# The necessity for response indicators in fisheries management

G. J. Piet, H. M. J. van Overzee, and M. A. Pastoors

Piet, G. J., van Overzee, H. M. J., and Pastoors, M. A. 2010. The necessity for response indicators in fisheries management. – ICES Journal of Marine Science, 67: 559–566.

Results are used from traditional fisheries management to explore two potential response indicators: (i) the extent to which scientific advice is incorporated in decision-making, and (ii) the compliance of industry and the relevant authorities to these decisions. Based on the most comprehensive set of data on the management process of 125 stocks for which ICES provided advice over the period 1987–2006, we explored these response indicators and found that for just 8% of the stocks, the official total allowable catch (TAC) equalled the scientific advice, and that in recent years the official TAC overshot scientific advice by >50%. Compliance levels appear to be reflected in the percentage of stocks for which landings exceeded the official TAC, decreasing from ~8 to 2%. However, because the TAC appears not to be limiting, compliance may not be the most appropriate indicator. Without transparent decision-making that takes scientific advice into account, or the compliance of industry as reflected by the type of response indicators explored, the effectiveness of new developments in fisheries management, such as the application of an ecosystem approach, will be compromised, as has been the case with conventional fisheries management measures.

**Keywords:** compliance, fish stocks, landings, sustainable fisheries, TAC.

Received 19 October 2008; accepted 30 November 2009; advance access publication 10 January 2010.

*G. J. Piet, H. M. J. van Overzee and M. A. Pastoors: Wageningen IMARES, PO Box 68, 1970 AB IJmuiden, The Netherlands. Correspondence to G. J. Piet: tel: +31 317 87188; fax: +31 317 87326; e-mail: gerjan.piet@wur.nl.*

## Introduction

The pressure–state–response (PSR) framework was initially developed by the Organisation for Economic Co-operation and Development (OECD) to structure its work on environmental policies and reporting. It considers that human activities exert pressure on the environment that affects the quality and the quantity of natural resources (state) and that society responds to these changes through environmental, general economic, and sectoral policies and through changes in awareness and behaviour (societal response; OECD, 1993).

The PSR framework has also found its way into recent developments in fisheries management (Garcia and Staples, 2000), in which the ecosystem approach requires managers to take account of how fisheries impact a wide range of marine ecosystem components when setting ecosystem objectives (Heslenfeld and Enserink, 2008). Meeting these objectives will require reliable scientific advice, effective management decision-making, and an operational management framework (Murawski *et al.*, 2000; Pope and Symes, 2000; Link, 2002; Hall and Mainprize, 2004; Pikitch *et al.*, 2004). Management objectives tend to focus on the condition, or state, of each ecosystem component in question, highlighting the need for indicators of state that can be applied to monitor change in the condition of each component (Link, 2002; Link *et al.*, 2002; Rochet and Trenkel, 2003; Trenkel and Rochet, 2003; Jennings, 2005). If objectives of state are not achieved, managers respond by modulating pressure (i.e. anthropogenic impacts on the ecosystem) through specific actions, quantified by a response indicator, to achieve the stated objectives.

In traditional single-species management, the PSR framework is not explicitly applied. However, the scientific advice for managing most of the fish stocks in EU waters is provided by ICES through annual stock assessments that report on what is considered to be the best state indicator (SSB, spawning-stock biomass) and best pressure indicator (*F*, fishing mortality), on which the scientific advice for a specific total allowable catch (TAC), is based.

In this scientific process, there is considerable uncertainty caused by the availability and quality of the input data, as well as the capacity of the methodology generally used, i.e. virtual population analysis, to deal with it (Delaney *et al.*, 2007; Schwach *et al.*, 2007), undermining the credibility of the advice. The uncertainties are incorporated in the advice through the implementation of the precautionary approach, in which reference points are used to take account of the uncertainties in the assessment process (Cadrin and Pastoors, 2008), but implementation has mainly been biased towards stocks for which relatively abundant information is available, and scarcely for data-poor stocks. An evaluation of the advisory process for all stocks in the greater North Sea (Piet and Rice, 2004) concluded that if the most conservative precautionary criteria were applied to determine whether a stock was within safe biological limits (SBLs), i.e. $SSB > SSB_{pa}$ and $F < F_{pa}$, the correct advice was given for just 59% of the stocks that were outside the SBL and for 66% of the stocks within the SBL. These values, which are only slightly above the chance score of 50% (e.g. the assessment showing that SSB is either above or below $SSB_{pa}$), are consistent with managers commonly treating $SSB_{pa}$ as a target, despite frequent ICES admonitions not to (Piet and Rice, 2004). Also, the difference between the values is in line with the claim of Schwach *et al.* (2007) that the assessment process performs least well when most urgently needed, i.e. when a stock is depleted.

Despite such problems in the scientific process, the TAC-based advice for a stock is what the ICES scientific community believes is the most appropriate upper limit of catches from a stock within the precautionary management framework. The advice is generally phrased as "catches not exceeding XXX t", but in effect this upper limit is often used as the basis for the management decisions in terms of a set of legally binding single-stock TACs. The managers that take these decisions take the position that, broadly speaking, they follow the scientific advice (Delaney *et al*., 2007), but some do concede that other factors may be taken into account, and that national governments, through the Council of Ministers, do modify the CEC (Commission of European Communities) proposals. An example given by Patterson and Resimont (2007) shows that managers may deviate from scientific advice to limit interannual variations in landings because, from an industry perspective, such variations are undesirable because they disrupt market chains and result eventually in less profitability.

The current management system in EU waters is widely acknowledged to be performing poorly in terms of sustainable exploitation (CEC, 2001; Sissenwine and Symes, 2007). Piet and Rice (2004) found that <10% of the stocks managed under the Common Fisheries Policy (CFP) were within their SBL, despite mostly correct scientific advice being provided. Based on an analysis of cod stocks in the NE Atlantic, Cardinale and Svedang (2008) state that this situation is caused by the prevalence of short-term socio-economic demands over scientific advice, and an evaluation by Rice and Cooper (2003) of the management of flatfish fisheries around the globe found that more than any other factor examined, failure to comply with scientific advice greatly increased the risk of unsustainability. Finally, there can be large discrepancies between official landings and real catches from the fishing grounds, through slipping, discarding, highgrading, etc. This could easily affect the outcome of a policy, resulting in agreed TACs not generating the intended outcomes.

Already by 1993, it had been noted that most indicators of societal response had a shorter history and were still in the development phase, both conceptually and in terms of data availability, compared with the indicators of environmental pressure and many indicators of environmental condition (OECD, 1993). Probably as a consequence of this finding, response indicators are not often used in fisheries management. Finally, the most recent development in fisheries management is the implementation of long-term management plans and the introduction of an ecosystem approach. Long-term management plans attempt to describe the future (management) actions based on some known state variables. With the increasing number of management plans being implemented, the single-species advice should change too, but thus far, only a few management plans have been classified by ICES as meeting precautionary standards and hence suited to form the basis of single-species advice.

The introduction of an ecosystem approach shows that much of the indicator development has so far been focused on state (Rogers and Greenaway, 2005), and considerably less on pressure (Piet *et al*., 2007) or the relationship between the two (Piet and Jennings, 2005; Shin *et al*., 2005; Jennings, 2007). This focus on pressure and state indicators and their relationship suggests a belief that if this part of the PSR framework is fully developed, achievement of the management objectives should follow. Here, we use the results from traditional fisheries management to challenge this belief and to make a case that unless response indicators become an integral part of fisheries management, applying an ecosystem approach will not result in any marked improvement in the status of the stocks or the environment.

As an example of the type of indicators that could be used to improve transparency of the fisheries management process, we focus on single-species management and collate into a single database all the relevant information used in this process, for all stocks for which ICES provides advice. This database should then allow a comprehensive assessment of the extent to which biological scientific advice is integrated into decision-making. Based on the information in this database, we propose response indicators that could be used for two important parts of the fisheries management process that are often neglected: (i) the extent to which scientific advice is incorporated in decision-making, and (ii) the compliance of industry and the relevant authorities to these decisions. Such response indicators are relevant, because without the integration of scientific advice in decision-making or the compliance of industry, there is less chance that new developments such as an ecosystem approach to fisheries management will achieve their objectives.

## Material and methods

Every year the ICES Advice report series is published. This consists of ten regional-ecosystem volumes and can be downloaded from the ICES website (http://www.ices.dk). Each volume includes summaries of the fish stocks in the regional ecosystem that the volume describes. These summaries were used to create a database which consists, at present, of 125 fish stocks assessed by ICES (Table 1) and includes the following information for each stock:

(i) ICES Advice—a written definition stating the scientific advice for the stock;
(ii) predicted landings/catch corresponding to the advice minus the scientifically advised TAC;
(iii) agreed (official) TAC for the stock;
(iv) official landings, i.e. recorded formally.

The database currently runs from 1987 to 2007, but it does not always contain continuous time-series for all stocks, because the required information is not always available. In addition, ICES offers advice for several stocks per area. For this study it was necessary to split these stocks by area. For example, stock ang-ivvi (anglerfish in ICES Areas IV and VI) is treated as two substocks because separate information was available for areas IV and VI (Table 1).

In cases where the scientific advice did not specify a TAC but phrased it in terms of lowest possible catch or lowest possible *F*, we interpreted the advice to be for zero catch. Here, we considered the following potential response indicators:

(i) The integration of scientific advice in decision-making: for each record (stock × year) for which there was scientific advice other than zero, plus an official TAC, the proportion of stocks with official TACs set by the CEC equal to scientific advice as well as the mean TAC overshoot from that recommended by scientists (i.e. ICES), was determined. The latter was calculated for those TACs greater than scientifically advised according to the formula (official TAC × 100%/ scientifically advised TAC) − 100%. For the overshoot indicator, we calculated the mean per year across all stocks. As stocks for which a zero-catch advice is given, i.e. scientifically

**Table 1.** Fish species and corresponding stock, ICES, and/or region.

| Species | ICES Area/ Subdivision | Stock | ICES Advice report[a] |
|---|---|---|---|
| Anchovy | IXa | ane-pore | 7 |
| | VIII | ane-bisc | 7 |
| Anglerfish | VIIIc, IXa | ang-8c9a | 7 |
| | VIIb–k, VIIIa,b | ang-78ab | 5 |
| | IV | ang-ivvi | 5 |
| | VI | ang-ivvi | 5 |
| Atlantic sea bass | VIIa,d–h, IVb,c, VIII, IX | *sea bass*[c] | 2 |
| Blue whiting | I–IX, XII, XIV | whb-comb | 9 |
| Capelin | V, XIV, IIa | cap-icel | 2 |
| | I, II | cap-bars | 3 |
| Cod | VIa | cod-scow | 5 |
| | VIIa | cod-iris | 5 |
| | VIIe–k | *cod-7e–k* | 5 |
| | 22–24 | cod-2224 | 8 |
| | IV | cod-347d | 6 |
| | VII | cod-347d | 6 |
| | IIIa | cod-347d | 6 |
| | Part IIIa | cod-kat | 6 |
| | 25–32 | cod-2532 | 8 |
| | Vb1 | cod-farp | 4 |
| | Vb2 | cod-farb | 4 |
| | XIV | *cod-ewgr* | 2 |
| | Va | cod-iceg | 2 |
| | | cod-arct | 3 |
| | I, II | cod-coas | 3 |
| Greenland halibut | I, II | *ghl-arct* | 3 |
| | V, VI, XII, XIV | ghl-grn | 2 |
| Haddock | Va | had-iceg | 2 |
| | VIa | had-scow | 5 |
| | VIb | had-rock | 5 |
| | VIIa | had-iris | 5 |
| | VIIb–k | had-7b-k | 5 |
| | IV | had-34 | 6 |
| | IIIa | had-34 | 6 |
| | I, II | had-arct | 3 |
| | Vb | had-faro | 4 |
| Hake | IIIa, IV, VI, VII, VIIIa,b,d | hke-nrtn | 9 |
| | VIIIc, IXa | hke-soth | 7 |
| Herring | VIIj | her-irls | 5 |
| | | her-riga | 8 |
| | VIa(N) | her-vian | 5 |
| | VIa(S), VIIb,c | her-irlw | 5 |
| | 30 | *her-30* | 8 |
| | 31 | *her-31* | 8 |
| | 22–24, IIIa | *her-3a22* | 6 |
| | 25–29, 32 | her-2532-gor | 8 |
| | IV, VIId, IIIa | her-47d3 | 6 |
| | Va | her-vasu | 2 |
| | | her-noss | 9 |
| | VIIa(N) | her-nirs | 5 |
| Horse mackerel | IXa | hom-soth | 7 |
| | IIIa, IVb,c, VIId | hom-nrtn | 6 |
| | IIa, IVa, Vb, VIa, VIIa–c,e–k, VIIIa–e | hom-west | 9 |
| Mackerel | | *mac-nea* | 9 |
| | | mac-nea-w | 9 |
| | | mac-nea-n | 9 |
| | | mac-nea-s | 9 |
| Megrim | VIIb–k, VIIIa,b,d | mgw-78 | 5 |
| | VIIIc, IXa | meg-8c9a | 7 |
| | VI | meg-scrk | 5 |

*Continued*

**Table 1.** *Continued*

| Species | ICES Area/ Subdivision | Stock | ICES Advice report[a] |
|---|---|---|---|
| Nephrops | IIIa | *nep-iiia*[b] | 6 |
| | IVa | *nep-iva1*[b] | 6 |
| | IVa | *nep-iva2*[b] | 6 |
| | IVa | *nep-iva3*[b] | 6 |
| | IVb,c | *nep-ivbe*[b] | 6 |
| | IVb,c | *nep-ivbw*[b] | 6 |
| | IXa | *nep-9a*[b] | 6 |
| | VIIb,c,j,k | *nep-7bcj*[b] | 6 |
| | VIIa | *nep-7a*[b] | 6 |
| | VIIIa,b | *nep-8ab*[b] | 6 |
| | VIIIc | *nep-8c*[b] | 6 |
| | VIIa,f,g | *nep-7fgh*[b] | 6 |
| | VIa | *nep-via*[b] | 6 |
| Norway pout | VIa | nop-scow | 5 |
| | IV | nop-nsea | 6 |
| | IIIa | nop-kask | 6 |
| Plaice | VIIf,g | ple-celt | 5 |
| | IIIa | ple–kask | 6 |
| | VIIa | ple-iris | 5 |
| | VIId | *ple-eche* | 6 |
| | VIIe | *ple-echw* | 5 |
| | VIIh–k | ple-7h-k | 5 |
| | IV | ple-nsea | 6 |
| | VIIb,c | ple-7b-c | 5 |
| Rays and skates | IV | ray-iv[b] | 6 |
| | I–XIV | nea spurdog[b] | 9 |
| | I–XIV | nea basking shark[b] | 9 |
| | V–XIV | kitefin shark[b] | 9 |
| Redfish | V, VI, XIV | smn-con | 2 |
| | V, VI, XII, XIV | smn-ocn | 2 |
| | I, II | smn-arct | 3 |
| | I, II | smn-arct | 3 |
| Saithe | Vb | sai-faro | 4 |
| | I, II | sai-arct | 3 |
| | IV, IIIa | sai-3a4 | 6 |
| | VI | sai-6 | 6 |
| | Va | sai-icel[b] | 2 |
| Salmon | 32 | sal-32 | 8 |
| | 22–31 | sal-2231 | 8 |
| Sandeel | IIIa | san-kask | 6 |
| | VIa | san-scow | 5 |
| | IV | san-nsea | 6 |
| | | san-shet | 6 |
| Sardine | VIIIc, IXa | sar-soth | 7 |
| Shrimp | I, II | pan-arct | 3 |
| | IIIa, IVa | pan-sknd | 6 |
| Sole | IIIa | sol-kask | 6 |
| | VIIa | sol-iris | 5 |
| | VIId | sol-eche | 6 |
| | VIIe | sol-echw | 5 |
| | VIIf,g | sol-celt | 5 |
| | VIIIa,b,d | sol-bisc | 7 |
| | VIIh–k | sol-7h-k | 5 |
| | IV | sol-nsea | 6 |
| | VIIb,c | sol-7b-c | 5 |
| Sprat | IIIa | spr-kask | 6 |
| | VIId,e | spr-ech | 5 |
| | 22–32 | spr-2232 | 8 |
| | IV | spr-nsea | 6 |

*Continued*

**Table 1.** *Continued*

| Species | ICES Area/ Subdivision | Stock | ICES Advice report[a] |
|---|---|---|---|
| Whiting | VIa | whg-scow | 5 |
| | VIIa | whg-iris | 5 |
| | VIIe–k | *whg-7e–k* | 5 |
| | IIIa | whg-kask | 6 |
| | IV | whg-47d | 6 |
| | VIId | whg-47d | 6 |

The ICES Advice report column refers to the book in which the stock is described. The stocks for which the ICES Area does not correspond to the stock definition are italicized.
[a]This column refers to the chapter of ICES (2007) in which the stock is registered unless otherwise indicated.
[b]Information for these stocks was derived from ICES (2006).
[c]Information for this stock was derived from ICES (2004).

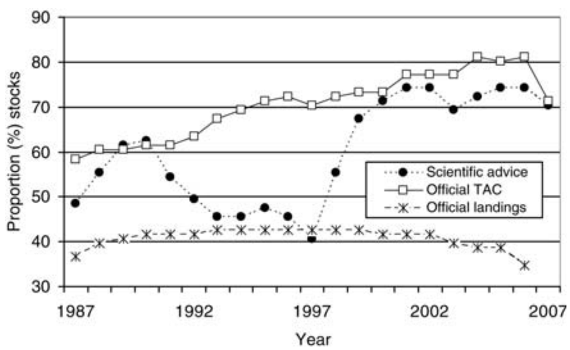


**Figure 1.** Proportion of assessed stocks for which the scientific advice provided a TAC, an official TAC was set, or official landings data were available.

advised TAC = 0, cannot be included, the proportion of stocks with such advice are reported as part of this indicator.

(ii) The compliance of industry and the relevant authorities: for each record (stock × year) for which a TAC was set and landings in the following year were known, the proportion of stocks for which the official landings exceeded the TAC, along with the mean overshoot of those landings compared with the official TAC, was determined. The overshoot was calculated according to (official landings × 100%/official TAC) − 100%. For the overshoot indicator, we calculated the mean per year across all stocks.

Stocks for which there was a mismatch between the advice and TAC areas were excluded from the list. For example, when the stock advice referred to Areas VIId and VIIe separately and the TAC applied to Area VII, those stocks were removed from our list. This resulted in 24 stocks not being included in the calculation of the indicators on integration of scientific advice.

## Results

To evaluate the appropriateness of our approach based on the agreed official TAC, we looked at the proportion of the 101 stocks in the database for which the scientific advice was based on a TAC, an official TAC was set, and landings data were available. Figure 1 shows that over the past 20 years, the proportion of stocks for which an official TAC was set increased from just over 60 to >80%. The proportion of stocks for which scientific advice was given increased in the late 1990s from ∼50 to >70%. However, official landings data were only available in the summary tables for ∼40% of the stocks.

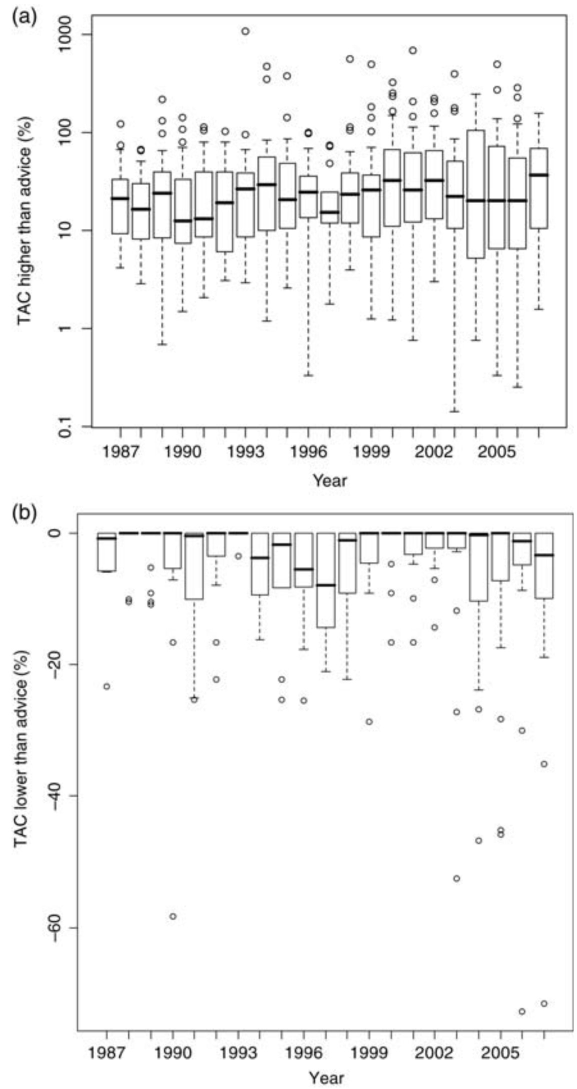


**Figure 2.** Deviation of the official TAC from the scientific advice for those stocks for which the official TAC was (a) higher (note the logarithmic scale) or (b) lower. Indicated are the median, first and third quartiles, 95% confidence limits, and outliers.

We explored the integration of scientific advice into decision-making by distinguishing in our database between the cases where the official TAC was equal to scientific advice (182 cases), higher than the scientific advice (588 cases; Figure 2a), or less than the scientific advice (125 cases; Figure 2b). This showed that if the official TAC was higher than the scientific advice, the variance could be from <1% to ∼1000%, but on average was 47%. If the official TAC was less than the scientific advice, the difference never exceeded 100% and was on average 12%. Based on this finding, several potential indicators for integrating scientific advice into decision-making were developed. Although these indicators were calculated for a consistent suite of stocks over time, the number of stocks for which this percentage was calculated may differ from year to year. Stocks for which no scientific advice and/or TAC was given over the entire period of study

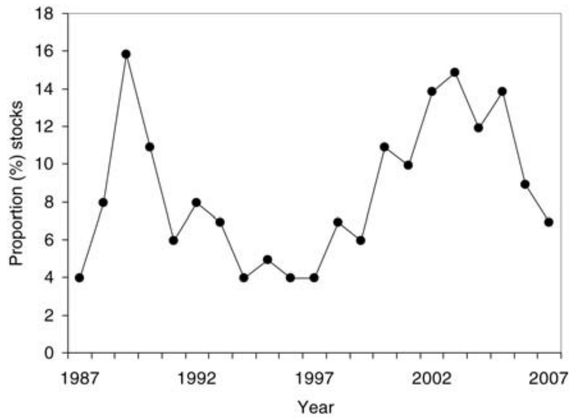


**Figure 3.** Proportion (%) of stocks for which the official TAC was equal to the scientific advice.

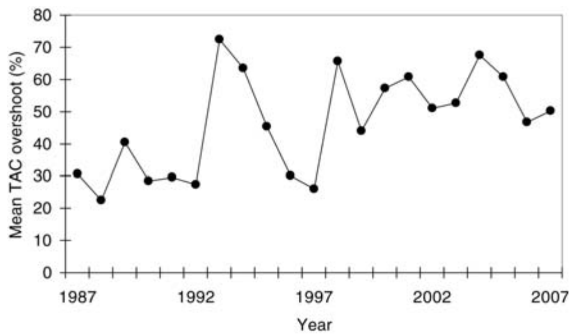


**Figure 4.** Mean TAC overshoot relative to scientific advice.

were excluded from the suite, but within the selection there were several stocks for which annual scientific advice was not consistently given. This may be due to different reasons, for instance the stocks were not considered, the advice was combined with that of other stocks, or the advice was phrased in text rather than in numbers.

The obvious response indicator for the integration of scientific advice would be the proportion of stocks with the TAC equal to that scientifically advised (Figure 3). That indicator fluctuates over time without any distinct pattern around an average of ~8%. Another indicator could be the mean overshoot across stocks of the official TAC relative to scientific advice (Figure 4). This showed a gradually increasing trend over the period analysed from about 20–30 to >50%.

If science advised a TAC of zero, it was not possible to calculate the deviation from the TAC, which could be a source of bias. We explored this by calculating the percentage of the stocks per year for which zero-catch advice was given (Figure 5). This shows that from 2000, the percentage increased from ~5 to 17% in 2007. For 12% of the stocks for which zero-catch advice was given in 2007, the advice was followed by management.

The overshoot of the official landings relative to the TAC set was explored by distinguishing between the cases where the landings exceeded the TAC (119 cases; Figure 6a) and those with smaller landings (457 cases; Figure 6b). The proportion of stocks where the landings exceeded the official TAC decreased gradually over time, from ~10 to 3% (Figure 7). The mean overshoot of the landings relative to the TAC varied increasingly with time,

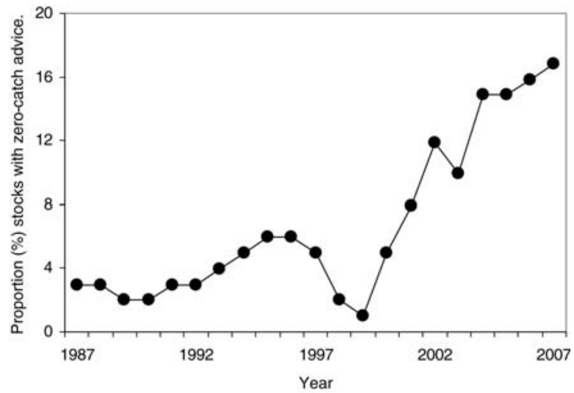


**Figure 5.** Proportion (%) of stocks with zero-catch advice.

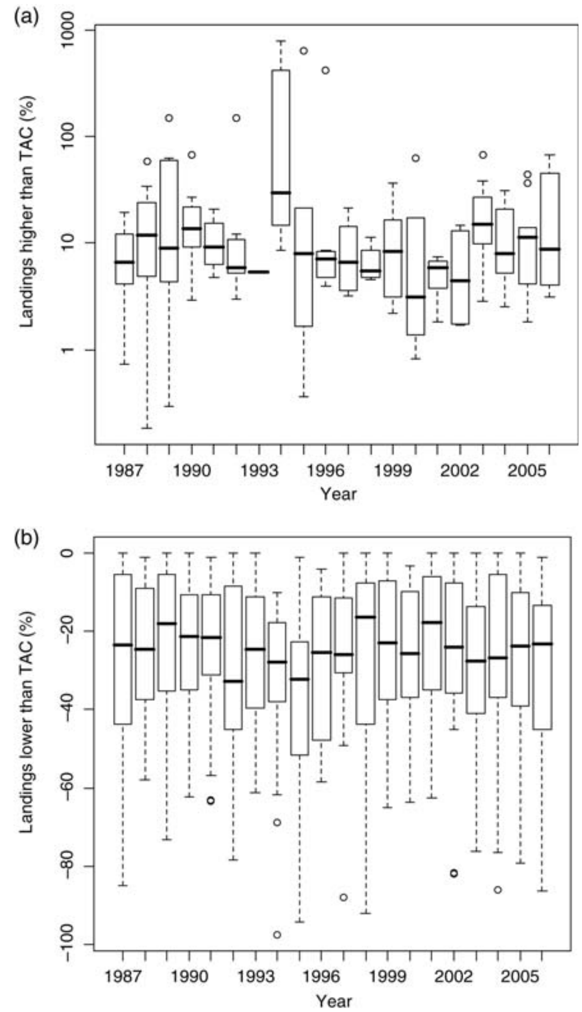


**Figure 6.** Deviation of the landings from the official TAC for those stocks for which the landings (a) exceeded the official TAC (note the logarithmic scale) and (b) were less than the official TAC. Indicated are the median, first and third quartiles, 95% confidence limits, and outliers.

with low values in the late 1990s and very high values of up to 325% in recent years (Figure 8). This steep increase, however, is influenced by a single stock (haddock at Rockall) for which

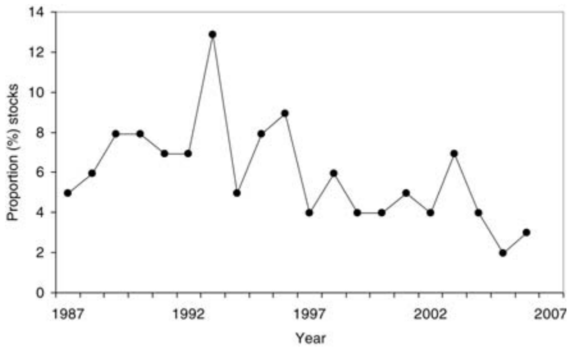


**Figure 7.** Proportion of stocks for which the landings exceeded the official TAC.

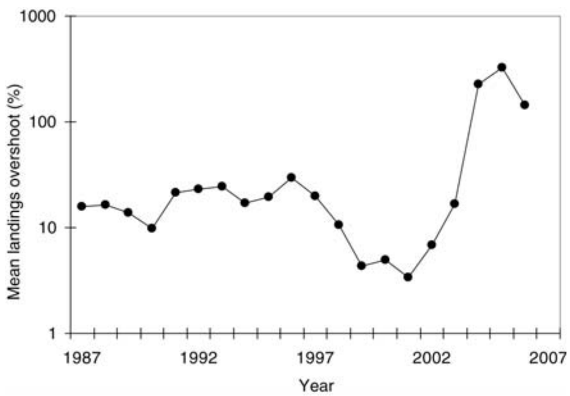


**Figure 8.** Mean landings overshoot in relation to the official TAC. Note the logarithmic scale.

only a TAC been set and calculation of an overshoot rendered possible.

## Discussion

To calculate these indicators, we used all stocks currently in the database (Table 1). However, over time stocks may drop out of the list, e.g. when assessments are no longer conducted, and new ones emerge, e.g. as a new fishery develops. In addition, the database may not provide sufficient information to calculate specific indicators. It is important that the reported time-series of the indicators are based on an agreed suite of stocks that is consistent over time. When this suite is revised, a new time-series will need to be calculated.

The reporting of official landings does not appear to be fully consistent in the sense that official landings have only been reported in 40% of the cases. The reason for this can be a mismatch between stock and landings area, strong indications of illegal landings, or other reasons. Obviously such issues need to be resolved, and the source of information needs to be comprehensive before such indicators can become operational.

Our evaluation of the integration of scientific advice into decision-making was based on a comparison of the official TAC with the scientific advice. The obvious first choice for an indicator would be the proportion of stocks for which the official TAC was equal to the scientific advice (Figure 3), but as this covers only a small proportion of the cases listed and does not show the extent to which the limit is exceeded, a more informative indicator would probably be the overshoot of the official TAC relative to the scientific advice (Figure 4). However, the increase in the number of zero-catch scientific recommendations from 2000 (Figure 5) shows that this indicator by itself may not reflect the true pattern. The reason the increasing trend of the indicator seems to level off in the late 1990s may be a shift towards zero-catch advice for those stocks with the greatest overshoot, rendering this finding less an indication of improved integration of scientific advice and more the result of a deterioration in stock health of an increasing number of stocks, to the point where science can only recommend zero catch. This shows that the proportion of zero-catch advisories is complementary to the overshoot indicator, so these two should be presented and considered together. Likewise, the proportion of stocks where the TAC equals the scientific advice complements the overshoot indicator because the latter becomes less informative as the TAC becomes equal to scientific advice for more stocks. Therefore, for integrating scientific advice into decision-making, we suggest three indicators that should be considered together:

(i) the proportion of stocks for which the official TAC is equal to scientific advice;

(ii) the mean overshoot of the official TAC relative to scientific advice;

(iii) the proportion of stocks for which zero catch is advised.

Hammer and Zimmermann (2003) compared official TACs with scientific advice and reported the mean level of deviation from the advice. However, as the TAC is considered the most appropriate upper limit of catches from a stock within the precautionary management framework, only the overshoots should be considered a problem, and they cannot be rectified by supporting undercatching of other stocks. The mean deviation is therefore not an appropriate response indicator.

For compliance with management measures, we compared the recorded landings with the official TAC and drew up several indicators. The percentage of stocks for which landings exceed the official TAC is an indicator that suggests that compliance is high because most stocks (>95% in recent years) land less than the TAC (Figure 7). Of course, the reported landings do not necessarily correspond to the actual catches taken from the sea, so the indicator may only indicate the reporting compliance of industry and the relevant authorities.

An indicator describing the mean overshoot of the landings in relation to the TAC shows that, because the value of the indicator is determined by increasingly fewer stocks, the validity of the indicator only reflects the situation for the increasingly fewer stocks for which landings exceeded the official TAC in that particular year, and hardly adds any generic information on compliance (Figure 8). These results suggest that the TAC is often no longer limiting, possibly because of burgeoning other measures, such as effort limitation, closed areas, and gear restrictions. If indeed the TAC is no longer limiting, this implies that indicators comparing landings with the TAC may not be appropriate in evaluating the compliance with management measures. In that respect, the slight decrease year-on-year in the proportion of stocks for which scientific advice is phrased in terms of a TAC is interesting. Often, this is because the advice appears to be moving towards $F$-based management, e.g. phrased as $F < F_{pa}$, XX% reduction in

*F*), which implies that future evaluations of how scientific advice is being integrated in decision-making may require the use of the *F*-based equivalent of the indicators presented here. Therefore, with the information currently available in the database, the most appropriate indicator for describing the compliance of industry and the relevant authorities is probably the percentage of stocks for which the landings exceed the official TAC, but other response indicators may become necessary in future to take account of further changes in management.

A complication that may contradict the above interpretation of this indicator follows from the fact that the allocation of the TAC into different national quotas can result in differences between countries to the extent that a TAC undershoot is the result of some countries not taking their part of the quota, whereas others, for which the TAC is limiting, may even exceed their TACs and hence not be compliant.

As one of the latest developments in fisheries management, the application of an ecosystem approach is intended to ensure that the planning, development, and management of fisheries will meet social and economic needs without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems (FAO, 2003). According to the wording of the new CFP regulation (CEC, 2002) and the emerging European Marine Strategy Framework Directive (CEC, 2007), the ecological pillar probably has ultimate precedence because the eventual loss of an ecological resource base will mean that no social and economic benefits can be derived from the sea. It is therefore essential that science to support management advice focuses on understanding how ecological constraints affect progress towards social and economic objectives and how this is incorporated in the decision-making process. Currently, when management measures such as TACs deviate from those recommended by science, political motivation is usually not provided, but the reason is very likely to be economic or social rather than biological (Delaney *et al*., 2007). Therefore, in a management system supported by indicators, the requirement is that indicators be available to describe the social and economic consequences of achieving ecological targets, as well as the political response to this information. The indicators that we have developed and evaluated clearly aim to show the political response to achieving ecological objectives, so similar indicators will need to be developed for social and economic objectives. Together, these indicators should contribute to making the process of managing towards stated objectives more transparent by clearly making deviations in different parts of the science–policy–implementation trajectory visible. Evaluative statements about fisheries management are often voiced in broad terminologies such as "failure" or "not effective". The indicators developed here can provide a more rational basis to underpin the evaluations of fisheries management and to provide a transparent and accountable framework that all participants in the process can access to review the evaluative information.

## Acknowledgements

This work was partly funded by the European Commission through the project "Indicators for Fisheries Management in Europe (IMAGE, FP6 044227). The constructive comments of Poul Degnbol and an anonymous reviewer greatly helped us improve the manuscript.

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doi:10.1093/icesjms/fsp293