2. Data on by-catch

2.1. Fishing gear leading to cetacean by-catch

A detailed description of the specifications of all gear used in individual fisheries in each Member State of the EU is beyond the scope of this report. The fishing industry is very dynamic and the gear used changes regularly in response to technological advances (the 'technology creep', King 1995), legislative regulations and changes in the abundance and value of marketable species. Some fishermen carry up to five different kinds of fishing gear (Sequeira & Ferreira 1994) and alternate their use as necessary. There is also variation in fishing strategies, i.e. the manner in which particular kinds of gear are deployed (Waring *et al*. 1990; De Haan *et al*. 1997). Gear specifications tend to vary with the target species sought while fishing strategies tend to reflect factors including tide height, water depth and, theoretically, local legislation.

However, most studies of cetacean by-catch concern specific fisheries operating in specific areas and the published reports often include descriptions of the fishing process, providing details such as mesh sizes, net height, net length and trawl mouth dimensions[4]. It is thus possible to build up a picture of the type of gear associated with by-catch. Here we briefly describe the use of main types of fishing gears, in European waters, that have been associated with cetacean by-catch.

2.1.1. Passive fishing gear

Gillnets are designed to be inconspicuous, so that fish cannot detect them when set (Gill 1999). They are left anchored to the seabed and thus are classified as passive fishing gear (Lowry & Teilmann 1994; Read 1994; Sequeira & Ferreira 1994; Secchi *et al*. 1997; Tregenza *et al*. 1997a,b). They are cheaper to deploy than longlines, are more selective - allowing young fish to escape entrapment, and can be used over rough ground (Gill 1999). Gillnets form an effective barrier through which fish greater than a certain size cannot pass. They work on the principle that fish trying to pass through the mesh get stuck and, as they struggle, the twine gets caught behind the operculum.

[4] See Appendix II for gear specifications

Gillnets comprise a series of smaller net panels which are joined together at the bridles to form one long net (Figure 1a). The length of individual net panels typically varies from 72 m (Silvani *et al*. 1999) to 90 m (Tregenza *et al*. 1997a) and, when joined together, they constitute nets ranging in length from 1,600 m (Sequeira & Ferreira 1994; Tregenza *et al*. 1997a) to 13,000 m (Sequeira & Ferreira 1994). When each boat in a fleet sets nets in an area, up to 10,000 km of net can be in the water at any one time as observed in the Danish gillnet fleet (Lowry & Teilmann 1994).

Each net panel consists of a floatline which holds the net taut in the water when balanced against the weight of the leadline, and the mesh itself (Figure1a). The floatline comprises a series of air-filled chambers which are spaced evenly along the length of the net. The leadline consists either of a continuous length of lead-weighted rope or a rope with individual weights attached at intervals (Lear & Christensen 1975). These two parts of the net are considered to be the only parts that are substantial enough to facilitate detection by cetacean sonar (Goodson 1993; Goodson *et al*. 1994a; Hatakeyama *et al*. 1994; Goodson & Mayo 1995; Nakamura *et al*. 1998). However, the target strengths of the floats used are often fairly weak and the leadline tends to become buried in the sediment and is thus no longer available as a target for detection.

Three types of nylon filament are used for the mesh. Monofilament nylon twine, multifilament nylon and multi-monofilament nylon. Monofilament mesh is made from transparent or blue nylon twine, ranging from 0.2 to 0.7 mm in diameter. This netting is generally stronger and stiffer than the other two filament types, it is cheap and is considered to be the best type of twine for enmeshing fish by the gills. Perhaps most importantly for fishermen, and most problematic for cetaceans, is that monofilament mesh is almost undetectable in the water. Multifilament twine consists of two or more silky filaments spun together. Generally it is more visible in the water than monofilament meshing, stretches less and is not quite as strong. Multi-monofilament twine consists of up to 10 strands of monofilament twine twisted together. It is strong and is more visible in the water but is considered better for tangling fish than for enmeshing them by the gills (Gill 1999).

The hanging co-efficient (or hanging ratio) of a net describes the length of the floatline as a proportion of the length of the mesh. This influences the shape of the net, and the effective size and shape of the mesh. For example, in a net with a hanging co-efficient of 0.5, the net is twice as long as the floatline and is therefore quite loose. A hanging ratio of 1.0 would result in the mesh being set square and taut. Standard gillnets usually have a hanging co-efficient of approximately 0.67 and, although this varies with the target species, a stretched mesh size ranging between 70 mm – 150 mm (Clausen & Anderson 1988; Lowry & Teilmann 1994; Sequeira & Ferreira 1994; Tregenza *et al*. 1997a; Gill 1999).

Tangle nets are a slightly different form of set gillnet which are laid loosely on the seabed. They lack a floatline - so the net is not held taut, have a hanging co-efficient of around 0.5, and a stretched mesh size in the range of 180 mm – 305 mm (Tregenza *et al*. 1997a; Gill 1999). They tend to be made with multi-monofilament twine and, as the name suggests, they operate by entangling the target species rather than trapping them by the gills. Wreck nets are multifilament gillnets set over shipwrecks, with steel rings on the leadline used to hold the net in place. These have a hanging co-efficient of around 0.05 and a mesh size between 160 mm – 190 mm (Clausen & Anderson 1988; Tregenza *et al*. 1997a; Gill 1999). A further variation on the gillnet is the monofilament or multi-monofilament trammel net. These nets comprise three layers. The outer two panels have stretched mesh sizes of about 600 mm while the inner layer is set very slack with a mesh size of about 120 mm (Lowry & Teilmann 1994; Gill 1999). Trammel nets operate by trapping fish in a pocket of the inner mesh as they swim through from one side of the outer mesh to the other (Gill 1999) and are generally considered to be less selective than other types of gillnet (King 1995). With three meshes instead of one, trammel nets must be more expensive. However the fish caught may be in better condition and they may be better protected from scavengers once caught. The species targeted by set gillnets are all groundfish and include: cod (*Gadus morhua*), hake (*Merluccius merluccius*), pollack (*Pollachius virens*), ling (*Molva molva*), flatfish (Pleuronectidae), and dogfish (*Scylliorhinus caniculus*) for standard gillnets and wreck nets (Clausen & Anderson 1988; Benke *et al*. 1991; Read 1994; Tregenza *et al*. 1997a,b; Gill 1999) and crawfish (*Palinurus elephas*) and rays (*Raja* spp.) for tangle nets (Tregenza *et al*. 1997a,b; Gill 1999).

The height of the gillnet as it sits above the seabed varies. Gillnets used in British and Irish hake and cod fisheries are usually set with the floatline about 5 m high off the seabed (Tregenza *et al*. 1997a) while gillnets used in the German North Sea are only 0.3 – 0.5 m high. Those in the Western Baltic are about 2-3 m high (Kock & Benke 1995, 1996). Other variables include soak time, the depth at which nets are set, the number of panels tied together (and, therefore, the length of the net), and the time of day and tide at which the nets are shot. The most common strategy is to set the gillnets in the evening and to retrieve them the following evening, so leaving them deployed overnight (Clausen & Anderson 1988; Benke 1994; Read 1994; Tregenza *et al*. 1997a; Gill 1999). Consequently the most common soak time is 24 hours (Goodson 1994; Read 1994; Sequeira & Ferreira 1994; Bravington & Bisack 1996; Carlstrom & Berggren 1996; Gearin *et al*. 1996; Trippel *et al*. 1996) although in the Danish gillnet sole (*Solea solea*) fishery, nets are occasionally left out for up to eight days. Soak time is reduced in this region when the water temperature increases however, for the higher the water temperature the greater the scavenger and decomposition damage to the catch (Lowry & Teilmann 1994). Benke (1994) suggests that overnight sets aim to take advantage of the diurnal migration of fish species and their prey. Regardless of the effect on fish catches, this is an important aspect of the fishing strategy since the by-catch of marine mammals tends to occur mainly at night (Smith *et al*. 1983; Waring *et al*. 1990; Benke *et al*. 1991; Read 1994; Sequeira & Ferreira 1994; Couperus 1997b; De Haan *et al*. 1997; Fertl & Leatherwood 1997; Tregenza & Collet 1998; Morizur *et al*. 1999; Silvani *et al*. 1999).

The time at which nets are set is influenced by the tides and efforts are usually made to ensure that the nets are set for at least one full tidal cycle (Tregenza *et al*. 1997a; Gill 1999). Britain experiences semidiurnal macrotides (Castro & Huber 1992) and fishermen prefer to set their nets during slack water to try to avoid the strong tidal currents entangling the nets as they are shot. Additionally, because drag from strong tidal currents can decrease the net height, fishermen usually set their nets parallel to the flow of the tidal current to maximise the catch (Tregenza *et al*. 1997a).

The depths at which the nets are set is probably less of an active strategy and more of a geographical practicality. Gillnets are rarely set deeper than 200 m and can be set in water as shallow as 7m (Benke *et al*. 1991; Read 1994). In general however, decisions on when and where to set nets and what type of net to deploy will always be based on local knowledge of currents, tides, depth, the distribution and movements of the target species and the current market value of the target species sought.

2.1.2. Trawls

Trawls can best be described as large mesh pockets with a pouch (the "cod-end") at the distal end and are towed behind boats to scoop up the sea life they encounter (Figure 1b). The use of trawls spread throughout the NE Atlantic in the 1980s and the extent of their impact on marine mammals has only come to light recently (Morizur *et al*. 1999). With the boats continually present during the fishing operation, and since the net moves to catch the fish, trawling is categorised as an active fishing procedure (De Haan *et al*. 1997).

As with gillnets, trawls come with a range of different specifications and are used with different strategies in accordance with the target species of the fishery. The gear specifications that vary include the mesh size in the body of the trawl, the mesh size in the codend, the size of the trawl itself and the dimensions of the trawl mouth (Kock & Benke 1995, 1996; Couperus 1997b; De Haan *et al*. 1997; Fertl & Leatherwood 1997; Morizur *et al*. 1999). Aspects of deployment which can be varied and may affect the target catch quality include the depth and speed at which a trawl is towed, the distance behind the boat, time of day, haul duration (or soaktime) and the speed at which it hauled back onto the boat (Kock & Benke 1995, 1996; Couperus 1997b; De Haan *et al*. 1997; Fertl & Leatherwood 1997; Wassenberg *et al*. 1998; Morizur *et al*. 1999). Additional variations in the trawling process include the way in which the catch is brought onboard the deck for sorting. This occurs either by lifting the cod-end onto the deck, tying it off and emptying it or by bringing the cod-end alongside and pumping the catch onboard (Hartmann *et al*. 1994; Couperus 1997b; Tregenza *et al*. 1997b; Morizur *et al*. 1999). The latter method is of particular concern in relation to cetacean by-catch for these mammals are too big to be taken aboard by the pump with the result that they are usually discarded when pumping is complete and consequently are missed by observers.

Trawls can be broadly divided into:
(a) mid-water trawls, which target pelagic fish species such as mackerel (*Scomber scombrus*), horsemackeral (*Trachurus trachurus*), herring (*Clupea harengus*), pilchard (*Sardina pilchardus*), cuttlefish (*Sepia officinalis*) and anchovies (*Engraulis encrasicolus*);
(b) demersal trawls, which are towed along the seabed to disturb and catch species such as hake, flatfish, monkfish (*Lophius piscatorius*) and various crustacea (Couperus 1997a,b; Tregenza & Collet 1998).

While the mesh size of trawls is important in determining the catch compositions, the type of mesh used is of less importance for cetacean by-catch in active fishing gears. Because trawls do not rely on invisibility to enhance their catch productivity, it is not necessary for them to use inconspicuous monofilament twines. The priorities for choice of mesh types are that the mesh be strong and resistant to rot.

Mesh sizes used for mackerel, horse-mackerel and herring range from 40 – 100 mm in the codend (Couperus 1997b; Tregenza *et al*. 1997b) to up to 30 m near the entrance of the trawl (Couperus 1997b). The mouth dimensions of the trawl vary from 30 – 60 m high and 80 – 120 m wide (Couperus 1997b). The depth of the tow depends largely on the behaviour and location of the fish, both of which can be monitored from the boat with fish-finders. There appear to be no hard and fast rules relating to tow depth or haul-back speed. Trawls are usually in the water for 2 – 4 hours (Sequeira & Ferreira 1994) at a time. With the advent of freezer trawlers, fishing trips can last for up to five weeks (Couperus 1997b). The average total annual catch of the Dutch freezer trawlers alone is approximately 300,000 metric tons. In the absence of on-board freezer facilities, trawlers are usually at sea for only a few days at a time (Sequeira & Ferreira 1994). Pumps are a modern advancement in the trawling procedure and by-catch of marine mammals is usually underestimated when they are in use (Hartmann *et al*. 1994; Tregenza & Collet 1998; Morizur *et al*. 1999).

2.1.3. Driftnets

Driftnets are effectively floating monofilament gillnets and are therefore considered as a passive fishing technique (Lear & Christensen 1975; Richards 1994). They usually have a low hanging co-efficient, so that they are loosely hung, and have a mesh size of around 130 – 140 mm (Figure 1c). Whilst driftnets are quite selective (Berrow pers.comm), the total amount of net set means that by-catch of non-target fish and non-fish species can be ecologically significant (Lear & Christensen 1975; Richards 1994, Berrow pers.comm). Many authors comment that driftnets have been banned, however, this will not be effective until 2002 after which time the use of driftnets will be banned under the EC Regulation No. 1239/98. This prohibition however, will not apply in the Baltic where the salmon drifnet fishery does not target any of the species listed in Annex VIII of Regulation 1239/98. The major driftnet fisheries remaining in operation are the French and Irish fisheries, targeting albacore tuna (*Thunnus alalunga*) from May to September (Goujon *et al*. 1993, Berrow pers.comm). Tuna nets are usually 5 – 7 km long (Goujon *et al*. 1993) and are left to float with the wind and the tide. They are set to coincide with the tuna migration (Richards 1994).

2.1.4. Other fishing gear

The main gears responsible for by-catch are thought to be gillnets, trawls and driftnets, all of which are reviewed above. However, by-catch is associated with many other kinds of gear, including cod traps, herring weirs, lobster pots, long lines and purse seines (Smith *et al*. 1983; Read & Gaskin 1988, 1990; Perrin 1992; Hall 1994; Read 1994; Sequeira & Ferreira 1994; Lien *et al*. 1995; Carlström & Berggren 1996; Gill 1999; Pierce & Santos 2000).

These gears will be discussed in less detail, either because their impact on cetaceans is thought to be less important, e.g. due to lower fishing effort or their operative design, or because their impact has been sufficiently mitigated to justify less attention.

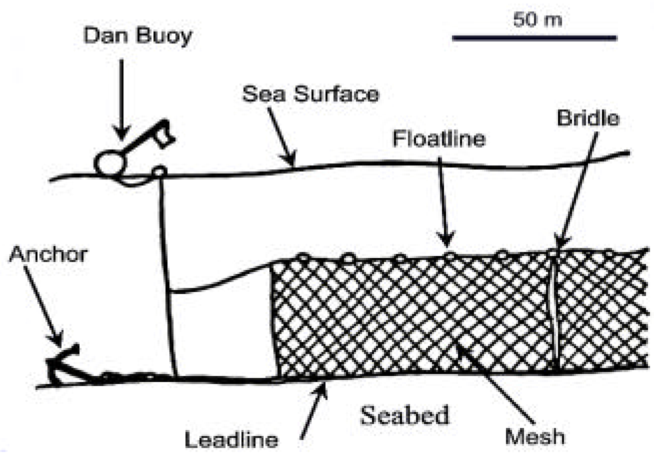
Cod traps are open-topped mesh boxes, which are about 25 m wide on each side (Read 1994). The traps are anchored both to the seabed and to the shore with leader ropes, which deflect the fish toward the trap. Fishing with cod traps is seasonal and takes advantage of the cod run (Read 1994).

Herring weirs are kidney-shaped nets that are secured to the seabed by wooden stakes with their mouths facing the shore (Read 1994). As with the cod traps, they have leader ropes anchoring them to the shore, which guide the herring into the traps during their inshore migration (Read 1994). The fish are collected from the traps with small purse seine nets and the traps are removed in the autumn following the conclusion of the juvenile herring migration (Read 1994).

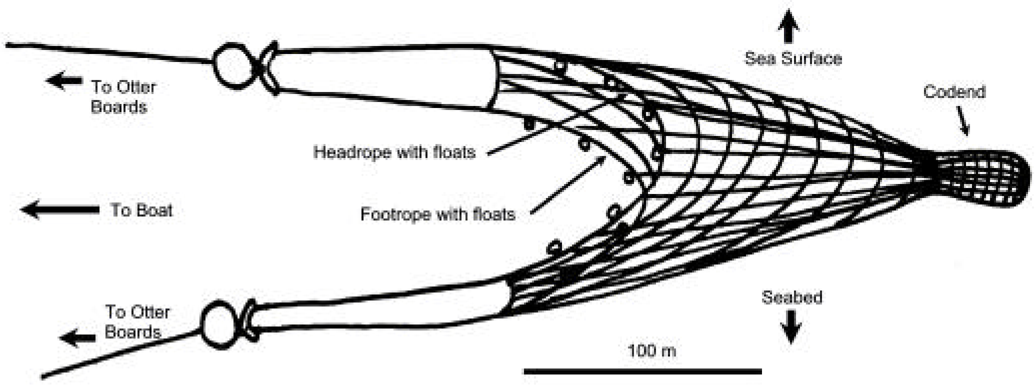
Long-line fishing is a very effective way of catching fish and has been reported to achieve higher catches than many other gear types including gillnets (Gill 1999). Long-lines are still used to catch sea bass (*Dicentrarchus labrax*), conger eels (*Conger conger*), sargo bream (*Diplodus* spp.) and various shark species (Sequeira & Ferreira 1994). The return per unit effort is often low however, since the deployment of the lines is time-consuming (Figure 1d) and, consequently, many fisheries have replaced their use with the more selective gillnets (Gill 1999).

Purse seines are probably the type of fishing gear most infamously associated with dolphin mortality, following the much-publicised dolphin – tuna problem (Chivers *et al*. 1989). In the Eastern Tropical Pacific (ETP), tuna are fished in three ways (Hall 1994; Perkins & Edwards 1996) largely due to their tendency for polyspecific associations (Lo *et al*. 1982; Hall & Boyer 1987; Au 1991). 'Dolphin sets' involve setting nets around pods of dolphins which are associated with tuna and the catch usually comprises older, larger fish which have already been recruited into the tuna population (Punsly *et al*. 1994; Perkins & Edwards 1996). 'Log sets' involve the setting of nets around inanimate floating objects with which the tuna are associated and tends to result in the catching of young fish (Hall 1994; Perkins & Edwards 1996). 'School sets' involve the setting of nets over tuna that are not associated with any other objects and the catch usually comprises immature fish (Hall 1994; Perkins & Edwards 1996). The tuna caught in log and school sets are generally smaller and/or younger than those caught in dolphin sets and large proportions of the catch are discarded (Punsly *et al*. 1994). Consequently, using dolphin sets to catch tuna is generally considered better for the tuna stock and for the fishermen (Punsly *et al*. 1994; Perkins & Edwards 1996) although it clearly has the potential to be damaging to dolphin populations and is no longer utilised in the North Atlantic (Berrow pers.comm).

Figure 1. Diagrams of types of fishing gear involved in cetacean by-catch. Adapted from Strange (1981) and Meadows & Campbell (1993).

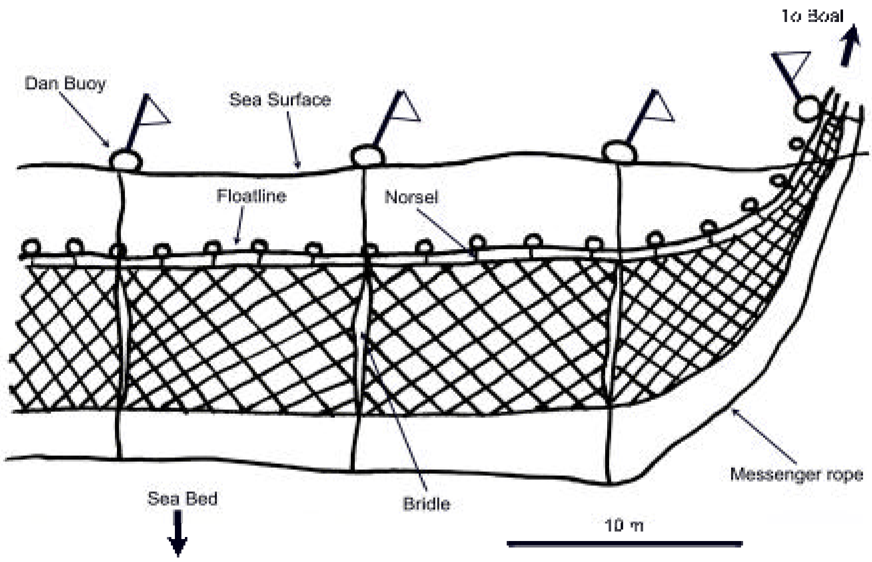


a) Diagrammatic sketch of a bottom-set gillnet as adapted from Strange (1981). Used to catch cod, hake, pollack, ling, flatfish and dogfish, the structure of gillnets varies in different regions of use.

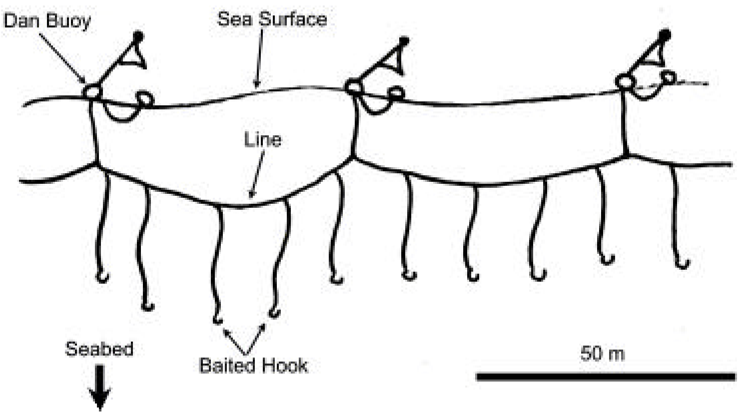


b) Diagrammatic sketch of a mid-water trawl as adapted from Meadows & Campbell (1993).

Used to catch mackerel, horse-mackerel, herring, pilchard, cuttlefish and anchovies.



c) Diagrammatic sketch of a driftnet as adapted from Meadows & Campbell (1983), currently in use mainly to catch tuna and salmon.



d) Diagrammatic sketch of a longline as adapted from Meadows & Campbell (1983).