

## 2.2. Mechanisms of by-catch

There has been much speculation about the mechanisms by which cetaceans are by-caught, and, if by-catch is to be reduced, understanding how it occurs is imperative (Goodson *et al.* 1994a). Studies have been carried out both in captivity and on wild animals to observe cetaceans' responses to different types of net and to assess their ability to negotiate such obstacles (De Haan *et al.* 1997; Hatakeyama *et al.* 1994; Kastelein *et al.* 1995a,b; 2000). Debate continues as to whether entanglement occurs because the animals cannot or do not detect the nets, do not perceive the net as an impenetrable barrier or threat, or perceive the threat but become distracted by their prey (Anon. 1965; Goodson 1993; Goodson *et al.* 1994a,b; Goodson & Mayo 1995). This is of particular concern, for interactions with nets are usually fatal and thus do not facilitate a learning process. A secondary debate exists as to when, during fishing operations, cetaceans become caught in the nets and at what part of the fishing procedure they are most vulnerable (Couperus 1997b; Tregenza *et al.* 1997a).

In addressing the major points of argument over this issue there can be no definitive conclusion for, although a number of studies have been undertaken, the data can rarely be considered irrefutable, nor can they be assumed to apply to all species under all conditions. Due to the differences between the gear types that cause by-catch and the consequent differences in the mechanisms by which the animals become caught, we will address the issues of how and when animals become caught in gillnets and mid-water trawls separately.

### 2.2.1. Entanglement in gillnets

Gillnets have the same density as seawater and are usually made of twine which is invisible to the human eye when immersed (Tregenza *et al.* 1997a). They produce minimal 'self-noise', such that ambient water noise is frequently enough to mask it (Goodson *et al.* 1994a; Lien *et al.* 1995), and thus offer no cues to a non-echolocating cetacean. Gillnets are a very effective type of fishing gear and cetacean by-catch increased markedly in the 1970s and 1980s with the advent of gillnets and synthetic materials (Alling & Whitehead 1987; Hall 1999).

The only substantial parts of a gillnet, from which an echolocating cetacean might receive a return signal, are the floatline, the leadline, the bridles and the knots in the corners of the mesh (Kastelein *et al.* 2000). In driftnets, the floatline lies at the surface, thus obscuring it. In bottom-set gillnets where the leadline is set on the seabed, the leadline becomes buried. In all gillnets, the reciprocal echoes from the knots are very weak, further reduced in intensity if the incident angle of approach departs from 90° (Goodson & Datta 1992, Goodson *et al.* 1994a; Au 1994). These characteristics of gillnets are the cause of conjecture about whether cetaceans can detect these nets in the water and numerous studies have attempted to clarify the issue.

Most studies conclude that both dolphins and porpoises are able to detect gillnets (Hatakeyama & Ishii 1987; Au 1994; Hatakeyama *et al.* 1994; Kastelein *et al.* 2000). However uncertainty remains as to the detection distance (i.e. the distance from which they will receive a significant echo), whether this distance allows time for an avoidance reaction, and how much the target strength varies with the angle of approach (Au 1994; Kastelein *et al.* 1995b). Au (1994) used synthesised broadband bottlenose dolphin calls to test the target strength of four different materials: monofilament gillnet at 0.49 mm, Makah tribal net consisting of 0.97 mm twisted cord, twisted polyester rope of 0.635 cm diameter, and household light switch chain of 0.30 cm diameter. He concluded that the target strength of the monofilament was some 20 dB lower than that of the polyester rope and the chain but that dolphins should still be able to detect a monofilament gillnet within 1.2 – 25 m (Au 1994). In a similar study, Kastelein *et al.* (2000) concluded that the target detection distance for the bottlenose dolphins was greater than that predicted by Au (1994) and stated that *Tursiops* should be able to detect the net within 25 – 55 m, which would allow plenty of time for appropriate avoidance behaviour. Both these studies concluded however that the returning echoes from the nets were probably not sufficient to enable the animal to distinguish it from the ‘volume-scattered’ echoes of other penetrable barriers such as schools of small fish or the deep scattering layer (Goodson & Datta 1992; Au 1994; Kastelein *et al.* 1995b). Consequently in the presence of prey, the return echoes from a gillnet may be of little significance to a feeding cetacean (Goodson & Datta 1992).

Goodson & Datta (1992) described the echolocation behaviour of a solitary wild bottlenose dolphin and found echolocation calls (characterised according to the Pulse Repetition Frequency or PRF) could be divided into three discernable categories. These were ‘foraging

search', while the animal was seeking a target, 'initial target detection', during which the animal 'locked-on' to its target, and 'interception', when the animal was 'range-locked' on its prey. In a subsequent paper Goodson *et al.* (1994a) stated that an animal was unlikely to detect objects that were 'over-range' once it had become 'locked-on' and so it would be unlikely to notice a gillnet unless it did so before detecting its prey (Goodson *et al.* 1994a).

Kastelein *et al.* (2000) demonstrated that the target detection distance for a harbour porpoise approaching a gillnet at 90° was only 3 – 6 m and that this detection distance decreased further with an incident angle of approach other than 90°. In arguing that the ambient noise level during the study was outside the porpoises' hearing range, they concluded that the harbour porpoise would probably be unable to detect a gillnet in time to avoid collision (Kastelein *et al.* 2000). There is evidence however to suggest that, in a heightened state of awareness, Dall's porpoise (*Phocoenoides dalli*) and the bottlenose dolphin can both detect and avoid gillnets in ample time to execute avoidance behaviour (Hatakeyama & Ishii 1987; Hatakeyama *et al.* 1994). Hatakeyama *et al.* (1994) attempted to catch wild Dall's porpoises to conduct studies on their acoustic behaviour in captivity. Ironically, when being herded by four boats toward a gillnet set specifically to catch them, the porpoises persistently scattered and successfully avoided the nets by swimming around them or under them. On a couple of occasions a third porpoise swimming behind two conspecifics failed to avoid the net and simply burst straight through it leaving a hole which other animals were subsequently able to detect and to use, apparently as a means of avoiding entanglement (Hatakeyama *et al.* 1994). These data suggest that, when being chased by a predator, the sonar capability of porpoises is quite sufficient to detect nets and their understanding of the net as a threat is sufficient to make them behave accordingly, and to avoid them.

A number of studies have been carried out on captive animals to directly assess their behaviour in response to obstacles in the water (Kastelein *et al.* 1995a,b). Kastelein *et al.* (1995a) observed the behaviour of two captive harbour porpoises in response to 13 mm diameter nylon ropes strung vertically and horizontally across their pool. One of the animals was estimated to be 20 months old while the other was only eight months old. Both animals' reactions to the ropes were monitored in light, in darkness, in the presence of live fish and in the presence of each other. The authors concluded that both animals were very reluctant to swim over the ropes, swam under them more than 90% of the time under most conditions, and generally avoided the rope that was closest to the pool floor (Kastelein *et al.* 1995a). It

was noted that the results were consistent with other reports that dolphins generally prefer to keep an obstacle above them rather than below them, and that dolphins caught in tuna nets were reluctant to swim over the floatline of a purse seine net, even when it was lowered for them to do so (Moore 1980; Mendes *et al.* 1986). The younger animal was less cautious in the presence of the older animal and, in the presence of live fish, the urge to forage made both animals less attentive and less cautious of the ropes (Kastelein *et al.* 1995a).

Kastelein *et al.* (1995b) observed the behaviour of the porpoises when actual nets were placed in the pool. The aims were to observe how the animals became entangled, whether distraction overruled caution, how they negotiated the barrier once they had become aware of it and whether they learned to avoid the net after non-lethal entanglements. Nets were placed in the pool, with the floatline above the water so that only the net was presented to the animals, and a number of different net configurations were tested. The maximum mesh size of the test nets was 20 cm. Generally, the sessions ended with entanglement of the animal or with an apparent awareness of the net and appropriate avoidance reactions. Entanglements generally involved, or at least began with, the mouth - followed in frequency by the pectoral fins, the dorsal fin, and then the flukes. The porpoises managed to free themselves from 8.7% of entanglements, all of which were fluke tangles (Kastelein *et al.* 1995b).

The introduction of live fish into the pool decreased the older animal's impact frequency (although entanglement did occur when the animal was feeding directly on fish caught in the net), but increased that of the younger animal. This may indicate a heightened awareness of its environment in the older animal and added distraction in the younger of the two. Overall, the behaviour pattern observed was that the animals always became entangled when they were first released in the pool with a new net configuration, but learned to avoid the net following entanglement. After this however, their confidence around the net increased so that they became more easily distracted, causing a secondary increase in the impact frequency. The authors concluded that the animals did not seem to be aware of the nets prior to their entanglement and, although they did learn after an assisted release, distractions increased the likelihood of their impacting the net again (Kastelein *et al.* 1995b).

The suggestion that younger animals are more susceptible to distraction is consistent with by-catch data on harbour porpoises, common dolphins and striped dolphins, calves and juveniles

of which are caught more frequently than adults (Smith *et al.* 1983; Silvani *et al.* 1992; Goujon *et al.* 1993; Cockcroft 1994b).

The animals' apparent inability to detect the nets in these experiments is contrary to the findings of Au (1994), Hatakeyama *et al.* (1994) and Kastelein *et al.* (2000). However, this may have been an artefact of animals echolocating less in captivity than they might while foraging in the wild or simply that they echolocate less in a familiar environment (Goodson *et al.* 1994a).

Hatakeyama & Ishii (1987) demonstrated that bottlenose dolphins successfully avoided entanglements in a similar study in which the animals were also pursued and harassed in their pool. When feeding on fish caught in a net, the dolphins frequently grazed of the nets with the tail flukes but avoided entanglement. Their study showed that the animals were apparently able to detect the net visually during daylight sessions and learned to detect it with echolocation in the dark.

Little mention is made in any of the papers about the likelihood of other animals becoming entangled as a consequence of their staying with the animal which first becomes trapped. Mizroch & Hutchinson (1996) described an observation of epimeletic behaviour in the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), in which a number of conspecifics remained with a dead animal after its entrapment. Given that many cetaceans will sometimes strand following the plight of only one animal (Wood 1979), the idea that one distraught animal may lead to the entanglement of others can not be discounted (Anon 1965).

The inability of Kastelein *et al.*'s (1995b) porpoises to apply what they had learnt in one pool session to the next session in which the net configuration was changed, provides an interesting link with data taken from wild animals. Cockcroft (1994b) checked shark nets set off beaches in South Africa on a daily basis and constructed a data matrix for each by-caught cetacean, to try to find common factors which affected the by-catch of all the different cetacean species in the area. He concluded that by-catches of all species caught were related to changes in the prevailing current. More by-catch occurred when the current in the area had turned and was opposite to the typical direction. Given that the shark nets were a permanent fixture, it might be expected that local cetacean populations would be aware of their presence and learn to avoid them, however this was not the case. It is conceivable that changes in the

prevailing current alter the shape of the net, which may simulate a different net 'configuration', as with Kastelein *et al.*'s (1995b) animals. Thus, even with permanent nets, the net may continue to pose a risk to cetaceans in the area due to naturally occurring changes in the 'configuration'.

Discussing strength of currents, rather than direction, Tregenza *et al.* (1997a) argues that by-catch rates in set gillnets are lower in faster currents due to (a) the porpoise preys' tendency to move up through the water column and (b) a decrease in the net height (caused by drag). No direct evidence exists however to suggest that decreased net height leads to a decrease in by-catch rates (Lowry & Teilmann 1994).

The stage of the fishing operation during which cetaceans become caught in gillnets is difficult to determine. Techniques used to answer this question include the attachment of Time Depth Recorders (TDRs) to wild harbour porpoises (Westgate *et al.* 1995; Westgate & Read 1998), the assessment of scavenger damage on carcasses (Tregenza 1994) and even the experimental shooting and immediate re-hauling of gillnets (Read & Gaskin 1988). Suggested methods to assess the process of entanglement include the application of automated porpoise click detectors, as designed and tested by the International Fund for Animal Welfare (IFAW) (Chappell *et al.* 1996). Ultimately however, few authors agree about when entrapment occurs.

During an observer study on by-catch of common dolphins in gillnets, the dolphins seemed to be attracted to the boats during the shooting and hauling of the nets and one dolphin was caught alive during hauling (Tregenza *et al.* 1997b). It was on these occasions, when dolphins were sighted around the boats, that most by-catch occurred, thus providing circumstantial evidence that common dolphins become caught in gillnets during the shooting and hauling of nets (Tregenza *et al.* 1997b).

Unlike dolphins, harbour porpoises are more likely to become entangled when the nets are on the sea bottom (Read & Gaskin 1988), although these authors also record that a live harbour porpoise was hauled up in a gillnet during normal fishing operations in the Bay of Fundy. Tregenza *et al.* (1997b) argue that porpoises are rarely sighted around boats when gillnets are being set and hauled, due to their shy nature. Also, porpoises hauled in the nets are usually already dead.

By attaching TDRs to wild harbour porpoises in the Bay of Fundy, Westgate *et al.* (1995) showed that porpoise dive profiles are "flat-bottomed" and that bottom time accounted for 27 – 39% of the overall dive time. These authors note that most by-catch of porpoises in the Bay of Fundy occurs at depths between 50 – 120 m, with a peak frequency in nets set between 80 – 100 m.

Some papers have suggested that porpoise entanglements occur during shooting and hauling of nets because the depth at which the nets were set was thought to be beyond depths normally frequented by porpoises. Larsen (1990) considered herring nets set between 100 – 200 m to be too deep to pose a threat to porpoises. However, this is not supported by available evidence. Westgate *et al.* (1995) recorded one porpoise diving as deep as 226 m in the Bay of Fundy, which has a maximum depth of 230 m. Smith & Read (1992) suggested that the presence of euphausiids (*Meganycitiphanes norvegica*) in the stomachs of weaning calves caught in nets indicated that they dive to depths greater than 100 m.

An interesting approach to estimating the time of death in cetaceans and, indirectly, the time of entanglement is described by Couperus (1997b). By measuring the cooling rate of a dolphin carcass in a laboratory tank, simulating sea conditions, he was able to derive a standard curve characterising the relationship between time since death and carcass temperature. The body temperature of a carcass is expected to rise shortly after death as metabolic activity continues in the absence of blood flow and, hence, the cessation of the counter-current heat exchange system. However, the behaviour of the animal prior to its death may affect its post-mortem cooling rate. If the animal struggled to escape entanglement, its body temperature will have increased immediately prior to death, which could lead to an underestimation of the time lapsed since death and hence uncertainty as to which stage of fishing activity led to death. More work is required before the method can be applied in practice (Couperus 1997b).

In conclusion, evidence suggests that both dolphins and porpoises are capable of detecting gillnets and that, in a heightened state of awareness, they perceive the threat and thus will avoid nets, or at least become entangled less frequently (Hatakeyama *et al.* 1994; Kastelein *et al.* 1995b). However, there is some evidence that harbour porpoises may not detect nets until they are too close to avoid entanglement (Kastelein *et al.* 2000). Kastelein *et al.*'s work

(1995a) suggests that harbour porpoises learn to avoid nets only after non-lethal entanglements. Prior to entanglement, they did not seem aware of the nets in the pool - although, in the experimental pool, the floatline of the net was at the surface, thus reducing detectability of the net.

### 2.2.2. Entanglement in mid-water trawls

The operational distinction between trawls and gillnets is sufficient to suggest that, although both contribute significantly to high mortality of cetaceans, the mechanism by which cetaceans become entangled must be very different. Aside from high by-catch mortality, one similarity is that both fishing techniques target marketable species which are also eaten by cetaceans (Wurtz *et al.* 1992).

Due to the noise that trawls make when in operation there can be little doubt that cetaceans must be aware of the net in the water. Furthermore, the speed at which the gear is towed should allow the cetaceans ample time to avoid the net (De Haan *et al.* 1997; Fertl & Leatherwood 1997). Apart from engine noise from the boat, several parts of a trawl vibrate when operated - such as the chains and pennants, which strum causing a high frequency reverberation. Thus the capture of cetaceans in trawls is thought to be a far more active process than capture in gillnets (De Haan *et al.* 1997).

The number of cetaceans caught in trawls is thought, by many authors, to be a function of the fishing strategy (e.g. tow speed, haul back speed and net opening size) rather than simply a function of total fishing effort, as is the case with gillnets (De Haan *et al.* 1997; Morizur *et al.* 1999). In an observer study of foreign vessels fishing in the US Economic Exclusion Zone (EEZ), a Dutch boat targeting squid caught more dolphins in mid-water trawls than did German boats, despite the former spending fewer days at sea. This difference was thought to be related to the different gear configuration and haulback speed used by the two fleets (Waring *et al.* 1990).

However the question remains, as with gillnets, as to whether dolphins perceive the trawl as a threat. De Haan *et al.* (1997) and Morizur *et al.* (1999) argued that dolphins may associate the sound of trawling with an 'easy-meal'. The fact that the dolphins must be aware of the



fishing gear and yet still get caught lends weight to this argument. As further evidence for this, the stomachs of dolphins by-caught in trawls often contain the species that the fishery was targeting (De Haan *et al.* 1997). Fishermen in Sardinia complain that the presence of dolphins following their boats during fishing operations is related to decreases in the catch of certain species (Consiglio *et al.* 1992). In the Gulf of Mexico, bottlenose dolphins have been observed entering the mouths of trawls (Fertl & Leatherwood 1997). De Haan *et al.* (1997) speculated that dolphins may swim into the trawl, having been attracted to the fish struggling in the cod-end (where the dolphins are also usually found), but may be reluctant to swim back out since this would entail approaching the source of the engine noise. Thus dolphins may associate the sound of the trawl with a mobile food patch which enables them to exploit a higher quantity of their prey, or prey with a higher calorific value, than they might ordinarily obtain (Fertl & Leatherwood 1997). With such an incentive, the perceived risk may be considered worthwhile.

Many fisheries operate at night using lights to lure the target species to the surface (Sequeira & Ferreira 1994), and it is an interesting feature of cetacean entanglement in trawls that it occurs significantly more frequently at night than it does in the daytime (Aguilar 1997; Crespo *et al.* 1997; De Haan *et al.* 1997; Fertl & Leatherwood 1997). In fact, De Haan *et al.* (1997) observed that cetaceans tend to keep a greater distance from vessels during the daytime and seem less inclined to interact with the trawl. During a study using a hydrophone array to assess the behaviour of dolphins around a simulated trawl, these authors observed that the dolphins seemed attracted to the deck lights used when trawling at night. When the lights were extinguished, the dolphins retreated from the boat and returned again on re-illumination. On one occasion up to 50 dolphins approached the illuminated boat (De Haan *et al.* 1997) although the reaction of the dolphins to the light may be secondary to that of their prey.

Waring *et al.* (1990) described high mortality of common dolphins in trawls operated without using light lures. However, International Collision Regulations state that fishing vessels must display white masthead and stern lights, in addition to standard navigation lights, to indicate their operation (Lange-Nielsen 1983), which may inadvertently act as attractants. In any case, the fishery was taking advantage of the diurnal migration of squid to the surface and it was suggested that the dolphins were probably doing the same (Waring *et al.* 1990). Tregenza (pers. comm.) stated that in the waters off SW England, night fishing occurs mainly to avoid

detection of illegal trawling in the mackerel box and does not confer any fishing advantage. Cetaceans that feed mainly at night, as observed for bottlenose dolphins (Goodson *et al.* 1994a), may be spatially separated from their prey during daylight hours and thus less susceptible to by-catch at this time (Waring *et al.* 1990).

In reviewing the literature about by-catch, it becomes clear that a fundamental difference between the by-catch in trawls and that in gillnets is in the cetacean species that are caught. This is a point rarely dwelt upon in the literature but suggests that by-catch may be as much a function of the behaviour of different species as it is of the fishing gear.

After a mass stranding of by-caught common dolphins on the SW coast of England, the English hake set-gillnet fishery fell under suspicion. An observer program in the hake fishery however demonstrated that the by-catch in these gillnets comprised mainly harbour porpoises and common dolphins made up only 8.5% of the by-catch (Tregenza *et al.* 1997a). Subsequently, a similar study showed that mid-water pelagic trawls, targeting mackerel in the same area, were responsible for catching more common dolphins than harbour porpoises (Tregenza & Collet 1998). Generally it seems that, although both dolphins and porpoises are vulnerable to entanglement in driftnets, by-catch in trawls usually comprises dolphins (Smith 1983; Hartmann *et al.* 1994; Hatakeyama *et al.* 1994; Couperus 1997b; De Haan *et al.* 1997; Tregenza *et al.* 1997a,b; Tregenza & Collet 1998; Morizur *et al.* 1999) while that in gillnets mainly comprises porpoises (Larsen 1990; Smith & Read 1992; Hatakeyama *et al.* 1994; Kinze 1994; Westgate *et al.* 1995; Tregenza *et al.* 1997a). This may be a function of the gregarious nature of dolphins and their attraction to boats in contrast to the elusive nature of porpoises (Tregenza *et al.* 1997a). This point could be disputed, since dolphins, as well as porpoises, get caught in gillnets, albeit with lower frequency. However, circumstantial evidence suggests that dolphins get caught in gillnets during the shooting and hauling of gillnets (Tregenza *et al.* 1997b), a noisy process arguably similar to the towing of a trawl. No papers reported porpoises being caught in trawls.

### 2.2.3. Entanglement in other fishing gear

The mechanisms of entanglement in other types of fishing gear generally receive less attention in the literature, either because of the rarity with which cetaceans become caught or because the mechanism is generally quite well understood.

Cod traps are classed as a category III fishery under the US MMPA. Traps are used seasonally, and are set with leader ropes anchored to the shore (Read 1994). Cetaceans become caught in the leader ropes rather than the traps themselves and the most commonly caught cetaceans are humpback whales (Lien *et al.* 1995). Pierce & Santos (2000) recorded some mortality of common dolphins associated with traps set for various species in Galician waters (NW Spain) in Spain. An interview survey led to an estimate of around 25 animals killed annually.

Herring weirs are also used seasonally and are listed as Category III under the US MMPA (Read 1994). Harbour porpoises are the cetacean most commonly caught in herring weirs, although the numbers involved are small (Read & Gaskin 1988) and only 39% of those caught are actually killed (Read 1994). It is thought that the porpoises enter the weirs and become trapped simply because they cannot negotiate their way back out. When trapped in weirs, porpoises appear stressed, with a fast breathing rate and circular swimming motion (Smith *et al.* 1983). They are usually caught at night (Read 1994) and the by-catch contains a disproportionately high number of yearlings (Smith *et al.* 1983). Death occurs indirectly during the collection of the fish catch with purse seine nets, or directly when animals are shot by the fishermen, who perceive them as direct competition (Currey *et al.* 1990; Read 1994). Smith *et al.* (1983) found that weir fishermen generally have a positive attitude toward porpoises, the stomachs of which are usually empty when removed from the weirs. In 1990, a co-operative system began between the weir fishermen in the Bay of Fundy and Canadian biologists to ensure the release and TDR tagging of as many by-caught porpoises as possible (Read 1994; Westgate & Read 1998).

Cetacean by-catch in long-lines can be quite high and the large pelagic long-lines deployed in the Gulf of Mexico were declared as a category I fishery under the MMPA (NMFS 1999a). Entanglement may occur on the baited hooks or in the line itself and by-catch of other animals can also be a problem, e.g. between 1000 – 3500 seabirds are caught per year in the

Japanese longline tuna fishery (Gales *et al.* 1998). Perrin (1992) observed mortality to cetaceans in Alaska, caused indirectly by long-lines. Killer whales were costing fishermen up to \$2,300 per day by eating black cod from long-lines and the whales were often shot by the fishermen (Jefferson & Curry 1996). In Peru, cetacean meat is sometimes used as bait on longlines (Van Waerebeek *et al.* 1997). Pierce & Santos (2000) recorded small numbers of common and bottlenose dolphins caught in long-lines in Galician waters.

Dolphins frequently become caught in purse seine nets due to the practice of using 'dolphin-sets', in nets which are set around schools of dolphins to take advantage of their known association with tuna. Entrapment occurs as the purse is drawn tight around the tuna. A major by-catch problem, with an estimated annual by-catch of 133,000 dolphins in 1983, was identified in the ETP (Hall 1994). With cetacean by-catch occurring in US and non-US fleets, the high mortality was considered sufficient to seriously affect spotted and spinner dolphin populations (Allen & Goldsmith 1982; Hammond & Laake 1983; Oliver *et al.* 1983; Buckland *et al.* 1992; Anganuzzi & Buckland 1994). The Inter-American Tropical Tuna Commission (IATTC) started a programme of by-catch reduction measures in 1979 and, by 1993, the by-catch rate had fallen by 97% (Allen & Goldsmith 1981; Hall 1994). Mitigation measures, implemented by the National Marine Fisheries Service (NMFS), included the implementation of "kill quotas", compulsory onboard observers, education of skippers and modified fishing procedures including the release of encircled dolphins using the "back-down" method (Hammond & Laake 1983; Chivers *et al.* 1990; Hall 1994). Between 1989 and 1991, observers were placed on all US registered fishing vessels (Peltier *et al.* 1992) and, by 1995, observers were placed on 100% of the international tuna fleet (Hall & Lennert 1997). Consideration of a complete ban of dolphin sets continues (Punsly *et al.* 1994).

A largely ignored impact on cetacean populations is that caused by recreational fishing (Wells *et al.* 1998; Fluharty 2000). This is considered to be a problem particularly for bottlenose dolphins. In Sarasota Bay, Florida, losses to recreational gear are thought to pose a greater threat to the local bottlenose dolphin population than gillnets did prior to their ban in 1995 (Wells *et al.* 1998). As with other gear, fishing lines cut loose and discarded continue to cause harm to cetaceans in a way analogous to "ghost-fishing" by discarded nets, which can make up 76 – 85% of the weight of beach litter in some coastal areas of the US (Fertl & Leatherwood 1997; Wells *et al.* 1998)

#### 2.2.4. Conclusion

In conclusion, the only common denominators apparent in the mechanisms of by-catch for different cetacean species in different types of fishing gear are that it occurs at all and that food is involved. Some cetacean species can detect the nets easily with echolocation while others are less equipped to do so and yet both get caught. Furthermore, detection distances vary in all species in relation to ambient water noise, the angle of approach to the net and the attentiveness of the echolocating individual (Au 1994; Hatakeyama *et al.* 1994; Kastelein *et al.* 2000).

After reviewing the various published studies, we believe that it is safe to assume that small cetaceans possess the acoustic capabilities necessary for net detection and that they can perceive the threat. However, as Dawson (1994) argues, problems probably arise because cetaceans do not echolocate all the time and may be easily distracted, especially when foraging.

Most by-catch reduction devices operate on the premise that porpoises and dolphins cannot detect the net or, at least, that they do not echolocate all of the time and are therefore not aware of the net (Goodson *et al.* 1994a; Jefferson & Curry 1994; Kraus *et al.* 1995). An interesting, albeit simplistic, argument is that trawls can be considered to provide a field test of whether increasing the noise profile of a net decreases by-catch. Here is a net that makes considerable noise when being shot, hauled and operated. It is undisputed that cetaceans must be aware of this net in their environment and yet by-catch still occurs. This fact alone suggests that by-catch reduction devices which aim to make a net noisy may be limited in their long-term success.

The question remains as to whether cetaceans perceive nets as a threat, and there is conflicting evidence on this. If cetaceans distinguish the nets from other volume-scattered echoes and perceive them as impenetrable barriers, then why do they persistently approach them? In the absence of the opportunity for the animals to exercise learnt behaviour in perceiving nets as a threat, it would be worthwhile looking at ways to increase the threat that nets pose. By-catch Reduction Devices (BRDs) and their respective successes and failures will be discussed later in the report, however an important point to remember is the difficulty that Hatakeyama *et al.* (1994) had when trying to deliberately catch porpoises in set gillnets.