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The management of whaling

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Introduction

It is now a widely accepted principle, reaffirmed at the 1992 Earth Summit in Rio de Janeiro and in the resulting Agenda 21, that the exploitation of the living resources of the world's oceans should be managed so as to ensure the conservation of the resource base and the sustainability of the exploitation. The attempt to put modern commercial whaling onto a sustainable basis is an important and in many ways instructive example of recent developments in the field of fishery management, not least in view of the considerable public interest in the great whales.

Although there were previous attempts to regulate whaling at the international level, the modern period of whaling management began in 1946 with the establishment of the International Whaling Commission (IWC), an intergovernmental body that has met annually since 1949. As is well documented elsewhere (Tønnessen & Johnsen, 1982), the IWC was initially not very successful at bringing the exploitation of whales under control. By the time Antarctic blue whales, in many respects the flagship species, were protected in 1965, only a tiny fraction of the original stock remained. The first systematic attempt to place the management of whaling on a scientific basis with the aim of ensuring sustainability began in 1975 with the adoption of what was then called the New Management Procedure (NMP). The NMP was a set of rules for deciding which stocks of whales should be open to exploitation, and how many whales from each stock could be caught.

The NMP ensured the protection of the most severely depleted stocks of whales and led to the closure of Antarctic fin and sei whaling soon after its adoption (Table 1). When it came to determining sustainable catch limits for those stocks still numerous enough to support some exploitation, however, it became steadily more clear that the scientific information required for applying the NMP was not available. Consequently, the IWC decided in 1982 on a temporary cessation of commercial whaling, to come into effect in 1986 and allow time for improving knowledge of whale stocks and developing more satisfactory approaches to management. The moratorium was inevitably rather controversial, but by 1988 virtually all member countries were abiding by it. In the meantime, fishery scientists set to work to develop an alternative method of managing whale stocks to replace the flawed NMP. A skeleton version of the new procedure was accepted by the IWC in 1991 (International Whaling Commission, 1992), to form the basis of a so-called Revised Management Procedure (RMP). A final version of the RMP was prepared by the IWC Scientific Committee in 1993 (International Whaling Commission, 1994), and accepted by the IWC in 1994 (International Whaling Commission, 1995). It has not yet been legally adopted because other elements necessary for the effective management of whaling, including a system of observation and inspection to ensure that regulations are followed, are still under development.

Table 1. The Management of Whaling

1946	International Whaling Commission established
1965	End of whaling for blue whales in the Antarctic
1975	IWC adopts New Management Procedure
1976	End of whaling for fin whales in the Antarctic
1978	End of whaling for sei whales in the Antarctic
1986	Commercial whaling moratorium
1991	IWC accepts 'C' procedure as basis for future RMP
1992	IWC accepts draft specification of RMP
1993	IWC accepts finalised specification of RMP

This paper outlines some of the problems that beset earlier approaches to the management of whaling and explains how these problems have been addressed in the development of the RMP.

The New Management Procedure

The RMP is best understood by comparing it to its predecessor, the NMP, so called because it was new when it was adopted in 1975. The NMP is still

theoretically in effect, although the IWC has decided that any future authorisation of commercial whaling would only be on the basis of the RMP. The NMP is based on the principle of Maximum Sustainable Yield (MSY). At the time it was at the forefront of modern approaches to the management of marine living resources. The MSY concept was first accepted as a general basis for the management of marine living resources with the signing of the Law of the Sea Convention in 1982, which did not formally come into force until November 1994.

Under the NMP, whale stocks which were judged to be below the level providing the MSY were to be protected, while catches from other stocks were not to exceed the MSY, so that, in theory at least, these stocks would not become depleted to below their MSY levels. Already at the time it was realised that the data required to implement the rules relating to MSY would not be available for many stocks, so two supplementary rules were included. One was that in the case of stocks which had been subject to stable catches for a considerable period, catches would be allowed to continue at previous levels in the absence of any definite evidence of population decline. Another rule was that for 'new' stocks (stocks not previously subject to significant exploitation), catches would be limited to 5% of the estimated stock size. Indeed this latter rule was the first example of a more modern, precautionary approach to whale management, because it meant that a new stock could not be exploited until there was a population estimate. The figure of 5% is now considered too high for safe management, especially when one takes into account the high variance of most population estimates, but the principle was a sound one. It was partly due to this rule that stocks of Bryde's whale (*Balaenoptera edeni*) were not depleted to the same extent as those of other baleen whale species.

The main problem with the NMP was that there were insufficient data for its implementation. For most stocks there was no reliable estimate of population size, let alone an estimate of the MSY or the relation between the current population and the MSY level. Furthermore there was no particular incentive to collect data. In cases where data were insufficient to determine the catch limit, there was either no limit, i.e. unlimited catches, or catches were allowed to continue at past levels, as indicated in the previous paragraph. Even if relatively good data had been available, there would still have been considerable uncertainty about the state of whale stocks with respect to the NMP criteria, but there were no guidelines for handling these uncertainties. Finally, the 'behaviour' of the procedure was unknown. In other words, it was not possible to predict the long-term consequences of applying the procedure to stocks.

In summary it can be stated that the NMP provided for the protection of very depleted stocks—those which, even on the most generous assessment, could not be construed as being above their MSY levels, such as Antarctic blue, fin and sei whales—but it failed to provide an adequate basis for the sustainable management of other stocks. In practice catch limits tended to be determined as much by political bargaining as through any scientific process.

Information on the state of whale stocks

During the decade since the moratorium was decided, there has been considerable progress with the collection of data, the lack of which was one of the main shortcomings of attempts to apply the NMP. At the beginning of the 1980's, the information on the state of whale stocks could be summarised roughly as:

- very few direct estimates of abundance;
- some information on trends in abundance from catch and effort data, but usually unreliable or disputed;
- some biological data (e.g. reproductive rates, etc.) which could be used to place bounds on likely sustainable yield rates.

The current situation is substantially improved. There now exist:

- an accepted methodology for estimating abundance from visual surveys;
- absolute abundance estimates for most important stocks;
- considerable residual uncertainty over population structure and stock identity.

Although techniques now exist for determining genetic differences between populations and even for determining from which species and area whale meat derives (Baker & Palumbi, 1994), methods are still not available for determining the rates of interchange and extent of overlap between adjacent stocks. Moreover, the dynamics of metapopulations are poorly understood. Most stock boundaries adopted for management purposes have been chosen on the grounds of convenience (Donovan, 1991). These limitations are important where the goal of management is to conserve discrete biological stocks, but less important if the aim is merely to conserve the abundance of each species in each major region.

Analysis of management procedures

While progress was being made with the collection of data on whale stocks, work also proceeded on the other problems with the NMP, in particular the

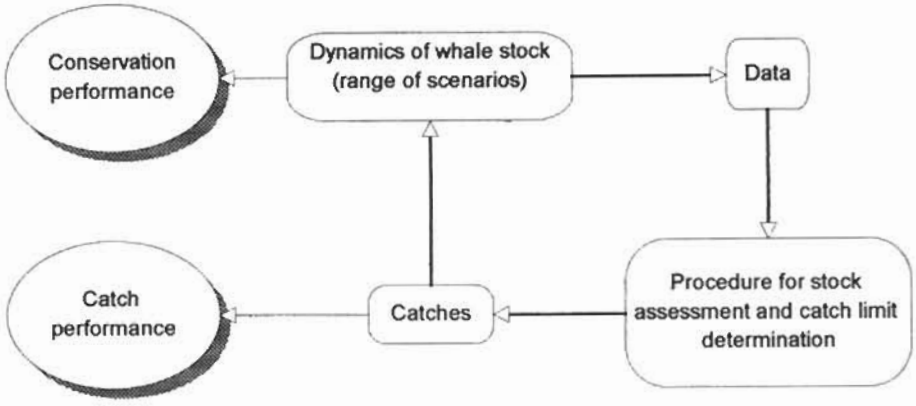

Figure 1. Structure of simulation tests for management procedures.

question of how it could be expected to behave as a management system. To understand this question one needs to think of a management procedure as a closed loop (Fig. 1). A management procedure can be thought of as a set of rules for determining the allowable catches from stock of whales based on the available data. These catches affect the whale stock, from which data are collected as input into the process for setting catch limits the next time the fishery is assessed. An important scientific development was the realisation that this process could be simulated for the purpose of determining how a given management procedure might be expected to behave over a long period of time.

Simulation studies can be set up as follows. First, the management procedure must be precisely specified in terms of the explicit rules for determining catch limits and other management measures from the available data. Then, models are constructed to simulate the dynamics of the whale stock which determine how it is affected by the catches. Since there are many aspects of the dynamics of whale stocks that are poorly known, it is not valid to build a model of a whale stock and assume that it corresponds to reality. A wide range of alternative models need to be built to cover as exhaustively as possible the full range of ways in which the stock might conceivably respond. The process of collecting data from the stock, through surveys or by other means, also needs to be modeled. The statistical properties of the ways used to make population estimates from survey data need to be determined and included in the simulations.

An essential feature of such simulations is that the part of the programme that implements the rules for setting catch limits must operate only on the data that are collected. It may not 'cheat' by looking directly at the part of the programme simulating the whale stock. When a real stock is managed, the true state of the population is unknown. We see it only through the data that are collected, which in many cases, especially with dispersed pelagic populations, are necessarily very limited.

Simulations are then run to see how the management procedure would operate in different situations. One should start with fairly simple scenarios, in which it is assumed that the whale population functions and responds in a standard 'textbook' manner, the data are unbiased, catch limits are adhered to, and no anomalous or unpredictable events occur. Only if a management procedure performs satisfactorily under such ideal circumstances is it worth proceeding to see how well it can perform in more realistic and difficult circumstances.

Figure 2a shows what would happen to a hypothetical whale stock managed under the NMP in an example scenario. As it stands, the NMP is not a fully specified management procedure, because it does not stipulate exactly how the available data are to be used to assess the state of a stock. In order to simulate its operation, it was necessary to fill in some gaps in the rules: I assumed that the NMP would be applied as it had been by the IWC Scientific Committee in the most recent years prior to the moratorium. I also assumed that modern types of data (in particular, regular and reliable estimates of absolute abundance from surveys) would be available, even though these were usually not collected while the NMP was in effect. The graph shows the range of population trajectories from a set of 100 replicate trials of the NMP on the hypothetical whale stock. The stock is assumed to be unexploited initially, so that there is inevitably an initial period of decline in the stock size. The middle line shows the average of the 100 simulations. In terms of the average the procedure seems to perform quite well: after an initial decline the stock stabilizes and even begins to recover slowly.

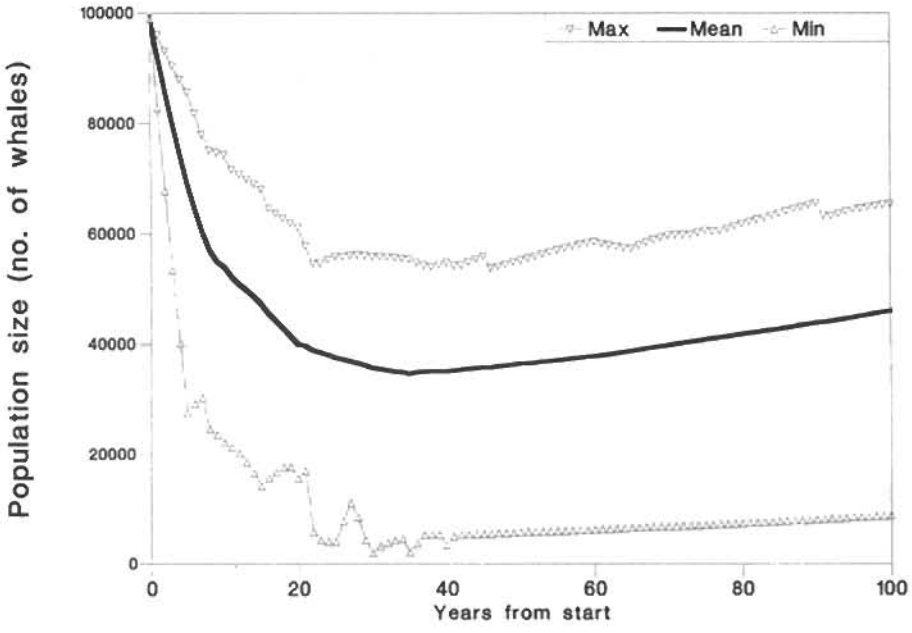

Figure 2. Performance of the NMP in a test scenario. (a) Population level; (b) catches.

However, there is an enormous range of results around this average. In the worst case, the stock is driven to extinction. The procedure thus fails to ensure that exploitation does not impose unacceptable risk to the survival of the stock. The catch quotas that the NMP generates in these simulations are shown in Fig. 2b: they fluctuate wildly from one year to the next, a feature which would not be desirable in terms of rational management of the fishery.

Both from the conservation point of view and from the industry's perspective, the NMP would not be expected to perform well in the long term, even under relatively ideal circumstances. The main problem is that the population estimates from surveys have considerable variances, which means that there is always considerable uncertainty about the state of the stock. The NMP does not handle this uncertainty in a robust way.

Simulation tests vs. real tests of management procedures

Can simulation tests really indicate how a real whale stock might fare under a real management procedure? Results of simulation tests should never be interpreted too literally. However there are several important reasons for conducting such studies rather than relying on real experiments to develop a management procedure. First, real tests take a long time because they have to be done in real time. When developing a management procedure, the first prototypes tend to perform poorly. For example, all the early versions of the RMP tended to exterminate whale populations in the simulation tests. If these tests had been done on real populations, many whale stocks would have been depleted or possibly extirpated in the process. Since there is a large element of chance in the performance of any management procedure, a large sample of tests is required to provide a reliable indication of the range of performance that can be expected: there are not enough real whale stocks in the world to 'practice' on. Most real whale populations are difficult to monitor, so although in a real test one knows how well the procedure has performed in terms of providing adequate catches for the industry, it is difficult to be certain about how well it has conserved the stock. If things go wrong, it may not be possible to diagnose the reasons.

With simulation tests, there is virtually no limit to the number that can be performed. After each test it is known how well the procedure performed in terms of conserving the simulated stock. Since one may have little idea how closely any one simulated scenario corresponds to reality, good performance in a single test scenario provides little indication of how well a procedure would perform in reality. Poor performance in a test scenario does indicate that the management procedure is unsound, unless other information is available that shows that the scenario considered is unlikely to pertain in practice. To conclude that the management procedure is sound, it is necessary for it to show good

performance in a wide range of simulated scenarios which as far as possible exhaust the range of conceivable eventualities. There remains a residual risk that the management procedure might fail for a reason that was not considered at all.

Evaluation and selection of management procedures

The evaluation and selection of management procedures require the specification of reasonably well defined objectives. The IWC stipulated the following objectives to be met by the revised management procedure (International Whaling Commission, 1988: 36):

(i) stability of catch limits, which would be desirable for the orderly development of the whaling industry;
(ii) acceptable risk that a stock will be depleted (at a certain level of probability) below some chosen level (e.g. some fraction of its carrying capacity), so that the risk of extinction of the stock is not seriously increased by exploitation;
(iii) making possible the highest continuing yield from the stock.

These objectives are based on the International Convention for the Regulation of Whaling, which is the legal instrument on which the operations of the IWC are based.

The IWC undertook to develop a procedure for meeting these objectives in the following way. A number of groups of scientists independently devised management procedures aimed at achieving these objectives. These candidate procedures were subjected to a common set of (initially quite simple) simulation tests. The first versions of each candidate procedure tended to perform poorly on the simulation tests, and needed to be improved. Once satisfactory performance on the simpler tests had been achieved, the candidate procedures were subjected to a more demanding range of tests. As noted above, the NMP failed even the simplest of tests.

The more demanding tests included scenarios involving: population dynamics with unexpected properties; biases or other errors in input data, especially the survey data and the catch data; changes in the environment, such that the stocks might increase or decline for reasons unrelated to the catches; epidemics and other surprise events such that a large part of the stock might disappear *suddenly and unexpectedly*; uncertainty about the identity and range of discrete populations; and interchange or overlap between different populations. The actual list of factors that have been examined in the development of the RMP is considerably longer than this.

The main conclusions of the simulation tests were:

(i) Regular, direct surveys to estimate absolute abundance are a prerequisite for satisfactory management. Despite considerable efforts, no one was successful in finding a management procedure that worked at all well without such data.
(ii) When abundance estimates from regular surveys are available, the availability of other types of data provides only a marginal additional benefit, except that knowledge of the total catches is also useful. Regular absolute abundance estimates from surveys are thus both necessary and sufficient for good management.
(iii) Safe management can only be achieved by limiting catches to a small proportion of the absolute abundance, as directly estimated from surveys. Procedures which allow higher catches and rely on the detection of trends in abundance, such as relying on a decline in abundance as an indicator of overexploitation, do not perform well.

Factors influencing the performance of management procedures

Table 2 summarises what the simulation studies showed about the relative importance of various factors for the performance of management procedures. That stock identity issues emerged as very important is to some extent an artifact of the performance criteria selected. The avoidance of depletion of individual populations was one of the conservation criteria. When the range of individual populations is poorly known, there is a danger of unwittingly depleting or even extirpating an individual population even when the total stock of whales of a given species in an ocean is not excessively depleted. If conservation performance were expressed merely in terms of the overall depletion, stock identity might not have emerged as such an important factor. In terms of the depletion of individual populations, uncertainties in stock identity cause the most problems when whales of different stocks overlap on their feeding grounds, and when the extent of this overlap is variable from year to year. Unfortunately, the evidence suggests that this situation may be typical for baleen whales.

A moderately important factor is bias in the abundance estimates, but only if it is quite severe such as 50% or more. A persistent bias is more serious than a temporary bias affecting only the first few abundance estimates. Thus as survey methodologies mature it is more important to try to improve their accuracy and reduce bias than it is to maintain comparability with previous surveys. A technical factor that emerged as important is the validity of the estimates of variance of the abundance estimates. Problems can arise when a given

Table 2.

Development of the Revised Management Procedure: conclusions of simulation studies
Estimates of absolute abundance from direct surveys are essential
Other information is of marginal value, except catch figures
Procedures which limit catches to a small fraction of estimated abundance can perform well
Procedures which rely on detection of trends perform poorly
Relative importance of factors affecting performance of management procedures
Very important:
— Stock identity issues
Moderately important
— Bias in abundance estimates
— Validity of variance estimates
Less important
— Details of population dynamics (age structure, reproduction, density dependence, etc.)
— Environmental changes
— Catastrophic events (epidemics and other mass mortalities)

abundance estimate is erroneously believed to be very precise when in fact it is not. Imprecise estimates are not a problem provided that they are recognised as such.

Amongst the factors that emerged as relatively unimportant for management are the details of the population dynamics such as age structure, density dependence, etc. Interestingly, environmental changes also appear to be relatively unimportant, but again this is to some extent dependent on how performance is measured. Performance with regard to conservation objectives is normally expressed relative to the no-whaling case. Although environmental factors can have a severe impact on whale populations, the extra relative impact of exploitation under an otherwise sound management procedure is no greater in the presence of environmental deterioration than it is in stable environmental conditions. If one were to measure conservation performance in absolute terms of some kind, environmental factors could be revealed to be important even in the absence of accompanying exploitation.

The C procedure

The procedure that was eventually selected by the IWC as the basis for its RMP was the 'C' procedure, developed by the author (IWC, 1992). The only data used are time series of catch and absolute abundance data by area. No catch is allowed from a stock until there is at least one estimate of absolute abundance. Apart from this there are no minimum data requirements, but the allowed catch is low if data are few. It takes account of the variance of abundance estimates. Thus a substantial investment in surveys yieding precise and frequent abundance estimates will be rewarded with higher catches, while the risk of stock depletion is approximately constant regardless of the amount of information. In contrast to the old NMP, there is an incentive to put sufficient effort into data collection. Past catches are taken into account such that if they are large compared to current abundance (an indicator of a depleted stock), catch limits are small or even zero. Otherwise, catches are limited to a small fraction of abundance estimates, typically under 2% although it can be as high as 5% in some circumstances. An additional safety measure that was added at a late stage is that where there is uncertainty over stock identity the total catch limit is allocated to smaller areas in proportion to the estimated abundance. This considerably reduces the consequences of inappropriate choices for stock areas.

Figure 3 shows the performance of the C procedure in terms of population level (Fig. 3a) and catches (Fig. 3b) in simulation trials of the same straightforward scenario used in Fig. 2. The data supplied for the two simulation exercises are the same: surveys are conducted every five years to obtain updated estimates of the absolute abundance of the stock. In this scenario the NMP allows the stock to approach extinction in some cases (Fig. 2), while the C procedure keeps the stock within reasonably narrow bands. They are not shown in this graph, but the catches under the C procedure are also much more stable in this scenario, even though the average catch is similar for the two procedures. The key difference is that the C procedure uses the data in a statistically more sensible way and thus behaves more reliably.

A large number of simulation tests covering a wide range of scenarios has shown that the C procedure has robust properties. Provided the procedure is adhered to, it ensures that the risk of

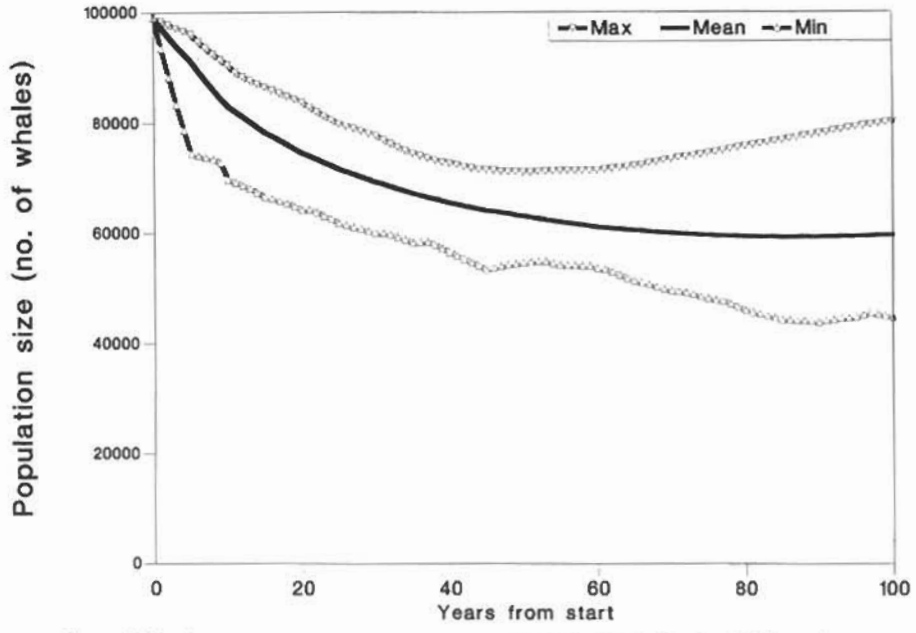

Figure 3. Performance of the RMP in a test scenario. (a) Population level; (b) catches.

depleting a stock to less than half its non-whaling abundance is less than 5%.

The RMP in its current form applies only to baleen whales. Modifications may be required before it can be successfully applied to odontocetes.

The Revised Management Scheme

The determination of catch limits is only one element of a comprehensive framework for the management of whaling. Recognising this, the IWC in 1992 conceived the Revised Management *Scheme* (RMS), of which the Revised Management *Procedure* (RMP) is but one element. The remaining elements of the RMS to be developed include a system of observation and inspection to ensure that catch limits are enforced, and procedures for ensuring that data used for the operation of the RMP are truthful and of sufficient quality. Recognising the undesirability of placing complete reliance on a single approach to management, the IWC has also taken steps to establish whale sanctuaries in the Indian and Southern oceans.

The science of whale management has advanced considerably in recent years. A management procedure, in the form of the RMP, is now available that overcomes many of the deficiencies of previous attempts. It is not yet clear whether commercial whaling will resume on a substantial scale, but if it does, the tools exist to ensure its sustainability. There will be no excuse for allowing whale populations to be depleted by failing to apply these tools.

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