limerick, Co. Limerick.
- The lower Shannon Estuary from Beal Point to Kerry Head, Co. Kerry.
- Lambay Island, Ireland's Eye and St. Patrick's Island, Co. Dublin.
- Mohil-Fennagh area, Drumkerrin and Lough Allen, Co. Leitrim, Kilglass Lake and Lough Boderg, Co. Roscommon.

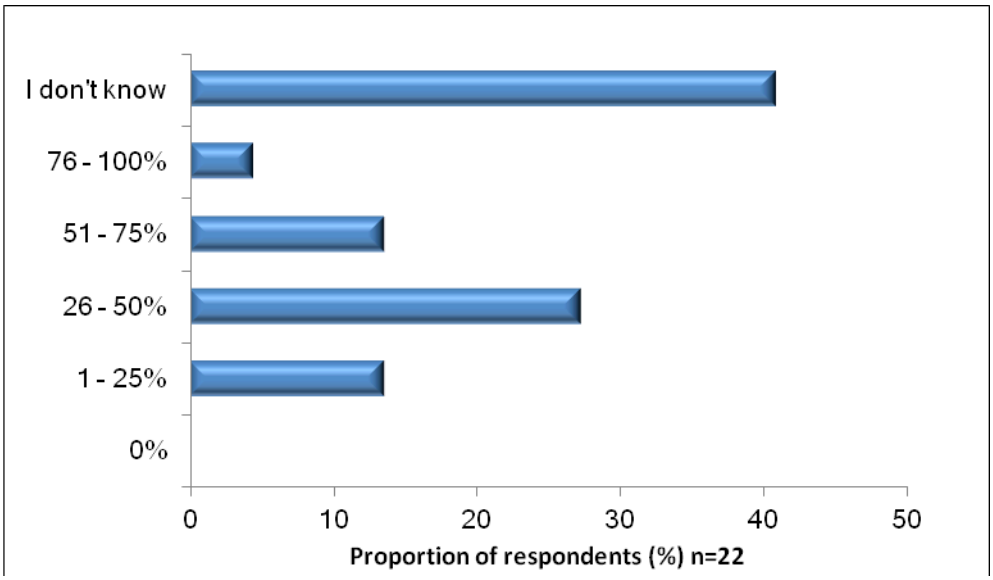
Q. 23 In your area, do you think Cormorants feed more on marine or freshwater fish?



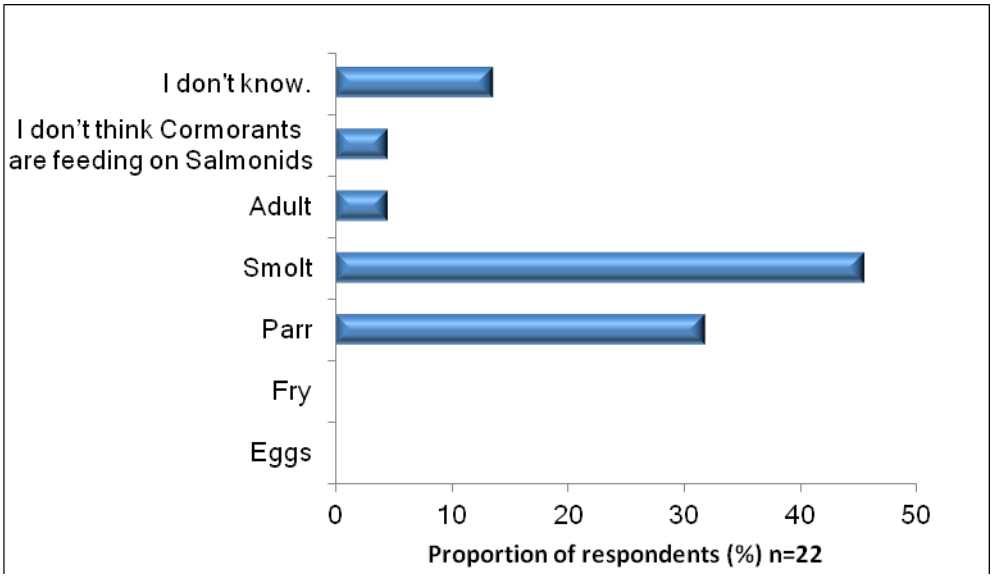
Q. 24 In your area, which freshwater fish species do you think are most important in the Cormorant diet, please rank with 1 being the most important.



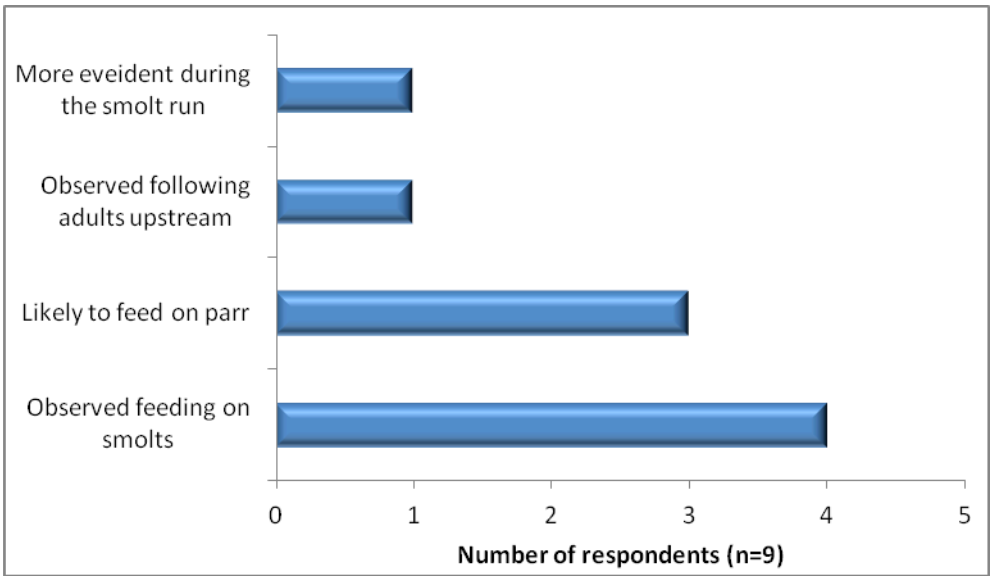
Q. 25 In your area, approximately what percentage of the Cormorant diet do you think compromises of salmonids?



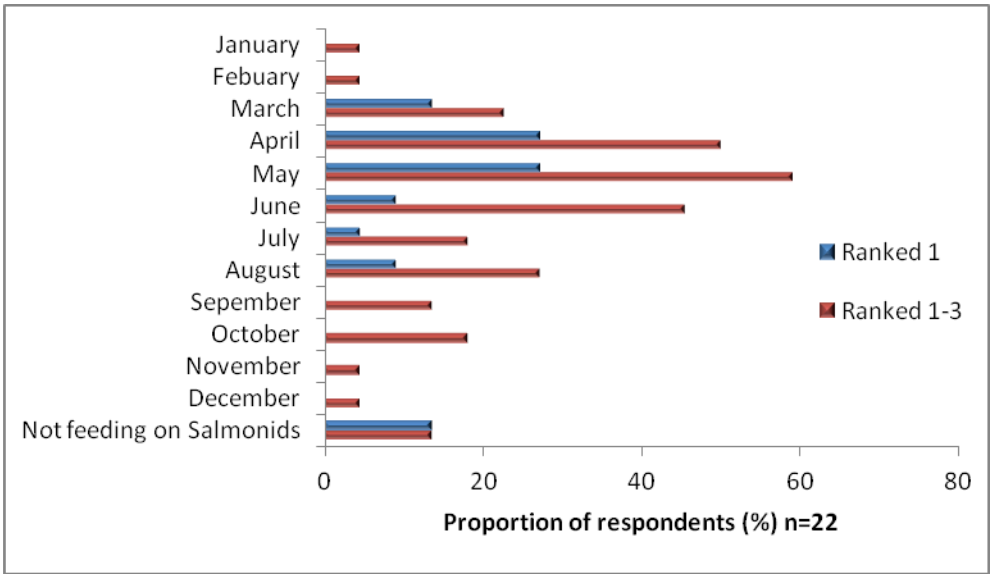
Q. 26a At what stage of the salmonid life cycle do you think Cormorants are primarily feeding on them?



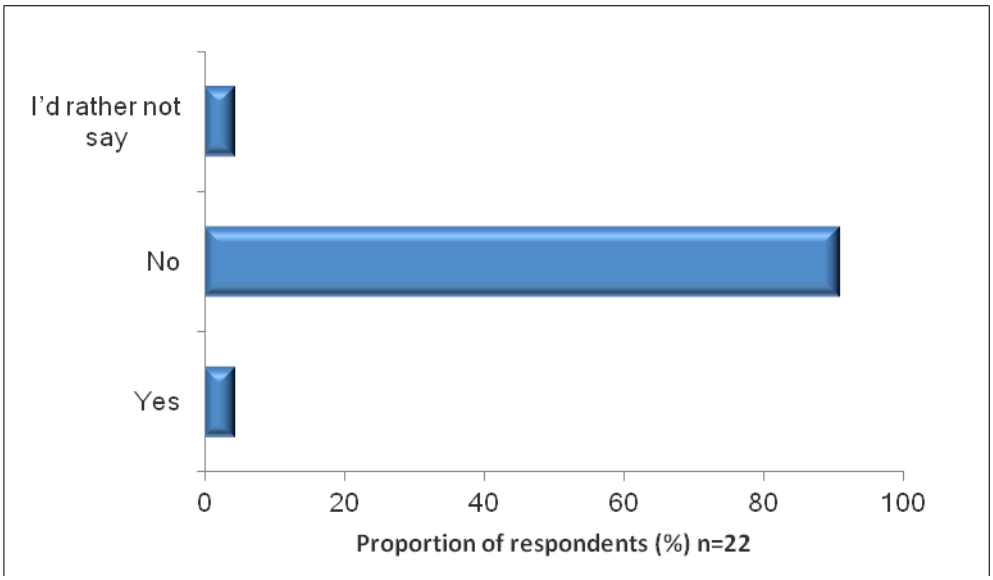
Q. 26b Please add comments to explain your choice.



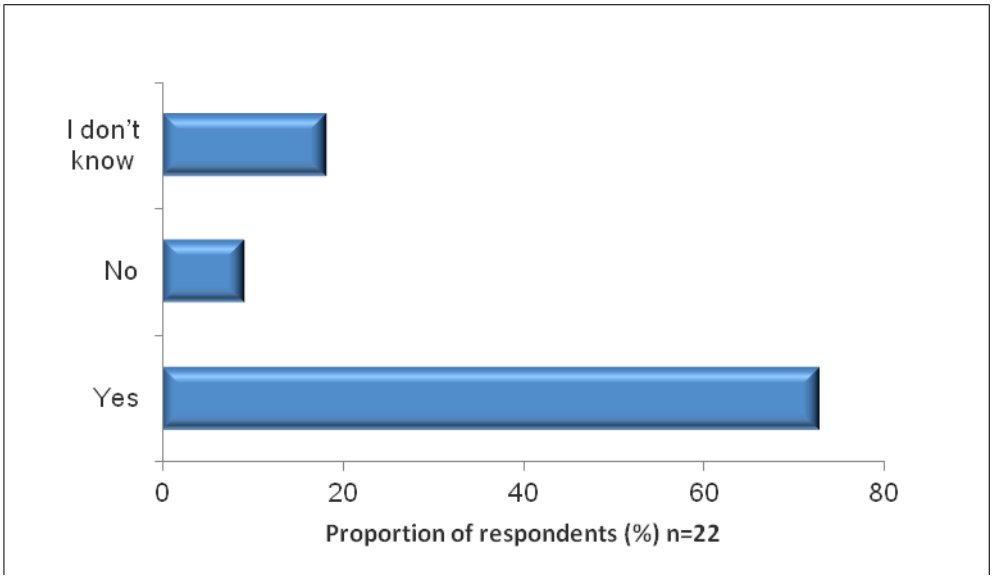
Q. 27 Which months of the year do you think Cormorants are mainly feeding on salmonids in your area? Please rank (months that you don't think Cormorants are feeding on salmonids, please leave blank).



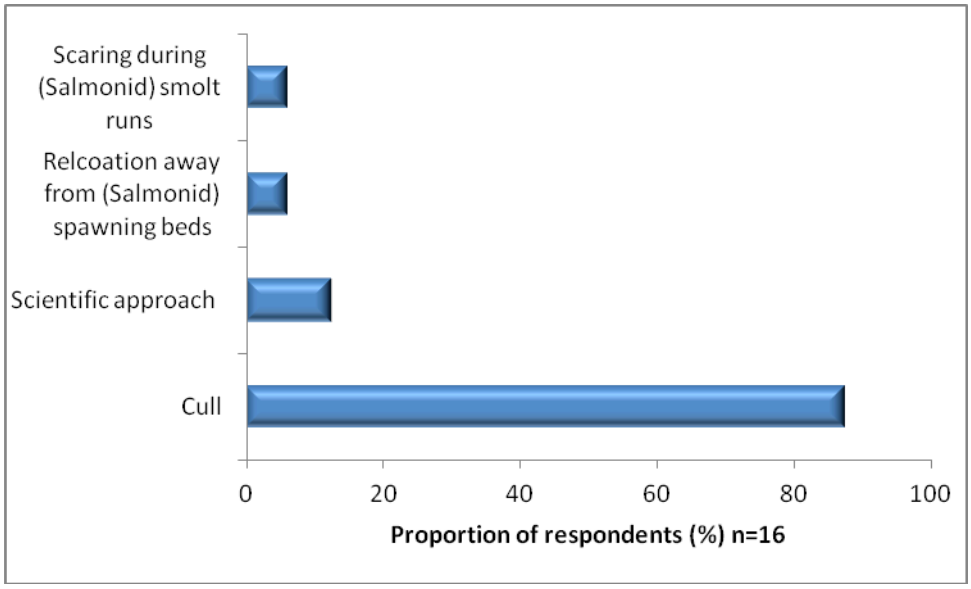
Q. 28 Are you aware of any shooting or other killing of Cormorants in your area?



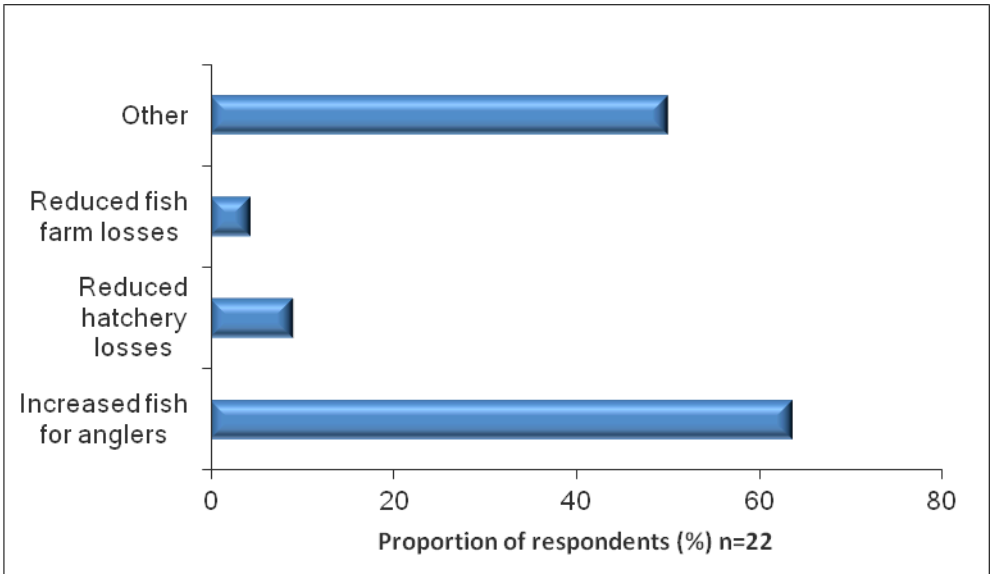
Q. 29 In your opinion, do you think there is a need for measures to be put in place to reduce the impacts of Cormorants on salmonids?



Q. 30 If so, please describe what measures you think should be taken?



Q. 31 How do you think these measures would impact positively on your fishery?



Q. 32 Please use this box for any comments you have on the impact of Cormorants on salmonids. Eight respondents completed this question:

1. *"The impact of Cormorants on salmonids on an annual basis in this system has not been assessed however data from short term studies would suggest that the main impact occurs during the smolt migration. Given the high mortality rate of salmon at sea measures to reduce the impact of cormorants would likely have little or no major impact on overall survival of salmonids."*
2. *The respondent doesn't see a need to take measures to protect against Cormorants in the work areas stated. However, Lough Corrib, Co. Galway contains large numbers of Cormorants and the respondent suggests that scaring could be an effective approach to reduce the numbers there. (This person completed the questionnaire over the phone).*
3. *"Are causing detrimental and untold damage to stocks. Urgent action required."*
4. *"Very steady increase on the numbers of cormorants on Lough Corrib in the past 5 to 6 years. This has to have a negative effect on the number of salmonids and Eels in the lake."*
5. *"I think that the impact cannot be dealt with with a blanket rule, and there will have to be site specific measures put in place."*
6. *"This survey has little relevance to the type of fishery here. Perhaps a survey focused on non-salmonids would be more relevant."*
7. *"As stated Cormorants are a problem on bigger rivers and lakes. Grey Herons are an equally as big a problem on smaller streams for Trout and Salmon production."*
8. *"Refer to question 30."*

6. DISCUSSION

6.1 Methods

Rigorous empirical analysis is required to efficiently categorise the impact of Cormorants on fish populations at specific sites. Data on local fish abundance, fishery catches, local Cormorant population densities, foraging behaviour and diet is required for robust and effective analysis. Of all studies to date that have assessed the impact of Cormorants on specific fish populations, few have inclusively addressed each of these elements (DEFRA 2003). Collation of data on fish populations within the specific survey areas was outside the scope of this study and therefore was not possible to incorporate within the analysis, however comprehensive data on Cormorant densities, foraging behaviour and diet provides the basis for well informed estimates of the impact of Cormorant predation on salmonids and other fish species within the selected study areas.

Previous survey work on Cormorants in Ireland has largely focused on monitoring the distribution, abundance and status of populations on a local or national basis to determine trends (BTO Breeding Bird Atlas (2007-11); Cramp *et al*., 1974; Gibbons *et al*., 1993; Lack 1986; Lloyd *et al*., 1991; MacDonald 1987; NPWS Cormorant Colony Census 2010; Sellers 2004; Sharrock 1976). Few studies have monitored Cormorant numbers and foraging behaviour on a regular basis at specific foraging sites over a prolonged period. Although certain studies have focused on monitoring Cormorant use of particular foraging sites over a single season, or a period of months (Dirksen *et al*., 1995; Kennedy and Greer 1998; Warke and Day 1995), none have investigated trends and fluctuations on such a regular basis or over such an extensive time period as the current study. The survey element of this project therefore represents the most comprehensive monitoring assessment of spatial and temporal densities of Great Cormorants at specific feeding areas over one year. The resulting data facilitates insights into fluctuations and trends in densities of Cormorants over this period as well as information on foraging habitat selection and how this varies throughout the year.

Prey selection observations were also trialled in conjunction with this survey in an attempt to determine the broad categories, species and sizes of fish taken by Cormorants in relation to specific foraging areas. This method has been infrequently used with moderate success to gather data on the foraging behaviour and prey selection of Cormorants and other piscivores (Voslamber *et al*. 1995; Kalas *et al.,* 1993), however it proved to be largely impractical for the purposes of the

current study. On large water bodies, particularly coastal areas and larger lakes it was often impossible to adequately monitor and record the foraging behaviour of focal birds. From the focal observations conducted, it was also apparent that Cormorants were swallowing prey under the surface, as they often displayed behaviour consistent with having consumed fish after surfacing, including head shaking and dipping. It proved difficult to assign fish to broad categories with any degree of confidence, as either prey handling time was too short or the focal bird was at too great a distance from the observer. As the quantity of time devoted to conducting such observations was not balanced by the collection of useful data, it was decided to abandon this aspect. More emphasis was therefore placed on visiting roosting and breeding colonies to collect diet samples for subsequent analysis to more accurately determine the prey selection and dietary intake of birds utilising the survey areas.

In the absence of radio telemetry, satellite tagging or GPS tagging the movements of individual birds cannot be accurately determined, and it was therefore not possible to definitively link birds observed within the survey areas to specific colonies. To increase the likelihood of analysing the diet of birds most likely to utilise the survey areas the closest, accessible Cormorant roosting sites and breeding colonies to these sites were chosen for the dietary assessment. The location and proximity to the survey sites of additional known roosts and colonies were also recorded. It is unlikely that any previously unrecorded colonies were missed due to the obvious nature of such sites and the level of existing comprehensive information on the locations of Cormorant colonies. Any such sites which were not identified by this study or previous surveys would most likely be recently established and hold small numbers of birds. Therefore, this aspect in conjunction with the data from the Cormorant survey allows for the effective determination of the likely impacts of Cormorant predation on local fish populations within the survey areas.

One of the primary objectives of this study was to specifically identify the impact of Cormorants on salmonids, particularly the level to which Cormorants exploit smolts during their seaward migration in late spring and early summer. In situations where Cormorants have been documented specialising on smolts to a level which may cause a significant population level impact, birds tend to focus foraging activities in freshwater habitats (Kennedy and Greer, 1998; Warke and Day, 1995) when numbers of smolts are locally abundant while they are congregating and preparing for migration. To capture comprehensive data on Cormorant foraging behaviour and use of the survey areas during this period, the survey effort was increased from two surveys per month (normal survey period) to two surveys per week during April and May 2011 (intensive survey period). The timing of the intensive survey period and count schedule was informed by available data from IFI regarding the timing and duration of the smolt run from previous years. In

the absence of traps or counting devices on the four selected river systems, it is not possible to ascertain the specific timing of the smolt run or to estimate approximate densities of smolts in each of the survey areas. However, given the intensive survey schedule during April and May 2011, and based on the timing and duration of the smolt run in previous years, it is extremely unlikely that Cormorant counts during the intensive survey period did not coincide with the smolt run.

The count methodology was standardised across both survey elements (normal and intensive survey periods), to ensure the results for both survey periods were directly comparable. Due to the methods employed, it is unlikely that Cormorants were frequently missed or numbers misrepresented. The individual count methods for each site ensured complete coverage of the survey area and counts were abandoned if weather conditions were likely to compromise the findings. In addition, the daily activity patterns of the birds and any resulting bias arising from the timing of surveys was also taken into consideration to ensure that this aspect did not influence the survey data. A range of counts were carried out at dawn and dusk throughout the survey period at three sites (Owenea, Ballynahinch and Suir) to determine any evident daily activity patterns in foraging behaviour and to assess if birds tended to select specific feeding areas at certain times to avoid disturbance. This assessment confirmed that the survey results were not affected by the time of initiation of the surveys.

6.2 Impact of Cormorant predation on salmonids

The findings of the survey suggest that Cormorant predation had a limited impact on salmonids across the four selected study areas during the survey period due to; low densities of birds utilising each of these survey areas, particularly during the sensitive smolt run period; and low densities of foraging birds observed in freshwater habitats. This is compounded by the results of the dietary assessment at the Loughahalia and Roaninish colonies, which show a predominance of marine based prey items and a low occurrence of salmonids. Together, this indicates that Cormorant predation had a limited impact on salmonids at the Ballynahinch and Owenea sites.

On average Cormorant numbers were low across all survey areas, particularly within the Owenea, Ballynahinch and Suir where the average number of birds observed per visit was 2.5, 7.6 and 9.4 respectively. Significantly more birds were recorded in the Slaney, with an average of 66 birds observed per visit. Based on the surface area of the survey sites however, the Suir emerges as the site with the highest density of birds, with one Cormorant recorded per 14.4 hectares, followed by

the Slaney where one bird was observed per 15.3 hectares. The densities for the Ballynahinch and Owenea survey areas were substantially lower at one bird per 242 and 832 hectares respectively.

These recorded densities, even in the absence of data on local fish abundance, suggest a limited impact on fish populations. The energetic requirement, and hence the daily food intake of Cormorants is governed by a number of biotic and abiotic factors which are site specific, including weather conditions, water temperature, water depth, foraging distances travelled, availability and quality of prey and stage of reproductive cycle (Grémillet *et al*., 2003). At a breeding colony in Germany, Grémillet *et al*., (1995) calculated daily food intake rates of 238g for incubating birds, 316g for birds with small chicks, and 588g for birds rearing downy chicks. Grémillet *et al*., (1997) subsequently estimated a daily food intake of 828g for breeding Cormorants in France, and for Cormorants wintering in Scotland Grémillet *et al*., (2003) calculated an intake rate of 672g per day. Dirksen *et al*., (1995) calculated this value to be between 146 and 699g per day for birds in Holland in the October to March period. An approximate intake rate of 500g of fish per Cormorant per day was used by Santoul *et al*., (2004) and 600g per day by Cech (2008b). If a daily intake rate of 600g per day is applied to the current dataset, the maximum daily fish intake within each of the survey areas is considerably lower than that reported in other European studies (section 1.4) and is very unlikely to constitute a conflict situation, regardless of the prey species taken. For instance, Cech (2008b) estimated that wintering Cormorants in the Czech Republic consumed 5.5 tonnes of fish per day in 2005, and in France, Santoul *et al*., (2004) calculated that wintering Cormorants were responsible for taking approximately 450 kg per day, and estimated that 65 tonnes of fish would be eaten in the October to March period

Seasonal trends in Cormorant densities differed significantly between the four survey areas, indicating that there were no related seasonal patterns between the survey sites. It is likely that the seasonal movements of Cormorants at particular sites is influenced and governed by numerous geographical and ecological factors, which may vary markedly between the survey sites. Peaks in densities as well as declines in numbers were noted in all four survey areas but the timing of these did not correspond between sites. However, in general the average number of birds utilising the survey areas decreased during the intensive survey period within all survey areas. Fewer Cormorants used the survey areas during the smolt run period in comparison to other times of the year, indicating that Cormorant foraging efforts were not targeted towards smolts in the survey areas during their seaward migration.

The habitat use of Cormorants within the survey areas also provides further evidence to suggest a limited impact on smolts. Although densities of fishing Cormorants and their habitat foraging

preference in relation to the availability of freshwater and marine habitats varied between the survey areas, the numbers of observations of birds feeding in freshwater areas were low across all sites. The majority of Cormorant "fishing" observations were recorded from marine and estuarine habitat types (93.7%), and Cormorant use of all these broad habitats was relatively consistent throughout the survey period. Cormorants therefore did not focus foraging efforts on freshwater habitats, particularly specific river systems, during the smolt run period and therefore predation of smolts is unlikely to have had a significant impact on salmonid populations, at least during this phase of their life cycle. Cormorants foraging in estuarine and marine habitats may still select and predate salmonids at different stages of their life cycle; however such predation is less likely to have a negative population level impact in comparison with predation in freshwater habitats where large densities of smolts gather in condensed areas.

The diet data from analysis of pellets and regurgitates corroborates the findings of the survey regarding the limited impact of predation on smolts. At both "marine" breeding colonies where Cormorant diet was assessed, it was either predominantly marine based (78.5% of diet at Roaninish) or exclusively marine based (Great Saltee). As diet collections at both colonies were conducted during the intensive survey period, and only regurgitates or fresh pellets were taken for analysis, the subsequent data is considered to be representative of Cormorant diet during this time period. The results from the diet assessment and analysis indicate that birds from these colonies have minimal impact on freshwater fish species during the breeding season. The diet at the two "coastal" colonies associated with the Ballynahinch survey area were also predominantly marine based (46.9% at Loughahalia and 63.6% at Lough Scannive), which supports the survey findings from this site which revealed a preference for marine foraging habitats. As several diet sample collections (n = 6) were analysed from both colonies, it can be inferred that birds preferentially selected marine and coastal feeding areas above freshwater feeding areas during the breeding season, which coincides with the timing of the smolt run. Although salmonids were represented in the diet in each of these sites, their relative importance reiterates a limited impact resulting from Cormorant predation. The proportion of salmonids in the diet for these colonies combined was 5.1%, ranging from 1.8 - 6.3%. Carss and Ekins (2002) similarly found that birds breeding at inland colonies favour marine species, if they were within suitable commuting distance from the sea. Bearhop *et al*., (1999) also revealed that, if possible, Cormorants tend switch to a predominantly marine based diet during the breeding season, which supports the findings of the current study.

There are varying estimates for the maximum foraging range for breeding Cormorants. Platteeuw and Van Eerden (1995) consider 20km to be the upper limit that a bird can fly while still

maintaining an energetic balance, however Warke and Day (1995) report that breeding Cormorants often forage in Lough Neagh, which is some 60 km from the colony. The diet at the Silver island colony, which is located approximately 50 km from the coast, was comprised exclusively of freshwater prey. Salmonids represented 21.7% of the diet in terms of frequency at this site. This suggests that Cormorant predation is likely to have a greater impact on freshwater species, including salmonids, at typical inland sites where Cormorants have no access to coastal foraging areas, or where the energy expenditure required to travel to the coast on foraging trips is not profitable. Unfortunately, it was not possible to locate Cormorant roost or breeding sites within the specified proximity to the Suir survey area. Out of the four survey areas, this site was located furthest from the coast and therefore it is possible that birds using this site feed to a greater extent on freshwater species. Although the greatest densities of Cormorants per surface area were recorded at this site, these densities are unlikely to constitute a significant negative impact. However further work to determine movements of birds utilising this site and their prey selection is required to determine the full extent of Cormorant predation on salmonid populations in the Suir survey area.

Owenea

The recorded density of birds within the Owenea survey area was low across the entire survey season, averaging 2.5 birds per visit, which equates to one bird per 832ha. Extrapolation of the data shows that 0.54 birds were encountered per observer hour, with 10 visits conducted on which no birds were recorded. Based on these findings alone, Cormorant presence within the survey area is unlikely to represent an issue in relation to salmonid stocks.

If the average daily intake of 600g of fish per Cormorant per day (Cech, 2008b) is applied to the Owenea dataset, then an estimated maximum of 3.9 kg of fish would be consumed by Cormorants over a 12-hour period within the survey area, which equates to 0.69 kg per hectare per year. This is likely to be a significant overestimate of the true figure however, based on the fact that a large proportion of Cormorants observed throughout the survey period were not actively foraging at the time of observation (45.1%). Furthermore, Cormorants are known to range over large distances (Warke and Day, 1995), therefore birds encountered as part of the survey were unlikely to focus all feeding activity on a daily basis within the specified survey area.

Similar to the other survey sites, the average number of Cormorants per visit declined during the intensive survey period (n = 0.7) in comparison to the normal survey period (n = 3.8). The maximum numbers of birds were recorded in June (n = 10), December (n = 9) and March (n = 9) demonstrating that foraging Cormorants did not specialise on smolts during their seaward

migration. Based on all fishing observations recorded (n = 45), there was no clear preference for freshwater over marine habitats, with one bird per 1,145 hectare and one bird per 1,534 observed foraging in these habitat types respectively. However it must be noted that the sample size of records from freshwater habitats (n = 1) is too low to infer significant trends in habitat preference at this site.

The Roaninish island group, which supported 27 AONs in 2011, is the closest known Cormorant colony to the Owenea survey area, situated approximately 8.3km away. Due to difficulties in accessing this remote island group (which is located 4km from the shore), only a single visit was made to this colony on the 6th May 2011 to monitor breeding and collect diet samples, at a time when most adults were feeding chicks and some were still incubating. This visit coincided with the intensive survey period and the diet data can therefore be considered representative of this period. Prey items identified (n = 55) were predominantly marine species (78.5% of the diet), with salmonids comprising 3.1% of the diet by frequency. This partly explains the low numbers of Cormorants recorded within the survey area during the intensive survey period, particularly in freshwater habitats and further enforces the lack of conflict at this site. The next nearest known colony to the survey area is Slieve League, County Donegal, which supported 20 AONs in 2010 and lies approximately 18km to the south west of the survey area. Breeding Cormorants have been known to travel up to 60km on daily foraging bouts (Warke and Day, 1995), but Platteeuw and Van Eerden (1995) consider 20km to be the upper limit distance that breeding birds can fly to foraging grounds. It is unlikely that breeding birds from this colony would therefore travel to the Owenea survey area for foraging purposes during the intensive survey period, but a radio telemetry, satellite tagging or GPS tagging research programme would be required to confirm this. It is possible that non-breeding birds that are not associated with the Roaninish breeding colony use the Owenea system during the breeding season however the numbers of these birds are unlikely to constitute a significant problem, as highlighted by the overall low densities (immature birds accounted for 46% of all birds recorded aged (n = 32)).

Slaney

The highest numbers of Cormorants were recorded on the Slaney, with an average of 66 birds encountered per visit, which represented the second highest density of Cormorants per surface area (after the Suir), with one bird recorded per 15.3 hectares. Notable trends in numbers included a peak in August 2010, when a maximum of 187 Cormorants was recorded, thereafter the numbers continuously dropped until January, before peaking again at 117 in March. The average number of birds per visit was also lower at this site during the intensive survey period (n = 44.9) compared with all other visits. A total of 38.97 birds were recorded per observer hour.

Based on the same criteria used to estimate the daily fish intake of birds within the Owenea survey area, a maximum of 286.2 kg of fish would therefore be consumed by Cormorants in the Slaney survey area over a 12-hour period, which equates to 103.65 kg per hectare per year.

There are a number of known roost and breeding colonies within proximity to this survey area, which may explain the relatively high densities of birds recorded within this study site. Little Saltee, County Wexford which held 273 AONs during Seabird 2000 is located approximately 24km from the survey area. Another colony, on the Keeragh islands, County Wexford that was not surveyed for Seabird 2000, held 239 AONs during the SCR Census (1985-88), and is located approximately 25km from the survey area. Due to difficulties accessing these colonies, the only colony visited as part this study was Great Saltee, which lies 28km from the survey area. This colony held 145 AONs in 2011. Diet samples were collected at the colony on 20th May 2011, which coincided with the chick-rearing stage, and also fell within the intensive survey period. The diet at this site was comprised exclusively of marine species, dominated by Ballan Wrasse (60%). Although relatively high numbers of birds utilised the survey area during the intensive survey period (maximum of 88 birds), in the absence of radio tracking, satellite tagging or GPS tagging, it is not possible to determine which roost or colony these birds were associated with. In order to comprehensively determine the diet and movements of birds using this site it is necessary to employ the aforementioned research techniques. As 47.8% of the birds recorded in this survey area were immature, it is possible that they were not associated with the colonies detailed above. Although no salmonids were recorded in the diet from Great Saltee, it is possible that salmonids are taken by Cormorants foraging within the survey area.

As the majority of the survey area is estuarine, it was not possible to differentiate between birds feeding in marine or freshwater habitats at this site. Dietary samples were collected from the Great Saltee breeding colony, which is 28 km from the survey site, therefore further more detailed work would be required to ascertain the impact of Cormorants on salmonids and other fish populations at this site.

Ballynahinch

An average of 7.6 Cormorants per visit were observed across all counts of the Ballynahinch survey area, which equates to one bird per 242 hectares. Ballynahinch was the only survey area where densities of Cormorants hit a maximum peak (n = 19) within the intensive survey period. However, the numbers recorded were still relatively low, and on average lower than the normal survey period. The majority of Cormorants recorded during this maximum peak were in marine or estuarine habitats as opposed to freshwater, with only two birds observed on the Owenmore River. This trend was maintained throughout the survey period and in general, fishing birds

exhibited a distinct preference for non-freshwater habitats, with an average of one bird per 578 hectares recorded in coastal or estuarine areas compared with one bird per 2,397 hectare in freshwater.

An average of 1.96 birds were observed per hour of count effort, therefore a predicted maximum of 14.1 kg of fish would be consumed over a 12 hour period, based on the estimated daily consumption rate of 600g per bird. This equates to 2.8 kg per hectare per year.

Diet data from Loughahalia and Lough Scannive compliment the findings and trends from the survey data. Loughahalia and Lough Scannive are the two closest known colonies to the survey area, located approximately 18.6km and 3.7km from the Ballynahinch survey area. Each colony supported an estimated 27 AONs and 167 AONs respectively in 2011. Although both colonies are situated in freshwater lakes, both are classed as "coastal" (Sellers 2004) due to the fact they are situated less than 5 km from the mean high water mark (located 1.9km and 3.7km respectively from the coast). Therefore, birds using these roosting and breeding colonies have a choice of marine and freshwater foraging habitat types. Several collections of pellets and regurgitates were made from these colonies between 27th January and 15th April 2011 (n = 6), with a single visit to each colony carried out within the intensive survey period. Marine species, (46.9% in Loughahalia and 63.6% in Lough Scannive) dominated the diet at both colonies overall, with Ballan Wrasse being the most important prey item by frequency at both sites (29.4% at Loughahalia and 54.6% at Lough Scannive). At Loughahalia, Ballan Wrasse, which was absent from the diet samples collected on the first two collection dates (27th January, 23rd March), formed 5.7% of the diet sample collected on the 15th April and was the most dominant prey item (87.0%) in the diet sample collected on the 1st June. This species comprised 52.8% of the diet samples collected on the 15th April and 57.9% on the 1st June at the Lough Scannive colony. Salmonids represented 6.3% and 1.8% of the diet respectively. Carss and Ekins (2002) similarly found that birds breeding at inland colonies favour marine species, if they were within suitable commuting distance from the sea. Seasonal variation in the direction foraging flights was also reported, with the proportion of birds leaving the colony towards the coast increasing in the breeding season. Without the benefit of research to track the movements of specific birds, it is not possible to confirm that the birds recorded within the survey area were associated with these colonies. However, this is very likely the case given the proximity of these colonies to the survey area and the fact that the next nearest recorded colony is located on Deer Island in Galway Bay approximately 60km from the survey area. Based on the diet data in conjunction with the information on Cormorant distribution and abundance from the survey element, the impact of

Cormorant predation on salmonids within the survey area during 2010 and 2011 appears to be negligible.

Suir

The highest densities of Cormorants were confirmed in the Suir survey area. An average of 9.4 birds per visit was recorded in the Suir survey area, which equates to one bird per 14.4 hectare. Following the same pattern as the other survey areas, a reduced number of birds were recorded within the intensive survey period (n = 6.6 birds per visit) compared with the normal survey period (n = 13 birds per visit), with the most notable peak in numbers occurring in Oct 2010 (n = 38) which is when this survey was initiated. A total of 1.84 birds were observed per hour of surveyor effort. Based on the same figures regarding estimated daily intake of fish as applied to the other survey datasets, Cormorants at this site are likely to consume a maximum of 13.2 kg of fish over a 12 hour foraging period or 35.59 kg per hectare per year.

The density of birds recorded fishing in freshwater habitat was slightly higher than that recorded in the estuarine areas of the survey area. The average number of birds observed actively foraging in estuarine habitat was one bird per 86 ha, compared with one bird per 66 ha in the freshwater environment. The average number of birds fishing in this survey area was higher than that recorded for the other three survey areas.

It was not possible to locate accessible roosts or colonies within proximity to the Suit survey area therefore there is no available diet data to represent this study site. The closest known Cormorant colony is at the Keeragh Islands, which is situated approximately 30km from the survey area. The Suir recorded the highest relative occurrence of immature birds (64.2%), and therefore it might provide a staging ground for birds of this age class prior to sexual maturity and subsequent establishment at a breeding colony.

6.3 Perceptions of Cormorants and implications for salmonid conservation

This study comprehensively assessed Cormorant densities, foraging behaviour and diet at two selected sites in the north and west of the country. At the two remaining sites, the Slaney and the Suir, a thorough assessment of Cormorant diet was not possible as no dietary samples could be collected from close to these survey areas. Limitations were the lack of detailed data on the movements of individual birds utilising these sites as well as information on fish species abundance within the survey areas. Across Europe, the majority of conflicts between Cormorants

and fishery interests occur at freshwater sites (Carss 2003). With the documented shift towards increased inland wintering and breeding in Britain and Ireland (BTO Bird Atlas (2007-2011); Crowe 2005; Kirby *et al*., 1996; Sellers 2004), a greater diversity of study sites, specifically typical inland sites would have provided further insights beneficial to the objectives of this work. Comparison of Cormorant diet between the marine and coastal colonies to data from the single inland site at which prey selection was assessed as part of this study, shows a greater occurrence of salmonids at the latter. Further work to determine Cormorant densities and diet at more typical inland sites would facilitate crude but useful estimates of the extent of Cormorant predation on salmonids and other fish species dependent on basic factors such as site or fishery type and geographic location, which would prove beneficial in determining and allocating conservation or mitigation resources. To this end, a series of recommendations for future work are set out in the following chapter (Chapter 7).

Although the survey areas were selected to represent important salmonid fisheries in Ireland, it must be stressed, as demonstrated by the findings of this study that Cormorant densities, foraging behaviour and feeding ecology, in addition to their impact on specific local fish populations varies significantly between sites and is dependent on a wide range of factors. It must also be noted that the presence of Cormorants in a particular area does not constitute a conflict (DEFRA 2003). These study areas were chosen, among other reasons, because they were known or had been reported to be frequented by foraging Cormorants. This was confirmed by the Cormorant survey, however, as shown by the survey data, the densities were generally low and this information coupled with data on diet suggests that Cormorant predation, at least within the Owenea and Ballynahinch survey areas, had a limited impact on salmonids over the survey period. It is not possible to speculate on the proportion of salmonids in the diets of birds frequenting the Slaney and Suir survey sites, however the survey data shows that, at a population level, Cormroants at these sites do not target the salmonid smolt run,

This is one of only a small number of studies that have attempted to categorise the affect of Cormorant predation on fish populations in Ireland (MacDonald 1987; Kennedy and Greer 1988; Warke *et al*., 1994; Warke and Day 1995; West *et al*., 1975). As previously stated, a detailed and multifaceted research protocol is required to categorically achieve this objective (DEFRA 2003). Nevertheless, in the absence of such systematic research there prevails a clear perception that Cormorant predation has a negative population level affect on salmonid and other fish populations at specific sites in Ireland. This is confirmed by the number of licenses granted by NPWS between 2007 and 2011 to cull (n = 18) or scare Cormorants (n = 14), and is also obvious from the collective opinions of IFI staff who participated in the survey questionnaire. The results

of which reveal that the threat and impact of Cormorant predation as perceived by the sample of fishery staff that responded to the questionnaire is significantly disparate to the observed situation as recorded in the defined Owenea and Ballynahinch survey areas as part of this study. As there are no breeding colonies in the vicinity of the Suir and Slaney survey areas, a dietary analysis could not be used in conjunction with the survey data to comprehensively document the situation at these sites. As has been documented in studies across Europe, conflicts with Cormorants do occur and the species can have a detrimental effect on local fish populations in certain situations (Carss 2003; Carss and Ekins 2002; Dirksen 1995; Engstrom 2001; Kennedy and Greer 1988; Veldkamp 1995b). However salmonid populations face pressures from a diverse range of other avian and mammalian predators as well as a wide array of additional anthropogenic and environmental factors including the creation of barriers, deterioration in water quality, habitat degradation, climate change, the effects of fish farming and over exploitation (Hendry and Craig-Hine 2003; ICES 2010; NASCO 2011). To effectively conserve salmonid populations, it is imperative that the level to which each of these factors impact local populations is understood, so that conservation priorities and resources can be implemented in the most effective manner. In some cases, this may involve mitigating the impact of Cormorants and other piscivorous predators at specific sites, however without scientific evidence to indicate such efforts will have the desired effect of improving the conservation status of salmonids, these actions may well have the opposite effect by redirecting focus and resources away from the underlying causing factors.

7. RECOMMENDATIONS

The findings of this study indicate that, at a population level, Cormorants do no selectively target salmonid smolts during their seaward migration, at the four sites studied. At the Owenea and Ballynahinch survey sites, where data was available on Cormorant diet composition, predation has an insignificant population level impact on salmonids. However, it must be noted that this assessment was carried out over one year, and therefore only provides a short-term estimate of the true impacts of Cormorant predation on salmonids within this period. The study was also confined to discrete and geographically isolated areas. Given the wide range of factors that influence the extent and impact of Cormorant predation on fish populations, these findings cannot be considered to be representative of the situation nationwide. The findings from the Slaney and Suir survey sites are less comprehensive, as it was not possible to locate accessible roosts or colonies nearby, in order to link the survey findings with the dietary composition. Radio telemetry or GPS tagging would be required to accurately determine the movements of individual birds and definitively link birds observed within the survey areas to specific roosts or colonies.

The findings also highlight the perceptions of fishery interests in relation to Cormorants, who view the species as posing a significant threat that necessitates proactive mitigation to rectify.
Further work is required to:

- effectively determine the level and affect of predation in a range of different situations and habitats, particularly at inland sites where the affect of predation on salmonids and other freshwater species may be more extreme
- effectively predict how these impacts will vary over time dependent on changes in Cormorant population dynamics
- identify the requirement for mitigation so that conservation resources for salmonids are prioritised appropriately and to define the sites and best protocol to implement such mitigation if deemed necessary.

In addition to addressing its objectives, the current study has also facilitated detailed insights on the most appropriate direction for future research and monitoring efforts to address the underlying issues outlined above. A series of recommendations are listed below in order of priority. Additional detail on specific elements can be provided on request.

1. Cormorant breeding survey 2012

Evaluation of available data on Cormorant population dynamics and status in Ireland reveals that despite substantial regional variations, the population in general has increased in recent times and has also experienced a gradual shift towards increased densities of wintering and breeding birds in inland situations (BTO Bird Atlas 2007-11; Sellers, 2004). With an expanding population and particularly increased densities at inland sites, the perceived impacts as well as the potential for conflict will rise (MacDonald 1987). It is imperative therefore to understand Cormorant population dynamics and predict the areas where these conflicts may occur based primarily on the distribution and abundance of Cormorants and supplemented by dietary assessments and additional research.

Specific Cormorant surveys in Ireland to date have generally focused on coastal and marine colonies (Cramp *et al*., 1974; Lloyd *et al*., 1991), and it is unlikely that multispecies surveys have encapsulated the full picture regarding Cormorant distribution, abundances and inland colonisation (BTO Bird Atlas 2007-11; I-WeBS). NPWS carried out a partial survey of known breeding colonies in 2010, however coverage was not complete and the methods employed would not have identified recently established colonies. A pan-European Cormorant survey, co-ordinated by the Cormorant Research Group is planned for 2012 (Thomas Bregnballe, *pers. comm.*) which provides a unique opportunity to comprehensively assess the status of the population in Ireland within a European context. This survey would provide recent population trends as well as the extent of inland colonisation, against which future changes in distribution and abundance could be compared. Survey effort would also aim to locate newly established colonies.

The presence of the "continental" *Phalacrocorax carbo sinensis* has not been confirmed in Ireland, and therefore *Phalacrocorax carbo carbo* is the only sub-species of Great Cormorant recorded as a breeding and wintering bird to date in this country. However, there has been no formal or concerted effort to determine the presence of *sinensis* in Ireland. Distinguishing the two sub species is difficult and generally requires DNA confirmation (Marion and Le Gentil 2006), therefore it is possible that *sinensis* is already established as an undocumented breeding species in Ireland. The recent population and range expansion of Cormorants in Great Britain can be partially explained by the influx of *sinensis.* The continued increase in inland colonies (both establishment of new colonies and increases in numbers at existing colonies) is fuelled by recruitment of *sinensis* from mainland Europe (Carss and Ekins, 2002). It is likely that some inland colonies in England are initially established by *sinensis* and subsequently joined by *carbo* from other colonies (Sellers, 2004). It is necessary therefore to assess if *sinensis* has become established in Ireland, and to investigate the implications of its colonisation or expansion for

fisheries in the future. As all known colonies will be visited over the course of the proposed 2012 breeding survey, feather samples will be collected to assess the presence of *sinensis* via DNA analysis.

The survey will also provide the opportunity to assess breeding parameters at a range of colonies, allowing detailed comparison of breeding success and productivity between coastal and inland breeding colonies. Visits to monitor breeding colonies will also facilitate the collection of diet samples (pellets and regurgitates) allowing an analysis of the diet from a geographical range of breeding sites to determine the areas where predation is most likely to impact salmonid populations.

The breeding survey in 2012 will utilise existing BirdWatch Ireland resources as well as its extensive network of experienced volunteers to undertake this work in an efficient and cost effective manner.

The output of this work will be:

- A comprehensive review of the status and distribution of the Irish Cormorant population
- Detailed data on the locations, size and recent trends of all registered colonies
- Identification of recently established colonies
- Determination of the extent of inland colonisation
- Determination of the presence of *sinensis*
- Assessment of the implications of the colonisation or expansion of *sinensis* for fisheries
- Collation of data on breeding parameters from a range of colonies
- Assessment of breeding parameters between marine and inland colonies
- Collection of diet samples from a diversity of coastal and inland sites

2. Cormorant winter roost survey - January 2013

The wintering Cormorant population has increased in recent times (Crowe 2005) and has experienced a range expansion to inland areas (BTO Bird Atlas 2007-11). However, as outlined above for the breeding season, it is unlikely that multispecies surveys have encapsulated the full picture regarding Cormorant winter distribution, abundance and range expansion (BTO Bird Atlas 2007-11; I-WeBS), as inland sites are less well monitored compared to coastal sites during core counts (Crowe 2005).

Specific Cormorant surveys in Ireland to date have taken place during the breeding season (Cramp *et al*., 1974; Lloyd *et al*., 1991) and comparatively little is known about numbers and distribution during the winter. A pan-European Cormorant survey, co-ordinated by the Cormorant Research Group is planned for January 2013 (T Bregnballe, pers. comm.) which provides a unique opportunity to comprehensively assess the status of the wintering population in Ireland within a European context. This survey would provide a thorough assessment of the number of wintering birds as well as the extent of inland wintering, against which future changes in distribution and abundance could be compared. As winter roosts often serve as precursors for breeding colonies (Carss and Ekins 2002), this survey would provide an indication of the potential for the establishment of new breeding colonies.

As outlined for the breeding survey, the winter roost survey will utilise existing BirdWatch Ireland resources as well as its extensive network of experienced volunteers to undertake this work in an efficient and cost effective manner.

The output of this work will be:

- A comprehensive review of the status and distribution of the wintering Cormorant population
- An inventory of Cormorant roost sites in Ireland
- Identification of recently established roosts
- Determination of the extent of inland wintering
- Collection of dietary samples from suitable roosts

3. Assessment of Cormorant diet

The diet analysis element of the current study proved successful and complimented the survey data to provide effective and informed estimates of the impact of Cormorant predation on salmonids. An expansion of this aspect, particularly focusing on inland roosting and breeding colonies would facilitate a greater understanding of the level of impact of Cormorant predation on specific fish populations in different habitats and areas of the country where the extent of salmonid predation may be greater. The dietary assessment undertaken in the present study focused on known roosting and breeding colonies likely to be associated with the survey areas, all of which were either marine or coastal colonies. For comparison purposes, diet samples were also collected and analysed from a single inland colony on Lough Derg on the border of Counties Galway and Tipperary. Salmonids represented a greater portion of the diet at this inland site compared with the marine and coastal sites. This work package proposes to assess the diet at a

selection of inland sites (minimum of five) which are located at specified distances from the coast. Sites will be selected to incorporate colonies which are within distance to the coast to allow breeding birds to make foraging trips to marine feeding habitats as well as colonies which are wholly inland. Habitat preference and the extent and impact of Cormorant predation on salmonids and other fish species can therefore be assessed at a range of site types.

A strategic sampling protocol will be established to determine seasonal variation in the diet, with particular emphasis on the smolt run period. Diet analysis will involve standard pellet and regurgitate identification methods, however stable isotope methods can also be incorporated as this method has been successfully used to determine Cormorant foraging preference (Bearhop *et al*., 1999; Mizutani *et al*., 1990).

The output of this work will be:

- A detailed assessment of Cormorant diet at a range of inland colonies
- Determination of Cormorant foraging habitat preference in relation to availability
- A criteria for estimating the extent of Cormorant predation based on specific site characteristics

4. Assessment of Cormorant foraging behaviour, dispersal and movements

This work package will employ a combination of research techniques including Satellite or GPS tagging, radio telemetry and colour ringing to provide comprehensive data on Cormorant foraging ecology, dispersal and survival. Satellite tagging, GPS tagging or radio telemetry will facilitate detailed data on Cormorant use of specific feeding areas on a seasonal basis. Tracking the movements of individual birds will allow them to be linked to specific colonies and provide data on ranging behaviour and activity patterns. Information on the roosting behaviour or locations of breeding sites of individuals will also allow collection of diet data, which can then be related to specific feeding areas. Data on site fidelity and seasonal movements will inform the effectiveness of mitigation protocols. BirdWatch Ireland staff have extensive experience of all required aspects involved in satellite, GPS and radio telemetry programmes, including capturing, fitting tags, collation and effective analysis of the data. Colour ringing has been carried out on Cormorants previously in Ireland; an expansion of this work incorporating a geographic spread of sites would facilitate beneficial and detailed data on juvenile dispersal and survival rates.

The output of this work will be:

- Detailed data on Cormorant foraging ecology, including habitat preference, home range and activity patterns
- Determination of Cormorant ranging behaviour and feeding area fidelity and seasonal movements
- Providing a link between use of feeding areas and breeding colonies for individual birds
- Determination of juvenile dispersal, seasonal movements and survival rates

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