H229

Chapter 14

Environmentalists, Fishermen, Cetaceans and Fish: Is There a Balance and Can Science Help to Find it?

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1. INTRODUCTION

1.1 Historical Background

It is only relatively recently that cetologists have considered anything other than direct exploitation as an important threat to cetaceans. Given the centuries old tradition of whaling and the history of attempts to regulate the industry (*e.g.* see review in Donovan, 1992), this is perhaps not surprising. The issue addressed in this chapter, that of non-deliberate or incidental captures of cetaceans in fishing gear, was not seriously considered a problem until the late 1960s when biologists on board fishing vessels observed high levels of incidental catches of dolphins in the tuna purse-seine fishery in the eastern tropical Pacific (Perrin, 1968). This fishery is now one of the best-studied examples (Joseph, 1994; Hall, 1998) and we will use it throughout the chapter as a case study to illustrate one approach to address a particular bycatch problem.

The tuna-dolphin problem led people to consider other fisheries, and the first attempts at a broad review were made in the mid-1970s, in particular under the auspices of the Scientific Committee of the International Whaling Commission (IWC) and its sub-committee on small cetaceans (Mitchell, 1975a, b); it soon became apparent that many species of cetaceans were being killed incidentally around the world, particularly in gillnets.

Perhaps the most important scientific initiative regarding this problem was the holding of an IWC Symposium and Workshop on the Mortality of Cetaceans in Passive Fishing Gear and Traps held in California in 1990. Much of the content of this chapter concerns ideas arising out of discussions held during that workshop, and studies carried out in response to its recommendations (see Donovan, 1994; IWC, 1994b). Its particular strength was that it brought together not just cetologists but also experts in fisheries biology and management, gear technology, and fishermen themselves.

However, as will become apparent, the issue of cetacean (and indeed all marine mammal) bycatches in fisheries is a multi-layered, multi-disciplinary issue involving not just 'scientific' disciplines but also politico-ethical (Donovan, 1992) considerations, and the cetacean focus may not be the most appropriate in the wider context. The effects of incidental mortality of cetaceans in fisheries should be assessed taking into account the basic framework of ecological principles for conservation described in Mangel *et al.* (1996).

2. PROBLEM - WHAT PROBLEM AND WHOSE PROBLEM?

Very often people refer to the 'problem' of incidental catches of cetaceans. Although it may appear to be self evident, in this section we would like to examine just what can be considered to be a problem and by whom. Let us define an incidental catch as the unintended mortality of a cetacean during the operation of the fishery. From the perspective of the cetacean population, the impact of this mortality, when considered with all other causes of mortality, may or may not be significant. The total mortality may upset the balance of births and deaths that has, up until the present, resulted in the persistence of the population in question. In ecological terms, the development of a fishery is equivalent to an invasion of an area by a new predator and/or competitor. Irrespective of whether the 'prey' is consumed, this new source of mortality was not part of the evolutionary context in which the population evolved, and succeeded in surviving. If mortality is very low in relation to population abundance, the reaction of the population may be only minor and perhaps very difficult to detect. If it is high, it will elicit more dramatic (*e.g.* density-dependent) responses. If these can compensate for the added losses, the population will stabilise at a new level, with a different age structure, and perhaps a different biomass. If they cannot compensate, then the population will decline over time towards extinction. The new selective pressure added to the system will also result in long-term genetic changes, favouring particular behavioural and ecological adaptations that improve the fitness of the individuals possessing them in the "new" ecosystem that now includes the fishery.

From the perspective of the fisherman, cetacean bycatches are almost always a problem, although the severity of the problem will vary depending on the circumstances, for example:

very severe problem - the gear is completely destroyed (*e.g.* in some instances with large whales, the gear may be towed away by the animal which subsequently dies, see Kraus, 1990);

severe problem - although not completely destroyed, operations must cease whilst repairs to the gear are made;

relatively minor problem - some time is lost as the entangled cetaceans must be cut free from the net;

no problem - if the commercial value of the cetacean is relatively high compared to the target species for the fishery, or if the cetacean can be used for bait (*e.g.* in some South American fisheries - see Read *et al.*, 1988; Bjørge *et al.*, 1994, pp. 99-100).

From the perspective of the cetacean population dynamicist, whether or not bycatches are a problem depends on the status of the cetacean population involved relative to the number of incidentally caught animals. Similarly, from the point of view of the resource manager, who has to keep one eye on the fishery and the other on the ecosystem, the marine mammal bycatch issue is essentially one of management and thus one in which science and biologists have a major role to play.

However, other issues superimposed on this complicate the issue. These are what might be termed the politico-ethical issues referred to earlier.

(1) Particularly in the USA and Western Europe, there are those who consider that cetaceans represent such a 'special' group of animals that they should not be killed, deliberately or incidentally, under any circumstances (*e.g.* Barstow, 1990). From this perspective, every incidental catch of a cetacean would be a severe problem. (Of course, by extension, it makes every single catch of a cetacean a severe problem for the fisherman too.)

(2) Notwithstanding the above, there is a general perception that bycatches (of any species) are a wasteful use of both life and resources and thus a problem. However, as we shall return to later, this relatively simple view is not necessarily always the case from an ecosystem perspective (*e.g.* Hall, 1996).

The weight given to points (1) and (2) above provide the political dimension, particularly when addressing the problem involves an international dimension, where the viewpoints of countries/cultures may be diametrically opposed.

The views of scientists on the politico-ethical issues are generally worth no more and no less than those of others. Given this, a potential danger arises if a scientist adopts a moral/ethical position that affects the interpretation or communication of scientific facts to managers or the public. The role of the scientist is to provide the best information possible to enable decision-makers to base their choices on the best available information and to enable the public to understand the issue as well as possible.

3. MANAGEMENT

Simplistically, the cetacean bycatch problem can be viewed solely as a wildlife management issue. From the population biologist's perspective, whether or not the 'target' species is utilised is irrelevant (in this case, of course the cetacean, whilst being the management 'target', is not the fishery target). At this point, it is worth recalling that the history of cetacean management is not a particularly happy one (*e.g.* see review in Donovan, 1992). However, considerable advances have recently been made with respect to the management of large cetaceans, as summarised in Donovan (1995). This approach can be usefully considered when examining the cetacean bycatch problem, although as we shall see, there are a number of important conceptual differences as well as similarities.

3.1 Objectives

In attempting to develop a resource management scheme, the most important initial step is to define management objectives. It is relatively easy to define two 'extreme' objectives, for example:

a) avoid extinction of the cetacean species incidentally caught;

b) do not hinder the operation and profitability of the fishery in any way.

It is clear however that within these two general categories (interests of the bycaught species/interests of the fishermen), there are a number of potential options, and that there must be some form of trade-off between the objectives. The options chosen and the balance struck between them are generally taken as largely political rather than scientific decisions. However, there is a clear ecological change when the marine mammal population is stabilised at a level that is much lower than the initial one. Whether we see a fishery as a predator to some species, a competitor to others, or a mutualistic partner to others, the niche that the fishery occupies will not match exactly the one of those replaced/displaced by it. Furthermore, as recent history shows, fisheries lack the density-dependent mechanisms to regulate their evolution, and frequently their expansion is so fast that it overwhelms the capacity of the other species in the system to adapt to it.

In addition to the scientific objectives discussed below, however, it must be recognised that there are 'user' objectives that must be borne in mind. These include:

a) the management strategy adopted must be as easily understood by the users (*i.e.* the fishermen) as possible and perceived as 'fair';

b) the strategy should be practical given the circumstances of the fishery, *e.g.* a strategy that will work for an industrialised commercial fishery in a developed country may well not be applicable to an artisanal fishery in a developing country;

c) it should be enforceable.

3.1.1 Possible Management Objectives with Respect to the Cetacean Bycatch

3.1.1.1 Zero Mortality

Choosing a 'zero mortality' option would mean that no cetaceans are allowed to be incidentally killed in a fishery under any circumstances. For those people who believe that it is immoral to kill cetaceans, this would always be the chosen management objective and would receive priority over all other considerations.

From a 'purely scientific' perspective, this may also be the chosen option under certain circumstances, for example, where the cetacean species or population being caught is in danger of extinction, *e.g.* the vaquita (see summaries in Bjørge *et al.*, 1994; Vidal, 1995).

There can be difficulties with the zero mortality option if it is considered the overriding management objective, whatever the status of the cetacean population involved. Fishermen confronted with such an objective perceive this as a direct threat to their livelihood, because for most fisheries, the only way to achieve this level is to shut them down. This may be counter-productive and result in little or no co-operation with biologists and/or managers. In most cases where cetacean bycatch levels have been reduced in fisheries, this has been achieved with the direct co-operation of fishermen, for example, in changing fishing gear or practices (IWC, 1994b).

There are likely to be similar problems in an international context if politico-ethical considerations based solely on the perceived values of cetaceans are used as the overriding management objective – not all nations, cultures, or socio-economic classes value species or groups of species in the same way (*e.g.* Donovan, 1992; Joseph, 1994).

3.1.1.2 Maintain a Trend in Population Abundance

This option appears to be intuitively appealing from a scientific perspective. For example, some level of cetacean bycatch may be acceptable if that population is (a) increasing in abundance or (b) not decreasing in abundance. Although superficially similar, these two options are quite different as they place the burden of proof on different sides of the problem. This was the focus of considerable debate in the IWC Scientific Committee in the early 1980s with respect to the management of large whale populations. The power of statistical tests for determining trends in cetacean populations is generally low (Gerrodette, 1987), and it may take decades to verify statistically that a whale or dolphin population is increasing. If that increase has to be demonstrated prior to any takes, the fishery in question will be closed for a long time. If on the other hand, a statistical decrease in abundance is required before taking action on a bycatch problem, the fisheries will operate for many years, and the cetacean populations affected may decrease considerably before the evidence becomes significant.

3.1.1.3 Maintain the Population of the Bycatch Species at Some Specified Level

This is a common general objective in managing wildlife populations. It of course implies that some level of bycatch level is sustainable. However, the major question is at what level should a population be kept. A number of different approaches have been proposed, normally in the context of directly harvested species.

3.1.1.3.1 Return the Population to its Pre-exploitation Level and Maintain it at that Level

This approach would allow the cetacean populations to recover to their 'pre-exploitation level'. There are at least two major problems with this approach: (i) the pre-exploitation levels of populations are rarely, if ever, known; and (ii) even if they are known, it is unlikely that the rest of the ecosystem, which has also been disturbed by human activities, will find a stable equilibrium point with a single population of an 'arbitrarily selected' key species.

In practice, even if it were possible to eliminate all human activities in an area, this would not guarantee that the ecosystem would return to its pristine condition; it is much more likely it would reach a new equilibrium and that this may take a very long time.

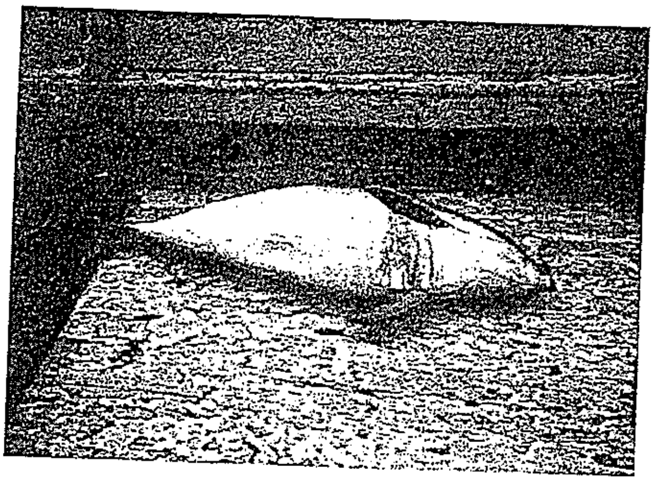

Figure 1. In several areas of the North Atlantic, especially the Bay of Fundy/Gulf of Maine, North Sea and Celtic Shelf, the bycatch of harbour porpoises is estimated to be above the values that would enable the populations to maintain their current level. (Photo: N. Tregenza)

3.1.1.3.2 Maintain the Population at the Current Level

Under this option, the bycatch is brought to a sustainable level, assuming that the current population level of the cetacean will reach an equilibrium with the other components of the system. It may, of course, be closely related to item 3.1.1.2, as one way to meet this objective would require the monitoring of the population size to ensure that it is not increasing or decreasing. This is not easy, as we have seen. Another way of trying to meet this objective is one that has been used in certain cases as a 'temporary' measure, and that is to make assumptions about the reproductive capacity of cetaceans (*e.g.* a maximum increase rate of 4%), and then take a conservative position such that the bycatch should not exceed half that rate (*i.e.* 2%), and that concern should be warranted if bycatches exceed 1% of the estimated population size (see also below). However, as is well recognised (*e.g.* IWC, 1996), this is a somewhat arbitrary approach. One apparent advantage of it is that it does not require estimating an 'optimum' level. It is also a relatively easy concept to explain. However, if the current population level is very low, there may, for example, be undesirable genetic consequences for the population, even before it is endangered or threatened, and/or the population will be more susceptible to environmental stochasticity, diseases, pollution, *etc*.

3.1.1.3.3 Maintain the Population at Some Maximum Productivity Level

Choosing an appropriate level is not a trivial exercise, and a number of such levels have been proposed. For example, the first attempts to develop serious scientific management procedures for fish and for large whales focused on the concept of the *maximum sustainable yield* or MSY[1]. Indeed, one of the problems with the IWC's so-called New Management Procedure developed in the mid-1970s was the difficulty in estimating MSY and related factors (Donovan, 1995).

Irrespective of the difficulties of establishing the particular level, such a strategy would allow incidental takes if the population is above or at the chosen level, but would reduce or eliminate them when the population is below it. To some extent, this is the approach adopted in the IWC's Revised Management Procedure, where the procedure is 'tuned' to a somewhat arbitrary target level (see Donovan, 1995). It is also relevant to the PBR (Potential Biological Removal) approach adopted by the USA to manage marine mammal populations where the goal is to maintain populations at or above their 'Maximum Net Productivity Level', which is assumed to lie between 50-70% of carrying capacity (Wade, 1998). This approach will be discussed in more detail later. However, given that the population experiencing the incidental mortality is not utilised as a resource, the rationale for maintaining it at a high productivity level is unclear. This was reflected in the discussion and adoption of objectives agreed by ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas) at its 2nd Meeting of Parties in 1997. They chose as an interim objective to aim to restore populations to, or maintain them at, 80% or more of the carrying capacity, on the grounds that this 'is above the

[1] In simple terms, at the initial equilibrium population size, the number of births balances the number of deaths by natural causes. As the population size is reduced, an excess of births over deaths (or animals reaching maturity) occurs as conditions (*e.g.* food supply) improve. The excess (or yield) reaches an absolute maximum number at a certain percentage of the initial population size. For whales, this was traditionally assumed to be at 60%.

level of maximum productivity and therefore more appropriate for a conservation agreement' (ASCOBANS, 1997).

3.1.1.3.4 Maintain Some Population Level that Results in a Known and Agreed-to Probability of Extinction

This approach emphasises the stochasticity of changes in abundance. Although obtaining the data to allow this to be explicitly determined would be extremely difficult, the principle underlying such an approach is similar to the approach adopted in developing the Revised Management Procedure of the IWC. That approach used simulation trials to determine how the management procedure would cope with a wide variety of scenarios, and in one sense looked at the probability of extinction under those scenarios. Table 1 gives some examples of the kinds of factors which the procedure had to deal with. How relevant these are to the bycatch issue will be referred to throughout the chapter.

Table 1. Some examples of the trials with which the IWC's Revised Management Procedure had to be able to cope

Several different population models and associated assumptions
Different starting population levels, ranging from 5% to 99% of 'initial' population size
Different MSY levels, ranging from 40% to 80%
Different MSY rates, ranging from 1% to 7% (including changes over time)
Uncertainty and bias in estimated population size
Changes in carrying capacity (including reduction by half)
Errors in historic catch levels
Catastrophes (irregular episodic events when the population is halved)
Various frequencies of surveys

3.1.1.3.5 Maintain Some 'Acceptable' Bycatch/Catch Ratio

If there is an ecological relationship (*e.g.* predator-prey) between the target species and the bycatch species, then it may be possible to establish a ratio between them that results in a minimisation of the impact on the system. If the exploitation removes the predator and prey in the 'correct' ratio, then the use may be deemed acceptable; if the ratio is very different from the optimal (in any direction), then changes to the fishing practices will be required. It is conceivable under this scenario that bycatches may have to be increased in some cases to maintain the ecological balance. Perhaps this option more than any other shows the necessity of considering the management of both catches and bycatches jointly, within an ecological framework. The major difficulty of such an approach is in successfully identifying ecological relationships in a predictive manner, a difficulty that affects all multi-species modelling and management.

3.2 Data Requirements

As has been well illustrated for other species, and particularly for the management of large whales, management objectives and schemes cannot be evaluated without consideration of data requirements and the ability of scientists and the industry to provide them (Donovan, 1995).

Several pieces of information are required if a quantitative assessment of the impact of bycatches on cetacean populations is to be made (Donovan, 1994; IWC, 1994b) irrespective of the management objectives (unless the zero option is chosen under all circumstances). These are:

(1) reliable estimates of bycatch numbers;

(2) knowledge of stock identity and migration;

(3) reliable estimates of abundance.

These will provide an estimate of the bycatch level as a proportion of current population size. However, to interpret this in the context of management objectives (particularly sustainability), at least some knowledge is required of:

(4) the dynamics of cetacean populations; and this should be viewed in the context of:

(5) other factors affecting the population such as direct catches, habitat changes *etc.*, and:

(6) the level of uncertainty of the basic information.

3.2.1 Reliable Estimates of Bycatch Numbers

Estimates of incidental mortality usually come from one of two sources: reports from fishermen, or observer records. Although both of these methods have errors and problems attached to them, the latter should provide results of higher quality, detail, and reliability (Northridge, 1996). In general, it should be possible to place observers on either all, or a representative sample, of boats in an 'industrial commercial' fishery. However, this has rarely been done (*e.g.* Hill *et al.*, 1990; Berrow *et al.*, 1994; Lennert *et al.*, 1994; Lowry and Teilmann, 1994; Vinther, 1999), with the notable exception of the tuna fishery in the eastern tropical Pacific, which now has complete observer coverage (Joseph, 1994; Lennert and Hall, 1996). This approach, however, is almost impossible where large numbers of small vessels are involved, as is the case for many artisanal fisheries in the developing world.

Other approaches, such as questionnaire surveys, are very difficult to interpret (Lien *et al.*, 1994), but may give some idea as to whether there is a potential problem.

Even observer schemes have sources of uncertainty that are not easy to estimate. Some may lead to underestimation of mortality, such as: (i) the observer may miss some of the mortality *e.g.* if the carcasses fall out of the net before it is hauled in; (ii) intentional under-reporting may occur if the observer asks fishermen to provide the information whilst he/she is not on watch, or if observers are bribed or intimidated; (iii) injuries caused by the fishing operations may lead to mortality some period later; (iv) stress caused by fishing operations may result in diminished survival or reproduction; (v) fishing operations may result in facilitated predation; and (vi) changes in the behaviour of the fishermen may be caused by the presence of the observer.

However, overestimation may also occur, for instance: (i) strained relationships between observers and crews may result in over-reporting; (ii) some of the injuries that are believed to result in death may not; and, probably the most important, (iii) some of the statistical techniques used for estimation, such as ratio estimates, tend to be biased at low sample sizes, and this may result in overestimates when observer or any other form of coverage is low (see Bravington and Bisack, 1996, and Vinther, 1999, for good discussions of the problems and approaches that should be considered when trying to estimate bycatch levels when complete coverage is not possible).

An extreme case of uncertainty takes place when an attempt is made to reconstruct a long time series for which there are no, or very few, valid observations. In the case of the eastern Pacific tuna fishery, a period of more than a decade (1959-71) when most of the mortality which occurred had no observer coverage; the only data available were from two letters of crew members, and a trip by a scientist. A U.S. National Academy of Sciences Committee (Francis *et al.*, 1992) reported:

> 'Thus, the data do not come from any sampling design. Trips were not selected at random or according to any pattern. The accuracy of the data is questionable because no standard procedure was used to collect the information, and interpretation of the data cannot be determined to be correct. ...... In summary, the mortality estimates for the period before 1973 .... have little or no statistical value, and the only conclusion that can be based on the data available is that mortality was very high.'

Similar problems can be found when trying to reconstruct long time series of catch statistics or CPUE (catch per unit of effort) data. It is problematic that these low-quality data are sometimes needed to determine the current status of the population with respect to some baseline condition.

In general, it must be recognised that for almost all fishery/cetacean interactions, we have, and will probably continue to have, only rough (often minimum) estimates of bycatch levels (see IWC, 1994b, Table 1). Management strategies developed must take this level of uncertainty into account, for example in a similar manner to the way that the RMP (Revised Management Procedure) takes into account uncertainty in the catch record (see Table 1). An important difference, however, is that the RMP assumes that once the management regime is underway, all future catches are known. This may well not be the case for incidental catches.

3.2.2 Knowledge of Stock Identity and Migration

Figure 2 illustrates just one of the problems that can arise when trying to manage a population with mistaken information on stock structure. Incidental catches are taken in the area bounded by the dotted line. The scientists believe that the area that they have surveyed (bounded by the thick black line) contains a single stock, when in fact it contains two stocks, an inshore and an offshore stock bounded by the thick grey line (an added complication is that such boundaries may vary temporally as well as geographically). They will thus underestimate the effect of the incidental catches on the inshore population.

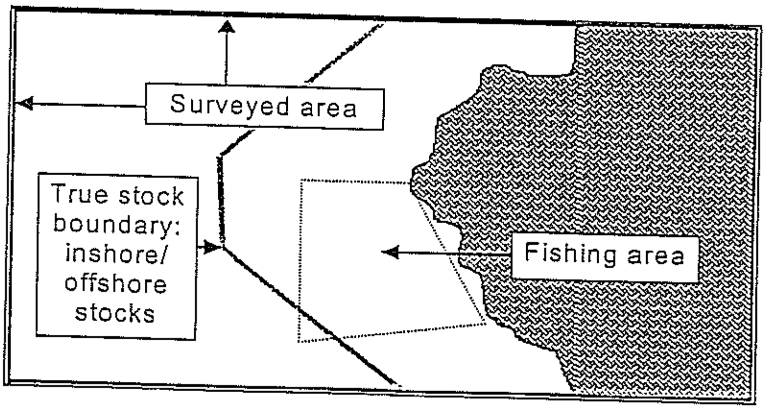

Figure 2. Hypothetical illustration of one potential stock identity problem (see text).

Another example of the difficulties encountered when trying to associate a stock with a geographical region is the set of changes that accompany the El Niño-Southern Oscillation events. The "normal" habitat of a stock may shift to a new location, and it may shrink or expand, because of the oceanographic changes. There is an interesting example of a massive migration of individuals of common dolphins (*Delphinus delphis* and *D. capensis*) that perhaps could be linked to El Niño, (although it has lasted longer than the event), from the more tropical parts of the eastern Pacific to Californian waters (Anganuzzi *et al.*, 1993; Forney *et al.*, 1995; Barlow *et al.*, 1997).

The question of stock identity is a persistent problem in cetacean studies (see *e.g.* Donovan, 1991; Perrin and Brownell, 1994), and our knowledge of stock structure is poor for almost all small cetacean species in all areas. Despite the progress in biochemical techniques made in recent years (*e.g.* IWC, 1991; Dizon and Perrin, 1995), there are no simple unambiguous ways to address this problem. It is important that a suite of techniques is used (*e.g.* Donovan, 1991), and that information on movements is also obtained. The inevitable uncertainty must be taken into account in any management procedure developed (for example by following an approach such as the *Small Area* approach used in the RMP-International Whaling Commission, 1994a). There has been some criticism that the US PBR method (Wade, 1998) does not take problems relating to stock identity sufficiently into account (IWC, 1997).

3.2.3 Reliable Estimates of Abundance

The question of estimating the abundance of cetacean populations (notwithstanding the stock identity problems noted above) has been thoroughly addressed in recent years and is beyond the scope of this chapter. Therefore, we will not discuss it here other than to say that while the techniques exist, they are expensive. For example, the recent survey of the North Sea and adjacent waters cost over £1,000,000 (Hammond *et al.*, 1995). At present, we have relatively few estimates of abundance for cetacean populations affected by fisheries, particularly for developing countries (IWC, 1994b, Table 1). Again, despite the relatively advanced state of knowledge with respect to population estimation, it is important to recognise that some uncertainty is inevitable in obtaining any estimate, and this uncertainty must be taken into account in any management scheme, as is the case for the RMP (Table 1).

3.2.4 The Dynamics of Cetacean Populations

It is clear that our limited understanding of the population dynamics of most, if not all, cetacean species, and our inability to obtain sufficiently precise and unbiased estimates of biological parameters, make it impossible to obtain detailed predictions of the future (*e.g.* Reilly and Barlow, 1986). This was recognised in the development of the RMP where the sensitivity to various assumptions about population dynamics models and parameters were incorporated (see Table 1). The fact that in most cases we have only a wide range of possible values for a parameter, and that our estimates usually have large variances, makes the detection of changes very difficult.

3.2.4.1 Other Factors Affecting the Population Such as Direct Catches, Habitat Changes, *etc*

Clearly, incidental catches alone are not the only problem facing populations. Any management strategy must consider these other factors, such as directed catches, habitat degradation, stochastic variability, pollution, either explicitly or implicitly. Again, the simulation approach adopted during the development of the RMP provides a useful starting point for taking these factors into account (see Table 1).

3.3 Classifying the Problem

In the past, the information above has been used to try to scientifically evaluate whether the bycatches are potentially a problem *from the perspective of the cetacean population.* The following categories (IWC, 1994b; Hall, 1996) have been used to classify bycatches. However, whilst classification of a problem can be a stimulus to action, it is important that it is not seen as an end in itself; the classification simply suggests the degree of urgency, and the level of the actions to be taken. Apart from the first category below, where it is probable that the zero mortality option must be taken, then the other categories require action, preferably in the context of a management scheme and its objectives, as discussed above.

• *Critical bycatches*: bycatches of populations or species that are in danger of extinction (*e.g.* the 'vaquita' - Rugh *et al.*, 1993; Vidal, 1995). The problem here is that there is no universally accepted definition of 'in danger of extinction', and that may leave the door open to extreme approaches.

• *Non-sustainable bycatches*: in this case, the populations are not immediately at risk, but they will decline under the current levels of bycatch.

• *Sustainable bycatches*: bycatches that do not result in declines of the population.

• *Biologically-insignificant bycatches*: bycatches that are so low as to be considered negligible from the point of view of the dynamics of the population involved. These bycatches are also sustainable; the difference between the third and fourth categories is arbitrary, but it is an attempt to separate one that requires some control and monitoring, from one that is so low that it may not be worth the effort. The definition of biologically insignificant is arbitrary; a mortality level of 0.5% of a conservative estimate of population abundance has been implied for cetaceans (*e.g.* IWC, 1994b). Most, if not all, of the eastern Pacific dolphin populations fall under this category (Lennert and Hall, 1995).

• *Bycatches of unknown level*: when we lack the basic data on abundance or total mortality to determine if it is sustainable or critical. Given the lack of data for most populations, this is the category with the highest number of cases. IWC (1994b) created one additional class of unknown level, called 'Potential', which is a suggestion of possibly unsustainable level. This in effect reflects the 'gut feelings' of some biologists about the abundance of a population, and/or its total mortality, which in itself is problematic from both a scientific perspective and in terms of obtaining the confidence of fishermen and managers. However, it may be useful in deciding priority fisheries for study.

• *Charismatic bycatches*: this category is added to reflect the politico-ethical issues raised earlier and the fact that the way a society perceives the bycatch of a species may be independent of the level of the impact exerted on the species, or of its conservation status. The response of the public, which influences or determines management actions, reflects the value assigned to the species in question. Although not strictly an incidental catch, the case of the three ice-entrapped gray whales in Alaska might be seen as an example of where the ecological impact is minimal but where the public's perception and the political 'attractiveness' lead to disproportionate effort (*e.g.* Anonymous, 1989; Fraker, 1989; Scheffer, 1989).

The categories listed above are not mutually exclusive. More than one cetacean species may be affected by a fishery at different levels (*e.g.* eastern Pacific dolphins, Hall and Lennert, 1994).

3.4 An Ecological Perspective

We mentioned earlier that, from an ecological point of view, the problem of cetacean bycatches (and indeed any bycatches) may look very different from the perspective taken simply by the cetologist. It is a problem that has been highlighted by consideration of the tuna-dolphin problem in the eastern Tropical Pacific (*e.g.* Joseph, 1994; Hall, 1995, 1996, 1998) but which has implications for all fisheries. All fishing and agricultural activities have ecological costs associated with them, although these are often not recognised or acknowledged. An important role of scientists and managers is to try to identify ways of utilising resources at the lowest possible ecological cost.

However, this area of research is extremely difficult. It is not easy either to assess the impact of fishing operations, or to compare the impacts of different gears or modes of harvest. For example, one way of harvesting a resource may require vast amounts of energy; another one may cause some undesirable bycatches; a third may physically damage the habitat.

One option is to eliminate the harvest of the resource and all ecological impacts will disappear, but of course, this is no guarantee that an affected ecosystem will return to its 'pristine' state. However, most countries facing increasing population and other socio-economic problems will be forced to choose among a more limited set of options.

Given alternative ways of harvesting a resource, the most ecologically 'benign' options should be chosen, of course, providing they can be identified. The major difficulty is in coming up with an acceptable universal 'currency' to evaluate options even when the general ecological costs can be identified (which in almost all cases, our knowledge of whole ecosystems, or rather our lack of knowledge, precludes).

Some of the difficult types of questions that will arise include:

a) How do we evaluate two different types of fishery, one which results in a small catch of a 'charismatic' species, and one which results in no 'charismatic' bycatches but large potentially damaging catches of less 'charismatic' species?

b) How do we compare a way of fishing that causes physical disturbances on the bottom sediments and incidental mortality in benthic populations, with another one that causes bycatches among demersal or pelagic species but has no impact on the bottom?

The tuna-dolphin problem has identified just such a complex situation. There is a strong but poorly understood association of dolphins and adult tuna in the eastern tropical Pacific (and to a lesser extent, in other oceans). The fishing method for catching tuna has been well described elsewhere (*e.g.* Perrin, 1968, 1969). In simple terms, a large area of netting (up to 1 mile long and 600ft deep) is laid around a school of fish (Fig. 3). When the circle is completed, a cable that passes through the bottom of the net is pulled on board. This forms a 'purse'–hence the name 'purse-seining'. Each time this is done it is termed a 'set'.

There are three strategies used in purse-seining, largely determined by how the school of tuna is detected:

a) by setting on dolphins, *i.e.* by exploiting the relationship between tuna and one of the three species of dolphins known to be associated with tuna (spotted dolphins, *Stenella attenuata*; spinner dolphins, *S. longirostris*; common dolphins, *Delphinus delphis*);

b) by setting of free-swimming schools;

c) by setting on floating objects ('logs').

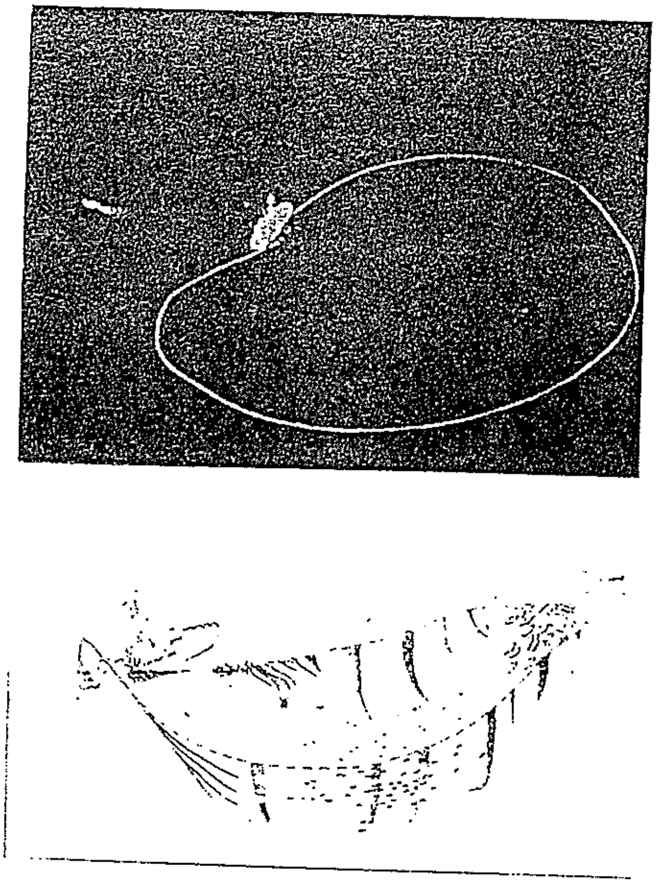

Figure 3. Purse-seine tuna net in operation in eastern tropical Pacific with diagrammatic representation of netting process (Photo: M. Hall).

The mortality of dolphins in sets on them was extremely high in the early days of the fishery (estimated at an annual average of some 350,000, although from very scanty data - Francis *et al.*, 1992), but as a result of a mixture of international co-operation, improved fishing techniques that included technological changes, training, and incentives for their performance (Hall, 1998, see below), and public pressure, has been reduced to around 3,000 in 1997 (Hall and Lennert, 1996) and mortality rates at less than 0.15% of the estimated dolphin population sizes.

Table 2 presents information on the total species composition of catches for the different types of sets, taken from data collected between 1993-1995.

It is not appropriate here to discuss the detail in the table or to debate the finer points of the extrapolation process but rather to highlight some of the general issues it illustrates. Firstly, it is clear that if dolphin catches themselves are excluded from consideration, then setting on dolphins reduces wasteful bycatches.

With respect to tuna, log fishing results in large catches of small tunas and a high level of discards (15%-20%). It also results in higher catches of skipjack, rather than the preferred yellowfin tuna. Setting on free-swimming schools ("school sets") is clearly better than setting on logs, with much lower discard levels (less than 5%), although the tuna caught are still smaller than for dolphin sets. However, some 40% of attempted sets produce virtually no yield (less than 0.5 tons), rendering the technique much less efficient. Dolphin sets result in almost exclusively market size tuna of the preferred species with discard levels of less than 1%.

On the assumption that the catches of dolphins are easily sustained by the populations, it would appear that setting on dolphins results in considerably less waste than setting on either free-swimming schools or logs, and may well be less ecologically damaging, depending on the status of the populations of the other bycaught species (Hall, 1998).

However, before leaving this issue, there is one more question that needs to be kept in mind, and that is the question of whether, from an ecosystem as opposed to a 'waste' (whether it be of yield or life) perspective, bycatches are necessarily a 'Bad Thing' and highly selective, targeted fisheries a 'Good Thing' (Hall, 1996)? To take a much simplified example, if you have a small unexploited lake and wish to begin a fishery, which is likely to alter the ecosystem more?–a fishery directed at a single species high in the food chain?–or a fishery that removes some proportion of all species present?

Table 2. Estimated average bycatch (in numbers of individuals unless stated) per 10,000 sets based on eastern tropical Pacific data from 1993-1998. (Sample sizes: n = 49,066 dolphin sets, n = 31,456 school sets, n = 23,870 log sets)

Bycatch	Dolphin sets	School sets	Log sets
Billfishes			
Sailfish	654	932	116
Swordfish	11	26	29
Black marlin	65	173	1,290
Striped marlin	86	189	313
Blue marlin	67	211	1,684
Shortbill spearfish	9	3	23
Unidentified billfish	108	20	119
Unid.entified marlin	35	48	234
Large bony fishes			
Mahi mahi	347	24,720	1,202,022
Wahoo	597	3,195	646,734
Rainbow runner	9	4,998	107,568
Yellowtail	2,297	60,838	92,563
Other large fish	45	49,908	57,766
Sharks and rays			
Silky shark	4,175	15,644	66,438
Whitetip shark	335	441	8,835
Hammerhead shark	160	1,141	1,883
Mantaray	614	4,050	260
Stingray	357	1,184	287
Other sharks	491	1,300	8,346
Unidentified sharks	928	1,606	12,200
Sea turtles			
Hawksbill turtle	0	1	1
Olive ridley	30	56	117
Loggerhead turtle	1	5	2
Green/black turtle	1	11	19
Unidentified turtle	12	19	38
Tuna discards (MT)			
Yellowfin	1,059	1,483	8,078
Bigeye	0	59	8,610
Skipjack	145	2,105	42,575
Other species	7	940	5,880

3.5 Action

3.5.1 Bycatch Reduction

On the assumption that cetacean bycatches are generally not a 'Good Thing' (either from the point of view of the cetacean population involved or the fisherman, for the reasons suggested earlier), in this section we will consider some of the practical measures that have been proposed to reduce cetacean bycatches. Despite our general lack of knowledge, one thing is clear. There is no single simple cause or solution to the incidental capture of cetaceans in fishing gear. Each case should be evaluated in the light of local conditions.

As suggested by Hall (1995), the bycatch can be considered as the product of the total effort and the bycatch per unit of effort. Reducing either or both of these simultaneously will reduce the bycatch.

Perhaps the most obvious way of reducing effort is to limit or ban effort by national or international regulations. And perhaps the best example of this was the ban on the high seas driftnet fishery from 1993, adopted by the UN General Assembly (Donovan, 1994). However, if such measures are to be successful, they must be perceived to be fair and to be enforceable. Complete bans should be seen as a last resort.

Another approach is to set a limit on the bycatch level, and then close the fishery when that level is reached. An advantage of this approach, provided again that it is enforceable, is that it encourages fishermen to develop ways to reduce the bycatch per unit effort (see below).

Both of these approaches require legislative action, but, whilst it is relatively easy to pass legislation and even to stress the need for enforcement, actually enforcing the law and monitoring the fishery can be logistically difficult, particularly in the case of artisanal fisheries with large numbers of small vessels (*e.g.* see Donovan, 1994; Van Waerebeek and Reyes, 1994, for a discussion of the situation in Peru).

There are a number of potential ways in which bycatch per unit effort can be reduced as discussed below.

3.5.1.1 Change in Fishing Practice/Modified Gear

This has proved particularly successful in the tuna-dolphin fishery, where careful fishing practice (the 'backdown' procedure) and modified gear (the Medina panel) have reduced bycatches dramatically to levels that should allow the populations of dolphins to increase (Joseph, 1994; Hall, 1998). There are encouraging signs that passive and acoustic modifications will be of value at least in some fisheries (*e.g.* Goodson *et al.*, 1994; Lien, 1994; Kraus *et al.*, 1995) and situations, although further work is needed to examine apparent differences between areas and seasons (IWC, 1997).

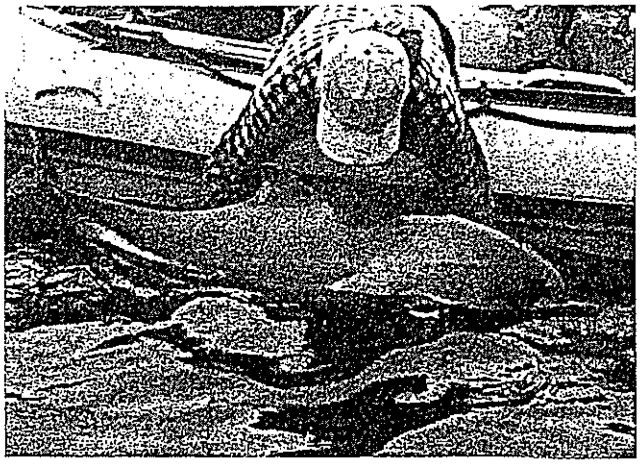

Figure 4. Harbour porpoise being released from fishing gear in the Bay of Fundy. Unfortunately only a small percentage of bycaught animals can be saved in this way. (Photo: J. Wang)

Modification of gear is one of many areas where co-operation between biologists, fishermen, and gear technologists is essential. For example, knowledge of the acoustic capabilities of the cetacean species involved is essential for determining suitable and effective gear modifications. Early efforts in this regard were hampered by general attempts to 'improve the detectability of nets' without reference to the behaviour and physiology of the species involved. An understanding of the 'biology of entrapment' is an important component in developing methods of bycatch reduction (IWC, 1994b). This information can be used to avoid setting nets at certain times of the day or year (*e.g.* sundown sets are prohibited in the tuna purse-seine fishery - Hall, 1995) or in certain localised geographical areas (*e.g.* see Gearin *et al.*, 1994). In certain fisheries for particular species (*e.g.* North Atlantic harbour porpoises), acoustic deterrents ('pingers') attached to nets have been shown to be effective in reducing bycatch levels, at least in the short-term (Fig. 5). This has been reviewed by the IWC Scientific Committee (IWC, 2000a).

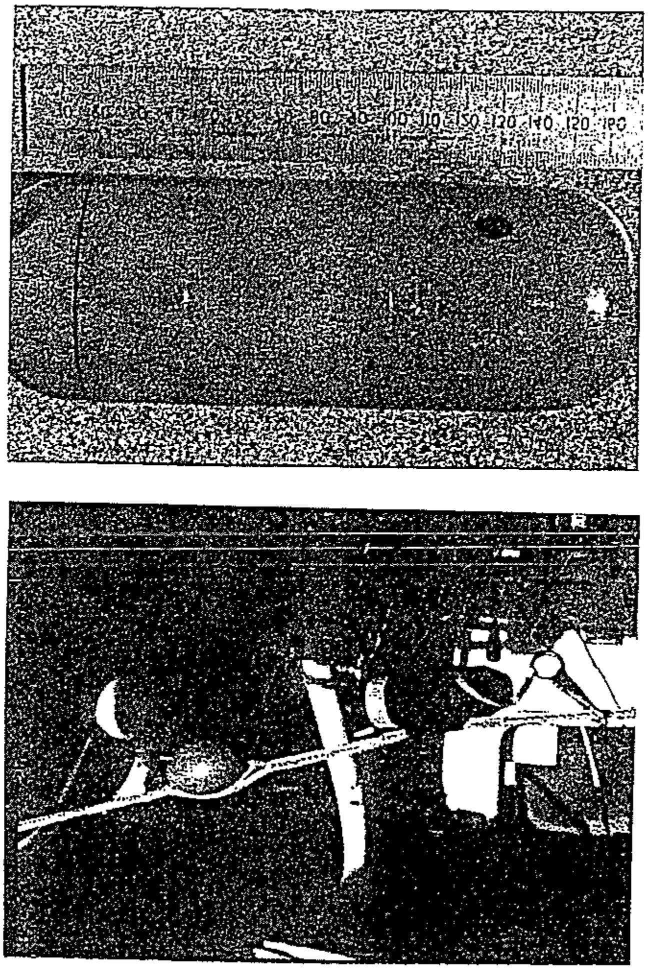

Figure 5. Pingers have been employed very effectively in a number of North Atlantic gillnet fisheries to reduce porpoise bycatch. (Photos: P.G.H. Evans/N. Tregenza and F. Larsen)

3.5.1.2 Alternative Ways of Fishing

This involves completely changing the fishing method rather than modifying it (*e.g.* switching from gillnets to longlines - Corcuera, 1994). It has potential in some areas, but the effect of such changes must be evaluated and then monitored for several reasons: (a) as we have seen, reducing bycatches of cetaceans may result in increased bycatches of other, potentially more vulnerable, species; (b) the new methods may result in directed catches of cetaceans for bait (*e.g.* Félix and Samaniego, 1994; Van Waerebeek and Reyes, 1994); and/or (c) the new method may turn out to also result in incidental catches or, in the case of cetaceans stealing fish from longlines, result in direct kills by the fishermen.

An additional consideration that cannot be stressed too strongly is that for any bycatch reduction/elimination measures to be successful, fishing communities must be made aware of the reasons behind calls for a reduction in bycatches, and become involved in the process of finding solutions. The co-operation of fishing communities makes it much more likely that an equitable and observed system can be developed to mitigate problems. Orders from 'on high' (either at national or international levels) without involving the affected communities can often be counter-productive.

3.5.2 Management Procedures

Throughout this paper, we have suggested that in an ideal world, the cetacean bycatch issue should be approached in a similar manner to the development of the IWC's RMP. Indeed, for large baleen whales, the RMP may indeed be appropriate, even for populations not subject to commercial whaling.

The important features of such an approach (Donovan, 1995) are:

a) scientists must accept their limitations and build the inevitable uncertainty explicitly into account;

b) data and analysis requirements must be realistic and specified-resource users must recognise that unless requirements are met, they will not be able to utilise the resource;

c) procedures should be rigorously tested using computer simulations;

d) objectives must be explicitly stated and assigned priorities;

e) a feedback mechanism to monitor the performance of the resource should be incorporated.

This approach, whilst achievable in the relatively straightforward situation of direct exploitation of baleen whales by commercial whaling operations from developed countries, still required a large commitment of effort and resources. Whilst the principles remain good, it must be recognised that the cetacean bycatch problem is vastly more complex, even simply in terms of the number of species. When the fact that artisanal fisheries in developing countries involving large numbers of vessels represent a major part of the problem is taken into account, it is clear that it will not be possible to develop fully fledged management procedures applicable to the wide variety of situations that exists throughout the world. For these countries and fisheries, it is vital that governmental and non-governmental organisations from the developed world offer financial and logistical support for the necessary scientific work to be carried out, to at least identify priority fisheries that require attention (Donovan, 1994). However, for commercial fisheries in developed countries, it should be possible provided that the resources are made available.

At present, there has been only one procedure adopted that attempted to follow RMP principles and that is the PBR approach developed in the US referred to earlier (Wade, 1998). As noted earlier, the goal of this approach is to maintain populations at levels above their Maximum Net Productivity Level, assumed to lie between 50-70% of carrying capacity. It uses information on abundance, bycatch, and population growth rates to estimate a parameter known as the Potential Biological Removal (PBR) level. It accounts for precision of the abundance estimate in an explicit fashion, and bias and precision in other factors in an indirect manner. Bycatch levels that consistently exceed the PBR value are assumed to lead to a depletion of the stock.

The PBR is defined to be the product of three factors:

$$N_{\min} \cdot 0.5 r_{\max} . F_r \qquad \text{Eq. 1}$$

where $N_{\min}$ is a minimum population estimate for the stock, $r_{\max}$ is the maximum theoretical or estimated rate of increase of the stock at a small size, and F_r is a recovery factor, whose value lies between 0.1 and 1.0. In practice, $r_{\max}$ is either the maximum observed population growth rate for a stock or a default value (0.04 for cetaceans) if no specific estimate is available.

The procedure was tested using computer simulations similar to those used in the RMP (Wade, 1998). It is clearly an advance over previous *ad hoc* approaches, although there are some concerns that: (a) it may not adequately take into account all of the associated uncertainty, particularly with respect to case specific examples (IWC, 1997); (b) there is no clear scientific basis to maintain the populations at the Maximum Net Productivity Level, a concept developed for harvesting resources, rather than for ecosystem management; and (c) the level of caution is so high that in some fisheries, the take of one individual every several years would require management actions.

The level of caution used in the implementation of the PBR concept demonstrates clearly the high value placed on these species. It also illustrates the difficulties in separating the politico-ethical considerations from the science, because the consequences of applying extreme caution are very close to the zero mortality goal discussed earlier. Another factor to consider is that when the PBR value is high (*e.g.* 3,097 short beaked common dolphins - Barlow *et al.*, 1997), despite the fact that it is cautious, it may still "sound" too high to a large sector of the public. Management, which is the intersection between science and reality, reflects these perceptions, and deviates from its scientific basis to include them.

An important potential advance in developing a scientific management approach has taken place as a result of co-operation between ASCOBANS and the IWC Scientific Committee. It is to be hoped that this co-operation will result in an effective management scheme for harbour porpoises in the northeastern Atlantic (*e.g.* see Reijnders and Donovan, 1999; IWC, 1999; IWC, 2000b).

4. CONCLUSIONS

Bycatches result from a complex combination of environmental, ecological, biological, and gear factors as well as the motivation and ability of the fishermen themselves. Identifying these factors and their relative priority is of major importance in attempting to develop solutions to cetacean bycatch problems. Research programmes should be designed to allow management actions to be based on established scientific facts. Observer programmes should be designed to assist in the search for solutions as well as assessing bycatch levels and compliance with regulations. Wherever possible, regulatory actions should be part of an overall management scheme that encompasses both science and management. The *ad hoc* approach to management should become a thing of the past in the management of natural resources.

It must also be remembered that there is no universal solution to the incidental capture of cetaceans in fishing gear. Each case will need to be evaluated in the light of local conditions, whilst taking into account experience elsewhere.

The experience of the eastern Pacific tuna fishery shows that under certain circumstances bycatch problems can be tackled successfully, but that a number of conditions must be met (Hall, 1996). Many of these are of more general relevance and they are summarised below:

• Recognition by nations and industries/fishing communities that a problem exists and a commitment to its solution.

• Continued and constructive interaction among fishing communities/ industry, scientists, managers and environmentalists, based on the objective of finding a solution that achieves the desired conservation goals, while allowing the continuation of the fishery. This implies that the demands of the extreme fractions of all sectors involved will, most likely, not be met.

• The development of a scientific programme to understand why the bycatches happen, and the conditions that affect their level. A critical part of this programme is the flow of information to the fishermen concerning all factors affecting incidental mortality. It should also inform managers and the public of the full ecological consequences of any alternative proposal put forward to mitigate or eliminate the problem (*e.g.* new type of gear, area closure, *etc.*).

• The development of clear objectives with regards to the mitigation of impacts, with a schedule dictated by a realistic approach to the problem. Where appropriate, they should be defined within an international context and with the participation of all nations involved.

• All concerned should work towards the objectives in an iterative manner via realistic short-term goals that will encourage fishermen to achieve them.

• The development of a system of incentives, from the level of the nation down to that of the individual fisherman, with an emphasis on individual responsibility whenever possible. The system should serve as a selective force, encouraging the fishermen to develop gear, techniques, and decision-making skills that would allow them to continue using the resources while at the same time reducing the ecological impacts of their activity.

• The development of a fair system of regulations, based on scientific findings and statistical analyses. This should be done in close consultation with the fishermen. The system should allow for creativity and experimentation, and avoid micromanagement. For instance, if individual vessel limits are imposed on the participants, then the operational details that may affect mortality rates should be left to the discretion of the fishermen.

• The development of observer programmes designed to determine the factors that cause, or increase, incidental mortality as well as the estimation of bycatch numbers.

• Continued monitoring for unforeseen developments after an apparent solution has been found.

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REFERENCES

Anganuzzi, A.A., Buckland, S.T. and Cattanach, K.L. (1993) Relative abundance of dolphins associated with tuna in the eastern Pacific ocean: analysis of 1991 data. *Report of the International Whaling Commission*, 43, 459-465.

Anonymous. (1989) Whales freed in the Arctic. *Pollution Bulletin*, 20 (1), 8.

ASCOBANS. (1997) *Second Meeting of Parties to ASCOBANS: 17-19 November 1997, Bonn, Germany*, p. 43. ASCOBANS. 67pp.

Barlow, J., Forney, K.A., Hill, P.S., Brownell, R.L.J., Carretta, J.V., DeMaster, D.P., Julian, F., Lowry, S., Ragen, T. and Reeves, R.R. (1997) U.S. Pacific marine mammal stock assessments: 1996. *NOAA Technical Memorandum NMFS-SWFSC*, 248, 1-223.

Barstow, R. (1990) Beyond whale species survival–peaceful coexistence and mutual enrichment as a basis for human-cetacean relations. *Mammal Review*, 20 (1), 65-73.

Berrow, S.D., Tregenza, N.J.C. and Hammond, P.S. (1994) Marine mammal bycatch on the Celtic Shelf., European Commission Document: DG XIV/C/1 Study Contract 92/3503.

Bjørge, A., Brownell, R.L.Jr., Donovan, G.P. and Perrin, W.F. (1994) Significant direct and incidental catches of small cetaceans. A report by the Scientific Committee of the International Whaling Commission to the United Nations Conference on Environment and Development (UNCED). *Report of the International Whaling Commission* (special issue 15), 75-130.

Bravington, M.V. and Bisack, K.D. (1996) Estimates of harbor porpoise bycatch in the Gulf of Maine sink gillnet fishery, 1990-1993. *Report of the International Whaling Commission*, 46, 567-574.

Corcuera, J. (1994) Incidental mortality of franciscanas in Argentine waters: the threat of small fishing camps. *Reports of the International Whaling Commission* (special issue 15), 291-294.

Dizon, A.E. and Perrin, W.F. (1995) Report of a Workshop on analysis of genetic data to address problems of stock identity as related to management. Paper SC/47/Rep3 presented to the IWC Scientific Committee, May 1995 (unpublished). 66pp.

Donovan, G.P. (1991) A review of IWC stock boundaries. *Report of the International Whaling Commission* (special issue 13), 39-68.

Donovan, G.P. (1992) The International Whaling Commission: Given its past, does it have a future? In: *Symposium «Whales: Biology-Threats-Conservation»* (Ed. by J.J. Symoens). Royal Academy of Overseas Sciences, Brussels, Belgium. 261pp.

Donovan, G.P. (1994) Developments on issues relating to the incidental catches of cetaceans since 1992 and the UNCED conference. *Report of the International Whaling Commission* (special issue 15), 609-613.

Donovan, G.P. (1995) The International Whaling Commission and the Revised Management Procedure. In: *Additional Essays on Whales and Man* (Ed. by E. Hallenstvedt and G. Blichfeldt). High North Alliance, Lofoten, Norway.

Félix, F. and Samaniego, J. (1994) Incidental catches of small cetaceans in the artisanal fisheries of Ecuador. *Report of the International Whaling Commission* (special issue 15), 475-480.

Forney, K.A., Barlow, J. and Carretta, J.V. (1995) The abundance of cetaceans in California waters. 2. Aerial surveys in winter and spring of 1991 and 1992. *Fishery Bulletin*, 93 (1), 15-26.

Fraker, M.A. (1989) A rescue that moved the world. *Oceanus*, 32 (1), 96-102.

Francis, R.C., Awbrey, F.T., Goudey, C.L., Hall, M.A., King, M.H., Norris, K.S., Orbach, M.K., Payne, R. and Pikitch, E. (1992) *Dolphins and the Tuna Industry*. National Academy Press, Washington,DC. pp. xii, 176.

Gearin, P.J., Melin, S.R., DeLong, R.L., Kajimura, H. and Johnson, M.A. (1994) Harbor porpoise interactions with a chinook salmon set-net fishery in Washington State. *Report of the International Whaling Commission* (special issue 15), 427-438.

Gerrodette, T. (1987) A power analysis for detecting trends. *Ecology*, 68 (5), 1,364-1,372.

Goodson, A.D., Klinowska, M. and Bloom, P.R.S. (1994) Enhancing the acoustic detectability of gillnets. *Report of the International Whaling Commission* (special issue 15), 585-595.

Hall, M.A. (1995) Strategies to reduce the incidental capture of marine mammals and other species in fisheries. In: *Whales, seals, fish and man: Proceedings of the International Symposium on the Biology of marine mammals in the North East Atlantic, Tromsø, Norway, 29 November-1 December 1994* (Ed. by A.S. Blix, L. Walløe and O. Ülltang) *Developments in Marine Biology*. 4. Elsevier, Amsterdam.

Hall, M.A. (1996) On bycatches. *Reviews in Fish Biology and Fisheries*, 6, 319-352.

Hall, M.A. (1998) An ecological view of the tuna dolphin problem: impacts and trade-offs. *Reviews in Fish Biology and Fisheries*, 8, 1-34.

Hall, M.A. and Lennert, C. (1994) Incidental mortality of dolphins in the eastern Pacific Ocean tuna fishery in 1992. *Report of the International Whaling Commission*, 44, 349-351.

Hall, M.A. and Lennert, C. (1997) Incidental mortality of dolphins in the eastern Pacific Ocean tuna fishery in 1995, *Report of the International Whaling Commission*, 47, 641-644.

Hammond, P.S., Benke, H., Berggren, P., Borchers, D.L., Buckland, S.T., Collet, A., Heide-Jorgensen, M.P., Heimlich-Boran, S., Hiby, A.R., Leopold, M.F. and Oien, N. (1995) Distribution and abundance of the harbour porpoise and other small cetaceans in the North Sea and adjacent waters., Final Report to the European Commission under contract LIFE 92-2/UK/O27. 242pp.

Hill, P.S., Jackson, A. and Gerrodette, T. (1990) Report of a marine mammal survey of the eastern tropical Pacific aboard the research vessel *McArthur* July 29-December 7, 1989., U.S. Dep. Commerc., NOAA-TM-NMFS-SWFC. 119pp.

International Whaling Commission. (1991) Report of the Workshop on the Genetic Analysis of Cetacean Populations, La Jolla, 27-29 September 1989. *Report of the International Whaling Commission* (special issue 13), 3-21.

International Whaling Commission. (1994a) Report of the Scientific Committee, Annex H. The Revised Management Procedure (RMP) for Baleen Whales. *Report of the International Whaling Commission*, 44, 145-152.

International Whaling Commission. (1994b) Report of the Workshop on mortality of cetaceans in passive fishing nets and traps, Annex G. List of cetacean species. *Report of the International Whaling Commission* (special issue 15), 70-71.

International Whaling Commission. (1996) Report of the Scientific Committee, Annex H. Report of the sub-committee on small cetaceans. *Report of the International Whaling Commission*, 46, 160-179.

International Whaling Commission. (1997) Report of the Scientific Committee, Annex H. Report of the sub-committee on small cetaceans. *Report of the International Whaling Commission*, 47, 169-191.

International Whaling Commission. (1999) Report of the Scientific Committee. Annex I. Report of the Standing Sub-Committee on Small Cetaceans. *Journal of Cetacean Research and Management (Supplement)*, 1, 211-225.

International Whaling Commission. (2000a) Report of the Scientific Committee. Annex I. Report of the sub-committee on small cetaceans. *Journal of Cetacean Research and Management (Supplement)*, 2, 235-263.

International Whaling Commission. (2000b) Report of the Scientific Committee. Annex O. Report of the IWC-ASCOBANS Working Group on harbour porpoises. *Journal of Cetacean Research and Management (Supplement)*, 2, 297-305.

Joseph, J. (1994) The tuna-dolphin controversy in the eastern Pacific Ocean: biological, economic, and political impacts. *Ocean Development and International Law*, 25, 1-30.

Kraus, S.D. (1990) Rates and potential causes of mortality in North Atlantic right whales (*Eubalaena glacialis*). *Marine Mammal Science*, 6 (4), 278-291.

Kraus, S., Read, A., Anderson, E., Baldwin, K., Solow, A., Spradlin, T. and Williamson, J. (1995) A field test of the use of acoustic alarms to reduce mortality of harbor porpoises in gillnets. Draft Final Report available from New England Aquarium, Central Wharf, Boston, MA 02110.

Lennert, C. and Hall, M.A. (1995) Estimates of incidental mortality of dolphins in the eastern Pacific Ocean tuna fishery in 1993. *Report of the International Whaling Commission*, 45, 387-390.

Lennert, C. and Hall, M.A. (1996) Estimates of incidental mortality of dolphins in the eastern Pacific Ocean tuna fishery in 1994. *Report of the International Whaling Commission*, 46, 555-558.

Lennert, C., Kruse, S., Beeson, M. and Barlow, J. (1994) Estimates of incidental marine mammal bycatch in California gillnet fisheries for July through December, 1990. *Report of the International Whaling Commission* (special issue 15, 449-463.

Lien, J. (1994) Entrapments of large cetaceans in passive inshore fishing gear in Newfoundland and Labrador (1979-1990). *Report of the International Whaling Commission* (special issue 15), 149-157.

Lien, J., Stenson, G.B., Carver, S. and Chardine, J. (1994) How many did you catch? The effect of methodology on bycatch reports obtained from fishermen. *Report of the International Whaling Commission* (special issue 15), 535-540.

Lowry, N. and Teilmann, J. (1994) Bycatch and bycatch reduction of the harbour porpoise (*Phocoena phocoena*) in Danish waters. *Report of the International Whaling Commission* (special issue 15), 203-209.

Mangel, M., Talbot, L.M., Meffe, G.K., Agardy, M.T., Alverson, D.L., Barlow, J., Botkin, D.B., Budowski, G., Clark, T., Cooke, J., Crozier, R.H., Dayton, P.K., Elder, D.L., Fowler, C.W., Funtowicz, S., Giske, J., Hofman, R.J., Holt, S.J., Kellert, S.R., Kimball, L.A., Ludwig, D., Magnusson, K., Malayang III, B.S., Mann, C., Norse, E.A., Northridge, S.P., Perrin, W.F., Perrings, C., Peterman, R.M., Rabb, G.B., Regier, H.A., Reynolds III, J.E., Sherman, K., Sissenwine, M.P., Smith, T.D., Starfield, A., Taylor, R.J., Tillman, M.F., Toft, C., Twiss Jr, J.R., Wilen, J. and Young, T.P. (1996) Principles for the conservation of wild living resources. *Ecological Applications*, 6 (2), 338-362.

Mitchell, E.D. (1975a) *IUCN Monograph No. 3. Porpoise, Dolphin, and Small Whale Fisheries of the World: Status and Problems*. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland. 129pp.

Mitchell, E. (1975b) Report of the Meeting on Smaller Cetaceans, Montreal April 1-11, 1974. *Journal of the Fisheries Research Board of Cananda*, 32 (7), 889-983.

Northridge, S.P. (1996) *JNCC Report.* A review of marine mammal bycatch observer schemes with recommendations for best practice. *Joint Nature Conservation Committee, Aberdeen, UK.* 42pp.

Perrin, W.F. (1968) The porpoise and the tuna. *Sea Frontiers*, 14 (3), 166-174.

Perrin, W.F. (1969) Using porpoise to catch tuna. *World Fishing*, 18 (6), 4 unnumbered.

Perrin, W.F. and Brownell, R.L. (1994) A brief review of stock identity in small marine cetaceans in relation to assessment of driftnet mortality in the North Pacific. *Report of the International Whaling Commission* (special issue 15), 393-401.

Read, A.J., Van Waerebeek, K., Reyes, J.C., McKinnon, J.S. and Lehman, L.C. (1988) The exploitation of small cetaceans in coastal Peru. *Biological Conservation*, 46, 53-70.

Reijnders, P.J.H. and Donovan, G. (1999) Report of the Scientific Committee. Annex L. Furthering Scientific Cooperation Between ASCOBANS and the IWC. *Journal of Cetacean Research and Management (Supplement)*, 1, 245.

Reilly, S.B. and Barlow, J. (1986) Rates of increase in dolphin population size. *Fishery Bulletin*, 84 (3), 527-533.

Rugh, D.J., Breiwick, J.M., Dahlheim, M.E. and Boucher, G.C. (1993) A comparison of independent, concurrent sighting records from a shore-based count of gray whales. *Wildlife Society Bulletin*, 21 (4), 427-437.

Scheffer, V.B. (1989) How much is a whale's life worth, anyway? *Oceanus*, 32 (1), 109-111.

Van Waerebeek, K. and Reyes, J.C. (1994) Post-ban small cetacean takes off Peru: A review. *Report of the International Whaling Commission* (special issue 15), 503-520.

Vidal, O. (1995) Population biology and incidental mortality of the vaquita, *Phocoena sinus*. *Report of the International Whaling Commission* (special issue 16), 247-272.

Vinther, M. (1999) Bycatches of harbour porpoises (*Phocoena phocoena*L) in Danish set-net fisheries. *Journal of Cetacean Research and Management*, 1 (2), 123-136.

Wade, P.R. (1998) Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. *Marine Mammal Science*, 14, 1-37.

NOTE ADDED IN PROOF

Since the completion of this chapter, a number of relevant papers have been published to which we would like to draw the attention of the reader.

Aguilar, A. (2000) Population biology, conservation threats and status of Mediterranean striped dolphins (*Stenella coeruleoalba*). *Journal of Cetacean Research and Management*, 2, 17-26.

Crespo, E.A., Alonso, M.K., Dans, S.L., García, N.A., Pedraza, S.N., Coscarella, M. and González, R. (2000) Incidental catches of dolphins in mid-water trawls for Argentine anchovy (*Engraulis anchoita*) off the Argentine shelf. *Journal of Cetacean Research and Management*, 2, 11-16.

Gearin, P.J., Gosho, M.E., Laake, J., Cooke, L., Delong, R.L. and Hughes, K.M. (2000) Experimental testing of acoustic alarms (pingers) to reduce bycatch of harbour porpoise, *Phocoena phocoena*, in the state of Washington. *Journal of Cetacean Research and Management*, 2, 1-10.

Murray, K.T., Read, A.J. and Solow, A.R. (2000) The use of time/area closures to reduce bycatches of harbour porpoises: lessons from the Gulf of Maine sink gillnet fishery. *Journal of Cetacean Research and Management*, 2, 135-141.

Rojas-Bracho, l. and Taylor,B.L. (1999) Risk factors affecting the vaquita (*Phocoena sinus*). *Marine Mammal Science*, 15, 974-989.

Tolley, K.A., Rosel, P.E., Walton, M., Bjørge, A. and Øien, N. (1999) Genetic population structure of harbour porpoises (*Phocoena phocoena*) in the North Sea and Norwegian waters. *Journal of Cetacean Research and Management*, 1, 265-274.

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