The Animal Welfare Implications of Cetacean Deaths in Fisheries

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Whale and Dolphin Conservation Society

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Executive summary

1. The incidental capture (bycatch) of cetaceans is a global conservation problem that threatens the future survival of some populations. However, little consideration has been given to the welfare impacts of bycatch. We: (i) review the literature on the welfare of bycaught individuals; (ii) compare the injuries in bycaught small cetaceans in the DEFRA (Poseidon) data base and the welfare significance of these injuries and (iii) compare animal welfare standards set out in general and sectorial legislation.

2. Bycaught cetaceans suffer a variety of injuries, ranging from skin abrasions to amputations. The degree and severity of injuries varies with method of fishing and species. There are no quantitative assessments of the relevance of these injuries to individual welfare, but they are likely to contribute significantly to *pre-mortem* stress and long-term survival if the animal escapes or is released.

3. Pathological data indicate that the majority of bycaught cetaceans asphyxiate in the nets. Asphyxiation is considered to be extremely stressful for a wide range of mammals and this is also likely to be the case for cetaceans.

4. The stress associated with capture, *pre-mortem* injuries and asphyxiation are likely to be high and, for individuals that escape, the effects of stress may cause subsequent mortality, or a decline in immune or reproductive function.

5. There are no quantitative data on the duration of suffering for bycaught cetaceans. The theoretical aerobic dive length and the maximum dive duration suggest that the duration of suffering may range from 3-6 minutes in harbour porpoises to 45-70 minutes in sperm whales. This will be more protracted for animals caught in nets set at or near the surface or for larger species of whales that are able to surface despite their entanglement, and so will be able to breathe for some time until they become too debilitated or weakened.

6. A hitherto unconsidered aspect of bycatch is the social implications for conspecifics of the death of particular individuals. These include the potential loss of important social knowledge and the stress caused by the death/dying of conspecifics.

7. The majority of international and EU legislation which has jurisdiction over bycatch is concerned with impacts at a population or species level i.e. the numbers of individuals caught, and does not consider the welfare of the individuals affected. Whilst domestic and international animal welfare legislation

prohibits the infliction of deliberate suffering and causing inhumane death, including by drowning, it does not address suffering caused as an incidental consequence of a lawful activity.

8. Animal welfare standards such as for the slaughter of farm animals and catching wild mammals in killing traps specify times to death that are significantly shorter than those predicted for bycaught cetaceans.

9. Mammal trapping standards provide a trauma scale to rank the injuries an individual suffers in a restraining trap; this provides a quantified framework for assessing the welfare consequences of different injuries that can form the basis for a trauma scale for that can be applied to bycaught cetaceans.

10. In conclusion, bycaught cetaceans often endure a range of poor welfare conditions, suffering injuries and/or a prolonged death due to asphyxiation, and their death may result in distress to surviving family or group members and disruption of social systems. Current legislation in the EU and elsewhere pertaining to fisheries in general, and cetacean bycatch in particular, fails to consider animal welfare in these circumstances, even though the duration of suffering of bycaught cetaceans is likely to be substantially longer than that accepted for trapping or commercial meat production.

Contents

1. Introduction

Incidental capture (bycatch) by fishing activities seriously threatens a number of whale, dolphin and porpoise populations worldwide, and has the potential to cause the local and global extinctions of many cetacean species over the next few decades (Perrin *et al*. 1994; D'Agrosa *et al*. 2000). In 1991, the International Whaling Commission reviewed the impact of bycatch in 190 regional cetacean populations (Perrin 1992). It concluded that incidental catches were clearly unsustainable in 8 populations, potentially unsustainable in 34, possibly unsustainable in 5, clearly insignificant in 12, possibly insignificant in seven and of unknown consequence in an alarming 114 of the regions assessed (Perrin 1992). Currently, several species, including the Maui's dolphin (see Appendix for the Latin names of all the species referred to in this report), vaquita and North Atlantic right whale, are immediately threatened by bycatch (D'Agrosa *et al*. 2000; Anon. 2004), whilst important data on many cetacean population sizes, trends and bycatch mortality are absent (Reeves *et al*. 2005). Small cetaceans (dolphins and porpoises) appear to be particularly at risk (Perrin *et al*. 1994), but larger whales are also caught incidentally (Baird *et al*. 2002; Johnson *et al*. 2005).

With increasingly intensive use of marine resources, the interaction between fisheries and cetaceans is likely to intensify (DeMaster *et al*. 2001; Read *et al*. 2006). Bycatch occurs in a wide variety of fisheries and with almost all forms of fishing gear (Perrin *et al*. 1994; Read & Rosenberg 2002), although the number of cetaceans caught depends on many factors, including the: species involved (Kastelein *et al*. 2000a); location of the fishery, such as inshore or offshore (López *et al*. 2003); fishing method, such as active or passive (Tregenza *et al*. 1997a); environmental variables, such as tidal speed or turbidity (Tregenza *et al*. 1997a); time, including diel and seasonal variation (Van Waerebeek & Reyes 1994; Tregenza & Collett 1998); and behaviours such as scavenging (Broadhurst 1998). With so many interacting factors, bycatch is likely to continue to be a problem for fisheries in the future, even with the deployment of mitigation strategies aimed at reducing cetacean deaths.

Bycatch has long been recognised as a significant conservation problem (Perrin 1969), yet it has taken many years to compile regional and global assessments of the number of bycaught cetaceans and the relative impact of each type of fishery because few countries have observer programs to provide reliable data on the numbers of cetaceans caught (Perrin *et al*. 1994; Lewison *et al*. 2004). Estimates of global cetacean bycatch during the 1990s range from 275,000 to 470,000 per annum (Read *et al*. 2006), but the scale of bycatch prior to the first quantitative assessments was already great enough to have a significant impact on cetacean populations (Jackson *et al*. 2001). The concern over cetacean bycatch has been so great that concerted efforts have been made by some fisheries to reduce the number of bycaught cetaceans (Reeves *et al*. 2005). These include banning certain fishing methods and the use of acoustic deterrent devices. Despite these measures, bycatch continues to threaten many cetacean populations globally (Reeves *et al*. 2005).

To date, the primary focus of most research has been the conservation aspect of cetacean bycatch and there has been little detailed consideration of the welfare implications. We therefore: (i) review the literature on the welfare of bycaught individuals; (ii) compare the injuries in bycaught small cetaceans in the UK Department of Environment, Food and Rural Affairs (DEFRA) Poseidon data base and the welfare significance of these injuries; (iii) compare animal welfare standards set out in general and sectorial legislation and (iv) highlight areas for future research.

2. The types of fisheries

It is impossible to review all the different methods of fishing in detail, but an overview of the main types is helpful as the species of bycaught cetaceans, the frequency of capture and types of welfare concerns differ with each type of fishing gear. The two main fishing methods are: passive techniques which involve the use of gear such as static or drifting nets, hooks or traps; or active techniques such as trawling or seining, in which the target organisms are pursued (Moore & Jennings 2000).

There are two types of pelagic static fishing gear that are relevant here: drift nets and longlines. Driftnets are a type of gillnet that are suspended from floats at the sea surface, and usually left to drift freely. Longlines use baited hooks on single or multi-branched lines splitting off a central line. Other passive fishing methods, such as set mono- or multifilament gillnets, tanglenets, traps and pots, are anchored to the sea bed and left to fish passively; lines usually link them with markers or buoys on the surface.

Midwater trawls and purse seines are used to catch pelagic and shoaling fish such as tuna, herring or mackerel. A purse seine net is used to encircle the shoal of fish and then the bottom of the net is drawn closed. A pelagic trawl net is like a very large funnel-shaped bag that is towed by one or a pair of vessels, again targeting whole shoals of fish. Demersal trawls such as otter and beam trawls are designed to catch bottom dwelling species; these generally have lower cetacean bycatch rates than pelagic trawls (Fertl & Leatherwood 1997).

There are inadequate data to assess the full significance of different gear types to cetacean bycatch on a global level, but stratified data from US fisheries indicate that gillnets are the most important source of cetacean bycatch, and that trawling and other methods vary in their importance (Read *et al*. 2006).

3. Causes of bycatch

A number of important factors affect which cetaceans are caught. Some cetacean species possess a sophisticated sonar or echolocation system that should assist in detecting and avoiding nets. Sonar signals vary between species (Au 1994; Akamatsu *et al*. 1998) and this can lead to different detection distances for nets and lines (Kastelein *et al*. 2000a). Most research has been carried out on static gill nets; there is considerable variation in reflective properties of different nets, but floats, ropes and lines may be more readily detectable (Akamatsu *et al*. 1991b; Hatakeyama *et al*. 1994). Further problems arise if the angle of approach to the net is suboptimal or if there is considerable ambient noise. Both these factors mean that for some species, the threshold for detection is below that for avoidance (Kastelein *et al*. 2000a). Cetaceans must then rely on detection of nets through senses in addition to sonar, including vision. In contrast to static gill nets, there has been little research into the detectability of trawls, partially due to the difficulties in monitoring underwater movements of cetaceans in the vicinity of pelagic trawls (Connelly *et al*. 1997). It is assumed however that dolphins are well aware of the presence of such nets, which would be very noisy as they move through the water (SMRU 2004).

A number of behavioural factors may contribute to incidental capture. Cetaceans that echolocate do not do so continuously and, within a school, only a few individuals may be echolocating at any one time (Akamatsu *et al*. 2005). It has been suggested that in some instances, the greatest risk of entanglements in surface or near surface nets is during sleep, when echolocation is significantly reduced (Goley 1999). Furthermore, visual detection of nets is not possible at night (Akamatsu *et al*. 1991b). Both factors may explain why several experiments and field observations found that, for some species and for some fishing practises, entanglements mainly occurred at night (Crespo *et al*. 1997; Tregenza & Collett 1998). However, cetaceans may also be attracted to nets by the prey captured in the nets or secondary scavenging of other bycatch (Fertl & Leatherwood 1997; Broadhurst 1998; Read *et al*. 2003). In these cases, entrapment may occur during night and day (e.g. Morizuer *et al*. 1999; Brotons *et al*. 2008). Entrapment can also occur through curiosity, carelessness whilst chasing prey or playing, or when escaping from predators or the fishing gear itself (Akamatsu *et al*. 1991a; Perrin *et al*. 1994; Kastelein *et al*. 1995). Prior experience and wariness of nets may be important; in experimental studies, harbour porpoises were caught less often once they were familiar with a static gill net (Akamatsu *et al*. 1991a).

It is unclear at what point during fishing bycatch is most likely to occur. For harbour porpoises caught in gill nets, *post-mortem* temperature and physiological data suggest that entrapment occurs during fishing, not when the nets are being hauled in (Tregenza *et al*. 1997a; Hood *et al*. 2003). Conversely, some dolphins appear to have been caught in gill nets during shooting or hauling the nets (Tregenza *et al*. 1997b) and during hauling in trawl nets (Morizur *et al*. 1999). Thus, for some species, entrapment occurs as a result of changes in the movement of nets (Waring *et al*. 1990; Couperus 1996).

Large baleen whales such as humpback and right whales seem particularly vulnerable to entanglement in the vertical lines e.g. buoy lines associated with gear such as lobster pots and bottom-set gillnets, which are the principle source of entanglement (Johnson *et al*. 2005). It is likely that these cetaceans do not detect the gear or may even be attracted to these areas because prey species are attracted to the sets (Lien 1994). Cetaceans may enter other passive traps, such as squid traps, in search of food but be unable to exit (Lien 1994). When hooks are used, cetaceans can become entrapped in the lines linking hooks to the surface, although the majority are hooked, either in the mouth or on other parts of the body (Forney 2003; Kock *et al*. 2006). This suggests that entanglement may occur both through depredation of fish already hooked and following collision with the fishing gear.

4. Ways of reducing cetacean bycatch

There is some controversy as to how cetacean bycatch can be reduced because of the great variability associated with fishery type, species involved and locality (Jefferson & Curry 1996). However, a number of approaches may reduce the impact of fisheries. These include: (i) reducing the likelihood of cetaceans encountering fishing activities; (ii) altering the ability to detect or understand that a net represents a barrier; and (iii) reducing the likelihood of entanglement when a cetacean collides with the net.

One method of reducing the likelihood of cetaceans encountering potentially hazardous fisheries is to introduce time and/or area closures of fishing activities (Myers *et al*. 2007), although such measures have had mixed results. Areas with permanent bans on fishing activities have been effective in reducing bycatch (Dawson & Slooten 1993), but fishing effort can be displaced elsewhere. Temporary time/area closures can result in displacement of fishing effort without reducing bycatch (Murray *et al*. 2000), but can be effective if bycatch is a seasonal problem. For some fisheries it may be difficult to identify areas suitable for time-area closures (Berrow *et al*. 2006), whilst closures are commonly flouted by some fisherman and are universally unpopular (Murray *et al*. 2000). Thus, it is not clear how effective permanent or temporary time/area closures are, and the likelihood of success probably depends on the species and fishery involved.

Modification of fishing gear, in particular its acoustic properties, can reduce bycatch (Dawson 1994; Goodson *et al*. 1994; Koschinski *et al*. 2006). Increasing stiffness of nets may reduce the likelihood of fins or tails being caught (Larsen *et al*. 2002; Cox & Read 2004; Mooney *et al*. 2007), whilst altering the colour of nets may aid visual detection for some species of cetaceans (Hatakeyama *et al*. 1994).

Acoustic deterrent devices or 'pingers' are currently used in several fisheries to reduce bycatch (Kraus *et al*. 1997; Trippel *et al*. 1999; Gearin *et al*. 2000; Barlow & Cameron 2003). Pingers work by producing sounds which either alert cetaceans to the presence of nets or are aversive to cetaceans, without reducing capture rates of the target species (Kastelein *et al*. 1995, 2000b; Culik *et al*. 2001). Concern has been raised about the effectiveness of pingers (Dawson 1994; Dawson *et al*. 1998); some studies have suggested that cetaceans can become habituated to pingers (Cox *et al*. 2001; Barlow & Cameron 2003) or may associate them with food (Cox *et al*. 2003). Also, the sound characteristics of the devices can cause different responses in different cetaceans and may not be aversive to some species (Kastelein *et al*. 2006a). Altering sounds or combining this with other measures such as net design may help maintain avoidance (Koschinski *et al*. 2006; Teilmann *et al*. 2006). Pingers have other disadvantages; they need periodic maintenance such as changing batteries and, if this does not occur or the device malfunctions, parts of the net will be left with no acoustic enhancement, which may be perceived by the cetaceans as escape windows (Culik *et al*. 2001; Koschinski *et al*. 2006). Concerns have also been raised about spatial displacement: Carlström *et al*. (2002) argued that acoustic deterrent devices could displace individuals from key habitats which may be critical for survival. Acoustic deterrents have had limited success on trawling nets (Northridge 2006), and so modifications such as exclusion grids and escape hatches are being tested in some trawl fisheries (Northridge *et al*. 2005; Northridge 2006).

5. The welfare of bycaught cetaceans

Cetaceans caught as bycatch can suffer physical injury, stress, direct mortality through asphyxiation, and indirect mortality as a latent result of injury or subsequent stress amongst surviving family or group members and disruption of social systems. However, there has been little consideration of the actual processes that occur during incidental capture and the implications of these for individual animals. Understanding these interactions may aid understanding of ways to reduce and prevent cetacean bycatch. Moreover, examination of the welfare implications of the process may provide a better assessment of the significance of bycatch.

5.1. The process of capture in nets and other fishing gear

Entanglement in gillnets can occur in a number of ways. Head-on collision, for instance, happens if the animal is travelling or pursuing prey and encounters a static or drift gillnet. In this case the first part of the body to impact is the head, when the netting often enters the mouth and becomes entangled on the teeth (Gearin *et al*. 1994; Kastelein *et al*. 1995). Fins and tail flukes also commonly become entangled (Akamatsu *et al*. 1991a); any notches on the tail or tubercules on fins can prevent the net sliding off the body (Kastelein *et al*. 1995). When entangled, individuals bend their body in dorso-ventral and lateral directions, increasing the likelihood of other extremities being caught, thereby causing more complex entanglements (Kastelein *et al*. 1995; Weinrich 1999).

In a study of 10,259 Dall's porpoises bycaught in driftnet fisheries, 27% were entangled by the flukes, 24% were 'complex' entanglements, 10% by the pectoral fins, and 9.5% by the mouth (Snow 1987). Harbour porpoises in particular are prone to getting entangled in bottom-set gillnets (Read *et al*. 1993; Tregenza *et al*. 1997a), apparently whilst foraging at or near the sea bed. Thus, their encounter with gillnets could start with any part of the body, including fins or flukes.

The incidental capture of cetaceans in active or towed fishing gear clearly involves other processes. Over the past four decades, the purse seine fishery for yellow-fin tuna in the eastern Pacific Ocean has recorded very high levels of cetacean bycatch, specifically spotted and spinner dolphins (Hall 1998; Gerrodette & Forcada 2005). Here, the tuna actively associate with schools of various species of dolphins, and so fleets targeted and chased the dolphins in order to catch the tuna swimming beneath them. The huge purse-seine net would be pulled round the whole shoal of fish, catching the dolphins in the process. Mortality of the dolphins occurred through asphyxiation of animals trapped underwater or the stress of the chase and capture process (Myrick & Perkins 1995; Cowan & Curry 2002).

Mid-water or pelagic trawl fisheries are also responsible for substantial bycatch of dolphins and small whales in several areas of the world. Dolphins are caught either at the closed (cod) end of the net where the meshes are relatively small, or further forward in the net in the larger meshes, presumably because they have detected the barrier ahead and tried to find an escape route (SMRU 2004). Alteration in the configuration of the net as a result of change in tow direction or hauling the net may be important factors in confusing the cetaceans. For some species it has been suggested that most individuals are entrapped as the net is hauled in (e.g. Tregenza et al. 1997b; Morizur *et al*. 1999). Rather than getting entangled in the net, dolphins typically die with their beaks stuck through a mesh, presumably trying to force an exit (SMRU 2004).

For other types of fishing gear, the process of entrapment is less clear. For baleen whales, entanglement mainly appears to be by the mouth or flukes, irrespective of the type of fishing gear (Knowlton & Kraus 2001; Johnson *et al*. 2005). With longlining, cetaceans may be hooked in the body or by ingestion of the hook (Forney 2003). The ingestion of hooks is generally classified as a serious injury, whereas hooks pinning other body parts are classified as non-serious (Angliss & DeMaster 1998). In both cases there is no information on individual reaction to entanglement, which would provide useful information on possible injuries caused by the fishing gear.

5.2. Physical injuries caused by capture in nets and other fishing gear

The distinctive injuries suffered by cetaceans caught in nets (Table 1) are used to determine whether an individual is bycaught (Kuiken 1994), although not all individuals have injuries. Furthermore, no single injury is diagnostic of bycatch, and the type of injuries will depend on fishing method and the individual response to entrapment (García Hartmann *et al*. 1994). It is difficult to assess the percentage of bycaught cetaceans which receive injuries, as some individuals may become entangled and escape alive or die but be dislodged prior to retrieval of the net (Tregenza *et al*. 1997a). Entanglement in net fishing gear typically causes traumatic external lesions such as abrasions, amputations, penetrating wounds, broken mandibles or teeth (Kuiken 1994; Kuiken *et al*. 1994a, b). Internal trauma may also be considerable, including bruising, fractured bones, punctured lungs, haemorrhagic pleural effusions (bleeding between the two layers of the pleura) and pneumothrorax (collapsed lung) (Jepson *et al*. 2000, 2005). Skin lesions on the body are generally associated with entanglement and attempts to escape from the net, whereas other traumatic lesions such as skull fractures are associated with being hauled on board the fishing vessel (Kirkwood *et al*. 1997).

Depending on how cetaceans become entangled, most skin abrasions occur on the head, dorsal fin, pectoral fins and tail flukes (Kuiken 1994; Siebert *et al*. 2001). The majority of large cetaceans are caught by the mouth or flukes, and so have abrasions in these areas (Johnson *et al*. 2005). Individuals caught on longlines typically have abrasions along the side of the body as a consequence of struggling against the line (Baird & Gorgone 2005). The primary external injuries found in bycaught individuals would not appear to be immediately lethal; some cetaceans may escape entanglement (Weinrich 1996) and many live cetaceans bear scars from previous interactions with fisheries (Parsons & Jefferson 2000; Ramos *et al*. 2001). In one study of a longlining fishery, 91% of entrapped cetaceans were alive at recovery and 61% had serious injuries (Forney 2003). Of the humpback whales sighted between 1997 and 1999, 88% had scarring associated with entanglement (Robbins & Mattila 2000), as did 75% of right whales observed between 1980 and 2002 (Knowlton *et al*. 2005). For large cetaceans, the number of interactions with fishing gear is believed to be four to five times greater than the number entrapped (Lien 1994).

The type of ropes and lines often used in fishing can lead to serious abrasions and amputation (Woodward *et al*. 2006). Depending on the injury, non-lethal encounters can cause serious health problems, and reduce survival or fecundity (Knowlton & Kraus 2001; Ramos *et al*. 2001; Moore *et al*. 2005). Tangled gear and certain injuries can increase the energetic costs of swimming, impair feeding and increase susceptibility to diseases (Knowlton & Kraus 2001; Ramos *et al*. 2001; Moore *et al*. 2005). Longlining injuries often occur on the dorsal fin, which in some species has an important role in the thermoregulation of the reproductive system (Rommel *et al*. 1993; Baird & Gorgone 2005).

More serious injuries include amputation of flukes (Urbàn *et al*. 2004) and blunt trauma causing fractures (Duignan & Jones 2005). In longline fisheries, cetaceans can become hooked in the mouth or ingest the hook (Forney 2003). In addition, the thrashing associated with being hooked can lead to the partial or complete severance of the dorsal fin (Baird & Gorgone 2005). Injuries caused by being hauled on board appear to be more serious (Kuiken 1994; Kirkwood *et al*. 1997). In trawls, the weight of fish may cause crush injuries, whilst amputations, stabbing, gaffing, rope marks and skull fractures are associated with being hauled aboard and dropped on the deck (Kuiken 1994; Kuiken *et al*. 1994a). Given that these injuries are caused on board the fishing vessel, by which point the majority of small cetaceans are already dead (Perrin *et al*. 1994; Yatsu *et al*. 1994), it seems likely that most of these injuries occur *post-mortem*.

5.3. Injuries recorded on small cetaceans bycaught in British waters

To assess the injuries of bycaught cetaceans, access was granted to the cetacean database of *post-mortems* undertaken for DEFRA (the Poseidon database). This spans 15 years and contains *post-mortem* data from 2302 cetaceans, of which 649 were classified as bycatch. However, there are several limitations on data quality. First, as knowledge of bycatch has increased, the number of injuries recorded has increased. Second, *post-mortems* were carried out at different localities and by different pathologists. Consequently, data quality varies, in particular the recording of internal injuries. Therefore, we limited our analyses to *post-mortems* of bycatch carried out at the Institute of Zoology during 1999-2005. This sample comprises 182 cetaceans (97 harbour porpoises, 80 common dolphins, 3 striped dolphins, 1 Risso's dolphin and 1 minke whale). This bias towards harbour porpoises and common dolphins is also reflected in the earlier part (1990-1995) of the DEFRA database (Kirkwood *et al*. 1997). As harbour porpoises and common dolphins comprised the majority of this dataset, we used these two species for the analyses. We limited our analyses to those animals where injuries appeared to have occurred *pre-mortem* i.e. injuries associated with haemorrhaging.

There were more juveniles in the sample of bycaught harbour porpoises (65% juveniles) than common dolphins (41% juveniles; χ^2_1=9.92, P<0.01). However, there were no differences in the sex ratios of juveniles and adults for either harbour porpoises (χ^2_1=0.60, P=0.44) or common dolphins (χ^2_1=0.07, P=0.79). Juveniles of both species normally form a higher proportion in bycatch samples (e.g. Siebert *et al*. 2001; Silva & Sequeira 2003), though this was not evident in our dataset for common dolphins. Juvenile porpoises may echolocate at a higher frequency than adults (Au *et al*. 1999); hence they may not be able to detect nets as rapidly as adults and so are at greater risk of entrapment. Sex-ratios were significantly different between species (χ^2_1=3.75, P=0.05), with bycaught common dolphins being more male-biased (65.0%) than harbour porpoises (50.5%). Other studies have found a male-bias in bycaught common dolphins (e.g. López *et al*. 2002; Silva & Sequeira 2003), but both male- and female-biased samples for harbour porpoises (Anon. 1998a; Siebert *et al*. 2006).

Net marks were found on 61.4% of the cetaceans (Table 1), though *post-mortem* damage to skin may mask *pre-mortem* damage and so may not be recorded. Net marks were not evenly distributed around the body (Figure 1), being found more commonly on the extremities (tail, pectoral fins, dorsal fins and head/beak) than the body. The tail, pectoral fins and head/beak were more likely to have net marks than the dorsal fin. A high proportion (42.3%) of bycaught individuals had complex entanglements involving multiple parts of the body. Unlike larger baleen whales (e.g. Johnson *et al*. 2005), few of these dolphins and porpoises had evidence of rope marks (7.7%) and few had penetrating subcutaneous injuries (10.4%). Amputations were noted frequently, but it was unclear whether these were due to entanglement in the nets or from being cut free. A significant proportion of cetaceans had broken maxillae or mandibles (24.2%) and/or broken teeth (17.0%). An examination of external injuries by species (harbour porpoises and common dolphins) and age (adults and juveniles) indicated no significant difference in location of net marks (χ^2_3=9.47, P=0.663). There were however significant species differences in the number of broken beaks (χ^2_1=20.99, P<0.01), with common dolphins (41.2%) having a higher frequency than harbour porpoises (11.3%); there were no age differences in the incidence of broken beaks for harbour porpoises (χ^2_1=1.68, P=0.20) or common dolphins (χ^2_1=1.45, P=0.23).

Whilst bycaught cetaceans can suffer a range of internal injuries, we did not consider aspects of lung pathology as these have been well-documented elsewhere (Tables 1 and 2). In general, a large proportion of bycaught cetaceans had generalized organ congestion (liver, kidneys, spleen and adrenal glands) caused by reduced blood flow. Internal injuries can be inflicted by the fishing equipment and also by the cetacean struggling to free itself. Muscle tears and haemorrhaging are frequently found in the longissimus dorsi muscle, peri- and sub-scapular areas, thoracic and intercostal areas, and sub-cranial and mandibular regions; the thoracic *rete mirabile* frequently also shows haemorrhaging (Figure 2). Since entrapped cetaceans typically make powerful dorso-ventral and lateral movements, these probably cause the haemorrhaging and tears in the longissimus dorsi muscle, which is the primary swimming muscle. Similarly, because the pectoral fins frequently become entangled, such movements will cause muscle tears and haemorrhaging in the peri- and subscapular areas, and torsion of the body leads to internal haemorrhaging of the thoracic *rete mirabile*. Whilst fractured skulls can occur when cetaceans are dropped on the deck of the fishing boat (Kirkwood *et al*. 1997), or go through the winches, such trauma was uncommon in this dataset, with only 1.6% having a fractured skull, although 8.8% had bruising and haemorrhaging on the dorsal aspect of the cranium.

There were significant differences in the levels of organ congestion between juveniles and adults (harbour porpoises 52.3% versus 73.5%, χ^2_1=4.11, P=0.04; common dolphins 60.6% versus 80.9%, χ^2_1=3.99, P=0.05). However, there were no differences between juvenile harbour porpoises and common dolphins (χ^2_1=0.59, P=0.44) or adults of the two species (χ^2_1= 0.61, P=0.43). There was a significant relationship between the incidence of haemorrhaging and tears in the longissimus muscle and both age and species (χ^2_3=26.70, P<0.01), with more injuries in adults than juveniles (harbour porpoises χ^2_1=19.99, P<0.01, common dolphins χ^2_1=6.66, P<0.01) but both juvenile (χ^2_1=0.95, P=0.33) and adult porpoises and dolphins (χ^2_1=0.28, P=0.60) did not differ significantly from each other. The overall prevalence of haemorrhaging/muscle tears in the longissimus dorsi muscle was low (18.1%), but were found in 40.7% of all adult harbour porpoises and common dolphins, compared with only 8.3% of the juveniles of both species. Haemorrhaging in the thoracic *rete* *mirabile* was not equally spread among groups (χ^2_3=23.75, *P*<0.01); juvenile harbour porpoises had a lower frequency (17.5%) of haemorrhaging than adults (41.1%;

Table 1. *Gross pathological changes observed in bycaught cetaceans. * indicates dolphins caught accidentally in USSR navy captive facilities. Species: 1 - Hector's dolphin, 2 - common dolphin, 3 - dusky dolphin, 4 - bottlenose dolphin, 5 - Atlantic white-sided dolphin, 6 - harbour porpoise*

Species	No. of animals	Probable bycatch (%)	Net marks (%)	Respiratory congestion (%)	Pulmonary emphysemas (%)	Foreign matter in lungs (%)	Regurgitated food (%)	Study
1, 2, 3		80	50	60	0	10	10	Duignan *et al*. 2004
1, 2	11	100	82	82	27	18	-	Duignan *et al*. 2003b
1, 2, 3, 4	12	75	58	83	8	0	0	Duignan & Jones 2005
1, 2	13	92	85	92	-	-	-	Duignan *et al*. 2003a
4	16*	100	94	-	44	-	6	Birkun 1994
1, 2, 3	20	95	75	70	0	10	15	Duignan *et al*. 2003c
6	31	100	100	48	-	-	3	Siebert *et al*. 1994
2, 5, 6	46	100	-	-	-	-	22	Knieriem & García Hartmann 2001
6	60	100	-	88	-	-	3	Jepson *et al*. 2000
6	12	100	67	83	58	-	-	Siebert *et al*. 2006
6	22	100	20	86	55	-	-	Siebert *et al*. 2006

Table 2. *Cardiac and pulmonary histology of autopsied cetaceans; these are minimum estimates, as some data are missing. * indicates dolphins caught accidentally in USSR navy captive facilities. Species: 1 - Hector's dolphin, 2 - common dolphin, 3 - dusky dolphin, 4 - bottlenose dolphin, 5 - Atlantic white-sided dolphin, 6 - harbour porpoise*

Species	No. of animals	Probable bycatch (%)	Pulmonary interlobular/lobular oedema/congestion (%)	Pulmonary alveolar emphysema (%)	Cardiac fibre contraction (%)	Cardiac fibre fragmentation (%)	Study
1, 2, 3	10	80	70	0	60	50	Duignan *et al*. 2004
1, 2	11	100	100	64	73	18	Duignan *et al*. 2003b
4	16*	100	69	-	-	44	Birkun 1994
1, 2, 3	20	95	65	0	60	45	Duignan *et al*. 2003c
6	31	100	100	-	-	-	Siebert *et al*. 1994
2, 5, 6	46	100	100	-	-	-	Knieriem & García Hartmann 2001
6	60	100	83	55	-	-	Jepson *et al*. 2000

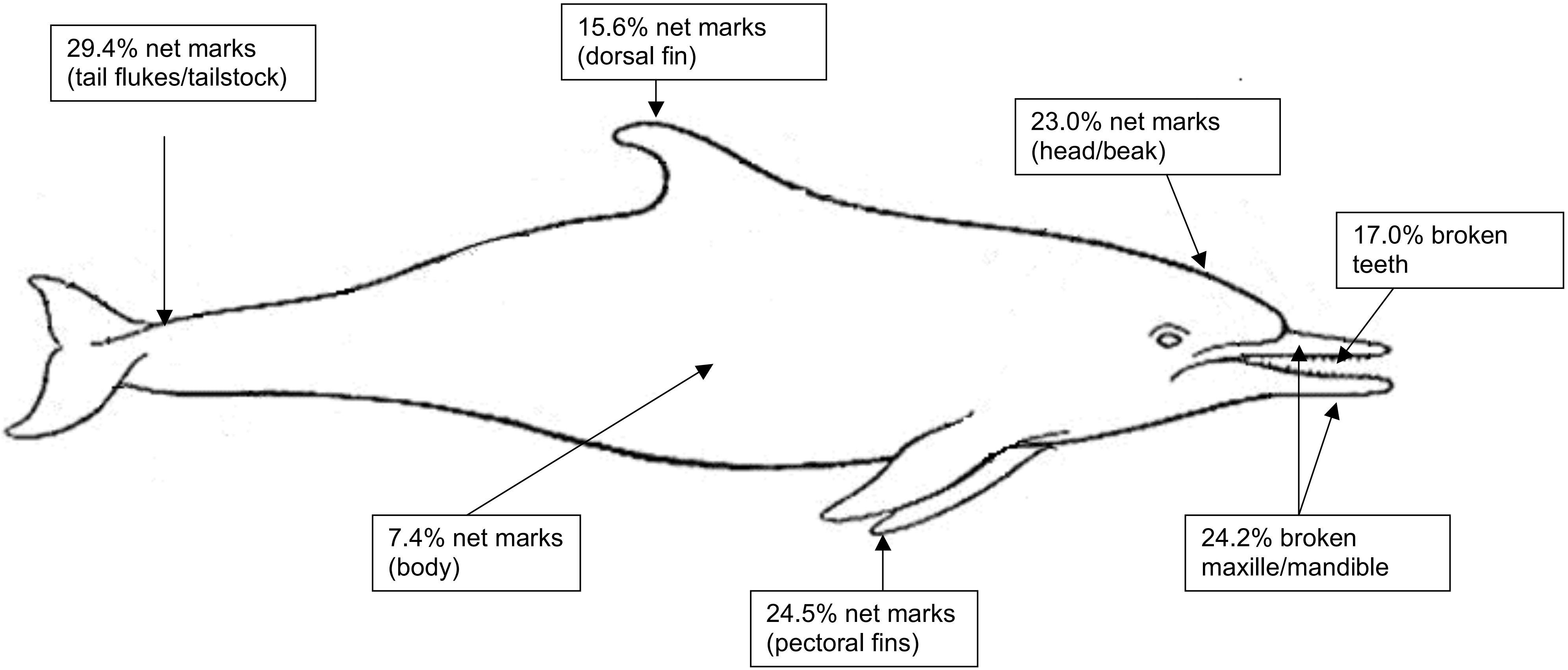

Figure 1. *External injuries recorded from post-mortem data. Figures are for a generic small cetacean*

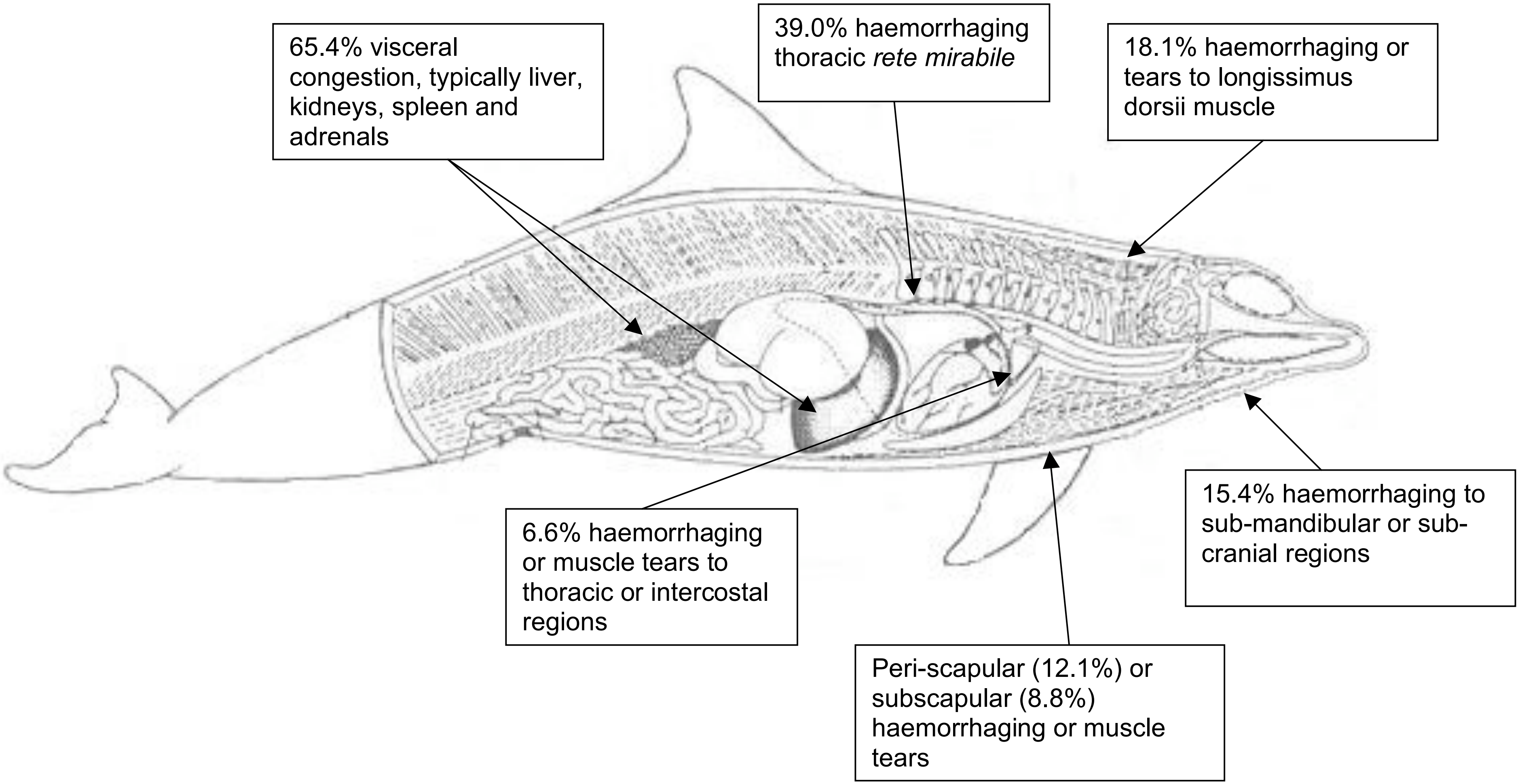

Figure 2. *Internal injuries recorded from post-mortem data. Figures are for a generic small cetacean*

χ^2_1=6.40, *P*=0.01), whereas incidence in juvenile (54.5%) and adult (59.6%) common dolphins was not significantly different (χ^2_1=0.20, *P*=0.65). There were differences in the frequency of haemorrhaging in the thoracic rete mirabile between juvenile harbour porpoises and juvenile common dolphins (χ^2_1=14.13, *P*<0.01) but not between adults (χ^2_1=2.68, *P*=0.10).

The frequency of haemorrhaging and muscle tears in the peri- and subscapular area was different between groupings (χ^2_3=23.75, *P*<0.01). Juvenile (9.5%) and adult (11.7%) porpoises did not differ in the frequencies of these injuries (χ^2_1=0.12, *P*=0.73), but juvenile (21.2%) common dolphins had a lower frequency than adults (42.6%; χ^2_1=3.95, *P*=0.04). Adult common dolphins had higher levels of peri- and subscapular injuries than adult harbour porpoises (χ^2_1=8.97, *P*<0.01), but there was no difference for juveniles (χ^2_1=3.15, *P*=0.07). There were no differences in injuries to the thoracic and intercostal regions between species and age categories (χ^2_3=3.40, *P*=0.33).

Overall, there are clear differences in the types and degree of injuries received by bycaught cetaceans, and these vary with species and age. These differences highlight how no single injury measure can be used to diagnose bycatch. Histopathological and pathomorphological studies are better indicators of bycatch (see next section). The injuries can arise for a number of reasons, but may include the type of fishing gear (trawl versus gill net) and age-related individual responses to entrapment. For example, juveniles may die more quickly and have a reduced period of struggling. Species differences in anatomy and development may also play a role. The thoracic *rete mirabile* is a complex of veins and arteries distributed on both sides of the thoracic vertebrae and extending between the ribs. The thoracic *rete mirabile* is found in all cetaceans, but differs greatly in extent and size (Vogl & Fisher 1982; Melnikov 1997). Whilst the function of the thoracic *rete mirabile* is unclear, it is thought to have mechanical and biochemical functions, particularly during diving (Vogl & Fisher 1982; Johansen *et al*. 1988), and age and species variations in its development may be related to differences in diving ability.

5.4. Asphyxiation as a cause of mortality for bycaught cetaceans

Once trapped underwater, a cetacean would drown because it was unable to rise to the surface to breathe. Drowning is a complex process and includes both wet drowning (aspiration of fluid) and dry drowning. Cetaceans do not aspirate water

(Jepson *et al*. 2000; Knieriem & García Hartmann 2001) and usually show 'atypical drowning lung' (Knieriem & García Hartmann 2001); death is thought to occur through asphyxiation, which causes gross and histological changes to the heart and lungs (Jepson *et al*. 2000). Gross physical indicators can include cardio-pulmonary changes associated with asphyxiation; these include diffuse pulmonary oedema, congestion of visceral organs, emphysema and congestion of pericardiac vessels, and ecchymotic haemorrhages on the endo- and/or epicardium (Table 1). Most studies report the presence of blood-stained froth in the airways of bycaught cetaceans caused by hypoxia (Kuiken *et al*. 1994a). Hypoxic lung tissue loses its ability to maintain membrane integrity, causing protein and erythrocytes to leak into the alveoli (Davis & Bowerman 1990); the protein is responsible for the froth. Although useful evidence, gross physical changes only provide indirect proof of bycatch (Knieriem & García Hartmann 2001).

Histopathological and pathomorphological studies are better indicators of bycatch (Table 2). The pathological and histological changes observed in bycaught cetaceans indicate that asphyxia is the main cause of mortality. Histological examination shows hypercontraction of myofibres along with fibre fragmentation and vacuolation in the heart (Duignan *et al*. 2003a, b, c). This contraction banding is seen in the coronary arteries of human drowning fatalities and is associated with hypoxia of the myocardium (Lunt & Rose 1987) and also with excess catecholamine (Baroldi *et al*. 2001). It may lead to myocardial necrosis if the animal manages to escape. The lungs also show distinct changes associated with asphyxia, including severe oedema within the alveolar spaces, intra-alveolar haemorrhages, rupture of the alveolar walls and myosphincters of the broncholi (Knieriem & García Hartmann 2001; Cowan & Curry 2002). These changes are similar to those reported from lungs of dolphins which asphyxiate from fish trapped in the trachea (Macrì *et al*. 1999). As in the heart, lungs can also show myofibre fragmentation (Duignan *et al*. 2003).

Whilst these pathological changes indicate that asphyxiation is the cause of mortality, they do not indicate whether this is a stressful process. However, physiological data suggest that the cardiac changes observed in bycaught cetaceans are caused by massive releases of catecholamines in response to stress (Cowan & Curry 2002). Similar responses are observed in other vertebrates with forced submersion (e.g. Lacombe & Jones 1991), but hypoxia, as occurs during asphyxiation, may exacerbate the effects of catecholamines on the myocardium, increasing the damage (Pack *et al*. 1994). Drowning is considered to be extremely stressful in most species (e.g. Conn *et al*. 1995) and cetaceans, with their high cognitive ability, are likely to find this process highly stressful.

5.5. Other indirect causes of mortality for bycaught cetaceans

In addition to any injuries that may reduce long-term survival of bycaught cetaceans, those individuals that escape after being caught may suffer significant stress-induced effects. Most studies have shown that cetaceans have a similar stress response to other mammals (Ortiz & Worthy 2000). However, the physiological stress of fisheries interactions has only been examined in the eastern tropical Pacific Ocean purse seine tuna fishery, which is not typical of bycatch in other fisheries, since dolphins are pursued and encircled by boats to catch the tuna that swim with them (Hall 1998). The duration of this process, and hence length of stressor, can last up to two hours (Pabst *et al*. 2002). Whilst entanglement in nets is the primary source of mortality, non-entanglement mortality also occurs (Pryor & Norris 1978); physiological studies have shown that pursuit and encirclement can cause increases in the body core temperature, maladaptive physiological changes and, in extreme cases, death (Pabst *et al*. 2002). Circulating plasma enzymes show that pursuit causes damage to the muscles (St Aubin 2002), which may lead to subsequent capture myopathy. There are also increases in stress hormones (St Aubin 2002); chronic stress can damage heart tissue (Turnbull & Cowan 1998), and 36% of dolphins caught in this fishery examined *post-mortem* had heart lesions, which are evidence of prior stress (Cowan & Curry 2002). Fisheries interactions can cause other long-term stress effects, including a decline in immune function (Romano *et al*. 2002), lipid depletion in the adrenal glands, causing adrenocortical colour change (Myrick & Perkins 1995), and macroscopic changes in adrenal glands, including an increase in mass (Clark *et al*. 2006). Southern *et al*. (2002) developed a panel of molecular markers that showed that the pursued dolphins were subject to sustained stress periods. Whilst these studies showed that this process is stressful, they could not conclusively link fisheries interactions to significant long-term effects such as survival or reduced fecundity (Forney *et al*. 2002).

Short periods of capture and restraint cause significant stress responses in cetaceans (Orlov *et al*. 1988; Ortiz & Worthy 2000); cortisol and aldosterone quickly increase in the blood, whilst insulin decreases (Orlov *et al*. 1988; Ortiz & Worthy 2000). Other stress indicators in captured cetaceans include decreased eosinophil counts (Thompson & Geraci 1986), imbalances of thyroid hormones (St Aubin & Geraci 1988) and elevations of glucose, iron, potassium and several enzymes in the blood (St Aubin & Geraci 1989). The immediate physiological consequences of stress may include cardiac myopathy and immune or reproductive dysfunction (Curry 1999). Some reports suggest that the immediate stress of entanglement alone can cause direct mortality (Hall *et al*. 2002). If they survive long enough, individuals entangled in nets may suffer cardiac and pulmonary fibre fragmentation and subsequent necrosis as a result of large doses of neurotransmitters (dopamine, adrenaline, noradrenaline) being released into the blood (Duignan *et al*. 2003a, b, c; Table 2). Hypoxia, as occurs in animals restrained underwater, may increase the effect of catecholamines, further increasing the damage to the myocardium (Pack *et al*. 1994). Stranded cetaceans show that cardiac scarring may cause mortality many days or weeks after the stressor (Turnbull & Cowan 1998; Herráez *et al*. 2007). There are no data on the survival of bycaught individuals that escape, but it is postulated that stress-related problems, including mortality, may manifest themselves days or weeks after entanglement (Angliss & DeMaster 1998) and have important welfare implications.

5.6. Duration of suffering for bycaught cetaceans

Response to incidental capture varies with individual, species and the nature of the entrapment. If an individual struggles, this will deplete oxygen reserves quickly and decrease the time to asphyxiation. Aspiration of water hastens death (Schmidt 1973; Suzuki 1996), but as cetaceans rarely aspirate water (Birkun 1994; Kuiken *et al*. 1994a), and are well adapted to hypoxia, asphyxia is likely to be a protracted process. *Post-mortem* data (Table 2) indicate significant physiological stress; in humans, contraction banding generally occurs only when death is protracted (>5mins) (Baroldi *et al*. 2001).

There are no exact data on how long it takes to asphyxiate following capture, but the theoretical aerobic dive limit (TADL) may provide likely times to death from asphyxiation during entanglement (Leaper *et al*. 2006). However, many diving species can exceed TADL (Boyd & Croxall 1996); larger cetaceans, for instance,

Table 3. *The theoretical aerobic dive limit (TADL) and the maximum recorded dive duration of different species of cetacean*

Species	TADL (min)	Maximum dive duration (min)	Study
Harbour porpoise	2-5.5	5.5	Reed *et al*. 2000; Westgate *et al*. 1995
Bottlenose dolphin	3-5	8	Williams *et al*. 1999; Noren *et al*. 2002
Beluga	8-10	18	Schaffer *et al*. 1997; Martin *et al*. 1993
Minke whale	10-18	13	Stockin *et* al. 2001; Leaper *et al*. 2006
Narwhal	14-21	26	Laidre *et al*. 2002
Fin whale	29	15	Croll *et al*. 2001
Blue whale	31	17	Croll *et al*. 2001; Lagerquist *et al*. 2000
Sperm whale	43-54	73	Watwood *et al*. 2006; Watkins *et al*. 1993

may be limited in the duration of dives due to the high energetic costs of foraging (Croll *et al*. 2001; Acevedo-Gutiérrez 2002). As both TADL and maximum dive duration vary with body mass and species-specific adaptations such as myoglobin content of the muscle (Noren & Williams 2000), the time to death in entangled cetaceans is likely to vary (Table 3).

Cetaceans have physiological adaptations to reduce oxygen use whilst diving. One of these is to slow the heart rate, a process known as brachycardia (Elsner *et al*. 1966). However, cetaceans that are startled or coerced into diving may not undergo brachycardia (Elsner & Gooden 1983), and struggling associated with entanglement will increase oxygen consumption. Harbour porpoises and bottlenose dolphins can dive for up to 6 to 8 minutes under natural conditions (Table 3), yet when forcibly submerged may asphyxiate in as little as 3 minutes (Irving *et al*. 1941). Conversely, the maximum dive time of Atlantic white-sided dolphins is around 6.2 minutes, and an individual was able to free itself after 5 minutes when entangled in a net underwater (Weinrich 1996), indicating that asphyxiation may occur rapidly in some cases and may take longer in others. Since the data are limited, the overall time to asphyxiate is unclear, but it is likely to occur somewhere between TADL and the maximum dive duration (Table 3). The likely time to asphyxiation is relevant to those cetaceans which are caught and unable to return to the surface to breath. This period will be more protracted for animals caught in nets set at or near the surface or for larger species of whales that are able to surface despite their entanglement and so are able to breathe for some time until they become too debilitated or weakened (Weinrich 1999).

5.7. Social implications of cetacean bycatch

Cetaceans are widely acknowledged as being some of the most intelligent animals (Simmonds 2006), with complex behaviours such as tool-use (Krützen *et al*. 2005), sociality (Mann *et al*. 2000), language including that denoting individual identity (Janik *et al*. 2006), self awareness (Reiss & Marino 2001) and culture (see Rendell & Whitehead 2001). Anthropogenic disruption to these species is considerable, with bycatch impacting cetacean populations through social disruption and direct mortality of conspecifics (Simmonds 2006). Although juveniles may be most at risk of being caught as bycatch (e.g. García Hartmann *et al*. 1994), the loss of older individuals may be particularly important. Cetacean societies are complex, with some formed through long stable matrilines (Lyrholm & Gyllensten 1998) and others formed by short- and long-term interactions among individuals (Lusseau *et al*. 2006). The loss of key individuals will be likely to cause breakdown of social groups and networks (Williams & Lusseau 2006) and a loss of social or other key knowledge (Simmonds, 2006; Lusseau 2007); thus the removal of older individuals and their knowledge will have serious consequences for populations of socially advanced mammals such as cetaceans (McComb *et al*. 2001).

Like chimpanzees, elephants and humans (Goodall 1986; Douglas-Hamilton *et al*. 2006), cetaceans show an interest in the remains of dead conspecifics (Dudzinski *et al*. 2003) and may protect them from scavengers (Hubbs 1953; Moore 1955; Harzen & Santos 1992). Furthermore, altruistic behaviours in cetaceans extend to aiding injured or ill conspecifics, through supporting or allofeeding (Siebenaler & Caldwell 1956; Lilly 1963; Connor & Norris 1982; Connor & Smolker 1985). Entangled cetaceans may emit distress calls (Hall *et al*. 2002), which may attract conspecifics (Lilly 1963), and adult cetaceans may try to free young entangled in nets or lines (Di Beneditto *et al*. 2001; Cremer *et al*. 2006). Observations of entangled calves indicate alterations in the behaviour of conspecifics (Mann *et al*. 1995); although difficult to prove, it is likely that distress calls made by entangled conspecifics would be stressful to other members of the social group. Whilst it is controversial to suggest that grief may occur, such behaviour has been suggested in cetaceans (Kilborn 1994; Rose 2000), and it is reasonable to believe that the loss of close kin would be stressful in a highly intelligent and social taxon.

5.8. Welfare conclusions

The primary welfare concern of bycatch is the stress caused by asphyxiation, the duration of which ranges from three to five and a half minutes in harbour porpoises to potentially over 60 minutes in sperm whales. Additionally, injuries caused by entanglement and attempts to escape add to *pre-mortem* stress and have a significant impact on the welfare and subsequent survival prospects for individuals that escape. The stress of entanglement can cause a range of short- and long-term effects, including direct mortality (Hall *et al*. 2002), a subsequent decline in fitness and/or delayed mortality. Injuries can also cause a reduction in long-term survival. The scale and type of welfare issues vary with species and fishery. For smaller cetaceans, the majority of individuals caught in nets asphyxiate, with many sustaining multiple and sometimes extreme injuries in the process. While larger cetaceans more commonly survive fisheries interactions, their injuries are also a significant welfare concern.

The indirect effect of bycatch on social and familial relationships is rarely taken into account, even though loss of close kin and distress vocalizations of an entangled conspecific in highly social species are likely to be very stressful. In the case of dependent calves, loss of a mother is likely to result either in death as a direct result of starvation or reduced survival chances, both of which outcomes would have associated stress and welfare implications. Furthermore, the loss of key individuals which act as repositories of knowledge may have serious detrimental effects on the social group. Given that all these stressors occur in a self-aware animal with sophisticated cognitive abilities, there must be great ethical concern about the impact of fisheries bycatch on the welfare of cetaceans (White 2007).

Globally, the number of cetaceans caught and killed in fisheries probably exceeds 300,000 animals per year (Read *et al*. 2006), with an undocumented number that escape from fisheries interactions but with resultant stress or injuries. Thus the scale of the welfare issue of bycaught cetaceans is considerable. To put this into a broader perspective, we compared the welfare concerns of bycaught cetaceans with welfare standards generally and in other relevant sectors, namely livestock slaughter and mammal trapping.

6. Animal welfare legislation relevant to cetacean bycatch

6.1. International legislation

Animal welfare legislation at the international level is poorly developed (Harrop 1997). Organisations such as the International Whaling Commission (IWC) have included welfare in their remit, whereas the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which is concerned with international trade in endangered species, excludes methods of hunting or capture and only exercises jurisdiction over the welfare of animals during transport for international trade (Harrop 1997; 2003). Globally, there are a large number of international and regional treaties, conventions and agreements which make specific commitments or resolutions on the incidental capture of cetaceans (reviewed in Ross & Isaac 2004). The US Marine Mammal Protection Act (1972), one of the most specific pieces of legislation regarding bycatch, has two goals: to reduce mortality or serious injury to marine mammals during commercial fisheries to below Potential Biological Removal and to reduce serious injuries and mortality to a rate approaching zero by 2001. Thus although serious injury is taken into account, it is treated as a measure of potential mortality rather than a consideration of the welfare implications for the animals concerned. This lack of consideration is reflected across bycatch legislation in general, where the focus has been on numbers rather than the welfare of captured individuals (Gillespie 2002).

6.2. European legislation

In Europe, the first legislative vehicle by which the problem of cetacean bycatch could be addressed was EC Directive 92/43/EEC on the conservation of natural habitats and wild fauna and flora, which requires member states to:-

> ‘monitor the incidental capture and killing of the animal species listed in Annex IVa…[Member States] shall take further research or conservation measures as required to ensure that incidental capture and killing does not have a significant impact on the species concerned’.

Thus, for the first time member states were required to monitor and mitigate bycatch within their fisheries. In April 2004, the European Council adopted Council Regulation (EC) 812/2004, which specified measures to reduce incidental catches of cetaceans in fisheries. In one respect this development marked a major step forward, as it formally acknowledged that the deaths of dolphins and porpoises in European fisheries was a serious problem that had to be addressed. However, while the Regulation contains some important provisions, major exclusions were inserted that substantially weakened its effect.

The three main provisions relate to: (i) the use of acoustic deterrent devices (pingers) in specified gillnet, tangle net and driftnet fisheries operated by vessels over 12m in length; (ii) onboard observer monitoring of bycatch for vessels over 15m in length in specified fisheries, particularly pelagic trawls; and (iii) the phase-out and elimination of driftnets in the Baltic Sea by 2008. However, these provisions only apply to specific fisheries and areas within EU waters as listed in the Annexes. The Regulation makes provisions for the reporting, assessment and review of its implementation and the Commission is due to report on the operation of this Regulation in 2008.

6.3. Animal welfare policy relevant to cetacean bycatch

The EU as a whole has well-established legislation dealing with animal welfare (Camm & Bowles 2000). This covers the protection of animals in general and the specific measures needed to protect farm animals, wild animals and animals used for experimental purposes in relation to rearing, housing, transport and killing (Caporale *et al*. 2005), although defined standards for humane death are limited to specific situations such as slaughtering or trapping. Welfare standards in other situations are less well-defined. In Britain two pieces of legislation are relevant to the welfare of bycaught cetaceans: the Wildlife and Countryside Act 1981 and the Wild Mammals (Protection) Act 1996. Bottlenose dolphins, common dolphins and harbour porpoises are listed on Schedules 5 and 6 of the Wildlife and Countryside Act, which specifies that:-

> ‘if any person intentionally kills, injures or takes any wild animal included in Schedule 5, he shall be guilty of an offence…...if any person - (a) sets in position any of the following articles, being an article which is of such a nature and so placed as to be calculated to cause bodily injury to any wild animal included in Schedule 6 … or any net’.

Similarly in the Wild Mammals (Protection) Act 1996:-

> ‘if … any person mutilates, kicks, beats, nails or otherwise impales, stabs, burns, stones, crushes, drowns, drags or asphyxiates any wild mammal with intent to inflict unnecessary suffering he shall be guilty of an offence.’

Elsewhere within Europe, the Lithuanian Law of Wildlife 1997 prohibits 'cruel behaviour towards wild animals’; this is supplemented by the Law on the Care, Keeping and Use of Animals 1997, which seeks to protect animals from ‘suffering, cruel treatment and other negative pressures’. Similarly, Poland's Animal Protection Act 1997 provides that ‘unjustified or inhumane killing of animals and their abuse is forbidden’. Globally, the majority of countries have laws that protect animals against pain and suffering (Gillespie 2003); for example, all US states and the District of Columbia have anti-cruelty laws, which generally prohibit the intentional torturing and killing of an animal (Gillespie 2003; Rowen & Rosen 2005).

Across most animal welfare legislation, causing death or suffering to wild animals is prohibited, including, in some countries, by drowning. However, it is the intentional, not incidental, causing of suffering or death that is prohibited, and so the negative welfare consequences for cetaceans that are bycaught as the incidental result of fishing activities are not covered by current welfare legislation.

However, guidelines to ensure an adequate level of animal welfare are well-defined for certain sectors; those that are relevant to cetacean bycatch are the standards for the slaughter of livestock and the trapping standards for killing and restraining traps.

6.4. Farm animal welfare and slaughter standards

Standards for the humane killing of farm animals are becoming commonplace within international law. The emerging consensus is that where animals are slaughtered commercially for meat, they must not suffer at the time of death, must be rendered immediately insensible and thus, are required to be stunned or anaesthetised before killing (Gregory & Lowe 1999). In a study of slaughtering methods, all 27 countries surveyed required ‘instantaneous’ death and, in most cases, this required a stunning process which lasted until death (Gregory 1989/90; Gregory & Lowe 1999). Stunning is carried out in three ways: head concussion, electric current and carbon dioxide

(Mellor & Littin 2004). Death is usually through a throat or neck cut, which severs the main blood vessels supplying and draining the brain, leading to rapid unconsciousness (Mellor & Littin 2004). Without stunning, the time to unconsciousness varies across species (Table 4). However, even without stunning, these times are significantly shorter than the likely time to death in bycaught cetaceans (Table 3).

Table 4. *Time to unconsciousness (seconds) of different livestock following exsanguination without stunning*

Livestock	Time to unconsciousness (seconds)	Study
Sheep: lamb	2-6.5	Blackmore & Newhook 1981
adult	2-29	Blackmore & Newhook 1981; Gregory & Wotton 1984a
Cattle: calf	17-168	Blackmore & Newhook 1981; Gregory & Wotton 1984b
adult	20-102	Daly *et al*. (1988)
Pigs	13-105	Blackmore & Newhook 1981; Wotton & Gregory 1986
Poultry: turkeys	30-64	Gregory & Wotton 1988
chickens	373±19	Savenije *et al*. 2000

6.5. International standards for killing and restraining traps

Two kinds of traps are used to catch terrestrial and semi-aquatic mammals: those that kill the animal (killing traps) and those that restrain it until contact is made by the trapper (restraining traps). It is recognised that trapping wild animals can cause poor welfare, and this has led to local, national and international legislation that restricts the types of traps used. For instance, 80 countries including the EU ban leg-hold traps (Fox 2004). Lobbying by animal welfare organisations led to the first attempt by the International Organization for Standardization (ISO) to define humane standards for killing and restraining traps (Harrop 2003). Despite considerable efforts, the commission appointed to draft the standards could not achieve consensus on the definition of humaneness or on the threshold time limits to unconsciousness for killing traps (Harrop 2003). Instead, the commission produced two documents to provide an agreed process for testing performance, efficiency and trauma levels of killing and restraining traps (ISO 10990-4 1999; ISO 10990-5 1999). Though the ISO standards do not offer any definition of acceptable welfare standards, they provide some comparative measures which can be interpreted in terms of animal welfare (Iossa *et al*. 2007).

Table 5. *The time limits to unconsciousness used to assess performance in killing traps for terrestrial and semi-aquatic mammals (Anon. 1998b)*

Time to unconsciousness	Species
45 seconds	Stoat
120 seconds	American marten, pine marten, sable
300 seconds	American badger, bobcat, Canadian beaver, Canadian otter, coyote, Eurasian badger, Eurasian beaver, Eurasian lynx, Eurasian otter, grey wolf, muskrat, raccoon, raccoon dog

The performance of each trap is assessed using a set of criteria. For killing traps, one criterion is the time elapsed between triggering the device and the onset of unconsciousness, which varies with body weight up to a maximum time of 300 seconds for the largest species (Table 5). For restraining traps the criteria are the number, type and nature of injuries. The ISO standards were agreed in 1999; subsequent technological advancements have reduced time to unconsciousness below these thresholds for many species (Iossa *et al*. 2007). However, even the times to unconsciousness stipulated in the ISO guidelines (Table 5) are significantly shorter than the predicted times to death in most bycaught cetaceans (Table 3).

A specific type of killing trap used for semi-aquatic mammals is the drowning trap, for which the method of death has significant similarities with cetaceans entrapped in fishing gear. Many of the species commonly caught in drowning traps have dive times that far exceed the 300 second threshold (Iossa *et al*. 2007), and experimental studies have shown that, even if an animal struggles and consumes more oxygen, electroencephalogram (EEG) activity occurs beyond the 300 second threshold (Gilbert & Gofton 1982). Drowning traps have been criticised because drowning-induced hypoxia is not considered an acceptable method of euthanasia by veterinary and laboratory researchers and does not meet accepted standards for killing traps (Close *et al*. 1996; Ludders *et al*. 1999; Beaver *et al*. 2001).

Restraining traps are designed to hold the animal unharmed with the minimum stress until the trap is checked. There are two principle considerations when assessing welfare: the mortality of target and non-target species and the injuries suffered by restrained individuals. Trapping standards are one of the few sectorial areas that utilises an assessment framework for injuries, which facilitate quantitative comparisons between trapping methods. Each captured animal is assessed on the number and types of injuries, which are scored on a scale reflecting the gravity of injuries, though not pain (Iossa *et al*. 2007). Whilst the use of injury scales is controversial, the development of the ISO trauma scale allows a standard framework to assess the nature of the injuries of trapped animals (Table 6). To comply with ISO standards, a minimum of 80% of trapped animals should have no or only minor wounds.

Previous discussions about the seriousness of injuries in bycaught cetaceans (Angliss & DeMaster 1998) suggest that a framework similar to the one used for trapped mammals (Table 6) could be devised to assess the injuries of bycaught cetaceans. This could then be used to examine how injuries may contribute to *pre-mortem* stress of bycaught cetaceans and assess the likelihood of survival for individuals that escape. This framework would therefore allow the first quantitative assessment and comparison of the welfare of bycaught cetaceans.

6.6. Legislative conclusions

Existing legislation includes no provisions for the protection of cetaceans from incidental capture on welfare grounds. Specific legislation on bycatch aims to reduce the number of cetaceans caught rather than consider the welfare implications of bycaught individuals. However, legislation on animal welfare is well developed in those sectors where animals are killed intentionally, such as in livestock slaughter. A comparison of various times to death indicates that bycaught cetaceans may suffer significantly greater stress than is permitted in a range of other sectors, including commercial meat production. The bycatch of cetaceans encompasses a range of welfare issues including: (i) asphyxiation, (ii) physical injuries, (iii) physiological and psychological stress and (iv) social disruption. Direct mortality by drowning/asphyxiation is not an acceptable method of euthanasia in other sectors. The welfare implications of injuries sustained by cetaceans range from very poor welfare in the short-term to reduced long-term survival. In highly social and intelligent species such as cetaceans, the loss of group members that act as repositories of information may affect the whole group and lead to social disruption. It also has the potential to cause significant psychological distress. These welfare issues need to be incorporated into legislation for the protection of cetaceans.

Table 6. *ISO trauma scale developed to assess the nature of injuries of terrestrial mammals trapped in restraining traps*

Pathological observation		Score
Mild trauma		
1)	Claw loss	2 points
2)	Endematous swelling or haemorrhage	5 points
3)	Minor cutaneous laceration	5 points[1]
4)	Minor subcutaneous soft tissue maceration or erosion	10 points
5)	Major cutaneous laceration, except on foot pads or tongue	10 points
6)	Minor periosteal abrasion	10points
Moderate trauma		
1)	Severance of minor tendon or ligament	25 points
2)	Amputation of 1 digit	25 points
3)	Permanent tooth fracture exposing pulp cavity	30 points
4)	Major subcutaneous soft tissue laceration or erosion	30 points
5)	Major laceration on foot pads or tongues	30 points
6)	Severe joint haemorrhage	30 points
7)	Joint luxation at or below the carpus or tarsus	30 points
8)	Major peristeal abrasion	30 points
9)	Simple rib fracture	30 points
10)	Eye lacerations	30 points
11)	Minor skeletal degeneration	30 points
Moderately severe trauma		
12)	Simple fracture at or below the carpus or tarsus	50 points
13)	Compression fracture	50 points
14)	Comminuted rib fracture	50 points
15)	Amputation of two digits	50 points
16)	Major skeletal degeneration	50 points
17)	Limb ischemia	50 points
Severe trauma		
18)	Amputation of three or more digits	100 points
19)	Any fracture or joint luxation on limb above carpus or tarsus	100 points
20)	Any amputation above the digits	100 points
21)	Spinal chord injury	100 points
22)	Severe internal organ damage (internal bleeding)	100 points
23)	Compound on comminuted fracture at or below carpus or tarsus	100 points
24)	Severance of major tendon or ligament	100 points
25)	Compound rib fractures	100 points
26)	Ocular injury resulting in blindness of an eye	100 points
27)	Myocardial degeneration	100 points
28)	Death	100 points

The terms and definitions are taken from ISO 10990-5: 1999 Animal (mammal traps) – Part 5: Methods for testing restraining traps, Annex C, C.1 Trauma scale (www.iso.org), and are reproduced with the permission of the International Organization for Standardization, ISO. Copyright remains with ISO.

[1] (max 15)

7. General conclusions

Direct estimates of bycaught cetaceans from observer programmes and indirect data, such as the proportion of stranded individuals bearing evidence of encounters with fisheries, indicate that this is a significant conservation issue. The importance of welfare aspects related to bycatch has only recently been recognised. A number of welfare issues have been identified. These include the injuries suffered, the length of time to asphyxiation and the social implications of individuals dying. These welfare issues are likely to be severe, indicating that the welfare of bycaught cetaceans is often very poor. However, there is a lack of quantitative data on these areas and further research is needed on the duration of suffering, the severity of stressors and its impact in the short- and long-term. In particular, what are the implications for individuals that may survive fisheries encounters? Such research will give a more comprehensive understanding of how bycatch affects cetacean populations.

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10. Appendix: Latin names of species referred to in text

American badger *Taxidea taxus*

American marten *Martes americana*

Atlantic white-sided dolphin *Lagenorhynchus acutus*

Beluga *Delphinapterus leucas*

Blue whale *Balaenoptera musculus*

Bobcat *Lynx rufus*

Bottlenose dolphin *Tursiops truncatus*

Canadian lynx *Lynx canadensis*

Chimpanzee *Pan troglodytesl*

Common dolphin *Delphinus delphis*

Coyote *Canis latrans*

Dall's porpoise *Phocoenoides dalli*

Dusky dolphin *Lagenorhynchus obscurus*

Elephant *Loxodonta africana*

Eurasian badger *Meles meles*

Eurasian lynx *Lynx lynx*

Eurasian otter *Lutra lutra*

Fin whale *Balaenoptera physalus*

Grey wolf *Canis lupus*

Harbour porpoise *Phocoena phocoena*

Hector's dolphin *Cephalorhynchus hectori*

Human *Homo sapiens*

Humpback whale *Megaptera novaeangliae*

Maui's dolphin *Cephalorhynchus hectori maui*

Minke whale *Balaenoptera acutorostrata*

Musk rat *Ondatra zibethicus*

Narwhal *Monodon monoceros*

North Atlantic right whale *Eubalaena glacialis*

Pantropical spinner dolphins *Stenella longirostris*

Pantropical spotted dolphins *Stenella attenuata*

Pine marten *Martes martes*

Raccoon *Procyon lotor*

Risso's dolphin *Grampus griseus*

River otter *Lutra canadensis*

Sable *Martes zibellina*

Sperm whale *Physeter catodon*

Stoat *Mustela erminea*

Striped dolphin *Stenella coeruleoalba*

Vaquita *Phocoena sinus*

Yellow-fin tuna *Thunnus albacares*