2.4. Published data on by-catch rates

2.4.1. NE Atlantic

The NE Atlantic harbour porpoise population is thought to comprise a number of local sub-populations (Anderson 1993). Based on skull morphometrics, 6 subpopulations were distinguished, in Dutch waters, Bay of Biscay and English Channel, Celtic Sea, Irish Sea, English North Sea and Baltic Sea (Gaskin 1984; Yurick & Gaskin 1987).

In reviewing the literature available about actual by-catch rates in the NE Atlantic, a recurrent theme becomes apparent. Most papers open with a statement about the problem of by-catch, followed by an account of anecdotal evidence that lends weight to the urgency of the problem. They conclude with an account of the difficulties inherent in trying to estimate the magnitude of a problem given such a vast number of potentially important variables. A common outcome is that there are insufficient data available for extrapolation to an annual by-catch rate. Indeed, often there are insufficient data to reliably estimate the by-catch rate within the time-scale of the project. There are a number of reasons for this paucity of data but largely it results from the rarity with which incidental entanglements occur in the short term.

Across the NE Atlantic, the total number of cetaceans caught in all types of fishing gear is almost certainly enough to be cause for concern about the sustainability of this anthropogenic mortality rate within individual cetacean populations. Identifying patterns in these data however is difficult, not least because, in the short term, by-catch appears rare due to the small number of boats observed at any one time and the short duration of each observer project (Read 1994). At the level of the individual fishing vessel, a cetacean entanglement may only happen once every 30 hauls or so (Read 1994) or, in many fisheries, much less frequently. Thus, even when a relatively large proportion of the annual fishing effort in a fishery is observed (e.g. 10%), there will often not be enough data to lend any statistical power to subsequent analyses.

In their report on Study Project 97/089, Pierce & Santos (2000) note that thousands of observer trips may be necessary to demonstrate the existence of the problem and to adequately quantify it. However, observer programs can be very expensive and financial restrictions on data collection may preclude meaningful extrapolation of local by-catch rates

to annual totals for a fishery. It is also difficult to collect sufficient data to test the relationships between by-catch rate and putative explanatory factors.

The different sampling units used in different projects, usually determined by local circumstances and the type of fishery studied, also make comparisons between different studies difficult.

Even more so than in most field sciences, the return of useful data per unit of time and expenditure appears to be very poor. Studies that do not make use of on-board observers tend to produce less satisfactory results but are valuable in helping to identify where there is a by-catch problem. However, they can provide only minimum estimates of the by-catch rate and reliable estimates usually require back up from a comprehensive observer program.

Many reports and publications provide estimates of cetacean by-catch rates in particular fisheries involving particular combinations of fishing gear, fishing grounds and target fish species[8]. However, as noted above, the wide range of different measurement units and sampling regimes employed, restricts comparisons. Results quoted in previous reviews range from accounts of 1,000 harbour porpoises being caught between 1922 and 1937 in the Polish salmon (*Salmo salmar*) driftnet fishery (Skora 1988) to meticulous estimates of the number of animals caught per hour with extrapolations to annual rates per fishery. The former is an extreme example but highlights the vague nature of much of the available data. An exhaustive inventory[9] of the anecdotal and comprehensive data pertaining to by-catch rates in European waters is contained in the CETASEL report (De Haan *et al.* 1997). Here we will focus on the few systematic studies that have yielded comparable results.

In recent years a number of detailed and comprehensive studies have focused specifically on estimating by-catch rates, and have contributed greatly to the state of knowledge. In such cases the sample size required for valid statistical analysis was considered at the outset of the study and useful results were therefore obtained. Results from these studies are discussed below, grouped by fishing grounds rather than by fishing gear or country.

[8] See Appendix V for table of by-catch data and location map
[9] See Appendix VI for CETASEL table

2.4.1.1. North Sea, Baltic Sea and Swedish coastal waters

The North Sea is fished by fleets from a number of European countries, principally Denmark, Britain, Germany, the Netherlands and France (e.g. Clausen & Anderson 1988; Benke 1994; Kock & Benke 1995, 1996; Carlström & Berggren 1996). Harbour porpoises are the most common cetacean in the North Sea (Sonntag *et al*. 1997) and ICES have estimated that that a total of 4,450 harbour porpoises are killed annually in all the fisheries in the area[10]. This figure amounts to 1.9% of the North Sea harbour porpoise population as estimated by the Small Cetacean Abundance in the North Sea and Adjacent Waters (SCANS) survey in 1994 (Hammond *et al.* 1995) and exceeds the 1% anthropogenic removal threshold proposed by the IWC (IWC, 1995), beyond which by-catch rates are considered to be unsustainable.

Despite the extent of fisheries in the North and Baltic Seas, there have been relatively few observer studies and most of the data available come from opportunistic carcass collection and voluntary reporting programs.

Reporting of by-caught animals in Danish waters between 1980 and 1981 resulted in the collection of 149 harbour porpoises – 61% of which had been caught in set gillnets (Clausen & Anderson 1988). Also in Denmark, Kinze (1994) estimated that 99% of all stranded animals had died owing to incidental capture. This estimate gives rise to concern, given that studies on the drift of cetacean carcasses have concluded that most carcasses sink immediately (Moreno 1993) and very few will eventually strand (Tregenza *et al.* 1997a). Furthermore, depending on the state of preservation of the carcass when recovered, it is not always possible to find evidence of by-catch. Such data, based on reports from a single year and from stranding schemes, probably represents an absolute minimum estimate of the by-catch problem in Danish waters.

In 1980, a reporting program was initiated in Germany to record cetacean by-catch in fisheries operating in the German North Sea and in the Baltic Sea (Benke 1994). The fisheries studied included bottom trawls targeting cod and flatfish, beam trawls targeting sole, plaice (*Pleuronectus platessa*) and brown shrimp, and set monofilament gillnets

[10] See Appendix III: Website reference No. 1

targeting sole. Between 1987 and 1990, 41 porpoise by-catches were reported, 90% of which were killed in the set gillnet fisheries (Benke 1994). In such reporting schemes, it is difficult to determine whether results are representative of the true picture. In 1990, to encourage reporting, a reward scheme was set in place in Schleswig-Holstein on the German North Sea coast, whereby fishermen were offered the equivalent of $35 for each porpoise carcass they handed in (Kock & Benke 1995, 1996). Despite this incentive, there was no marked increase in the rate of reporting. In fact, between 1990 and 1994 only 12 carcasses were collected from the North Sea fishery and 58 from the Baltic (Benke 1994). However, Danish gillnet fisheries were also operating in the North Sea region and were not part of the reward scheme, so their impact on the by-catch rate in the area went unreported. Thus it was considered that the German figures were not representative of the total by-catch in the area (Kock & Benke 1995, 1996).

There have been several opportunistic studies of cetacean by-catch in the North Sea (see Berggren 1994; Kinze 1994) that demonstrate the occurrence of by-catch but do not provide fully quantitative estimates of by-catch rates. Lindstedt & Lindstedt (1989) examined evidence from records of stranded porpoises in the Baltic. Over a 13 year period, they found that 62% of stranded animals had been caught in fishing gear, of which 86% had been taken in set gillnets. Based on reports by fishermen, Kock & Benke (1995, 1996) estimated that 20 ± 10 porpoises were caught annually by German gillnet fishermen in the Baltic, noting that there was a high degree of inter-annual variation. Both studies point out that the number of harbour porpoises in the Baltic has severely declined and that they are now rarely sighted (Lindstedt & Lindstedt 1989; Kock & Benke 1995, 1996).

Analysis of strandings records for Scotland during 1998-2000 indicates that around 20% of stranded harbour porpoises (the most frequently stranded species) were killed by entanglement in fishing gear (Pierce & Santos 2000). The overall pattern of harbour porpoise mortality in Scotland is somewhat unusual in that a substantial number of animals are killed by attacks from bottlenose dolphins. Setting aside this cause of mortality, by-catch accounts for 29% of the remaining mortality (Pierce & Santos 2000).

Three studies in particular have made specific efforts to produce definitive estimates of by-catch in the northern North Sea. All three limited their observations to the set gillnet fisheries (Clausen & Anderson 1988; Lowry & Teilmann 1994; Carlström & Berggren 1996). Such is

often the case with observer programs, which tend to focus on specific fisheries rather than all fisheries on a given fishing ground.

In 1993, the Danish Institute for Fisheries and Marine Research (DIFMAR) conducted an observer study of the gillnet fishery in Danish waters, which targets cod, sole and turbot (Lowry & Teilmann 1994). After observing 1-3% of the total annual fishing effort in this fishery they estimated that up to 7,000 harbour porpoises per year were killed in gillnets in Danish waters. In this study, the annual by-catch of harbour porpoises in the Danish turbot fishery was estimated as 4,449 (Vinther 1995). These figures clearly suggest that the ICES estimate of 4,450 harbour porpoises caught annually in all North Sea fisheries is entirely inadequate.

In a study in Swedish waters over two years, Carlström & Berggren (1996) observed 21% of the total annual fishing effort in the cod set gillnet fishery and estimated that the by-catch rate was 32 and 36 harbour porpoises caught per 10,000 net.km*hr in 1995 and 1996 respectively using soaktime and the length of the net as the means of expressing the by-catch rate. Carlström & Berggren (1996) concluded that, if this rate of by-catch could be extrapolated to the entire area of the Skagerrak and Kattegat Seas, 53 (95% CI: 22 – 85) porpoises would have been caught in 1995. In 1999, the same authors estimated that 110 porpoises were by-caught in the same fishery, although whether this came from new information or an increase in the annual fishing effort is unclear (Carlström & Berggren 1999).

Clausen & Anderson (1988) estimated that 3,000 harbour porpoises were caught in the Danish wreck fishery in the south-western North Sea and the English Channel. This is a particularly interesting figure since the harbour porpoise has been declining in the southern North Sea and the Channel (Evans & Lane 1989). Only six years later, in 1994, no harbour porpoise were recorded in the English Channel during the SCANS survey (Hammond *et al.* 1995).

The observed by-catch rate for porpoises in the UK set gillnet fishery in the North Sea and the Scottish west coast between 1996 and 1998 was 8.1 porpoises caught per 10,000 net.km*hr. These data lead to an estimate of 750–1,000 porpoises caught annually in UK fisheries in the North Sea (Northridge & Hammond 1999).

In a review of the results obtained during observer studies of by-catch in set gillnet fisheries in the North Sea, Jaaman (1998) highlighted that Danish and UK fisheries in the North Sea may catch as many as 112 harbour porpoises per 1,000 net.km*hr,. This estimate came from the central North Sea region where there was the greatest overlap between the UK and Danish fleets (Jaaman 1998). In the Danish fishery, by-catch was highest in the autumn and in the northern North Sea, whilst more by-catch occurred during summer in the UK fishery (Jaaman 1998).

In summary, by-catch estimates for harbour porpoises in the North sea and surrounding waters range from 32 porpoises/10,000 net.km*hr of net in Swedish waters (Carlström & Berggren 1996) to 1120 porpoises/10,000 net.km*hr in the central North Sea, in set gillnet fisheries alone. Most of the anecdotal data collected in the 1980s suggest that gillnets are the major contributor to the by-catch problem in the North and Baltic Seas (Clausen & Anderson 1988; Benke 1994; Berggren 1994; Kinze 1994; Lowry & Teilmann 1994; Pierce & Santos 2000) and that the harbour porpoise is the only species affected. Little information is available on by-catches in other fisheries, or of other cetacean species, in the North Sea.

The results summarised above clearly suggest that there is a by-catch problem in the North Sea. However most of the studies were conducted over one year or one fishing season and were not run concurrently with studies of the spatial and temporal distribution of the harbour porpoise population. This, and the dynamic nature of gillnet fisheries from year to year (Northridge & Hammond 1999), mean that patterns in inter-annual variation in by-catch rates cannot yet be fully described for the area.

2.4.1.2. Celtic Sea, Bay of Biscay and the Western Approaches

There is a great deal of circumstantial evidence suggesting that incidental capture in fishing gear in the Celtic Sea and surroundings areas causes a significant number of cetacean deaths. In contrast to by-catch in the North Sea, that in the Celtic Sea involves a number of different cetacean species, in particular harbour porpoises, common dolphins and white-sided dolphins (*Lagenorhynchus acutus*) (Rogan & Berrow 1996; Couperus 1997a; Tregenza *et al.* 1997a,b).

The Celtic Sea is a particularly productive fishing ground, supporting mackerel, horse-mackerel, tuna and hake fisheries, among others, involving number of different EU Member States (see Couperus 1997a; Tregenza *et al.* 1997a,b; Tregenza & Collet 1998). Midwater pelagic trawls, set gillnets, tangle nets and driftnets are all used in this region (Rogan & Berrow 1996; Couperus 1997a; Tregenza *et al.* 1997a,b; Berrow & Rogan 1998a; Tregenza & Collet 1998).

Evidence that by-catch is a problem in this and surrounding fishing grounds has come from anomalous mass strandings on the south-west coast of England, the south-west Irish coast and the northern coast of France bordering the Bay of Biscay (Kuiken *et al.* 1994; Tregenza & Collet 1998). There is still uncertainty over which fishery or fisheries were directly responsible for the mortality of these animals. Between January and April 1992, 118 small odontocetes stranded on the Cornish and Devon coasts (SW England). Fifty-four of these animals were common dolphins and post-mortems were conducted on 38 of them. Of the 30 animals in which cause of death could be established, 29 deaths were attributed to incidental entanglement in fishing gear (Kuiken *et al.* 1994).

The mass stranding occurred 15 months into an ongoing study of strandings in the area, facilitating comparison of the causes of death in the mass stranding and 'normal' strandings (Kuiken *et al.* 1994). Between 1990 and 1995, 422 post-mortems were carried out on cetacean carcasses stranded on the English and Welsh coasts. By-catch was found to be the cause of death in 49% of cases: 38% of harbour porpoises, 65% of common dolphins, and 17% overall for the other species examined (Kirkwood *et al.* 1997). The study indicated that the frequency of strandings of by-caught cetaceans was increasing, with 22% of stranded harbour porpoises in 1990 being by-catches, as compared to 65% in 1995. Similarly, 57% of common dolphin mortality was ascribed to by-catch in 1990, increasing to over 80% in 1994. Interestingly, no common dolphins stranded at all in 1995 (Kirkwood *et al.* 1997).

Additional evidence on fishery by-catch in this region comes from two mass strandings in France. In February 1989, more than 600 small delphinids stranded on the Landes coast and between February and March of 1997, 629 common dolphins stranded on the Brittany coast (Tregenza & Collet 1998). In the latter case, 198 post-mortems were carried out and 74% of the carcasses showed signs of by-catch (Tregenza & Collet 1998).

Bottom set gillnets were more likely to catch harbour porpoises around the Irish coast while studies on the herring trawl fisheries and anecdotal data suggested common dolphins were more likely to be caught by trawls (Rogan & Berrow 1996; Berrow & Rogan 1998; Berrow & Rogan 1999).

Because it is generally held that few cetaceans discarded at sea will eventually strand (Moreno 1993), these mass stranding events may represent only a small proportion of the number of animals dying in fishing gear in the Celtic Sea. Subsequently, a number of observer programs were set up specifically to record cetacean by-catch rates in fisheries in the area, leading to a series of reports and publications (Rogan & Berrow 1996; Couperus 1997a,b; Tregenza *et al.* 1997a,b; Berrow & Rogan 1998, Berrow *et al.* 1998; Tregenza & Collet 1998; Morizur *et al.* 1999).

Between 1992 and 1994, observers were placed on boats in the UK and Irish set gillnet hake fisheries in the Celtic Sea. Over 328 observed days, 41 harbour porpoises and four common dolphins were caught. This study estimated the annual by-catch of harbour porpoises, by Irish and UK fleets combined, to be 2,200 (95% CI: 900 – 3500). Boats less than 15 m in length were not included in the study so this estimate may be negatively biased (Tregenza *et al.* 1997a). This by-catch represents at least 6.3% of the estimated harbour porpoise population in the region (Hammond *et al.* 1995) and porpoise by-catch in the hake gillnet fisheries in the Celtic Sea is thus considered unsustainable (Tregenza *et al.* 1997a). In contrast, the by-catch of common dolphins was only 1.2 common dolphins per 100 days at sea, leading to an estimated total by-catch, by Irish and UK fleets, of 234 (95% CI: 78 – 702) animals (Tregenza *et al.* 1997b). It was suggested that the gillnet fishery was unlikely to be responsible for the high incidence of by-caught common dolphins in the recent mass stranding events (Tregenza *et al.* 1997b). Subsequently, attention has turned to mid-water pelagic trawls and driftnets deployed by British, Irish, Dutch and French fleets in the area.

The GERDAU project ("Germon et Dauphin" carried out in 1992-1993 by IFREMER under the auspices of the French Ministry of the Sea) observed 27% of the total annual fishing effort in French and UK tuna driftnet fisheries in the Celtic Sea (Tregenza & Collet 1998). The French tuna fishery was authorised to continue fishing with driftnets under Regulation (EEC) No. 345/92. The fishery caught 451 dolphins, 415 (95% CI $\pm$ 36%) of which were common dolphins. Goujon *et al.* (1993) reported the by-catch rate in this fishery to be 0.11

cetaceans per km of net and stated that it generally increased in August and September. The UK fleet caught 165 cetaceans, 61 (95% CI: 16 – 106) of which were common dolphins and the rest of which were striped dolphins (Tregenza & Collet 1998). These data amount to one dolphin being by-caught for every 1,232 tuna caught in the French fishery and one dolphin by-caught for every 211 tuna in the UK fishery (Tregenza & Collet 1998). Furthermore Goujon *et al.* (1994) estimated an annual by-catch of 1,700 dolphins in the tuna driftnet fishery operating from the Azores to the southern Celtic Sea in a study following the EC ban on driftnets.

The CHAPEL project ("Chalutier Pelagique") was funded by the CEC in 1993–1995 and involved IFREMER in France, the Netherlands Institute for Fisheries Research, University College Cork in Ireland and the Cornwall Wildlife Trust in the UK. Observations were carried out on 11 mid-water pelagic trawl fleets operating in and around the Celtic Sea including the Bay of Biscay and the Western Approaches to the English Channel. The fisheries observed included SW English mid-water pelagic trawls targeting mackerel and pilchard, French pelagic trawls targeting mackerel, pilchard and horse-mackerel and the Dutch pelagic freezer trawl fleet, which targets herring, mackerel and horse-mackerel (Tregenza & Collet 1998). They concluded that the overall by-catch rate in these fisheries was one dolphin/100 hours of towing or 3.8 dolphins/100 hauls (Tregenza & Collet 1998). They did not extrapolate from this result to derive an annual estimate.

Couperus (1997a) reports on a study carried out on the Dutch mid-water pelagic fleet, which caught half the animals recorded in the CHAPEL project (Tregenza & Collet 1998). Between 1989 and 1994, 312 dolphins were by-caught in this fishery, as recorded in 71 reports handed in by co-operative Dutch skippers, most being caught off the SW coast of Ireland. Supplementary to these reports, 61 carcasses were preserved for examination by Dutch freezer trawlers between 1993 and 1994. Post-mortems showed that, just prior to capture, 50% of the bottlenose dolphins caught had been feeding on horse-mackerel, which is the target species of the fishery, 6% of common dolphin stomachs contained horse-mackerel while none of the white-sided dolphins, which constituted the bulk of the by-catch, had been feeding on horse-mackerel (Couperus 1997a).

The MAMDIS project ("By-catch of marine mammals and discards in pelagic fisheries"), carried out by the Netherlands Institute for Fisheries Research between 1995-1996 and

financed by the CEC, continued to investigate by-catch by Dutch pelagic trawlers. During this study, most observed trawling took place at night and only eight cetaceans were recorded during 84 hauls over 45 days at sea. There were insufficient data for statistical analysis and therefore no effort was made to estimate annual by-catch rates. During the course of the study an additional 37 animals were recorded as by-caught in skippers' reports (Couperus 1997b).

A more recent project made further attempts to quantify cetacean by-catch in pelagic trawls in the NE Atlantic including the Celtic sea (Morizur *et al.* 1999). The study concluded with a by-catch estimate of one dolphin per 20.7 tows in the Dutch horse-mackerel fishery and the French tuna, sea bass and hake fisheries combined (Morizur *et al.* 1999).

Observations of Irish pelagic trawlers targeting herring in 1994 and 1995 demonstrated no cetacean by-catch (Berrow *et al.* 1998),. Other studies indicate that observers who carry out other duties whilst watching for cetacean by-catch are more likely to miss animals than observers who record only cetacean by-catches (Bravington & Bisack 1996).

As with the negative bias caused by 'drop-outs' during observations of gillnets (Vinther 1995; Bravington & Bisack 1996), there are also problems inherent in observing cetacean by-catches in trawls. Most modern trawlers haul the cod-end of the trawl towards the side of the boat and use large pumps to suck the catch onto the sorting platform (Morizur *et al.* 1999). After pumping is complete the left-overs in the cod-end are emptied outboard of the boat and, because they are generally too large to be carried aboard by the pump, cetaceans are often thus discarded without being recorded (Tregenza & Collet 1998; Morizur *et al.* 1999). This is a problem intrinsic to the trawling process and often the only way that attention will be drawn to the presence of a cetacean in the cod-end is if it blocks the mouth of the pump (Hartmann *et al.* 1994). The problem is exacerbated because trawling usually occurs at night to take advantage of the diurnal vertical migrations of fish (Tregenza & Collet 1998). Not only does darkness prevent detection of cetaceans in the net or when discarded but, as most authors point out, carcasses usually sink as soon as they are released (Moreno 1993; Tregenza *et al.* 1997a; Morizur *et al.* 1999). Thus by-catch estimates from trawls are likely to be negatively biased and should probably be treated as minimum estimates.

It is apparent from the literature on by-catch in the Celtic Sea is that there is a high level of inter-annual variation in by-catch rates. It is suggested in many reports that this variation and the episodic nature of the mass strandings is related to the temporal and spatial distribution of the cetacean populations, movements of their prey, variations in fishing effort and variations in the buoyancy of carcasses (Kuiken *et al.* 1994; Kirkwood *et al.* 1997; Tregenza & Collet 1998).

Evidence from stomach contents, from cetaceans by-caught during observation studies and from stranded animals with external lesions consistent with by-catch, suggest that the animals were usually feeding either on the target species of the fishery in which they were caught or were feeding on the same prey as the target fish (Cockcroft 1994b; Kuiken *et al.* 1994; Couperus 1997a; De Haan *et al.* 1997; Morizur *et al.* 1999). However, the same studies have shown that the by-caught animals' stomachs also contained otoliths from fish species associated with deeper, offshore, waters, such as lanternfish (Myctophidae), pearlsides (*Maurolicus muelleri*) and silvery pout (*Gadiculus argenteus*) (Couperus 1997a). It is generally reported that common and white-sided dolphins (*Lagenorhynchus acutus*) move into inshore waters of the Celtic Sea during winter to take advantage of the mackerel migration, which results in the interaction with fisheries, whilst at other times of the year they feed further offshore (Couperus 1997a). Inter-annual variation in by-catch rates may thus result from either differences in the density of mackerel or how close inshore they come during their migration (De Haan *et al.* 1997). For example, 1991 was a particularly good year for mackerel recruitment which would have resulted in a high abundance of juvenile mackerel in 1992, a year in which one of the mass strandings of dolphins occurred (Kuiken *et al.* 1994).

In summary, there is a great deal of evidence from strandings that suggests that incidental mortality of cetaceans in fishing gear is high in the Celtic Sea. In the first three months of 2000, 53 cetaceans showing evidence of entanglement in mid water trawling gear were recorded among strandings on the SW coast of England[11]. No single fishery is solely responsible for this mortality of common and white-sided dolphins: pelagic trawl fleets targeting mackerel and horse-mackerel and tuna driftnet fisheries probably both play an important role (Couperus 1997a,b; Tregenza & Collet 1998; Morizur *et al.* 1999). The hake

[11] See Appendix III: Website reference No. 3

set gillnet fishery is probably responsible for most of the harbour porpoise by-catch (Tregenza *et al.* 1997a).

Data collection is ongoing. A three-year project conducted by the Sea Mammal Research Unit (SMRU) and funded by the UK government MAFF began in autumn 2000, with the specific aim of assessing the impact of mid-water pelagic trawls on cetaceans in the Celtic Sea (P.S. Hammond pers. comm.).

2.4.1.3. Mediterranean

The number of different cetacean species by-caught in the Mediterranean is far higher than that in any of the fishing grounds discussed thus far. Harbour porpoise however are very rare in the area. There have been no sightings of this species along the French Mediterranean coast since the 19th century (Duguy 1977) and porpoises in the area are now considered to have gone extinct (Gaskin 1984). The most common cetacean in the Mediterranean is the striped dolphin (Notarbartolo di Sciara 1990), but by-catches also include species such as Cuvier's beaked whale (*Ziphius cavirostris*) (Notarbartolo di Sciara 1994), sperm whales (*Physeter macrocephalus*) and fin whales (*Balaenoptera physalus*) (Di Natale & Notarbartolo di Sciara 1994; Cognetti 1995). Larger species are often released from nets alive, largely because their plight is more visible (Read 1994).

Cetaceans have been legally protected in the Italian Mediterranean since 1980 (Di Natale & Notarbartolo di Sciara 1994) although no mention was made as to how this protection is enforced or what/who affords it. Since 1986, the Centro Studi Cetacei in Italy has operated a strandings reporting scheme, with a 24-hour telephone service in operation for the public to report stranded animals (Di Natale & Notarbartolo di Sciara 1994). Enforcing cetacean protection in fisheries is difficult and cetacean by-catches are less likely to be reported by fishermen if there is fear of legal sanction (Kershaw 1997). Such a decrease in the reporting of by-catch occurred in Portuguese fisheries when cetacean by-catch was made illegal in 1980 (Sequeira & Ferreira 1994).

Records of the interactions between the numerous fisheries in the Mediterranean and cetaceans are largely anecdotal (Di Natale & Notarbartolo di Sciara 1994). For example,

Silvani *et al.* (1992) reports on the existence of conflicts between fishermen and dolphins in the Balearic Islands but makes no effort to quantify the problem. In a synopsis of the fisheries that operate in the Mediterranean and those of the countries that border the sea, Di Natale & Notarbartolo di Sciara (1994) stated that the only countries that do not use gear which causes cetacean mortality are Libya and Monaco. All other countries bordering the Mediterranean, from Algeria to Turkey, use gillnets, traps and driftnets. These fisheries are all suspected of causing high levels of incidental mortality but as yet no data have been published on by-catch rates in the Mediterranean. Consequently there are few estimates of annual by-catch rates on which to base management strategies (Di Natale & Notarbartolo di Sciara 1994).

Those data which have been published mainly concern the swordfish (*Xiphius gladius*) and tuna driftnet fisheries which operated mainly in the Liguran-Corsican Basin and the Alboran Sea (Podesta & Magnaghi 1989; Cognetti 1995; Silvani *et al.* 1999) The Liguran Sea was heavily fished for swordfish and, in 1988, 37 by-caught striped dolphins constituted 50% of all cetacean by-catch in Italian seas and was caused by boats working in this area alone. These boats made up only 6% of the Italian fleet (Podesta & Magnaghi 1989).

A study conducted between 1988 and 1989 estimated that the cetacean by-catch rate off the Italian coast was as high as 7,000 per annum (Notarbartolo di Sciara 1990). A treaty designating the Liguran-Corsican Basin as a marine mammal sanctuary was signed in November 1999 by the Ministers of the Environment of French and Italy and the Monaco Minister of State (Notarbartolo di Sciara 1999).

Despite the UN Generally Assembly's global moratorium on the use of driftnets, issued in 1991, driftnetting continued in the Mediterranean until 1994, with 27 Spanish boats working the area (Silvani *et al.* 1994) among others from France, Italy and Ireland. Further, Greenpeace stated that illegal fishing operations were widespread throughout this region (Cognetti 1995) Driftnets are a particularly unselective type of fishing gear and, with only 7% of the total catch comprising of the target swordfish, discards made up a large part of each haul (Silvani *et al.* 1999). A study of by-catch in the Spanish swordfish fishery estimated by-catch rates of 0.11 and 0.15 dolphins/km of net in 1993 and 1994 respectively. This was equivalent to 366 (95% CI: 268 – 464) dolphins caught in 1993 and 289 (95% CI: 238 – 340) in 1994 (Silvani *et al.* 1999).

The lack of data on cetacean by-catch in the Mediterranean may reflect its status as an international body of water. Beyond the territorial waters of each border country, the Mediterranean is regarded as "high seas", with no EEZs (Cognetti 1995). No country has jurisdiction over the majority of the area in the Mediterranean and, until this problem is resolved, protection for cetaceans in international waters will be difficult to achieve (Cognetti 1995). The lack of action taken to monitor by-catch in these waters is reflected in the paucity of literature about this fishing ground.

2.4.2. NW Atlantic

Harbour porpoises in the NW Atlantic are thought to comprise four discrete populations, supported by evidence from morphometric and molecular genetic studies. These populations are located, respectively, in the Gulf of Maine and Bay of Fundy, the Gulf of St. Lawrence, Newfoundland waters, and off Greenland (Jefferson & Curry 1994; Trippel *et al.* 1996; Bisack 1997).

The Gulf of Maine and Bay of Fundy population is exceptionally well-documented in terms of data available on population size and by-catch rates (Jefferson & Curry 1994). Few data exist for the other populations. One paper describes results from a questionnaire survey conducted in the Gulf of St. Lawrence in 1988 (Fontaine *et al.* 1994). Alling & Whitehead (1987) interviewed fisherman as part of a preliminary study in Newfoundland and off the Labrador coast, estimating that 10.5% of the white-beaked dolphin population was lost to by-catch. An observer study was carried out on the by-catch in gillnets off the coast of Greenland (Lear & Christensen 1975), where driftnets and set gillnets were banned in 1993 due to depleted fish stocks (Read 1994)

2.4.2.1. Gulf of Maine and Bay of Fundy

Although it is generally held that the porpoises in the Gulf of Maine and Bay of Fundy comprise a discrete population (Read & Gaskin 1988; Caswell *et al.* 1996; Westgate & Read 1998), the Gulf of Maine falls under the jurisdiction of the US MMPA while the Bay of Fundy does not. Indeed, although the harbour porpoise has been listed as threatened by the

Committee on the Status of Endangered Wildlife in Canada (COSEWIC) since 1989 (Read & Gaskin 1990; Trippel *et al.* 1996), there is no legislation which effectively protects cetaceans in Canadian waters. The trans-boundary nature of the population means that data are collected separately in the two fishing grounds. Studies on by-catch in the Bay of Fundy began before those in the Gulf of Maine largely because fishing activity was less fragmented and easier to monitor in the former area, in contrast with the numerous vessels operating from small ports in the Gulf of Maine (Polacheck 1989).

Porpoises in the area are thought to remain in the lower Bay of Fundy and northern Gulf of Maine from September to May, moving to the southern Gulf of Maine in June to August, probably related to prey movements or temperature changes (Polacheck 1989; Bravington & Bisack 1996). Consequently, the animals move in and out of areas in which they are protected and where there are specific action plans to reduce their vulnerability to by-catch.

Gulf of Maine

The state of knowledge about by-catch in the Gulf of Maine is vastly different to that in European waters. The majority of the by-catch monitoring and mitigation work is driven by the dictates of the MMPA - most publications on the topic begin with a brief description of the MMPA, its most recent amendments and how the work described addresses the current issues (Read & Gaskin 1990; Hatakeyama *et al.* 1994; Read 1994; Bravington & Bisack 1996; Caswell *et al.* 1996; Bisack 1997). The most commonly used by-catch estimation methods prior to 1988 were questionnaire surveys and stranding programs (Smith *et al.* 1983; Fontaine *et al.* 1994) which had varying success but generally provided only minimum estimates of the problem. However, in 1988 and in 1994, amendments to the MMPA required that 20–35% of "category I" fishing vessels, namely those from fisheries causing a high mortality of porpoises (Read 1994), take observers onboard during their fishing activities (Read & Gaskin 1990). Fishermen also had to record all marine mammal by-catch in logbooks (Northridge 1996). Following these amendments, trained observers were supplied by the NMFS and their Northeast Fisheries Science Centre (NEFSC) as part of the Sea Sampling program to observe marine mammal by-catch (Bisack 1997). While the mandatory logbooks proved unreliable for estimating the level of by-catch (Northridge 1996), the observer scheme was very successful. Consequently by-catch rates and extrapolated annual

by-catch estimates are available for most category I fisheries in the Gulf of Maine from 1990 onwards (Bravington & Bisack 1996; Bisack 1997).

The methods used in the observer programs have remained largely unchanged from year to year, so that the annual estimates are comparable and population trends and the success of implemented by-catch reduction devices can be monitored. The sampling regime formulated by the NMFS for the Gulf of Maine involves "optimally and proportionally allocated" spatio-temporal stratification of the region (Bravington & Bisack 1996). The total annual fishing effort was determined from the NEFSC Weigh-Out (WO) program, which collected the fisheries landing statistics and information on catch locations. Initially, the spatial strata were based on NEFSC statistcal catch reporting areas and catch locations were established in dockside Agent Interviews. Following changes in the WO program in 1993, information on catch locations is now taken from logbooks and spatial stratification is by the home port of the fishing vessels. Given that gillnetting trips rarely last longer than one day, it was assumed that fishermen operated within a certain radius of their home port (Bisack 1997).

During each trip, observers noted the number of marine mammals by-caught per haul. The total annual number of 'live' fish landed in ports was divided by the number of fish caught per haul to give an estimate of the annual number of hauls and, hence, the number of porpoises caught per annum (Bravington & Bisack 1996; Bisack 1997). Prior to 1994, observer trips were divided into 'On-watch' and 'Off-watch' periods. Following the 1994 Harbour Porpoise Workshop, the NMFS began to classify observer trips as either 'dedicated marine mammal trips' or 'fish trips'. Data from 1990 – 1992 observer trips were recalculated with an 'off-watch' correction factor and only data from the dedicated marine mammal trips have been used since 1994 (Bisack 1997).

Bravington & Bisack (1996) used the aforementioned methods to estimate the by-catch rates in the Gulf of Maine sink gillnet fishery between 1990 and 1993, following a recommendation by the IWC, and following criteria set out by the MMPA, that the removal rate be reduced. There were fewer data available for 1990 than in subsequent years and the authors felt that this might explain the significantly higher by-catch rate calculated for this year (Bravington & Bisack 1996). Subsequently they excluded the 1990 data and calculated a mean by-catch estimate of 1,500 porpoises per annum from the 1991 to 1993 data (Bisack

1997). The annual harbour porpoise by-catch data for the Gulf of Maine are summarised in Table 1.

In 1994, the Gulf of Maine harbour porpoise population was declared as "strategic" under the MMPA (Caswell *et al.* 1996). This declaration in turn dictated urgent action to reduce the anthropogenic removal rate to a level compatible with the estimated Potential Biological Removal (PBR) level of 483, i.e. consistent with allowing the population to recover (Caswell *et al.* 1996; Bisack 1997; Trippel *et al.* 1999). The 1994 MMPA amendments required the NMFS to initiate a Take Reduction Plan (TRP) which aimed to reduce by-catch to levels approaching zero by April 2001 (Dawson 1998; Trippel *et al.* 1999). The progress of the TRP was monitored annually to ensure that the goals were being achieved (Merrick 1999). As part of the TRP, an increased proportion of the annual fishing effort was observed and, in 1995, the Northeast Fisheries Management Council implemented short-term trial fishery closures. All by-catch estimates subsequent to the implementation of the TRP are compared to the data collected between 1990 and 1993 (Bisack 1997).

In 1994, the annual by-catch estimate of 1637 porpoises/annum for the southern Gulf of Maine was similar to the 1990-1993 mean of 1606 (Bisack 1997). In the northern Gulf of Maine the annual porpoise by-catch decreased from 224 in 1990-93 to only 24 in 1994. However, south of Cape Cod, the by-catch estimate increased from 69 to 365 (Bisack 1997). This coincides with a decline in annual fish landings in the northern Gulf of Maine and increased landings south of Cape Cod (Bisack 1997). In 1995, the annual by-catch in the northern Gulf of Maine fell to 20 porpoises, again corresponding to lower fish catches. In the southern Gulf of Maine the annual by-catch estimate was dramatically reduced to only 799 porpoises, half the previous average, probably due to the trial closure of gillnet fisheries implemented in the mid-coast area. However, the by-catch south of Cape Cod increased further to 564 animals. This latter figure represents a 50% increase since 1994 and an alarming eight-fold increase from the mean of 69 porpoises/annum estimated for 1991 – 1993. The detailed pattern of by-catches in the area in the first half of he 1990s is difficult to explain. Although increases in by-catch south of Cape Cod coincided with increased fishing activity, in fact fish landings increased by only 6%, suggesting that fishermen had not simply shifted their activity southwards. It was suggested that such high inter-annual differences in by-catch may be related to changes in the porpoise distribution rather than to changes in the fishing effort (Trippel *et al.* 1996).

In addition to mandates governing the fishing operations of the US domestic fleet, the Magnuson-Stevens Fishery Conservation and Management Act (MFCMA) also lays down strict rules which must be adhered to by all foreign fisheries working in US fishing grounds. Distant Water Fleets (DWFs) started fishing in US waters in the 1960s and, in response to declining fish stocks, the International Commission for the Northwest Atlantic Fisheries (ICNAF) implemented stricter management measures. These measures ensured that foreign fleets could only catch under-utilised fish stocks. By 1999, observer coverage of the foreign fleets had reached 100% of fishing effort and the DWFs were allocated 'fishery windows' which were spatiotemporally restricted. Cetacean species by-caught in the DWF mid-water trawls included pilot whales and common dolphins. Of the common dolphins by-caught, 68% were caught over the continental shelf edge and 69% were caught in winter (Waring *et al.* 1990). No mention was made as to the by-catch rates estimated from observer programs in the DWF.

Overall, the average annual harbour porpoise by-catch for the NW Atlantic gillnet fisheries between 1992 and 1996 was 1,667 (Merrick 1999), a figure 3.5 times that deemed acceptable under the PBR recommended by Caswell *et al.* (1996). The reduction of by-catch in 1995 provided evidence of the effectiveness of closures and Merrick (1999) describes further measures implemented as part of the ongoing TRP. In 1998, two types of closure were instigated. The NMFS enforced closures to all gillnet fishermen who were not using by-catch reduction devices to acoustically enhance their nets and, occasionally, areas were completely closed to all gillnet fishermen. The success of the new measures in the TRP was monitored with concurrent observations of 5% of the annual fishing effort. At the same time, weekly aerial transects were supplemented by two, 19-day shipboard surveys. During the ship surveys, prey biomass was measured acoustically and the ambient noise levels in the water were recorded to assess the sound levels produced by the acoustic net enhancement devices (Merrick 1999).

Changes in the estimated by-catch due to the measures introduced in 1998 cannot be discussed for, as yet, no data have been published. However, it is expected that these measures will prove effective for they are aggressive and, more importantly, in the case of closures to fishermen who are not using by-catch reduction devices, they are responsible.

In summary, by-catch of harbour porpoises is high in the Gulf of Maine and is not considered sustainable. However, the MMPA mandates that measures be taken to reduce by-catch in this strategic stock. The problem is recognised and is being addressed, with the goal of reducing the take of these marine mammals below a specified PBR. Consequent reductions in by-catch were observed as long ago as 1995.

Bay of Fundy

No legislation requiring monitoring or protection of marine mammals applies in the Bay of Fundy. However, the regimented procedures ongoing in the Gulf of Maine are reflected in the literature about porpoise by-catch in the Bay of Fundy.

Smith *et al.* (1983) reported that, at the time of his publication, "no official reporting system existed" for the Bay of Fundy. He conducted a questionnaire survey of by-catch in herring weirs and reported a total by-catch rate of only 0.328 porpoises per annum. This low figure is not surprising however for it is recognised that herring weirs are low impact fisheries and are listed as category III under the MMPA (Read 1994).

Read & Gaskin (1988) reported an increase in the by-catch rates in the Bay of Fundy in 1985 and subsequently carried out observations to try to determine the extent of the problem. They concluded that 0.135 porpoises/km.day of net were caught in gillnets alone and speculated that the porpoise population was on the verge of decline. Polacheck (1989) reported that a by-catch of 5.5 harbour porpoises per fishermen was taken each year in gillnet fisheries in the western Bay of Fundy.

The most extensive study of by-catch in gillnets in the Bay of Fundy was conducted by Trippel *et al.* (1996) in 1993 and 1994. In the latter part of their study, Trippel *et al.* (1996) used spatio-temporal stratification of data collection, as in the Gulf of Maine studies, although they used the fishing trip as their sampling unit – a unit considered too vague by Bravington & Bisack (1996). Concluding that most by-catch occurred in August, Trippel *et al.* (1996) estimated a by-catch rate of 3.2 (SE: $\pm$ 1.74) porpoises per trip in 1993 and 0.5 – 0.61 per trip in 1994. These data were extrapolated to 424 (SE: $\pm$ 224) porpoises in the

Lower Bay of Fundy in 1993 and 101 (CI: 80 – 122) in 1994. The authors acknowledged that the higher rate of by-catch reported for 1993 may have reflected the lack of temporal stratification of data collection. Interestingly however, the by-catch was noted to have been particularly high at times during the 1993 season, such that some fishermen refused to co-operate with the study during these periods. Compliance by fishermen at times when by-catch was low and lack of co-operation when by-catch was high may resulted in negatively biased results. Another confounding factor was the running of field tests of an acoustic deterrent device in the same area during 1994, and it was suggested that these tests may have lowered the by-catch estimates for that year. Thus the estimate for 1993 may accurately represent the by-catch in the absence of any net enhancement devices. Trippel *et al.* (1996) concluded that while by-catch rates were higher in the Bay of Fundy than they were in the Gulf of Maine, the total annual mortality was less due to the lower total annual fishing effort in the region.

2.4.2.2. Gulf of St. Lawrence and Greenland

There are few published data on the by-catch problem in the Gulf of St. Lawrence and Greenland populations. Lear & Christensen (1975) conducted an observer study of porpoise by-catch in gillnets off the SW coast of Greenland and, although they estimated that 1,500 porpoises were taken in 1972, they concluded that the data were too sparse to fully understand the extent of the problem. Porpoise by-catch off the SE coast of Greenland is thought to be rare (Kapel 1977).

In the Gulf of St. Lawrence, Fontaine *et al.* (1994) sent out questionnaires to fishermen and concurrently offered a financial reward for the receipt of cetacean carcasses. They retrieved 148 specimens in one summer month and the questionnaire returns indicated by-catch rates of 1.97 (SD $\pm$ 6.3) and 2.41 (SD $\pm$ 10.9) porpoises per fisherman in 1988 and 1989 respectively, equivalent to annual by-catches of 1,907 and 1,767 animals. These figures are high but, given the method of data collection, they are likely to be minimum estimates of the by-catch rates and thus can only be cause for concern (Lien *et al.* 1994).

The data obtained were sufficient to demonstrate that 80% of the by-catch in the Gulf of St. Lawrence occurred in June and August, when only 51% of the total annual fish catch was

obtained (Fontaine *et al.* 1994). Furthermore, 72% of the by-catch events occurred in one area where only 41% of the total fish landings were caught (Fontaine *et al.* 1994).

Table 1. Annual harbour porpoise by-catch estimates for the Gulf of Maine/Bay of Fundy stock. The 95% confidence intervals are given in brackets.

Year	Total annual by-catch estimate	By-catch as % of most recent population estimate (Bisack 1997)	Data source
1990	2900 [CI: 1,500 – 5,500]	5.34	Bravington & Bisack 1996
1991	2000 [CI: 1,000 – 3,800]	3.68	Bravington & Bisack 1996
1992	1200 [CI: 800 – 1,700]	2.21	Bravington & Bisack 1996
1993	1400 [CI: 1,000 – 2,000]	2.58	Bravington & Bisack 1996
1994	2026 [CI: 1,400 – 2,900]	3.73	Bisack 1997
1995	1383 [CI: 900 – 2,500]	2.55	Bisack 1997
1996	No data available	N/A	N/A
1997	No data available	N/A	N/A
1998	No data available	N/A	N/A
1999	No data available	N/A	N/A
2000	No data available	N/A	N/A