ICES CM 2003/Y:05

A Framework for Communicating Qualities of Indicators

Kjellrun Hiis Hauge, Hilde Elise Heldal, Erik Olsen and Hein Rune Skjoldal

There is a growing focus on ecosystem-based indicators and what qualities they need to satisfy. However, the qualities and the characteristics of the already existing indicators vary substantially. Due to both scientific and societal aspects, so will the future indicators. With a growing interest for participatory decision processes it is crucial that scientific advice or knowledge based on these indicators is transparent. Advice should therefore be presented in such a way that a manager or a citizen is able to judge the rigidity and the relevance of the scientific information. This will also improve the communication of uncertainty. A common framework for presenting indicators could clarify such aspects by addressing qualities associated with the scientific knowledge and societal concerns. Some relevant qualities are how well an indicator is able to detect a manmade change, the rigidity of the scientific knowledge, how well an indicator threshold reflects a danger, how useful an indicator is for decision-making and the characteristics of the uncertainty. In this paper we discuss what features should be addressed in the communication of scientific knowledge and how this can be communicated through a general framework. The framework and the discussion of its content will be illustrated by case studies on measured technetium-99 levels in lobster and on Ecological Quality Objectives (EcoQOs) for commercial fish stocks and harbor porpoise by-catch.

Keywords: Characteristics, Indicators, Qualities, Uncertainty

Kjellrun Hiis Hauge: tel: +47 55 23 85 90, fax: + 47 55 23 86 87, e-mail: kjellrun@imr.no .
Hilde Elise Heldal: tel: +47 55 23 63 34, fax: +47 55 23 85 84, e-mail: hilde.elise.heldal@imr.no ,
Erik Olsen: tel: +47 55 23 86 06, fax: + 47 55 23 86 87, e-mail: erik.olsen@imr.no .
Hein Rune Skjoldal: tel: +47 55 23 69 46, fax: + 47 55 23 85 31, e-mail: hein.rune.skjoldal@imr.no.
All authors are from the Institute of Marine Research, P.O. 1870 Nordnes, N-5817 Bergen, Norway

1 INTRODUCTION

There is a growing focus on indicators for ecosystem-based management and what qualities they need to satisfy. However, it is not given that indicators with the suggested qualities will be found. The characteristics of the chosen indicators will probably vary substantially. With the new focus on participatory processes, like in the Common Fisheries Policy, there is a need to develop a clear and informative way to communicate indicators. Indicators and advice based on these should be presented in such a way that a manager or a citizen is able to judge the rigidity of the indicator, its relevance and the uncertainty connected to the scientific knowledge the indicator is based on. A common framework for communicating these aspects would thus be very useful.

Managing an ecosystem, although the idea is holistic, would necessarily include several management measures where some are more difficult to implement than others. Quite often Norwegian managers mention the preservation of coral reefs along the Norwegian coast as an example of ecosystem based management. This is indeed the case, but one should not expect all ecosystem related issues to be as simple to handle as in this case: i) The effect, damaged reefs, was obvious when it first was discovered in the 90s. One did not need to be an expert to understand from the video that they were damaged, ii) The irreversibility of the damage was obvious iii) The percentage of destroyed coral reefs (30-50%) was probably higher than an acceptable level for most people, iv) The cause of the damage was obvious, v) The damage is obvious immediately after bottom trawling, vi) It was clear what kind of regulations would stop further damage (no bottom trawling in these areas), vii) Most people value coral reefs for their beauty and richness, viii) The economical interest in continuing the activity that damaged the reefs was not substantial. The fishermen could go fishing other places than the coral reefs or use other equipment and ix) It was clear what kind of fisheries research could improve management (detect and map coral reefs).

The simplicity in this case you find at several levels: you know the effect and the cause, the time aspect between cause and effect is very short, finding decision rules is easy, there are not too conflicting interests between stakeholders and you know what kind of research or control is needed to help preventing more damage.

A counter example of simplicity in ecosystem-based advice and management could be the aggregated level of a certain chemical in marine organisms. i) The effect may not be obvious, ii) There may be a danger of irreversibility, but it is not obvious, iii) An acceptable level is disputable, iv) The cause of a high level may not be obvious, v) The time span between human activity and an eventual damage may be decades, vi) It may not be clear what kind of regulations will stop the development, vii) The issue is quite abstract, most people don’t relate to the problem, viii) There may be very strong economical interests against regulations and ix) It may not be clear what kind of research will be able to improve management decisions.

Imagine that we are defining indicators associated with these examples for the purpose of designing a management strategy to each of them. The two sets of indicators cannot possibly encompass the same qualities as the last example contains substantial uncertainty in several aspects. The issues however may be equally important. In communicating the indicators and management advice these differences in qualities should be clear. The managers, stakeholders and the public should be able, as far as possible, to judge the robustness, validity and the relevance of the scientific knowledge and advice. A feeling for the uncertainty is crucial in decision processes in managing the risks associated with the various stakes. A transparent way of communicating uncertainty and robustness is democratic, intellectually decent and is necessary in participatory processes. Showing the non-scientific choices, like simplifications, judgments, guesses, generalizations and underlying assumptions together with its impacts on the scientific knowledge, may improve the understanding of the uncertainty and may explain possible scientific disputes. We here suggest a framework with the intention of emphasizing transparency related to these aspects.

This paper begins with a background section on indicators. Then follows the suggested framework for communicating indicators for management purposes. The framework will be illustrated by three cases: levels of spawning stock biomass of the Northeast Arctic cod, technetium-99 levels in lobsters in Norwegian waters and bycatch rates of harbor porpoises.

2 BACKGROUND

There is currently a great interest and emphasis on the use of indicators related to environmental and resource management (EEA 1999, 2002; FAO 1999). As the term "indicator" indicates, it is a variable or index that contain information with a significance extending beyond the numerical value of the variable or index itself.

The European Environment Agency (EEA) use the following definition of indicator (EEA web page):
"Observed value representative of a phenomenon to study. In general, indicators quantify information by aggregating different and multiple data. The resulting information is therefore synthesized. In short, indicators simplify information that can help to reveal complex phenomena."

FAO (1999) provide an alternative definition:
"A variable, pointer, or index. Its fluctuation reveals the variations in key elements of a system. The position and trend of the indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and actions."

EEA (1999) provide a typology of indicators with classification into 4 main groups:
- Descriptive indicators
- Performance indicators
- Efficiency indicators
- Total welfare indicators.

Indicators are often used within the DPSIR framework, where D is driving force, P - pressure, S - state, I - Impact, and R - response (EEA 1999). The DPSIR elements are linked in causal chains where social and economic driving forces cause environmental pressures that influence the state of the environment with ecological and socio-economic impacts that in turn may lead to societal and political responses.

The relationship between indicators and the information on which they are based, can be illustrated with the so-called information pyramid (Hammond 1995) (Fig. 1). The ground layer of the pyramid consists of the raw data of various types collected from the environment (including the human systems) through regular monitoring, research, or other data collection means. These raw data and the information they contain can be processed at various levels of aggregation up through the pyramide. Indicators are often based on selected information aggregated at medium or high level. The aggregation may involve spatial or temporal integration (e.g. country/ecosystem and annual mean values) and/or combination of information on different variables from different sources (e.g fish catch statistics and survey information). Indicators at high level of aggregation may be composite indices.

Nature is complex in all its details of ever changing shapes, colours, names, numbers, and sizes. Scientists can only describe a small fraction of this complexity, and the challenge is to use the available resources to collect the most relevant information that will help us to achieve sustainability in our use of nature. Despite this selection in monitoring etc., the information content in collected data on environment and resources is large. It is an important and demanding task to communicate this information to the managers and decision-makers. Such communication is the main function of indicators (EEA 1999). They may help in communicating complex environmental issues to the public, politicians, and managers through simplification and illustration of key features and trends.

A second function of indicators may be to help in assessments of the environmental status, including the degree of human influence on the status (EEA 2003). Marine ecosystems are open, and often it is difficult to distinguish effects from different human activities that impact, directly or indirectly (through ecological relationships), the same components of the same marine ecosystem (EEA 1997). This means that causal chains are not simple and isolated, but that they interact through branching and linkages. Thorough assessments therefore require careful examination and evaluation of all available relevant information. Indicator-based assessments need therefore to be done with caution and by experts that are aware of the complexity and limitations in the approach. Nevertheless, regular reporting on pressure and state indicators may provide useful guidance (indications) to whether the situation is improving or not, particularly if it follows a more thorough environmental assessment where all available relevant information has been used.

In using indicators there are two key questions that need to be answered up front:

1. What is the indicator indicating?
2. What is the purpose for use of the indicator?

For instance, measurements of mercury in seabird feathers can be used as an indicator of the degree of mercury contamination of the marine environment. If it is used in this context, it must be evaluated how good or appropriate the indicator is and whether it is sufficient or need to be supported by other variables or indicators.

The different purposes of use of indicators can be illustrated in relation to the elements of an ecosystem approach to management. This has been defined as:
"*Integrated management of human activities based on scientific knowledge of ecosystem dynamics to achieve sustainable use of ecosystem goods and services and maintenance of ecosystem integrity.*"
The Bergen Declaration from the 5th North Sea Conference (NSC 2002) draws up a conceptual framework with the following main components:

- Objectives
- Scientific knowledge (monitoring and research)
- Assessment

- Scientific advice
- Management actions and policy decisions

Indicators can be used for a purely descriptive purpose to report information from monitoring activities. Related to this a further purpose can be to communicate outcome of assessments or to contribute to (simpler) assessments. Use of time series where the current situation is referenced against the historical development, is one main approach related to assessment. There can also be reference to assessment criteria which are numerical values associated with some biological or ecological effects or consequences. This can be minimum concentration levels of contaminants that have been found to have some biological effects in laboratory or other studies (ecotoxicological assessment criteria).

If an objective has been set related to an indicator, e.g. an ecological quality objective (EcoQO), reference to the objective can be used to form the basis for scientific advise for management actions. This may in turn trigger management actions with the aim to correct a situation to achieve agreed objectives.

ICES (2001, 2002a) has developed a set of criteria to help evaluate the usefulness of EcoQO metrics These were:

- Relatively easy to understand by non-scientists and those who will decide on their use;
- Sensitive to a manageable human activity;
- Relatively tightly linked in time to that activity;
- Easily and accurately measured, with a low error rate;
- Responsive primarily to a human activity, with low responsiveness to other causes of change;
- Measurable over a large proportion of the area to which the EcoQO element is to apply;
- Based on an existing body or time series of data to allow a realistic setting of objectives; and
- May relate to a state of wider environmental conditions.

These criteria emphasis the practical aspects of linkages with human activities and being manageable to achieve the objectives through corrective measures. This is no doubt an important consideration , particularly in the context of a short-term management framework where activities are frequently managed based on updated information about the current state. Extractive use of biological resources through fisheries is one example of such a short-term management framework. As noted by ICES (2002a), there could be additional properties of EcoQO metrics that also might be considered important. This could particularly be the case in relation to the overall environmental conditions or ecosystem health, where remedial actions may have to be taken within a longer-term management framework involving many activities in different societal sectors. Achieving the objective of eliminating eutrophication is a good example where there are many options for achieving the objective involving reduction of nutrient sources from many sectors (agriculture, human population, aquaculture, industry, etc.).

2.1.1

3 THE SUGGESTED FRAMEWORK

Our aim with this paper is to suggest and discuss a possible framework for communicating scientific knowledge based on indicators and thresholds. The main criteria for the framework have been to be informative, clear and transparent.

ICES has expressed the necessity of transparency and clarity in several contexts like in fisheries management (ICES 1999 and ICES 2002b) and in ecosystem based management (ICES 2001, ICES 2002a). Transparency makes advice more comprehensible for both scientists and stakeholders and makes quality evaluation of the science possible. In general, we can say that the society is moving away from the earlier understanding of the scientist as the one who finds the answer to resource problems and management. The focus of the Common Fisheries Policy on participation in decision processes is an example of this. The process of how a conclusion is made based on science may well be transparent for a scientist within the field, but may be quite opaque for a non-scientist. For a scientist, the name of the mathematical model, what data and how they are collected would probably be sufficient in order to know the strengths and weaknesses in the knowledge. For a non-scientist, on the other hand, methods, models and often the data as well will be too technical to judge. However, knowing the underlying assumptions and how they influence results, knowledge or advice, could help clarify the validity and the robustness.

An inspiration to the development of the framework has been the book *Uncertainty and Quality in Science for Policy* by Funtowitz and Ravetz (1990). They developed a notation scheme (NUSAP) for multi-disciplinary science projects. The idea was to give people outside a specific field of research a possibility to judge scientific knowledge and advice and a feeling for the state of the art. They realized that the common way of communicating results with quantities and quantified uncertainty is not sufficient for these purposes and aimed at developing a transparent notation scheme that is informative concerning other sorts than the quantified uncertainties. In policy issues with conflicting interests, they argued, all sorts of uncertainty must be communicated in order to obtain high quality in scientific advice. Their notation scheme includes the communication of a broad specter of characteristics like the quality of data, (if any), the status of the scientific theories, whether there are competing schools within the field and so on. As the relevance of science and judgments on quality is strongly dependent on the context of its application, their notation scheme aims at clarifying these aspects. Van der Sluijs and his co-authors have developed the ideas of Funtowicz and Ravetz further (van der Sluijs et al, 2002). They designed a diagnostic diagram based on the NUSAP notation scheme and a sensitivity analysis to detect and assess key uncertainties in a given system dynamics energy model. The design of our framework is influenced by the main ideas from these two works on representing scientific knowledge and uncertainties. They are considered to be effective in obtaining transparency and clarity.

From the discussions so far in this section, the preferences for a framework is to communicate the basic information and advice, the characteristics of the knowledge and the underlying assumptions together with an analysis on how they influence the measurements, the results, the knowledge or/and the advice. In order to achieve this, the suggested framework (Table 3.1) includes four parts, one descriptive and the rest analytical: *The Advice Statement, Power of Explanation, Robustness* and *Performance Ability by Management*. Each of these parts includes boxes with more specific topics/characteristics to fill in. In the next section we present three case studies to suggest how to fill in the boxes of the framework and discuss its strength and its limitations. We have chosen three performance indicators, as there are defined thresholds for management purposes in all three cases.

The first part, *Advice Statement*, covers what we usually find in scientific advice. It starts with a presentation of the indicator time series, either in a table or a graph, preferably with uncertainty measures. Qualitative time series are also possible. For clarity, we have included a box with *Indicator Category* because the existing categories are numerous. The indicators handled in this paper will all be state indicators that are also performance indicators, but their level of aggregation will vary. This aspect is important because a high aggregation level introduces qualitative uncertainties as the number of assumptions increases, especially if the indicator is composite indices.
Then follows the threshold value with its technical explanation and the concern. The thresholds can express a target, like the EcoQO metric, or a limit, like B_{lim}, the level of a spawning stock biomass where recruitment overfishing is considered a danger. Indicators are not necessarily accompanied by a threshold. In any case, the concern in question should be stated and how it relates to the indicator. Then the advice follows or a conclusion. How this is presented may vary from a single qualitative statement to quantified predictions or suggested scenarios based on qualitative input.

The next part, *Explanatory Power*, is meant to reflect the soundness of the scientific knowledge related to the actual indicator. In some cases, like the damaged coral reefs, it is obvious what caused the damage. (It may of course be difficult to *quantify* the effect of the damages or predict it.) In other cases, the cause – effect relation may be unknown like the cause-effect relationships between pollutants and seal population health (ICES 2002a). The choice of a threshold may sometimes be somewhat arbitrary like defining a danger by a certain quantity. There may not be a sudden change of threat exactly at a specific value, but a value is thought to be useful of management purposes. In such cases and where different choices of thresholds affect stakeholders differently, this must be clear. To some extent the choice of a quantity is political and ethical; who/what is going to gain on the choice of the threshold value. The Technetium-99 threshold for what is considered to be a health threat is a lot higher than what is measured in fish in Norwegian waters. Still, the Norwegian fisheries are concerned about the levels. They are afraid of loosing markets because of consumers' lack of trust in authorities. In such cases openness on how science and/or politics has reasoned is crucial. Non-scientific choices in science where there is uncertainty are sometimes denoted as *value choices* or *value-laden assumptions* in science for policy.

The purpose of time series is to detect possible changes. The ability to detect a change may differ as in some cases it may not be apparent until after some time or the change is too small to be observed although the effect may be of importance. In a management context it is useful to be able to separate natural variation from manmade effects, but may be possible to some extent only.

We have now reached *Robustness* in our framework. All scientific knowledge builds on assumptions. While it is perfectly acceptable in traditional science to restrict the validity of results to a certain set of assumptions, caution must be taken by scientists working with policy issues. The underlying assumptions may be critical to whether the science is relevant or not, no matter how good the science is. Let's say we want to describe mathematically a leaf falling from a tree. Newton's laws of motion is established theory, but may not be useful without assuming a series of simplifications. No friction is obviously a bad assumption in our case; describing the trajectory of a leaf with this assumption would be irrelevant. In general, communicating the validity of the assumptions and an analysis of their impact on the results are crucial in ensuring relevant science of high quality. Showing the non-scientific choices, like simplifications, judgments, guesses, generalizations and underlying assumptions together with its impacts on the scientific knowledge, may improve the understanding of the uncertainty and may explain possible scientific disputes.

Under *Robustness* we have two boxes where the underlying assumptions are to be stated. In some cases other expert groups than scientists or lay people may have valuable contributions to choosing assumptions. In any case, the list of assumptions may to some degree clarify the validity, the robustness and the relevance of the actual indicator. In some cases the indicator is a straight forward measurement with a controlled measurement error. In these cases a sensitivity analysis is irrelevant. In other cases the indicator is a result of complicated, opaque calculations of several, and perhaps uncertain, measurements. Often, the accuracy is not possible to determine or to verify and a sensitivity analysis is necessary. The underlying assumptions will influence the indicator value more or less, and it is crucial to have an idea to what extent. If such an analysis is not carried out because of lack of time or some other reason, this should be stated. Then the indicator is not validated properly, which introduces an indeterminate uncertainty.
Also in the defining of danger threshold or target, assumptions have to be made, as it probably quite seldom is unequivocal. As already addressed, there may not be a sudden change of threat exactly at a specific value, but a value is thought to be useful for management purposes. A presentation of underlying assumptions may clarify this aspect, and a sensitivity analysis will to some degree show whether the threshold is robust. The choice of thresholds will likely build on several assumptions while the indicator may not.

In a management context it is important to have an idea of how useful or applicable the indicator may be in relation to decision making. In *Performance Ability by Management* we look at this in a general way by trying to show to what extent we can adjust the indicator level. We suggest three boxes for this purpose. A state may be reversible but perhaps not by managing human activity. We can adjust fish stock levels to some extent, but it is not possible to manage the fisheries so that there are no fluctuations in the stocks. The benthos composition in a specific area may be difficult to reverse if there has been a change, and the background radiation level in the sea cannot be reversed.

“Danger” may be defined in such a way that the risk of irreversibility is a threat if the chosen threshold is crossed. As long as the condition or the state is kept at a distance from this threshold, we deal with reversibility. The reference points B_{lim} and F_{lim} are usually not associated with irreversibility of the state of the fish stock, but one may ask whether the state of the Northern cod is irreversible. The Technetium-99 level in lobster may be reversible but not the background radiation.

Managers may want to know whether further research or further control can improve the management. In the introduction we mentioned that further mapping of the coral reefs definitely has the potential of improving the goal of protecting the reefs. In fish stock assessment, the gain of further research is not that obvious for all stocks. Uncertainty may be reduced, but due to unpredictability of the environment, the uncertainty in stock predictions will never be reduced to measurement uncertainty.

Table 1 Framework

A) Advice Statement

Indicator Time Series			
A graph and/or table with historic values or characteristics if not quantifiable. The numbers should include uncertainty measures.			
Indicator Category	**Threshold(s)**	**Supporting Information**	**Conclusion/Advice**
DPSI or R(see above) The level of aggregation.	Value: Basis: Concern: Target or limit:	Additional time series or additional, qualitative knowledge	State/Description Predictions Scenarios Qualitative aspects

B) Power of Explanation

Cause-effect in Indicator	**Cause-effect in Threshold**	**Ability to Detect Change**	**Ability to Separate Effects**
Known and predictable Known but unpredictable Suggested Unknown	Well documented Experience in similar field Qualified guess Unqualified guess	Yes To some extent (partly or after some years) No	Yes To some extent No

C) Robustness

Underlying Assumptions in Indicator	
List of underlying assumptions	
Sensitivity Analysis, Indicator	**Sensitivity Analysis, Threshold**
A presentation of results Not relevant	A presentation of results Not relevant
Underlying Assumptions in Threshold	
List of underlying assumptions	

D) Performance Ability by Management

Ability to Adjust Indicator Level	**Reversibility of Danger**	**Possibility of Reducing Uncertainty**
Immediately Long time scale Irreversible Unknown	Yes To some extent No Unknown	Will scientific research reduce uncertainty? Will added control of human activity reduce uncertainty? In case, what?

4 CASE STUDIES

4.1 The level of spawning stock biomass

4.1.1 Background

Our first example is on the levels of spawning stock biomass (SSB) as an indicator. We want to illustrate our framework when both the indicator and the thresholds (the reference points) are based on aggregated information. The idea behind this indicator is very simple and compelling in a management context: there must be sufficient fish left to produce offspring. To measure, calculate or predict the biomass, on the other hand, is far more difficult. The same concerns the decision on appropriate thresholds. Several other time series are presented in the ACFM (Advisory Committee on Fisheries Management) report (see e.g. ICES 2002c): catch landings, fishing mortality rates and recruitment, but we have chosen spawning stock biomass since B_{pa} (precautionary reference point on spawning stock biomass) is an important part in ACFM advice and it is suggested as an EcoQO. We are aware that there are suggestions to combine thresholds of fishing mortalities together with the B_{pa} as an EcoQO (ICES 2003), but our intention is to illustrate the framework and not to evaluate ACFM advice or the choice of EcoQOs. We have chosen Northeast Arctic cod because there is a continuous discussion in the media and within the scientific community on the quality of scientific advice, both when it comes to deciding the level of spawning stock biomass and where the thresholds should be. We thus hope that the framework will make the AFCM advice more transparent.

4.1.2 Advice Statement

We now explain and discuss the different boxes of the framework and begin with the *Advice Statement* (table 2). In the ACFM (Advisory Committee on Fishery Management) report (ICES 2002c) the time series of spawning stock biomass is presented in a graph. Estimated uncertainty is not given in this graph, but there are some indications in the text of the uncertainty. Problems like underreporting and annual variation in growth are addressed in the text, and thereby communicate, although not so directly, uncertainty in the calculated spawning stock estimates and the predictions.

Continuing onto the next boxes, SSB levels is a state indicator with a high level of aggregation (see later discussion). The thresholds are then explained in accordance to the ACFM report. The originally intention of the spawning stock biomass thresholds was to be limit reference points although B_{pa} may be interpreted as a target reference point. As the spawning stock biomass is not measured directly, but estimated (or calculated, depending on how statistically strict you define “estimate”), it is an aggregated indicator. The data are interpretations, interpolations and extrapolations of the actual measurements (survey indices, age composition in catch data etc.). The indicator (and threshold) is composite since their values are calculations based on these data. The aggregations level is thus high. In addition to being thresholds, the intention of the precautionary reference points is to reflect the uncertainty in advice. Going to the next box, we have included some information stated in the text of the ACFM report.

The conclusion of the 2002 assessment is that the stock is outside safe biological limits. To be clear, it should perhaps say what event “safe” is related to. The ACFM advice is presented by a table of scenarios: landings according to different fishing mortality rates and predicted spawning stock biomass if such catches are taken. The shaded part of the table consists of options considered to be inconsistent with the precautionary approach.

4.1.3 Power of explanation

The next part, *Power of Explanation* (table 2) shows that the theoretical explanations for changes in indicator value are mainly understood but is not, and probably cannot be, quantified in detail. We know that both the environment and fishing affect the level of spawning stock biomass, but may be difficult to separate into quantities. The basis for choosing B_{lim} and B_{pa} is somewhat arbitrary because the knowledge is scarce on what happens when spawning stock biomass levels are very low. Further we note that the term "probability" (table 4.1) in the explanation for choosing the thresholds (ICES 2002) cannot be meant as a statistical term.

To some extent it is possible to detect changes in the indicator level, but often this takes a couple of years. Experience shows that because there is considerable uncertainty in assessing how much fish there is today, assessments occasionally fail to discover changes in trends. It is commonly accepted that when more data is collected from a year class, the certainty on how much fish there were increases.

4.1.4 Robustness

The underlying assumptions in calculating spawning stock biomass are numerous. Only a few are listed in this paper, but in an actual advice situation it should be judged which ones to include. We start with the assumptions linked to the catch data. The last 7 years it is assumed that there are no unreported landings, no misreported landings or no discards. Still among scientists, it is commonly agreed that this assumption is violated. The last study carried out, in 1992, suggested an underreporting of 130 000 tons while 356 000 tons were reported (ICES 2002c). The fact that the impact of this assumption is unknown will help the reader to judge or question the rigidity of the stock assessments and the forecasts in the catch option table.
Then follows assumptions on sampling, age reading and survey indices (which again build on several assumptions on survey coverage, sameness between years, species identification and fish migration). Then there are assumptions on mathematical functions like the relationship between indices and stock levels. Other examples are growth and maturity. In addition there are assumed constants like natural mortality and other model constants. The various data sources are considered to be of different quality. The sources are therefore weighted differently. Usually in fish stock assessment this is done manually so that the weighting adds to the list of assumptions. The last assumptions on the list is that the statistical distribution is appropriate, the mathematical problem is well defined and that it is numerical stable, that is, that we actually find the answer to the defined problem and that it is unique.

The list of assumptions is long and we probably don't know how they influence the indicator level adequately. A sensitivity analysis could suggest which assumptions influence the results the most and to what extent. Although no such analysis is presented in the ACFM report, it is usually done to a limited extent on the ICES working groups. ACFM advice could be more transparent and robust if the list of assumptions was presented together with how they influence stock estimates and the predictions.

$\mathbf{B_{lim}}$ is defined as a value below which there is a high risk that recruitment will 'be impaired' (seriously decline) and on average be significantly lower than at higher SSB (ICES 2002c – ACFM). The value is set on the basis of historical data. When information about the dependence of recruitment on SSB is absent or inconclusive, $\mathbf{B_{lim}}$ is set as a value close to the lowest observed spawning stock biomass in the time series. This is to minimize the risk of the stock entering an area where stock dynamics is unknown (ICES 2002c). When estimating the size of the SSB, there will always be estimation (and other?) uncertainty. Therefore ICES applies a 'buffer zone' by setting a higher SSB reference point $\mathbf{B_{pa}}$ (SSB precautionary reference point). By design the $\mathbf{B_{pa}}$ is intended to give a low probability that the true SSB is below $\mathbf{B_{lim}}$ when it is estimated to be at or above $\mathbf{B_{pa}}$.

The concept of $\mathbf{B_{lim}}$ is based on an assumption that there is a discontinuity zone or breaking point in the functional relationship between recruitment and SSB. This assumption has persisted since the classical and pioneering modeling work by Ricker (1954) and Beverton and Holt (1956). They supported their assumptions by theoretical arguments which implied mechanisms involving density-dependent mortality of larvae and juveniles. They had no empirical data for marine fish populations to support their models, although Ricker (1954) had some support in data for Pacific salmon spawning in rivers and good support in experimental data with Banana fruit flies in closed containers.

Since these pioneering works, the empirical data on recruitment and SSB has accumulated to a vast body of information. Typically these data show a 'shotgun' scatter diagram where it is difficult to fit any given curve with statistical certainty. As an average for many stocks, SSB explains 20 % or less of the variance in recruitment (ICES 2003 ACE rep.). This lack of any clear relationship made Rothschild (1986) characterize the situation as the 'recruitment-SSB paradox': why is it so difficult to see in empirical data a relationship which is of such a fundamental importance for dynamic properties of marine fish populations?

The reference points build on a range of assumptions (Table 2). They are based on averages on biological measures of the stock, average SSB-R relationships and averages on environmental conditions, assuming that historic averages are relevant for the situation today. The ACFM report (ICES 2002) adds a relevant warning in the text: that the reproduction potential per spawning biomass is probably lower and that annual variation on growth and maturity can be substantial for this stock. Indirectly, these two comments are uncertainty considerations on the underlying assumptions of the thresholds and advice. The impact of the assumptions on advice is not mentioned.

4.1.5 Performance ability by Management

When it comes to how management can influence indicator levels (*Performance Ability by Management*), this can be done to some extent by reducing or increasing total catches, although natural variation makes it impossible to control the development of the indicator fully. Besides the danger of recruitment overfishing, the possibility of irreversibility is also there due to changes in the ecosystem. One might ask whether the state of the Northern cod is irreversible. We don't have enough knowledge to predict such situations, and in the case of the Northern cod, we even do not know whether we are there.

Going to the last box, we can say that the uncertainty in fish stock assessment is evident. To a small extent it may be possible to reduce the uncertainty on a short time scale by increased research or increased catch control. It is not obvious whether we will be able to be markedly more precise in the future.

4.2 **Technetium (Tc-99) in lobster (*Homarus gammarus*)**

4.2.1 Background

Technetium-99 (Tc-99) ($t_{½}$ (half-life) = $2.13 \cdot 10^5$ years) is a waste product from reprocessing of spent nuclear fuel. This radioactive pollutant has been discharged from the reprocessing plants Sellafield (UK) (into the Irish Sea) and La Hague (F) (into the English Channel) since 1952 and 1966, respectively (Kershaw & Baxter, 1995). In 1994, the discharges of Tc-99 from Sellafield increased significantly (Fig. 2). Since 1994, the discharges from La Hague can be regarded as negligible compared to those from Sellafield.

In oxic seawater, technetium is found as the highly soluble pertechnetate anion (TcO_4^-). From Sellafield, Tc-99 is transported with ocean currents into the North Sea and northwards with the Norwegian Coastal Current (NwCC). Due to the increased discharges from Sellafield, the concentration of Tc-99 in the NwCC has increased by up to 10 times since 1994 (Kershaw et al., in press).

Following the increased concentrations of Tc-99 in seawater along the Norwegian coast, the concentrations of Tc-99 in marine organisms have increased (e.g. Brown et al., 1998). The highest concentrations have been observed in lobsters. The pollution of Tc-99 in seawater and marine seafood in Norwegian waters has been subject to large public concern during the past 5-6 years.

4.2.2 The advice statement

Measurements of Tc-99 in various marine organisms in Norwegian waters have been ongoing since 1997.The indicator time series in Table 4.2 consist of measurements performed by the Norwegian Radiation Protection Authority (NRPA) (Brown et al., 1998; Kolstad & Rudjord; 2000, Kolstad & Lind; 2002). The Tc-99 analysis is time consuming. Therefore, the time series is incomplete. Tc-99 is a pure beta-emitter, and a radiochemical separation of this radionuclide is required for quantitative analysis by means of beta-counting. A variety of separation methods have been published (e.g. Harvey et al., 1992; Kolstad et al., 1999). Independent of which method is used, the analytical error generally lies between 5 and 10 %. Since measurements of Tc-99 are direct, this state indicator has a low level of aggregation.

It is not developed intervention levels (thresholds) for normal discharges from a nuclear facility plant. The doses to the local population from the operation of a plant are kept to levels that are “as low as reasonably achievable and within internationally agreed dose limits and nationally prescribed constraints” (IAEA, 1994). Typically, the values of these dose constraints are smaller than local geographical variations in levels of radiation due to natural sources. However, in the event of a nuclear accident, intervention levels are recommended in Council Regulation (EURATOM) 3954/87 and in the supplement CR 2218/89. In our example we use the intervention level that applies for Tc-99, 1250 Bq/kg.

In the Irish Sea, Tc-99-concentrations up to 36,000 Bq/kg, 29 times higher than the threshold, have been measured in lobster (Swift & Nicholson, 2001). The levels of Tc-99 in marine organisms in Norwegian waters are far below this threshold, and not considered to be a threat to our health. The levels in Norwegian waters are expected to stay low in the future. However, there is a psychological negative effect of the presence of Tc-99, which may harm Norwegian fisheries.

4.2.3 Power of Explanation

There are no natural sources of Tc-99 in Norwegian waters. There is one source in addition to the two mentioned above: fallout from nuclear weapons testing in the 1950's and 60's. This fallout resulted in a Tc-99 "background concentration" in the North Atlantic of ~ 5 mBq m^{-3} (Dahlgaard et al., 1995). Thus, concentrations above this are due to discharges from Sellafield and La Hague. Further, the increases in Tc-99 levels in Norwegian waters and marine organisms since 1994 are undoubtedly due to the increased discharges from Sellafield. The approximate transport time for Tc-99 from Sellafield to various places along the Norwegian coast is known, and the approximate concentration in the Norwegian Coastal Current can also be predicted if we know the extent of the discharge. As far as we know, there are no other potential sources for Tc-99 in Norwegian waters. There is a potential for an accidental large discharge from Sellafield or La Hague, for example in connection with an attack from terrorists. It is difficult to predict the consequences of such an incident.

The intervention level/threshold is probably determined both on the basis of epidemic studies on humans after nuclear accidents and knowledge of the physical properties of the radionuclide in question. Matters as radiation type (α- β- or γ-radiation), half-live and in which organ the radionuclide is taken up, need to be considered. In some cases, there are social considerations to make when thresholds are being determined. This was the case when the threshold for Cs-137 was to be determined after the Chernobyl accident in 1986. First, the threshold was set to 600 Bq/kg. Later, the threshold in reindeer and a few other animals was raised to 3000 Bq/kg. The reason for this was that the concentrations of Cs-137 in reindeer in most cases were higher than 600 Bq/kg, and if this threshold were kept, reindeer herdsmen would loose their economic basis.

The ability to detect changes in the Tc-99 concentrations in lobsters is depending on correct analyses and a continuous monitoring program. The first can be ensured through international inter-calibration tests, the second can be ensured through allocating funds for sample collection and analyses.

4.2.4 Robustness

As Tc-99 is a directly measured indicator, and the measurements have a known error, sensitivity analysis is irrelevant. The underlying assumptions in the threshold relate to epidemic studies, and knowledge of the physical properties of the radionuclide in question. These are unknown to the authors of this paper, therefore we do not know of any sensitivity analysis.

4.2.5 Performance Ability by Management

Measurements of levels of Tc-99 in seaweed (*Fucus vesiculosus*) along the Norwegian coast since 1980 show that the levels decreased throughout the 1980s and early 1990s (e.g. Dahlgaard et al., 1997). This is due to a reduction in the discharges. As seen in Fig. 2, the 1978-discharge of Tc-99 from Sellafield was of the same magnitude as in 1995 (~190 TBq) (1 TBq=10^{12} Bq.). However, in 1979 and throughout the 1980s, the discharges were low relative to the 1978-discharge (2-7 TBq a^{-1}). A reduction of the concentrations of Tc-99 in both the NwCC and marine organisms along the Norwegian coast will be the result if the radioactive waste from Sellafield is stored on land instead of discharged into the Irish Sea, i.e. the concentrations in lobster are reversible. However, the background concentration of Tc-99 in the North Atlantic (see above) is irreversible, and may increase somewhat after mixing with the NwCC.

4.3 By-catch of harbor porpoise in North Sea fisheries

4.3.1 Background

Increase in fishing effort and understanding of fisheries effects on non-target species has generated greater interest on the by-catch of small cetaceans in different fisheries worldwide. In general by-catch of small cetaceans may happen in any fishery, but experience from the Northeast Atlantic has shown that in this area by-catch is most prevalent in pelagic trawl, pelagic drift-nets and demersal gill-net or tangle-net fisheries (ICES, 2001). There has been raised concern that the level of this by-catch, especially on North Sea harbour porpoise (*Phocoena phocoena*), is higher than the population growth rate leading to a population decline (Tregenza et al., 1997; Kock, and Benke, 1996).

The management goal set by the International Whaling Commission (IWC) and ASCOBANS for small cetaceans is such that all populations should be maintained at 80% of their carrying capacity or more (ICES, 2001). According to this defined goal all populations of small cetaceans which are at less than 80% of their carrying capacity are threatened by by-catch, and the anthropogenic impact should be reduced.

Commercial take of harbour porpoise is not allowed in any area of the North Sea. Therefore all anthropogenic impact on harbour-porpoise are by-products of human activities, ie. By-catch in fishing gear, pollution, ship collisions, habitat degradation, reduced prey availability through fishing of prey stock etc.

In this setting the European Commission asked ICES to further develop the basis for advice on cetacean by-catch and mitigation efforts in EU fisheries. This has also been used as input to the development of Ecological Quality Objectives (EcoQO) (ICES, 2001;ICES, 2002a) which led to the inclusion of level of harbor porpoise by-catch as one of ten EcoQO's agreed upon in the Bergen Declaration by North Sea Ministers.

In the following we will discuss the qualities of both the intrinsic qualities of the indicator 'harbour porpoise by-catch', and when used as a management tool in the context as an EcoQU, with a management goal set to the indicator level.

4.3.2 The advice statement

The basic indicator is the percentage of the total North Sea population of harbour porpoise caught as by-catch in commercial fishing operations each year. In principle it is a simple indicator, easy to calculate, simply by dividing the numbers of porpoise by-caught by the population size in the same year. In this sense the indicator is a state indicator relating the state of a parameter that is aggregated because it is composite of two variables: numbers by-caught and population size on a relatively vast area.

The threshold level is set to an annual by-catch of 1.7% of the population size. Under this level, by-catch induced mortality is lower than the population growth rate, allowing decimated populations to grow, hopefully towards the goal of 80% of their carrying capacity (ICES, 2001). Higher by-catch rate increases the risk of limiting population growth, or even decimating the population.

4.3.3 Power of Explanation

The most common form of by-catch is for porpoises to get entangled in fishing nets. Even though they are capable of holding their breath for up to 30 minutes most porpoises that get entangled eventually die from drowning. Some escapement does occur, by animals caught as nets are hauled, but this proportion is very low. It is also obvious that by-catch is a fully anthropogenically caused mortality.

Studies of reproductive rate of small cetacean populations have shown that the maximum growth rate of such populations is 4-15%. Choosing a cautious approach and using 4% as a conservative estimate of annual growth rate as an input in a population model suggested that the by-catch rate should be below 1.7% to ensure that the population remains stable, or does not decline (ICES, 2001). Studies have indicated that populations of harbour porpoise are below 80% of carrying capacity, and the goal from IWC and ASCOBANS is to ensure that the stock size is above this limit.

4.3.4 Robustness

To assess by-catch rate correctly one needs accurate estimates of the number of porpoises by-caught, and accurate population estimates, both on the same regularity, in addition to knowledge of the carrying capacity. The number of by-caught porpoises can either be counted directly through a mandatory reporting scheme, or estimated from observer data from a selection of the fishing fleet. Mandatory reporting schemes are unlikely to succeed as the fishermen know that the less by-catch they report, the less regulations that interfere with fishing operations to reduce by-catch will be put in place. Estimating by-catch from an observer regime requires a carefully set-up observation regime that covers all fishing areas, fishing grounds and seasons. So far observer schemes have only been carried out in limited areas of the North Sea, and these need to be expanded to all areas and countries for by-catch to be estimated correctly.

Population size estimates of harbour porpoises are based on visual surveys conducted by North Sea countries. As the population may fluctuate from year to year the population should also be estimated on an annual basis, which requires annual surveys. The most recent surveys of harbour porpoise abundance in the North Sea are from 1995, and at present this lack of recent data constitutes a major uncertainty in the estimation of by-catch rates. Lacking recent population estimates the most recent have been used to monitor changes in by-catch rate, but whether observed changes are due to real changes in the by-catch, or due to changes in the population size is unknown.

No sensitivity analysis has been conducted on the indicator, or the threshold level. Especially the threshold level should be subjected to such an analysis as it rests on an assumed annual growth rate of 4%. This is due to lack of high-quality demographic data for North Sea harbour porpoise, but studies have indicated ranges of 6-15% for the growth rate. If these estimates are true, the harbour porpoise can sustain a higher by-catch rate without suffering population decline or stagnation.

The approach also assumes that all un-natural mortality is caused by by-catch. Other human activities also induce mortalities, and their relative importance has not been studied. In addition, the population structure of the North Sea population of harbour-porpoise also plays an important role (Tolley et al. 1999). If there are sub-populations, the by-catch rate may vary widely between populations, being very high in some an small in others. If one assumes a homogenous population in a situation with many sub-populations, the by-catch level for some populations may be so high that these populations decline even thought the total by-catch rate for the North Sea is under the threshold level.

4.3.5 Performance Ability by Management

At present there is so much uncertainty connected to the underlying data used to assess by-catch rate that its use as an indicator of ecosystem health is very limited. However, implementing carefully designed observer schemes and annual sighting surveys in the North Sea can easily reduce the uncertainty. This does however require that the funding institutions (eg. National governments) around the North Sea to set in place legislature and funding to implement a thorough observation scheme and annual surveys.

In theory by-catch rate is easily reversible. Just stop fishing and by-catch will drop to 0%. In practice this is very unrealistic. Rather, legislature and mitigating procedures and technology are being developed and set in to place to reduce by-catch. Some of these have shown promising results, such as acoustic pingers and limiting net-fishing in areas and at times when by-catch is known to occur (Trippel et al., 1999). However, these mitigating procedures will never eliminate by-catch of small cetaceans completely, but if reduced to a sufficient level, by-catch will no longer have a potential negative effect on the population growth rate of North Sea harbour porpoise.

5 SUMMARY

We have suggested a framework for communicating advice based on indicators and thresholds. Our goal has been to make advice based on indicators transparent. In order to obtain transparency, the user should be able to evaluate the relevance and the robustness of the scientific information and get an understanding of its uncertainties. Presenting quantities only is obviously not sufficient for these purposes, and to explain the methods or technology is too ambitious. Non-experts must trust the expert that he/she knows the appropriate methods and technology. However, the underlying assumptions of the methods may hide non-verified beliefs or simplifications on the system in study. For the users, the public or scientists outside a particular field of science, the underlying assumptions are often easier to grasp and discuss than the scientific results or advice. Besides, the underlying assumptions may be crucial for the relevance of the scientific information. A study on the impacts of the different assumptions may indicate the robustness of the scientific results. The underlying assumptions, the robustness, ignorance and indeterminacy are qualitative aspects that affect the uncertainty associated with the scientific knowledge.

The idea behind the framework has been to communicate the main characteristics of the scientific knowledge; not only the indicator values, the threshold(s) (reference points) and advice statements. In this paper we have suggested three additional characteristics that should be addressed: the explanatory power of the knowledge, the robustness of the results or measurements and the management performance ability in connection with the chosen indicator. The headings of our framework are thus *Advice Statement, Power of Explanation, Robustness* and *Performance Ability by Managment*. The *advice statement* includes more or less the traditional way of communicating scientific advice or knowledge. The *Power of Explanation* serves as a way to communicate knowledge ignorance. It includes an evaluation of the knowledge on cause-effect and the possibility to detect and separate the causes of the problem in focus. *Robustness* includes lists of underlying assumptions and sensitivity analyses. *Performance Ability by Management* tries to characterize a management's possibility to "repair" a disfavored resource state and whether it is possible to reduce the uncertainty in the advice/scientific knowledge. These last two categories help illustrating the indeterminacy in the scientific knowledge and advice.

While the main goal with the framework is to improve the communication of scientific knowledge or advice based on indicators, there are other applications of the framework as well. In cases where an indicator is not decided yet, the framework can clarify indicators' benefits and drawbacks. Further, the framework can be a basis for discussing what kind of research could be helpful to the policy issue in question. It may thus generate ideas on both improvements on existing solutions and be of help on deciding new indicators and new research. In any case the framework can serve as raising awareness among us, the scientists, on the strength and limitations of the science involved.

To help us decide the category boxes in the framework, we explored it by applying it in three indicator case studies: the level of spawning stock biomass of Northeast Arctic cod, the Technetium-99 level in lobster and the number of by-catch of harbor porpoise in relation to stock level. A quite apparent feature with the SSB example was the numerous and wide specter of underlying assumptions in both the indicator and the threshold (B_{pa}). We reckon that if some of these assumptions were changed, the indicator measure or threshold would vary, and maybe substantially. It also seems that a thorough study on how these assumptions affect the calculations has not been carried out properly. At least it is not presented or referred to in the ACFM report (2002c). Keeping in mind the precision level in ACFM advice, we can therefore conclude that the catch option table is not a robust piece of advice, and that it is questionable whether the precautionary reference points reflect the uncertainty in a robust manner.

Our next example was the Technetium-99 levels in lobster in Norwegian waters. Unlike the first example this indicator introduces little uncertainty other than a rather low technical error. We (the authors of the paper) tried to find how the decision on the 1250 Bq/kg threshold was made, but managed so only partly. We expect however that there is more uncertainty connected to the threshold than to the indicator itself. The indeterminacy in this example is associated with unforeseen future events like accidents, terror actions and the like.

The example with by-catch of harbor porpoise suggests that the main problem is the data. The reported numbers on by-catch are not considered as reliable and the last surveys on this stock took place in 1994 (ICES 2002a). We may add that the question on separation of stocks does not seem to be settled either (Tolley et al. 1999). The non-quantifiable uncertainty is thus a significant part of the total uncertainty in this case.

Our examples have not been worked out in full detail simply because we, the authors, lack information and knowledge in all cases. Also, the text in the boxes should be considered more carefully. Still, the framework seems to be able to communicate important characteristics and that these may differ from topic to topic. This is a crucial quality now that we expect broader interest in resource management because of labeling according to sustainability and the increased focus on participatory processes in resource management.

However, our framework must be considered at a developing stage, as many aspects still need to be considered. It needs to be further developed to become clearer and to be sure that important aspects are not left out. Case studies on completely different problems, but still considered relevant for ecosystem-based management, will help us uncover weaknesses in the framework. Also we consider it necessary to work out a case study in full detail, and we need to find a way to present indicators that are strongly linked, like in multi-species issues. In such complex systems, there might be scientific disputes, which also should be presented as it illustrates qualitative uncertainty. Maybe we should have included a bow with *Competing Theories* or *Competing Hypotheses*. In this paper we have only considered state indicators, but we expect that valuable information or aspects may be lost when we divide the issue of eco-system based management into isolated categories. It would be interesting to see whether we could use the same ideas for presenting indicators other than state indicators, like indicators on driving force, pressure, impact and response.

Since the framework is about communicating knowledge and advice, it eventually needs to be evaluated. One or several workshop where we invite members from stakeholder groups (managers, NGOs, fishers, fishing industry, aquaculture, petroleum industry etc.)
would be helpful for the purpose of evaluating the clarity of the framework and how can it be improved.

6 REFERENCES

Beverton, R.J.H. and Holt, S.J. 1959. On the dynamics of exploited fish populations. Fishery Invest. London. Series 2. 533pp.

Brown, J., Kolstad, A.K., Lind, B., Rudjord, A.L. and Strand, P., 1998. *Technetium-99 contamination in the North Sea and in Norwegian coastal areas 1996 and 1997*. StrålevernRapport 1998:3. Norwegian Radiation Protection Authority, Østerås, Norway.

Dahlgaard, H., Bergan, T.D.S. and Christensen, G., 1997. *Technetium-99 and Caesium-137 Time Series at the Norwegian Coast Monitored by the Brown Alga Fucus Vesiculosus*. Radioprotection-Colloques, 32 (C2), 353-358.

Dahlgaard, H., Chen, Q., Herrmann, J., Nies, H., Ibbett, R.D. and Kershaw, P.J., 1995. On the background level of ^{99}Tc, ^{90}Sr and ^{137}Cs in the North Atlantic. Journal of Marine Systems, 6: 571-578.

EEA. 2002, Testing of indicators for the marine and coastal environment in Europe. Part 1: Eutrophication and integrated coastal zone management. Technical Report no. 84

EEA. 2003. Testing of indicators for the marine and coastal environment in Europe. Part 3: Present state and development of indicators for eutrophication, hazardous substances, oil and ecological quality. Technical Report no. 86

Funtowicz, S.O. and Ravetz, J.R. 1990 *Uncertainty and Quality in Science for Policy*. Kluwer academic publishers, ISBN 0-7923-0799-2

Harvey, B.R., Williams, K.J., Lovett, M.B. and Ibbett, R.D., 1992. Determination of technetium-99 in environmental material with rhenium as a yield monitor. Journal of Radioanalytical and Nuclear Chemistry, 158 (2): 417-436.

IAEA, 1994. Intervention Criteria in a Nuclear or Radiation Emergency. Safety Series No. 109, International Atomic Energy Agency, Vienna, 117 pp.

ICES 1999. *Report of the Coordinating Group on ICES Advice*. C.M. 1999/Del:21, International Council for the Exploration of the Sea. Copenhagen. 40 pp.

ICES 2001 *Report of the ICES Advisory Committee on Ecosystems*, *2001*. ICES cooperative research report no. 249. International Council for the Exploration of the Sea, ISSN 1017-6195, 75pp.

ICES 2002a *Report of the ICES Advisory Committee on Ecosystems, 2002*. ICES cooperative research report no. 254. International Council for the Exploration of the Sea, ISSN 1017-6195, 129pp.

ICES 2002b *The ICES Strategic Plan/ Plan stratégique du CIEM*. International Council for the Exploration of the Sea. Copenhagen

ICES 2002c Report of the ICES Advisory Committee on Fishery Management. ICES cooperative Research Report No. 255

ICES 2002d. Report of the Study Group on Biological Reference Points for Northeast Arctic Cod. ICES CM 2003/ACFM:11 Ref: SGPRP

Kershaw, P.J. and Baxter, A., 1995. The transfer of reprocessing wastes from north-west Europe to the Arctic. Deep-Sea Research Part II, 42 (6): 1413-1448.

Kershaw, P.J., Heldal, H.E., Mork, K.A and Rudjord, A.L., 2003. Variability in the supply, distribution and transport of the transient tracer ^{99}Tc in the NE Atlantic. Journal of Marine Systems, in press.

Kock, K. and Benke, H. 1996. On the by-catch of harbour porpoise *(Phocoena phocoena)* in German fisheries in the Baltic and the North Sea. Arch. Fish. Mar. Res. 44(1/2): 95-114

Kolstad, A.K, Lind, B. and Rudjord, A.L, 1999. Kalibreringsrutiner og metodebeskrivelse av ^{99}Tc-analyser. StrålevernRapport 1999:12 (in Norwegian). Norwegian Radiation Protection Authority, Østerås, Norway.

Kolstad, A.K. and Rudjord, A.L, 2000. Radioaktiv forurensning i marint miljø. ^{99}Tc i sjøvann og biota fra norske kystområder i 1998 og 1999. StrålevernRapport 2000:7 (in Norwegian). Norwegian Radiation Protection Authority, Østerås, Norway.

Kolstad, A.K. and Lind, B., 2002. Radioactivity in the Marine Enviroment 2000 and 2001. Technetium-99 concentrations in Norwegian coastal waters and biota. StrålevernRapport 2002:6. Norwegian Radiation Protection Authority, Øaterås, Norway.

NSC. 2002. Ministerial Declaration of the Fifth International Conference of the Protection of the North Sea. Bergen 20-21 March 2002. 50pp.

Ricker, W.E. 1954. Stock and recruitment. Journal of the fisheries Research Board Canada. 11:559-623

Rothschild, B.J. 1986. Dynamics of marine fish populations. Harward University Press, Harward, USA.

Swift, D.J. and Nicholson, M.D., 2001. Variability in the edible fraction content of ^{60}Co, ^{99}Tc, ^{110m}Ag, ^{137}Cs and ^{241}Am between individual crabs and lobsters from Sellafield (north eastern Irish Sea). Journal of Environmental Radioactivity, 54: 311-326.

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. 1:256-274

Tregenza. N.J.C., Berrow, S.D., Hammond, P.S., Leaper, R. 1997. Harbour porpoise (*Phocoena phocoena)* by-catch in set gillnets in the Celtic Sea. ICES Journal of Marine Science. 54:896-904

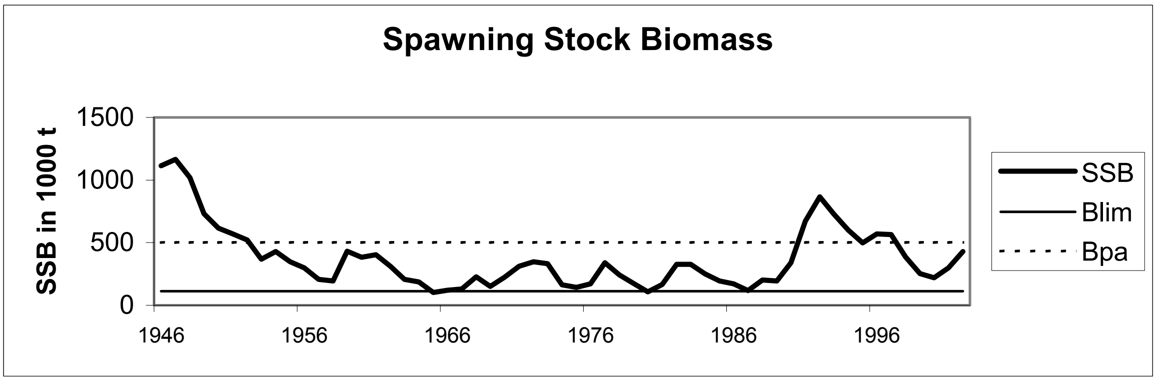
Trippel, E.A., Strong, M.B., Terhune, J.M., Conway, J.D. 1999. Mitigation of harbour porpoise (*Phocoena phocoena*) by-catch in the gillnet fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Science. 56:113-123

Van der Sluijs, J.P., Potting, J., Risbey, J., van Vuuren, D., de Vries, B., Beusen, A., Heuberger, P., Corral Quintana, S., Funtowicz, S., Kloprogge, P., Nuijten, Petersem, A. and Ravetz, J. 2002 *Uncertainty assessment of the IMAGE/TIMER B1 CO2 emissions scenario, using the NUSAP method*. Dutch National Research Program on Climate Change, Report no: 410 200 104, 227pp. Available from www.nusap.net

Table 2 Framework with presentation of SSB levels of Northeast Arctic Cod (data from ICES 2002c)

A) Advice Statement

Indicator Time Series



<table>
<tr><th>Indicator Category</th><th>Threshold(s)</th><th>Supporting Information</th><th>Conclusion/Advice</th></tr>
<tr><td>A state indicator
A high level of aggregation</td><td>B_{lim} = 112 000 t
(lowest observed spawning stock)
B_{pa} = 500 000 t
(the value below which the probability of below average year classes increases: a limit threshold)</td><td>Majority consists of first time spawners. Spawning stock consists of fewer age groups. Possible reduction of reproductive potential pr unit SSB.</td><td>The stock is outside safe biological limits.
Catch forecast for 2003:
<table>
<tr><th>F</th><th>Landings 2003</th><th>SSB 2004</th></tr>
<tr><td>0.00</td><td>0</td><td>850</td></tr>
<tr><td>0.17</td><td>134</td><td>740</td></tr>
<tr><td>0.34</td><td>251</td><td>647</td></tr>
<tr><td>0.42</td><td>305</td><td>605</td></tr>
<tr><td>0.51</td><td>355</td><td>566</td></tr>
<tr><td>0.63</td><td>425</td><td>512</td></tr>
<tr><td>0.84</td><td>529</td><td>435</td></tr>
</table>
(Weights in '000 t.)Shaded scenarios considered inconsistent with the precautionary approach.</td></tr>
</table>

B) Power of Explanation

Cause-effect in Indicator	Cause-effect in Threshold	Ability to Detect Change	Ability to Separate Effects
Environment and fishing affect SSB levels.	Probability reflections	To some extent (with a time lag)	To some extent

C) Robustness

Underlying Assumptions in Indicator	
• No unreported landings the last 7 year, • No discards, • Appropriate sampling, • Correct age reading, • Correct natural mortality, • Survey coverage assumptions, • Assumptions on scrutinizing echograms, • Assumed patterns on individual weights and maturity, Subjective weighing of data sources correct, • Stock interactions with capelin and cannibalism (more assumptions), • Appropriate statistical distribution, • The uncertainty is reflected in the precautionary reference points, • Mathematical model is well defined and numerical model is stable.	
Sensitivity Analysis, Indicator	**Sensitivity Analysis, Threshold**
Not presented in ACFM report	Done to some extent, but not presented in ACFM report
Underlying Assumptions in Threshold	
• Danger well defined, • Historic measures of SSB, recruitment and other of sufficient precision • Relationship R-SSB known, • Constant reference points valid independent of today's fluctuations in biological measures and in environmental conditions, • Uncertainty in estimated SSB constant from year to year,	

D) Performance Ability by Management

Ability to Adjust Indicator Level	Reversibility of Danger	Possibility of Reducing Uncertainty
To some extent: Reduce/increase fishing	To some extent If biological collapse occurs: possible irreversibility in rebuilding the stock	To some extent: Improve methodology, Improve catch control, (Improve presentation of advice)

Table 3 Framework with a presentation of technetium-99 in lobster

A) Advice Statement

Indicator Time Series

Year	Location	Levels of Tc-99 (Bq/kg WW)
1997	Outer Oslofjord	11 – 15
1997	Sunnhordland	35 – 42
1998	Outer Oslofjord	14,4 – 26
2001	Kvitsøy	2 – 42
2001	Stefjord	2,8 – 20

Indicator Category	Threshold(s)	Supporting Information	Conclusion/Advice
State indicator Low level of aggregation.	1250 Bq/kq A limit threshold A possible health threat to consumers above threshold.	The discharges are temporary stopped (until the end of 2003).	The levels are well below the threshold. It is considered safe to eat lobster in Norwegian waters.

B) Power of Explanation

Cause-effect in Indicator	Cause-effect in Threshold	Ability to Detect Change	Ability to Separate Effects
Known and on a short time scale predictable	Based on epidemic studies and knowledge of the physical properties of the radiation source.	Yes	Yes

C) Robustness

Underlying Assumptions in Indicator	
Correct measurements.	
Sensitivity Analysis, Indicator	**Sensitivity Analysis, Threshold**
Not relevant, direct measurements.	Unknown
Underlying Assumptions in Threshold	
• The underlying assumptions relate to the epidemic studies, and knowledge of the physical properties of the radiation source.	

D) Performance Ability by Management

Ability to Adjust Indicator Level	Reversibility of Danger	Possibility of Reducing Uncertainty
Immediately in marine organisms Irreversible on a global scale, not able to lower the background concentration of Tc-99 in seawater.	Probably reversible in marine organisms Irreversible if background concentrations have crossed threshold	The uncertainty in measurements is sufficiently low. The uncertainty in future unforeseen events is difficult to predict.

Table 4 Framework with presentation of by-catch of harbor porpoise

A) Advice Statement

Indicator Time Series

The by-catch rate of harbour porpoise in North Sea fisheries expressed as the percentage of the total population caught as by-catch in all North Sea fisheries.

Absolute by-catch. Data from ICES (2002a).

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Numbers by-caught	5322	5938	4973	5192	6311	6543	6709	7366	6738	5993	5308	5206	4228	4150	3888

Population size and by-catch rate. Data from ICES (2002a).

Area (ICES)	Year	Pop. Size	Lower 95% CI	Upper 95% CI
IIIa + b	1994	36 046	20 276	64 083
IIIc	1994	5 850	3 749	9 129
24 + 25	1995	599	200	3 300
Kiel & Mecklenberg Bights	1995	817	300	2 400
IV a	1994	98 564	66 679	145 697
IV b+c	1994	169 888	124 121	232 540
VIII f+g+h+j	1994	36 280	12 828	102 604
Total		348 044	228 153	559 753
By-catch rate (1994 pop size, own estimate)		2,1 %	3,2 %	1,3 %
By-catch rate (1995 pop size, own estimate)		1,9 %	3,0 %	1,2 %

Indicator Category	Threshold(s)	Supporting Information	Conclusion/Advice
State Some aggregation	An annual by-catch of 1.7% of best population estimate	Stranding of dead porpoises and other indications of high and unreported by-catch. Lack of quality data.	Identify areas of high by-catch and suggest mitigating efforts

B) Power of Explanation

Cause-effect in Indicator	Cause-effect in Threshold	Ability to Detect Change	Ability to Separate Effects
Porpoises get entangled in gear, and most die from drowning. This entanglement increases the population mortality rate.	Higher by-catch than threshold may lead to population decline. This is dependent on correct estimate of population growth rate.	Yes, annually and large-scale change only as the uncertainty in the parameters will mask small-scale changes.	To some extent. Other elements can cause population decline.

C) Robustness

Underlying Assumptions in Indicator	
Correct and annual data on the number of porpoises by-caught annually Correct and annual estimates of the population size	
Sensitivity Analysis, Indicator	**Sensitivity Analysis, Threshold**
No, but sensitivity analyses have been done for population size estimates.	None
Underlying Assumptions in Threshold	
Maximum growth rate of population is 4%, thus it can sustain a by-catch rate of max 1.7% Other mortality factors are estimated correctly Carrying capacity is estimated correctly Knowledge on separation of stocks A fundamental question is if the goal of reaching 80% of carrying capacity is realistic and can be integrated with other goals in ecosystem-based management. One cannot immediately expect a decimated population of a top-predator, such as harbour porpoise, to return to a level close to its historic carrying capacity given the increased human impact through fishing, shipping, recreation, pollution etc. that has occurred in the interval. Rather, goals for population sizes should be set so that they are in agreement with other aspects of the ecosystems, and human activities such as fishing, aquaculture and shipping.	

D) Performance Ability by Management

Ability to Adjust Indicator Level	Reversibility of Danger	Possibility of Reducing Uncertainty
Yes, through regulations of fishing effort and technical regulations	Reversible at “normal” population levels. At very low population levels by-catch at or above the threshold may push the population to extinction	Yes. Lack of data. By initiating comprehensive monitoring schemes and conducting regular and comprehensive population assessment and studies of demography.

Figure 1 Information pyramid