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CETACEANS: CAN WE MANAGE TO CONSERVE THEM?

THE ROLE OF LONG-TERM MONITORING

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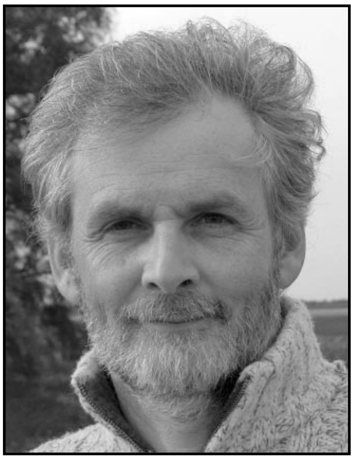

INTRODUCTION

The order Cetacea comprises the whales, dolphins and porpoises. There are over 75 species, traditionally divided into the 'great' whales (see Table 1) and 'small cetaceans'[1]. Confusingly perhaps, small cetaceans include species called whales (e.g. killer whales, *Orcinus orca*) as well as dolphins (e.g. the white-beaked dolphin, *Lagenorhyncus albirostris*) and porpoises (e.g. the harbour porpoise, *Phocoena phocoena*). Cetaceans encompass a wide range of social structures and habitats.

Cetaceans are completely aquatic and are not easy to study for a number of reasons. As mammals, they need to return to the surface to breathe ('blow'), where they are briefly visible – the rest of the time they are out of sight. Dive times vary considerably by species and behaviour and 'long dives' can vary from up to 1–1.5hours (e.g. sperm whales, *Physeter macrocephalus*; northern bottlenose whales, *Hyperoodon ampullatus*) to 2–3 minutes (e.g. short-beaked common dolphins, *Delphinus delphis*; North Atlantic

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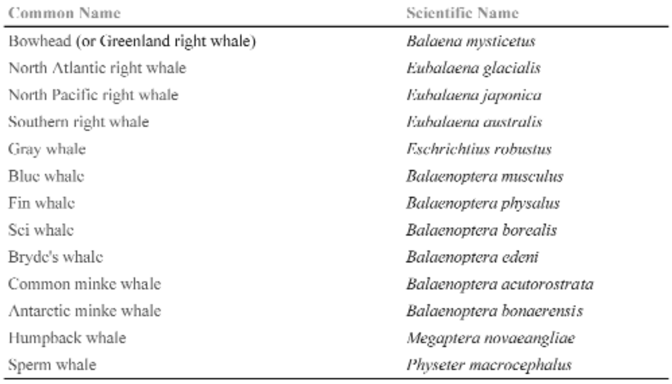
[1] A full list of common and scientific names can be found at http://www.iwcoffice.org

right whales, *Eubalaena glacialis*). Typically animals blow several times after a long dive. However, even seeing cetaceans when they are present can be difficult, particularly in unfavourable weather conditions.

An additional difficulty, particularly for the migratory great whales, is that they can have extremely large ranges. For example, the eastern North Pacific population of gray whales (*Eschrichtius robustus*) migrates between summer feeding grounds in the Arctic to winter breeding grounds off Baja California, Mexico – some 7,500–10,000 km. Other baleen whale species and the sperm whale exhibit similar long migrations.

Table 1: The 'Great' Whales



Common Name	Scientific Name
Bowhead (or Greenland right whale)	*Balaena mysticetus*
North Atlantic right whale	*Eubalaena glacialis*
North Pacific right whale	*Eubalaena japonica*
Southern right whale	*Eubalaena australis*
Gray whale	*Eschrichtius robustus*
Blue whale	*Balaenoptera musculus*
Fin whale	*Balaenoptera physalus*
Sei whale	*Balaenoptera borealis*
Bryde's whale	*Balaenoptera edeni*
Common minke whale	*Balaenoptera acutorostrata*
Antarctic minke whale	*Balaenoptera bonaerensis*
Humpback whale	*Megaptera novaeangliae*
Sperm whale	*Physeter macrocephalus*

Management and monitoring

Whether we like it or not, humans have directly and indirectly influenced the environment of almost all species to a greater or lesser extent. Management can be said to be our attempt to limit and control the effects of humans on our environment, whilst obtaining the maximum 'benefit[2]' from that environment. In fact, everything we do (including, and perhaps especially, doing nothing) can be said to be a management decision. Given that, I believe that we have an obligation to try to ensure that we follow a wise and long-term management strategy. Although it might seem a semantic point, it should be remembered that we cannot 'manage cetaceans' – we can only manage human activities that may have an impact on cetaceans.

Human impacts on cetacean populations can be broadly classified into two groups: those that result in instantaneous or near-instantaneous death (e.g. direct hunting, incidental catches in fishing gear, ship strikes) and those that whilst not resulting in rapid death, affect the overall 'fitness' of the population (e.g. habitat related issues including pollution, overfishing of prey species, habitat loss). Whilst the impact of the first group will be clearly significant at the level of an individual, it may not be significant at the population level, depending on the number involved relative to the

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[2] 'Benefit' here can mean many things, ranging from direct exploitation to preserving pristine environment and abundance for future generation

total abundance. However, factors associated with the second group may not appear significant at the level of an individual but may be significant at the management stock level (e.g. individual females may appear healthy but if pollutant-induced physiological changes hinder their ability to reproduce, this may have long-term consequences for a population).

The first and most essential step in any management process is to *define the objectives* with respect to the status of the cetacean population(s) concerned. The second is to *assess the status* of those populations in the light of those objectives. The third is *determine management measures* that we think will ensure that those objectives are met and will continue to be met (in other words to identify and where necessary mitigate possible threats). The final and equally important step is *to monitor* the populations to make sure that the management measures are indeed working. It is important to note that the monitoring stage is not an optional extra – in an uncertain world it is essential that however perfect we think our management measures might be, we check to ensure that they are indeed working as we expect them to. Thus monitoring must be seen as an integral part of management, not an optional extra.

The purpose of this paper is to give a perspective on the need for long-term monitoring of cetaceans in a management context and how this might be achieved. Although scientific in nature, this is not a formal scientific paper. I have therefore not included references in the text but rather included a bibliography of useful reading at the end.

WHAT IS A MANAGEMENT PROCEDURE?

The concept of the management procedure approach was originally developed by the International Whaling Commission (IWC) Scientific Committee in the context of the management of direct catches (both aboriginal and commercial). However, the general approach is equally valid for other situations such as the management of incidental catches in fishing gear, the management of a reserve or protected area etc. In summary, the management procedure approach for direct or indirect catches is as follows (and see Figure 1):

1) agree management and conservation objectives, state them explicitly and assign them priorities;
2) agree and specify realistic data and analysis requirements;
3) accept scientific and practical limitations and take the inevitable uncertainty explicitly into account by determining a precautionary method of calculating catch limits involving rigorous testing via computer simulations for both quantitatively and qualitatively known sources of uncertainty;
4) after steps (1) – (3), adopt a management procedure that incorporates the process right through from data requirements and analysis to determination of catch limits (or other management advice);
5) include feedback monitoring to ensure that the agreed objectives are being met.

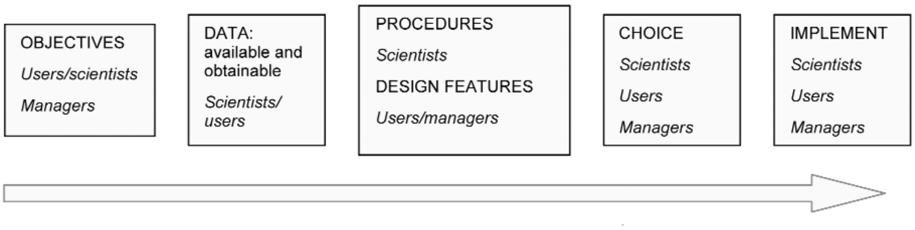

Figure 1: The steps to a management procedure.

An important feature of the process is that it should include all interested parties (stakeholders): scientists, managers and 'users'[3].

The advantages of such an approach are clear; everybody understands and agrees what are:

1) the conservation and use objectives;
2) the data requirements;
3) the data analysis methods.

This removes the problems associated in the past with *ad hoc* assessment methods that could sometimes lead to greatly fluctuating scientific advice on appropriate catch levels from year to year. Such procedures are designed for long-term (decades) management. This allows *inter alia* appropriate long-term research planning. The users, managers, scientists and indeed the exploited populations, all therefore benefit from the management procedure approach.

In fact the process for developing a good monitoring programme alone (or within an overall management procedure) is very similar to that for developing the procedure itself (Figure 2). I will concentrate on this for the remainder of the paper.

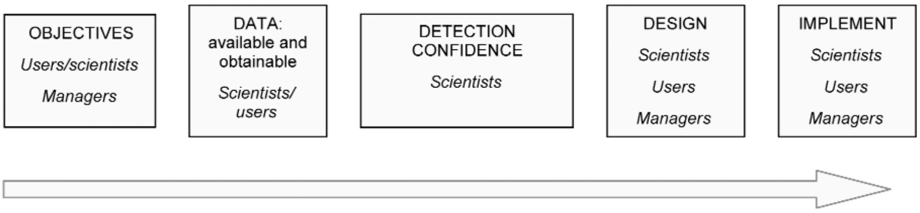

Figure 2: The steps to a monitoring programme.

OBJECTIVES

In attempting to develop a resource management or monitoring scheme, the most important initial step is to define management objectives. In effect, this means deciding

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[3] By 'users' here, I include all interested parties – this may include whalers, fishermen, local communities, non-governmental organisations etc.

what we want to achieve by management and how we judge if it 'works'. It is relatively easy to arrive at 'extreme' objectives for the management of any natural resource:

- that the resource is not driven to extinction;
- that the maximum sustainable harvest is achieved.

It quickly becomes apparent however that within these two headings (state of the resource/needs of the user):

1) there are a wide number of options (e.g. see Table 2);
2) there has to be some trade-off between objectives.

For example the lowest risk of extinction occurs when there is no harvesting – this option, however, results in no chance at all of achieving the objective of the maximum sustainable harvest.

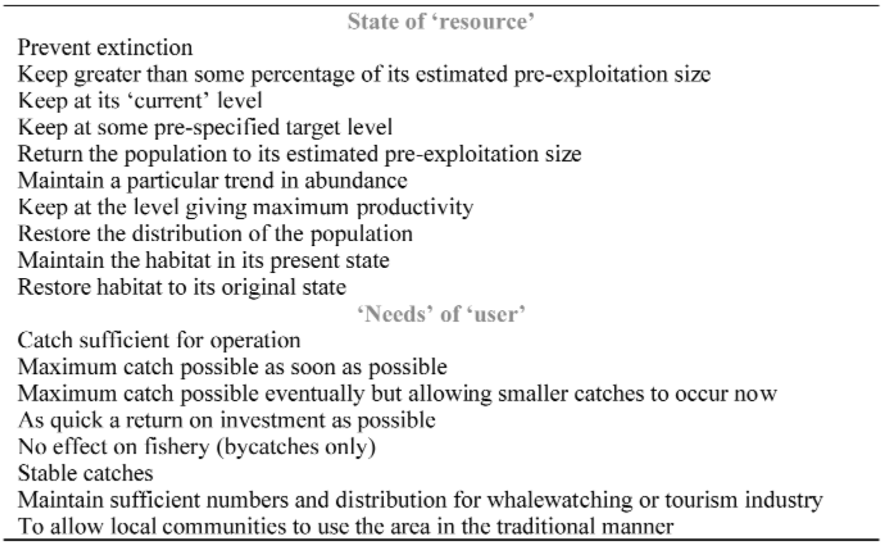
For cases where there is no desire to harvest a population, the objectives may be different but the principles remain the same. For example two objectives might be:

- maintain the population[4] at its present level;
- allow local communities to use the area in the traditional manner.

If it is found that the traditional activities (e.g. fishing) are a factor in the decline of the population, then again there will be a conflict between the objectives.

The setting of objectives and the relative weight given to those objectives (the trade-offs) ultimately require political rather than scientific decisions, although the scientist clearly has an obligation to explain the implications of any decisions that might be

Table 2: A few examples of possible management objectives



State of ‘resource’
Prevent extinction
Keep greater than some percentage of its estimated pre-exploitation size
Keep at its ‘current’ level
Keep at some pre-specified target level
Return the population to its estimated pre-exploitation size
Maintain a particular trend in abundance
Keep at the level giving maximum productivity
Restore the distribution of the population
Maintain the habitat in its present state
Restore habitat to its original state
‘Needs’ of ‘user’
Catch sufficient for operation
Maximum catch possible as soon as possible
Maximum catch possible eventually but allowing smaller catches to occur now
As quick a return on investment as possible
No effect on fishery (bycatches only)
Stable catches
Maintain sufficient numbers and distribution for whalewatching or tourism industry
To allow local communities to use the area in the traditional manner

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[4] The question of what comprises a 'population', whilst extremely important, is beyond the scope of this paper.

taken to the politicians, for example by providing them with a range of specific options. If management is to be successful then it is extremely important that all interested parties (the 'stakeholders' as they are becoming known in the literature) are involved in the discussions leading to the setting of those objectives. There is a clear inter-relationship between objectives and monitoring – it is essential that any objectives related to the state of the resource are discussed in the light of our ability to be able to monitor whether we are meeting them.

CHARACTERISING STATUS

In this section I will briefly summarise some of the methods available to characterise the status of a cetacean population. The most common of these involves estimating the absolute abundance (and/or relative abundance) of the population and how that changes with time (i.e. trends in abundance/relative abundance). Which of these methods is appropriate will depend on the objectives set earlier.

Sightings methods

Dedicated shipboard or aerial surveys

This is not the place to explain in any detail how cetacean population size is estimated – that would take a book in itself and there are many excellent articles that deal with this subject. Needless to say, estimating the abundance of cetaceans is neither easy nor cheap, particularly if the aim is to estimate absolute rather than relative abundance. Up until now, the primary method for estimating cetacean abundance has been to use visual surveys and an approach called 'distance sampling'. In short, the idea is that although it is not possible to cover every square metre of a large area of ocean, with an appropriate survey design it is possible to estimate the density of animals along a 'strip' of ocean either side of a series of tracklines within the major survey area, and from this extrapolate the density to the whole survey area. Figure 3 shows one example of such a survey design.

The density of animals can be estimated by:

$$\frac{\textit{The number of schools sighted} \times \textit{the mean school size}}{\textit{The strip width} \times \textit{the total length of transect searched}}$$

This approach can be undertaken from vessels or from aeroplanes and major surveys, such as the North Atlantic Sightings Survey (NASS) that covered the Central and Eastern Atlantic, or the Small Cetacean Abundance in the North Sea (SCANS) survey that covered the North Sea and adjacent waters, often use both. As with any such approach, there are a number of assumptions about the method that may be violated and thus any estimate of abundance (and series of abundance estimates in the case of monitoring) will have considerable uncertainty surrounding it. For example, this can arise from a number of causes ranging from differences in the abilities of observers,

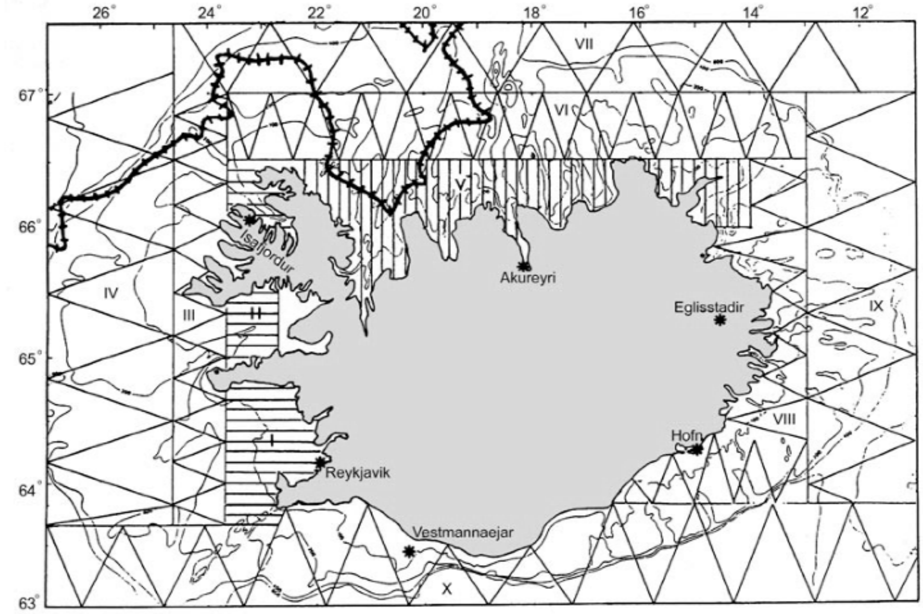

Figure 3:. Examples of track design from an aerial survey around Iceland

differences in weather conditions and problems in data collection, to differences in the distribution of animals over time for example due to changes in prey distribution due to oceanography, ice cover, etc (Table 3). It is important to try to collect data to allow a quantitative investigation of these factors. As discussed below, these are also all

Table 3: A few examples of some of the factors affecting the sighting of cetaceans. Whatever visual survey approach is adopted, it is important to collect data that enable these factors to be quantified.

Some factors affecting sightability even if animals are present
The ability (and mental state!) of the observer
The number of observers
The amount of time they spend searching
The nature (e.g. height, stability) of the sighting platform
The weather/sea conditions
The size of the animals
The group size of the animals
The behaviour of the animals
Some factors affecting whether animals are present in the survey area
Time of the year (if undertake seasonal migrations/movements)
Oceanographic factors (e.g. water temperature, salinity, currents)
Ice cover
Distribution of prey species (in suitable concentrations)
Distribution of competitors (including humans, e.g. vessels)

important in the context of the ability to determine trends. Good guidelines for such surveys can be found at www.iwcoffice.org.

In essence, although the theoretical and practical aspects of visual surveys have improved greatly in recent years, the limitations of the results must be recognised. What is obtained from a single survey is a 'snapshot' – an estimate of the number of animals in a particular geographical area at a particular time. Interpretation of such results requires knowledge of the relationship of that area and time to the 'behaviour' of the population. The collection of additional data either during surveys or from other simultaneous sources (e.g. with respect to oceanography, bottom topography, productivity etc.) to try to explain the distribution of cetaceans within the survey area is becoming increasingly common and important. A powerful argument for monitoring programmes is that a single 'snapshot' however well obtained can be misleading. There are plenty of examples of cetacean populations changing their distribution dramatically from one year to the next.

The question of using data collected on dedicated surveys to monitor populations is discussed under the 'Trends' section below.

Opportunistic vessel surveys

The cost of the vessel is clearly a major factor in the cost of surveying. It is tempting therefore to look at the possibility of 'piggy-backing' onto other vessels – either by using sightings information they submit or by placing observers on them. I will deal with each of these in turn.

Incidental sightings from platforms of opportunity

The most obvious advantage of such an approach is that data collection is essentially free; a further advantage can be that it does involve a variety of 'stakeholders'. However, there are a number of quite serious disadvantages that preclude the use of such data for reliably estimating abundance and relative abundance. These can be summarised as follows:

- lack of control as to the area and tracklines covered;
- lack of control over the timing of the effort
- lack of ability to estimate 'effort[5]';
- lack of control over the experience of the observer;
- lack of quality control – e.g. with respect to species identity, group size and other basic data.

All of this means that the data are of limited value. Despite this, a number of programmes (such as some based in the UK[6]) exist that do their best to take into account the above problems by providing advice and training materials and using stringent conditions before accepting the data. At the very least, a well-designed programme can

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[5] This is essential if information is to be used in any quantitative way. As a minimum one would need to know how much time was spent on concentrated searching and what the weather and sea conditions were.

[6] E.g. see http://www.jncc.gov.uk/Publications/cetaceanatlas/default.htm

give some information on occurrence and distribution throughout a broad area and time and provide assistance in designing dedicated surveys.

Dedicated sightings from platforms of opportunity

The next stage 'up' is where dedicated observers are placed on vessels which routinely operate in specific waters, often following specific routes. Examples of such vessels include research vessels, whalewatching vessels, coast guard vessels and ferries. The amount of information that can be obtained from such an approach is dependent *inter alia* on the nature of the vessel (size, speed, viewing platform, noise etc), the cruise tracks and the ability to divert from the track to confirm species and group size. In certain 'ideal' circumstances, data can be used to estimate density and even absolute abundance (e.g. this is the case for a collaborative programme in the Antarctic where cetacean observers participate on research vessels examining krill abundance[7]), in other cases sightings from ferries have been used to investigate distribution and relative abundance at different times of the year. However, where there is no control over the tracklines careful consideration must be given as to whether the results are representative of the population.

Once again, the individual circumstances will need to be examined in order to assess the suitability of the resultant data with respect to information on abundance and distribution.

The use of such data to monitor populations is discussed under the 'Trends' section below.

Land-based censuses[8]

Under certain relatively rare circumstances, it is possible to obtain absolute abundance estimates from shore. A major advantage of a shore-based census is that it is relatively cheap. It is also easy to collect all the necessary associated data (see Table 3). The two best examples are for the Bering-Chukchi-Beaufort Seas bowhead whales and the eastern North Pacific gray whales. In both cases the animals have a very narrow migratory corridor such that at a certain point along the migration route, all the animals pass within sight of the shore under ideal conditions. Although corrections need to be made for various factors, including weather conditions, animals passing beyond the range of the observers, night time migrations, the estimates produced from such censuses have produced some of the best time series of abundance estimates (see below).

Land-based/fixed base systematic observations

A major advantage of land-based surveys (or fixed-base platforms such as oil rigs) is that they can be cheap. It is also easy to quantify effort and other factors (see Table 3). Their most obvious limitation is the very small area that can be covered by the observers. Even with several 'stations' along a coast, observations will be limited to

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[7] See http://www.ccpo.odu.edu/Research/globec/iwc_collab/menu.html

[8] The word 'census' is used in this section because it is theoretically possible to count all of the animals in the population, unlike traditional distance-based surveys where abundance is estimated by extrapolating from a sampled area to the whole area.

coastal waters. Considerable care is thus needed in interpreting the data. It is clearly not appropriate to use this method to reach conclusions on the abundance of species with oceanic distributions. Care is also needed in making inferences about coastal populations – even a small change in distribution can lead to a false interpretation. However, they can produce interesting information on the distribution and relative occurrence of coastal species through time.

Mark-recapture methods

This is a relatively common way to estimate abundance of animal populations. The simple idea is that you 'capture' and mark a sample of animals and then release them. You then go out and capture another sample of animals and see how many of them are those you marked the first time. The ratio of marked to unmarked animals in the second sample is assumed to be equal to the ratio in the population at large. It is thus easy to calculate the total population size as:

$$\frac{\textit{The number of animals in the first sample} \times \textit{the number of animals in the second sample}}{\textit{The number of marked animals recaptured}}$$

Of course, nothing in life is that simple and there are a number of assumptions that are made that can never be completely fulfilled. It is beyond the scope of this paper to discuss them in detail but they include: the marked animal will always be recognised if it is caught; the marked animals are representative of the population; marking an animal does not make it less likely to be caught again; and each animal in the population has the same chance of being captured during any sampling occasion. As with the visual survey approaches, it is important that data are collected to allow one to see if the assumptions are being violated and if so, by how much.

There are two types of 'marks' that are used in cetacean studies. The most common is the use of photographic 'capture' of individual marks such as the colour pattern and outline of the flukes of humpback whales (see Figure 4) or the nicks and scars on the dorsal fins of bottlenose dolphins (see Figure 5)[9] – these are all individually different, rather like fingerprints in humans. The second, more recent approach has been to obtain small biopsy samples from free-swimming animals and then to analyse them to obtain their genetic 'fingerprint' – again a technique now commonly used in criminal investigations to identify individuals.

Such data can and have been used to estimate both abundance and trends in abundance of animals. For example a major study of humpback whales in the North Atlantic used both photographic and biopsy ‘marks’ to obtain an abundance estimate for the entire western North Atlantic of about 11,600 (95% confidence interval 10,100 to 13,200) in 1992/93. An annual increase rate for the Gulf of Maine humpback whales for the period 1979–1993 was estimated at about 3%. Another example of this approach being used is to estimate the abundance of bottlenose dolphin populations in various parts of the worlds including Ireland[10].

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[9] Not all species have easily recognisable natural marks.

[10] http://www.shannondolphins.ie/

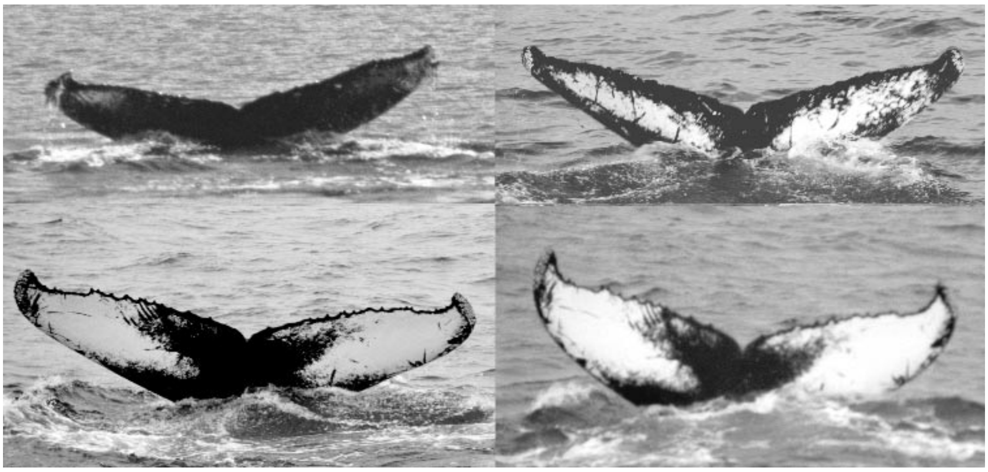

Figure 4: Examples of humpback whale fluke photographs suitable for individual identification studies. Note that the two bottom photographs are of the same whale on different days.
Photographs courtesy of the author).

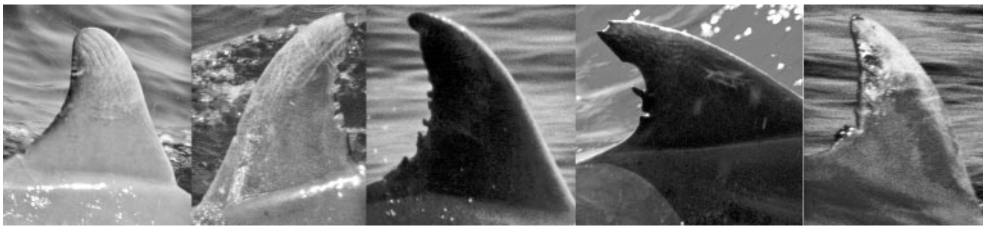

Figure 5: Examples of bottlenose dolphin fins suitable for individual identification studies, showing scars, nicks and colour patterns. ***(Photographs courtesy of Ana Cañadas, Alnitak, Spain).***

Acoustic methods

Many cetaceans produce sounds. The potential to be able use underwater sound detections to estimate absolute or relative abundance is attractive and considerable progress has been made in developing techniques to achieve this either using towed hydrophones (which can be used from both dedicated and 'opportunistic' vessels) or fixed hydrophones that can be attached to the sea-floor, particularly for harbour porpoises and sperm whales. Some advantages of such approaches are that they can be automated and can be used under poor weather conditions, but further work is required to try to overcome disadvantages such as the requirement for animals to be vocal and to try to determine the link between vocalisations and abundance. A combination of acoustic and visual surveys seems particularly promising. One specialist and elegant application of this is the use of acoustic location data to detect bowhead whales that migrate under the ice when passing the visual observers in the census referred to earlier.

TRENDS

Can we believe them?

Estimating trends in abundance at its simplest involves comparing two or more estimates of absolute or relative abundance. The most important aspect of any such comparisons is to determine whether or not the estimates are truly comparable. The key word is here is consistency. It is important that great care is taken to ensure that to the extent possible, surveys are carried out using the same methods and equipment, the same area and the same time of year. If 'improvements' are to be made in a series of surveys, it is extremely important that such changes are examined, not simply to see if they result in a 'better' estimate of absolute abundance but also whether the changes might compromise the interpretation of the series of results.

Where the absolute or relative abundance estimates refer to small areas, they may be of limited value in estimating trends. Relatively small changes in distribution (not unlikely in highly mobile animals such as cetaceans) can have a large impact on abundance estimates, making interpretation of apparent trends extremely difficult. Choice of an appropriate survey area is thus of great importance.

Even with well-designed surveys, interpretation of long time series can be difficult. A good example of this is the series of IWC Antarctic cruises to estimate Antarctic minke whale abundance undertaken since 1978. It is not possible to survey the Antarctic in one year and so parts are covered each year. Between 1978/79 and 2003/2004, the complete 'circumpolar' survey was achieved three times. Over that period, inevitable changes occurred with respect to crew, vessels, survey design, and environmental conditions (such as ice cover). Despite considerable effort it is proving extremely difficult to determine whether observed changes in *estimated* abundance reflect real changes in abundance, changes due to methods and personnel, changes in distribution or a combination of these.

An understanding of the reason why animals are distributed the way they are (e.g. by relating distribution and abundance to environmental factors) can prove a valuable tool in interpreting trend data; recently developed methods of 'spatial modelling' that attempt to do this are very promising.

A simple hypothetical example is given in Figure 6. If there had been a change in methods after year 20, then it would be difficult to state whether the observed increase in the estimate was real or merely an artefact of the changed methodology. This should not be taken as implying that methods should never change or be improved – rather it is a warning to ensure that if changes are thought to be necessary, it is important that the implications for a long-term data series are taken into account. For example, where possible the two methods should be used in parallel for a time to ensure compatibility.

Is it realistic to manage based on trends?

It should be clear by now that estimating abundance of cetaceans is difficult. Even with a well-designed survey in good weather, the uncertainty in an abundance estimate will be quite large. This makes determining a statistically significant change in population size difficult. If a proposed management objective is to manage a population based on a

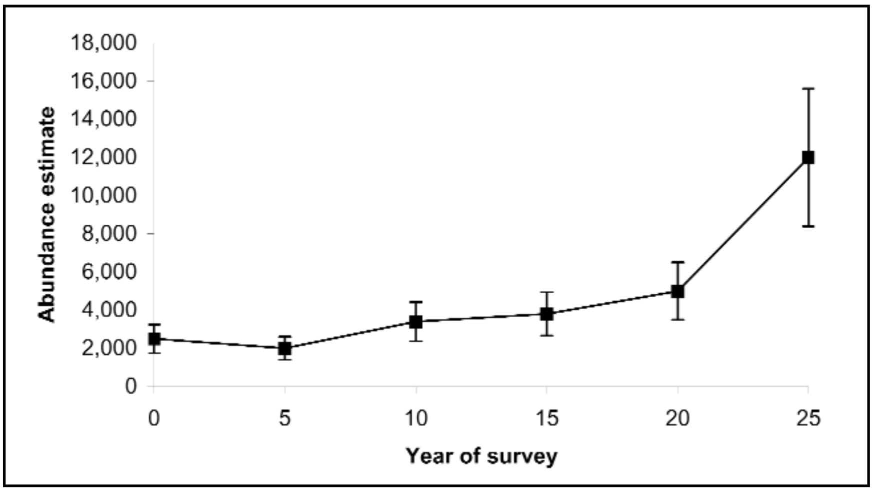

Figure 6: Hypothetical example of the results of abundance surveys over a 25 year period (see text).

characterisation of status that involves trends (e.g. to keep a population stable) then it is essential that you test whether it is possible to estimate a trend (or be sure that there isn't one) using your expected methods in a realistic time frame. It can take decades to detect changes in abundance. Without going into details, it is important to carry out a 'power analysis' to test this. In effect the approach is to assume that you will obtain an estimate with a particular level of confidence and then see how many abundance estimates carried out at a particular frequency will allow you determine whether the population has changed at a chosen rate (e.g. 10%, 20%, 50%). After examining the results of such an analysis, it may be necessary to adopt different objectives.

A conservative and precautionary approach to management has been adopted by the International Whaling Commission. In essence, it uses computer simulations of whale populations to choose an approach to setting catch limits that will still be safe even if the inevitable scientific uncertainty surrounding abundance estimates and trends (as well as many other factors) is taken into account.

DESIGNING A MONITORING PROGRAMME

It should be noted that the development of cost-effective monitoring programmes to determine whether mitigation measures for threats to cetaceans (e.g. bycatches) are successful is the subject of a number of ongoing research programmes – it is not a simple matter. The design of a monitoring programme must take into account all of the features discussed above – there is no single answer – it will depend on a number of factors and will almost inevitably be case-specific. The important thing is to develop a monitoring programme that will meet the needs of the management objectives chosen in a cost-effective manner and one which it is feasible to carry out at regular intervals over a long period. In many cases, a combination of methods will be appropriate. Each of the options should be examined for its strengths and weaknesses in the context of the chosen objectives. For example, large-scale surveys are extremely expensive. It may be that undertaking such surveys at regular but longer intervals (e.g. 10 years) in combination with more regular, cheaper smaller scale local surveys is appropriate. Acoustic approaches hold considerable promise but require further development. The use of computer simulations to test 'what if we get it wrong?' is an effective and relatively cheap way to determine if a programme will be effective – it can prevent unnecessary resources being expended on uninterpretable research and most importantly, the potential consequences for the animals are far less severe.

CONCLUSIONS

1) Long-term monitoring programmes are an essential part of management – not an optional extra.
2) Involve stakeholders at all stages of developing a management strategy.
3) It is essential to define management objectives – without these it is not possible to develop an appropriate monitoring programme.
4) Weigh up the needs of monitoring whether the management objectives are being met with the advantages and disadvantages of the various ways of estimating the abundance and distribution of the target cetacean populations – the use of power analyses and computer simulations cannot be over-emphasised.
5) Where practical, collect data that will enable a better understanding of why animals are where they are when they are – it is essential for properly interpreting trend data.

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