The weakening role of science in the management of groundfish off the east coast of Canada

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The link between science and decision-making for groundfish fisheries off Canada's east coast has weakened during the past two decades. The demand for a large degree of flexibility in the decision-making process by both the Department of Fisheries and Oceans and the Northwest Atlantic Fisheries Organization, as well as the perceived low credibility of scientific knowledge, has resulted in an under-utilization of science capacity to provide risk-based assessments and to evaluate management strategies for robustness to uncertainty and compliance with the precautionary approach. The transition from science-based to *ad hoc* fisheries management is described, and the potential impact of two new approaches, ecosystem-based fisheries management and shared stewardship, is considered.

Keywords: co-management, ecosystem-based management, groundfish, management strategies, precautionary approach, risk, uncertainty.

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Introduction

The decline and collapse of many Canadian east coast groundfish stocks in the late 1980s and early 1990s have been widely perceived to be the result, in part, of weaknesses in the scientific basis for management decisions (Hutchings and Myers, 1994; Walters and Maguire, 1996). Although there have been weaknesses in the assessments, including retrospective bias (Sinclair *et al.*, 1991), some of the criticisms can be disputed (Shelton, 2005a), and it can be argued that the collapses were largely the result of management actions that were risk-prone, given the assessment estimates (Shelton, 1998).

The post-collapse decision-making process in the Department of Fisheries and Oceans (DFO) was redesigned to allow greater input by the fishing industry. The Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC), a science-based structure within DFO that had operated since the extension of jurisdiction in 1977, and the industry-government Atlantic Groundfish Advisory Committee (AGAC) were replaced in 1993 by the Fisheries Resource Conservation Council (FRCC), which drew members from academia and the fishing industry and only *ex officio* representation by DFO scientists (Doubleday *et al.*, 1997). Under the new process, regional DFO laboratories provided groundfish stock assessments to FRCC, which in turn sought input and comment from academia and industry before advising the Minister on a proposed best course of action for managing the resources. Although FRCC met publicly with fishers, deliberations were behind closed doors, and the link between FRCC advice and DFO scientific assessments was not always evident. FRCC was no longer requested to provide advice on groundfish after 2003.

The International Council for Northwest Atlantic Fisheries (ICNAF) had a strong scientific presence before 1977 and provided advice on many important fisheries pursued by Canada and international fleets in the area. Extension of national jurisdiction resulted in Canada assuming greater responsibility for the management of groundfish stocks, and the international scientific presence at Northwest Atlantic Fisheries Organization (NAFO, successor to ICNAF) meetings became considerably weaker (Anderson, 1998). In contrast, diplomatic negotiations and trade-offs to solve management problems for straddling stocks came to assume much greater importance under NAFO, in some instances supplanting scientific analysis and review.

After the stock collapses, scientists focused on what they perceived to have been a major weakness in earlier assessments: too much emphasis on point estimates. Estimation of uncertainty and risk thus became the major research focus in Atlantic Canada in the decade that followed (Shepherd, 1991; Smith *et al.*, 1993; Shelton and Rivard, 2003). This was opportune because Canada signed the United Nations Fish Stocks Agreement and adopted the FAO Code of Conduct for Responsible Fisheries in 1995, and introduced a new Oceans Act in 1996, all emphasizing the need to take a structured science-based approach to managing fisheries, in which uncertainty and risk are evaluated within a precautionary approach (PA).

DFO management practices came under criticism by the Canadian Auditor General in 1997 for not implementing the PA, for lacking clear fisheries management objectives and performance measures, and for not having a national policy for sustaining and conserving the resource (http://www.oag-bvg.gc.ca/domino/reports.nsf/html/97menu_e.html; Shelton and Rivard, 2003). DFO responded by developing a new approach termed "objective-based fisheries management" (OBFM) that incorporated the PA. Under OBFM, clear and measurable objectives would be set, based on biological and socio-economic factors and risk-management principles, and PA would be implemented

(Shelton and Rivard, 2003). OBFM was a well-founded response to the Auditor General's criticism that met the terms of international agreements and the Oceans Act, and promised a new era of fisheries management. Science was expected to have a formalized key role in implementation because of the emphasis on risk quantification, reference points, and the PA. Pilot studies under OBFM were carried out, for example, on Pacific herring, but in practice, the only fishery with an OBFM framework in place is for Atlantic seals (Rivard, 2006). This framework (http://www.dfo-mpo.gc.ca/seal-phoque/reports-rapports/facts-faits/facts-faits20062010_e.htm) has yet to be evaluated quantitatively with regard to PA compliance through simulation trials (Rivard, 2006).

Most groundfish stocks off the east coast of Canada are now depleted, severely depleted, or collapsed, and few are recovering. In several cases, bycatch mortality and mortality from small directed fisheries are at levels that will delay or prevent rebuilding (Shelton, 2005b, c; Shelton and Morgan, 2005; Shelton *et al.*, 2006). Further, some cod populations have recently been assessed to be at risk of biological extinction by a committee of independent experts (Committee on the Status of Endangered Wildlife in Canada, COSEWIC; http://www.sararegistry.gc.ca/status/showDocument_e.cfm?id=122), under Canada's new Species at Risk Act (SARA).

I describe the move away from science-based to largely *ad hoc* decision-making for groundfish stocks in the Northwest Atlantic. The term *ad hoc* is used here to describe decisions made for the specific case at hand, rather than through a predetermined management strategy based on a scientific assessment, and is not intended to be derogatory. Time-series of spawning-stock biomass (SSB) and fishing mortality (F) are presented for some key stocks to illustrate the response to changing management approaches over time. Consideration is given as to why OBFM, PA, and SARA have not contributed substantially to the implementation of a more structured approach to managing fisheries, based on scientific knowledge. Attention is also given to the potential effectiveness and the role of science in two new policies for managing fisheries—ecosystem-based fisheries management (EBFM) and shared stewardship.

From science-based to *ad hoc* management strategies

Fixed F strategies

Initial management of groundfish was based on mesh size regulation, but in the early 1970s, ICNAF realized that additional measures were necessary, and catch quotas based on the F maximizing yield-per-recruit (F_{max}) were introduced as a proxy for the F maximizing the yield from a stock (F_{msy}; Anderson, 1998). By 1975, it was recognized that total allowable catch restrictions (TACs) based on F_{max} were not preventing severe stock declines (e.g. northern cod, southern Grand Bank cod, Grand Bank American plaice, and yellowtail flounder; Figure 1), and that a more conservative approach would be required (Rivard and Maguire, 1993). Scientists participating in ICNAF developed $F_{0.1}$ (F corresponding to the point on the yield-per-recruit function where the slope is 10% of the slope at the origin) to meet this need. $F_{0.1}$ was believed to represent a conservation-minded management strategy that would buffer against errors in the assessment and deficiencies in enforcement and would result in the rebuilding of SSB (Pinhorn and Halliday, 1990). Starting in 1977, under the extension of national jurisdiction, $F_{0.1}$ formed the basis for scientific advice and management of groundfish fisheries. For the severely depleted northern cod stock, F was set below $F_{0.1}$ from 1978 to 1983 to promote faster stock rebuilding.

The late 1970s and early 1980s were a period during which scientific advice was generally accepted and TACs were implemented, based on $F_{0.1}$. F declined to become relatively stable at approximately $F_{0.1}$ in many cases (Figure 1). Canadian fishing and processing capacity had not yet expanded to occupy the niche vacated by foreign fleets, which meant that there was less pressure on decision-makers to exceed $F_{0.1}$. Although a retrospective bias in the assessments (Sinclair *et al.*, 1991) caused catch forecasts to be overestimated in some cases, and catch underreporting was becoming an increasing problem, several stocks began to rebuild (Figure 1) as a consequence of generally lower F, as well as good recruitment and growth rates resulting from favourable environmental conditions.

The demand for greater flexibility

Increasing fishing pressure on domestic and straddling stocks and lesser productivity began to reverse stock rebuilding by the mid- to late 1980s (Figure 1). DFO and NAFO decision-makers came under increasing pressure to mitigate TAC declines by adopting more flexible approaches than a fixed $F_{0.1}$ strategy (Rivard and Maguire, 1993; Anderson, 1998). In 1986, NAFO agreed to an EEC (European Economic Community) request to include scientific advice on $F_{current}$ (equivalent to $F_{status\ quo}$—i.e. the same F as the previous year) and F_{max}, in addition to $F_{0.1}$, to allow greater flexibility in management decisions for straddling stocks and other stocks in the convention area (Anderson, 1998). Advice on these options was provided by the NAFO Scientific Council from 1988. In the mid-1980s, CAFSAC introduced the "50% rule" (if $2F_{0.1} > F_{y-1} > F_{0.1}$, then $F_y = F_{0.1} + 0.5(F_{y-1} - F_{0.1})$, else if $F_{y-1} > 2F_{0.1}$, then $F_y = 2F_{0.1}$, or if $F_{y-1} < F_{0.1}$, then $F_y = F_{0.1}$) to reduce variation in annual TAC and to cushion TAC reductions on declining domestic stocks (Rivard and Maguire, 1993). Under this approach, F is gradually reduced towards $F_{0.1}$, and $F_{0.1}$ became more of a long-term goal than a short-term objective (Rivard and Maguire, 1993). A subsequent study showed that the 50% rule is more likely to result in lower SSB than a $F_{0.1}$ strategy for only modest increases in average catch (Shelton, 1998).

Management strategies became even more flexible during the early 1990s. Rivard and Maguire (1993) observed a "renewed appreciation that the uncertainties in stock abundance estimates were such that annual adjustments to TAC could be more a reflection of variations in the data rather than real change in stock status". They suggested that this pointed to the need for alternatives to F-based strategies and a longer planning horizon. The outcome was that CAFSAC adopted "a flexible approach in which options were put forward in light of stock trends and expected productivity" (Rivard and Maguire, 1993). Under these so-called "multi-year management plans", F was allowed to float with the aim of minimizing the impact of stock declines on TAC. The most notable multi-year plan was introduced on northern cod in 1991 (Bishop and Shelton, 1997). This involved arbitrary stepwise reductions in TAC that were "too little, too late", leading to an unprecedented explosion in F and the collapse of the stock (Shelton, 1998).

Flexible strategies also characterized subsequent approaches adopted by FRCC. Within its broad conservation mandate, FRCC recommended "any measures considered necessary and appropriate for conservation purposes" (http://www.frcc.ca/mandate.htm).

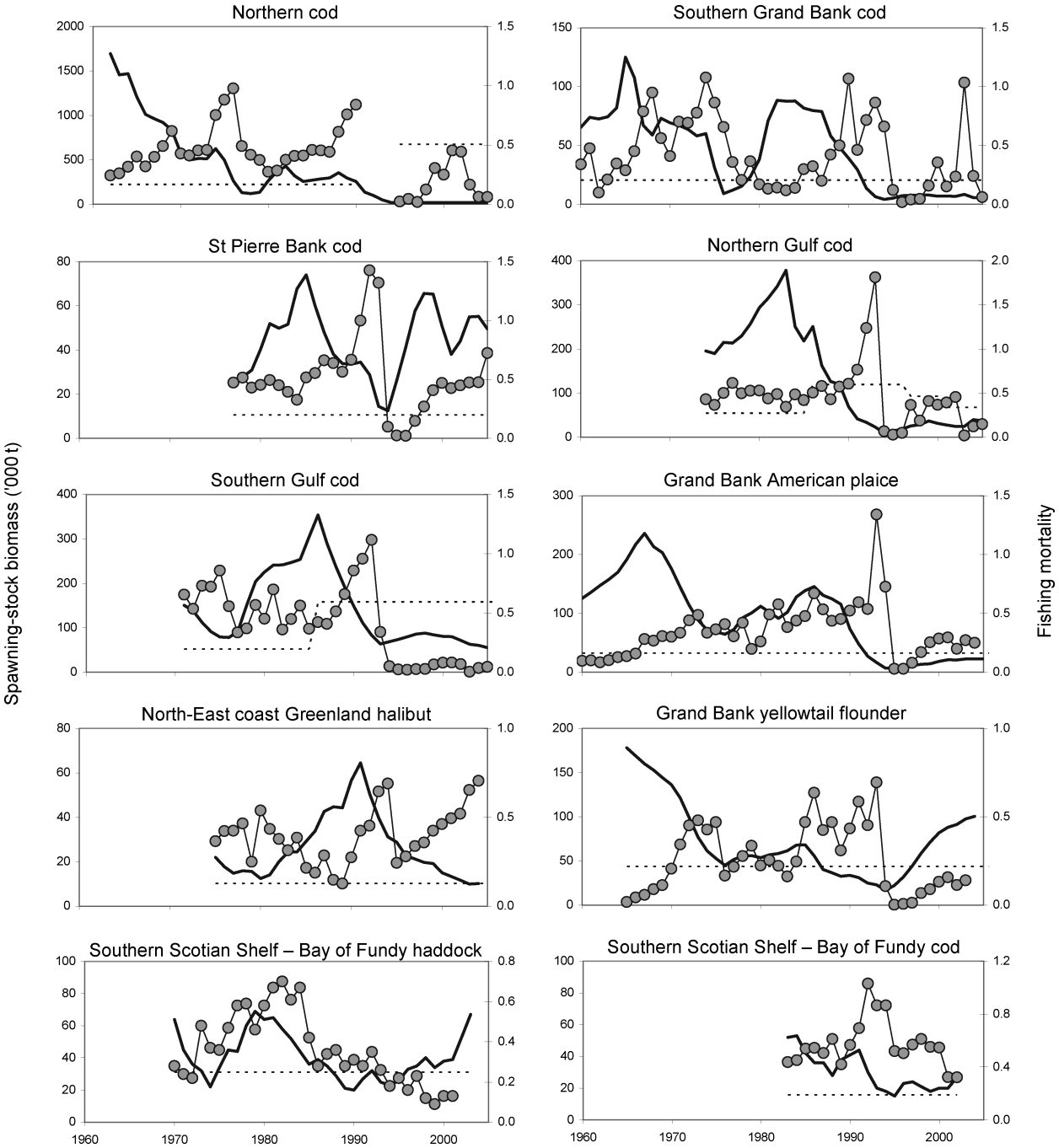

Figure 1. Time-series of estimates of SSB (solid lines) and average fully selected *F* (lines with circles) for some Northwest Atlantic groundfish stocks (dotted lines, $F_{0.1}$). Estimates for Grand Bank yellowtail flounder are from an age-aggregated production model, and biomass is exploitable biomass.

Advice on the appropriate TAC was based on an evaluation of the strengths and weaknesses of scientific assessment, as well as on traditional knowledge and opinions of those involved in the industry. Exploitation of four cod stocks placed under moratorium (northern, northern and southern Gulf of St Lawrence, and St Pierre Bank) resumed in 1997/1998, based on FRCC advice that they could sustain small fisheries. FRCC also argued that reopening these fisheries was necessary for informational purposes, given the uncertainty in scientific assessments. In only one case did the scientific assessment show that stock size had improved markedly over the brief moratorium period (St Pierre Bank cod; Figure 1). TACs advised by the FRCC for northern, northern Gulf, and southern Gulf stocks were unsustainable (Smedbol *et al.*, 2002; Shelton *et al.*, 2006), and what little rebuilding that might have taken place during the moratorium was quickly curtailed or reversed by the reopened directed fisheries.

Although flexibility currently characterizes the management of most Canadian east coast groundfish fisheries, some counter-examples exist. Flexibility is constrained in shared stocks across the USA–Canada boundary in the Gulf of Maine–Georges

Bank region. The management strategy in place for these stocks is to maintain a low-to-neutral risk of exceeding an F limit reference, F_{ref} (e.g. $F_{0.1}$). For overfished stocks, F may be further reduced to promote rebuilding. This approach is generally compliant with the structured approach required under the US Magnuson–Stevens Act. TAC advice for Southern Scotian Shelf–Bay of Fundy (4X) haddock continues to be based on an $F_{0.1}$ strategy. TAC advice for yellowtail flounder on the Grand Banks (3LNO) is currently provided on the basis of $0.67F_{msy}$ under NAFO.

PA and species at risk

Science within both DFO and NAFO, with input from managers, devoted considerable attention to the development of PA frameworks that would provide a more structured approach to managing fisheries (NAFO, 2003; Shelton and Rivard, 2003; DFO, 2006). The passage of SARA by Parliament in 2002 (proclaimed in 2003) raised concern that cod populations would be assessed to be at risk of biological extinction, forcing closure of reopened fisheries. DFO considered at the time that implementation of the PA, even if it led to the re-introduction of moratoria, was preferable to closing cod fisheries under SARA. In February 2003, three of the four cod stocks on which fisheries had reopened were assessed to be below their respective SSB limit reference points under a PA framework. Despite contrary advice from FRCC to keep the fisheries open, the Minister of Fisheries and Oceans announced in April 2003 that "All three of these stocks are below the levels where the harm is serious and it may be very hard to reverse this trend. It is clear that rebuilding is a long process but we must begin now" (Canadian Broadcasting Corporation, Video Archives). The decision to close the fishery was erroneously interpreted by scientists as implying that Canada had implemented the PA (Shelton and Rivard, 2003; Shelton *et al.*, 2003b). Indeed, directed fisheries reopened again on the two Gulf stocks in 2004 and a bycatch allowance of northern cod was introduced in a fishery for winter flounder, a species of limited commercial value, despite these stocks remaining below their respective PA limit reference points. Cod catches exceeded those of winter flounder in the northern cod fishery by a considerable amount (Lilly *et al.*, 2006), making it *de facto* a directed cod fishery. Recent scientific assessments predicted little or no recovery of these stocks under current removal levels (http://www.dfo-mpo.gc.ca/csas/Csas/status/2006/SAR-AS2006_010_E.pdf; /SAR-AS2006_014_E.pdf; /SAR-AS2006_015_E.pdf).

COSEWIC, charged with determining species-at-risk status under SARA, concluded in May 2003 that northern cod is endangered, northern Gulf cod is threatened, and southern Gulf cod is of special concern. Had DFO put in place a management strategy with explicit actions to achieve stock rebuilding supported by scientific analysis, COSEWIC might have expressed less serious concern regarding these stocks. Government acceptance of the classification of endangered or threatened would have placed heavy restrictions on any form of harm to the populations, and would have required formal rebuilding plans to be developed and implemented. Three years later in April 2006, government announced that the three cod stocks would not be listed under SARA. Instead, comprehensive recovery plans would be completed, and DFO would continue to pursue strong conservation measures with the provinces, fishers, and key stakeholders (http://news.gc.ca/cfmx/view/en/index.jsp?articleid=205909). Reasons given for not listing included economic and social costs, which were considered to outweigh the benefits (http://canadagazette.gc.ca/partII/2006/20060419/html/si61-e.html), based on results from a bio-economic model (http://www.dfo-mpo.gc.ca/species-especes/cod/main_e.asp). Because this model has not been reviewed independently by fisheries scientists or resource economists, the strengths and weaknesses of the analysis are unknown. Similar social and economic considerations have prevented listing of other species-at-risk, such as porbeagle, and may also prevent future listings of species under consideration, such as American plaice.

The comprehensive recovery plans alluded to in the decision on SARA listing refers to the products of three federal-provincial-industry cod action teams (CATs) established in Newfoundland/Labrador, Maritimes, and Quebec in 2003 (http://www.dfo-mpo.gc.ca/media/infocus/2005/20051123_e.htm). These teams developed long-term rebuilding strategies, which DFO anticipates will play a major role in the management of cod stocks in the coming years. However, no quantitative analyses were carried out to support this exercise, and the strategies are expressed in general terms only, with no specific goals or target rebuilding rates, in contrast to what would have been required had the populations been listed under SARA.

NAFO would appear to be taking a more structured approach to managing fisheries with respect to straddling stocks and those outside 200 nautical miles. Directed fisheries on several stocks placed under moratorium in the mid-1990s have remained closed, but excessive bycatch mortality is preventing recovery of Grand Bank American plaice and cod (Shelton and Morgan, 2005). Grand Bank yellowtail flounder did recover under the moratorium (Figure 1), and TAC advice based on a $0.67F_{msy}$ strategy has been accepted by the NAFO Fisheries Commission (FC) in recent years. The FC continues to request advice from the Scientific Council on TAC options associated with F_{msy}, F_{max}, and $F_{status\ quo}$. Although NAFO has not implemented the PA, advice is also requested on the risk of falling outside PA reference points. Grand Bank yellowtail flounder and Flemish Cap (3M) shrimp have been denoted as pilot studies to further evaluate the application of the PA framework. For depleted stocks, advice is sought on rebuilding options, but a specific commitment to goals, target rates, or strategies is lacking.

Despite the signs of a structured approach in these requests for advice, the TAC decision-making process within the FC is not transparent and may not be linked clearly to scientific advice. As an example, although a rebuilding plan for Greenland halibut specifying a stepped reduction in TAC was announced in 2003, the plan was not subject to scientific evaluation or peer review before its announcement (Shelton, 2005b, c). Subsequent simulation analyses have shown that it is not robust to uncertainty and is unlikely to be successful (Healey and Mahé, 2005; Shelton, 2005b, c). A recent assessment estimated that under the rebuilding plan, F has continued to increase to $3F_{max}$ ($>5F_{0.1}$), and that biomass is at the lowest observed level (Healey and Mahé, 2005; Figure 1). In contrast, a simulation study has shown that a more PA-compliant management strategy should be effective in promoting rebuilding (Shelton, 2005c).

Non-implementation of a structured approach

F-based management strategies are no longer in place on most stocks, and OBFM and PA have not been implemented mainly because of the desire for greater flexibility by DFO and NAFO decision-makers to meet continually changing social, economic,

and political pressures. Canadian legislation governing fisheries encompassed in the Fisheries Act and the Oceans Act provides wide scope for ministerial discretion. Unlike the US Magnuson–Stevens Act, there is no legislated requirement to take a structured approach. This poses challenges to fisheries scientists seeking to provide useful information to decision-makers, because each management exercise is to some extent unique (*ad hoc*). Within NAFO, flexibility is seen as key to reaching consensus among contracting parties, without which any objection filed to a regulation makes it non-binding. An attempt within the Scientific Council to increase flexibility in the implementation of the PA, while still remaining compliant with the essential elements (Shelton *et al.*, 2003a), has not hastened implementation.

Weak credibility of the scientific knowledge is also a possible reason that structured management strategies are not being implemented. Advice may be considered too unreliable. Decision makers, subjectively weighing up what they perceive to be certain social and economic consequences of uncertain stock projections, might appear justified in down-weighting scientific information. However, this is inconsistent with the PA. The expectation that managers would formally utilize estimates of uncertainty and risk within some form of risk-based management to implement decisions consistent with a low risk of serious harm to the resource, as outlined in OBFM and the PA, has not materialized. An alternative approach of implementing strategies tested, through simulation in a Management Procedure framework to be robust to overall uncertainty (Kirkwood and Smith, 1996; Butterworth, 2007), has not been given much consideration with regard to these groundfish stocks (note that $F_{0.1}$ was originally developed with robustness to uncertainty in mind).

Without a direct link between uncertainty and management decisions, emphasis on improving precision and accuracy of scientific assessments has weakened. Chronic research-vessel problems and downsizing of the stock assessment team through attrition is also affecting the quality of scientific advice. Under risk-based management and the PA, greater uncertainty should lead to more conservative management actions, but instead there may be a tendency to down-weight scientific advice further.

Potential effectiveness of new approaches

Ecosystem-based fisheries management (EBFM)

New initiatives may provide structure to decision-making. In keeping with a number of international treaties and agreements, Canada's Oceans Act, and directional changes in other institutions, both DFO and NAFO have recently indicated that they will be moving towards EBFM (DFO, 2004; http://www.nafo.int/about/media/press/press05.pdf). Some may view the argument as persuasive: management has failed because individual fish stocks have been viewed in isolation instead of taking into account the interaction among species and between species and their environment. Because of the Oceans Act, DFO is also considering an even wider ocean management approach based on "integrated management", which, in addition to fishing, includes other human activities such as pollution, oil exploration, and seismic testing. Although these issues may require a broader approach, it can be argued with respect to fishing that properly applied single-species management could go a long way towards achieving many so-called "ecosystem objectives" (Mace, 2004).

Although groundfish management is becoming less constrained by single-species scientific advice, EBFM remains largely conceptual. Only the simplest manifestations have been put into practice, such as a few marine protected areas and bycatch regulations. Trophic-based approaches (Christensen and Walters, 2004) may prove useful in augmenting single-species approaches (Plagányi and Butterworth, 2004). However, effective implementation for managing cod fisheries would require reinstatement of programmes that have been cut, such as the monitoring of capelin biomass and cod diet. This is unlikely to happen given funding limitations.

If EBFM is not going to be achieved through enhanced basic research on trophic relationships, can it be achieved by some other means? Indicator-based approaches (Cury and Christensen, 2005) may suggest an attractive shortcut, given limited research budgets and the increasing complexity of management problems. However, few if any ecosystem indicators that might contribute to a pragmatic ecosystem approach to managing fisheries appear to have emerged thus far (Daan, 2005).

Shared stewardship

Concurrent with the move towards adopting EBFM, DFO is reviewing stock assessment activity in general and considering an alternative co-management approach to setting TAC called "shared stewardship" (DFO, 2004). Shared stewardship is compatible with quasi-property rights extended to individuals and groups to use the east coast groundfish resource for profit. Under shared stewardship, it is expected that DFO will engage in providing more general ecosystem-level advice and overviews rather than carrying out annual assessments of a large number of stocks. Resource users are expected to assume greater responsibility for monitoring and assessment activity, with DFO playing a supporting role in programme management and quality control. This approach is expected to lead to greater industry involvement in integrating available information to reach decisions on TAC and other management measures (DFO, 2004). Preliminary exercises by industry and managers to develop TAC decision rules consistent with shared stewardship were carried out in 2005 for the two Gulf of St Lawrence cod stocks. The rules have not been quantitatively evaluated, but an unpublished qualitative DFO internal scientific review suggests that they are largely non-compliant with the PA. Irrespective of the scientific merits of these rules in their current form, the approach meets the objectives for shared stewardship by directly involving stakeholders in the interpretation of information to arrive at TAC decisions affecting their livelihood, and is likely to become more common in future fisheries governance.

Discussion

The link between science and decision-making for groundfish fisheries off Canada's east coast has weakened over the past two decades. Some argue that this is justified given uncertainty in the assessments and the need for decision-makers to respond in a flexible manner to changing political, social, and economic pressures. Although fisheries science may be too uncertain to fine-tune annual TAC adjustments, *ad hoc* management decisions that downplay scientific information may be "throwing the baby out with the bathwater". Quantitative fisheries science has developed the capability of providing potentially useful risk-based assessments and tools to evaluate management strategies for robustness to uncertainty and compliance with PA objectives. However, the demand for flexibility in the decision-making process in both DFO and NAFO has resulted in this capacity being underutilized.

EBFM appears to be replacing the PA as the overarching conceptual framework for managing fisheries. It could be argued that single-species stock assessments and implementation of the PA on component stocks are an essential step in achieving EBFM. However, with a de-emphasis of single-species stock assessment in Canada, EBFM will probably be supported by more general qualitative advice on the likely impact of management scenarios on overall ecosystem "health", using an indicator-based approach. Ecosystem-level objectives, and management strategies for achieving these, are likely to be more nebulous than those prescribed under single-species management and the PA. This will make it difficult to audit performance and point to specific weaknesses in the scientific basis for decisions. This, in turn, may further reduce the demand for quantitative scientific analyses to support the decision-making process.

The new policy of shared stewardship is also expected to affect how groundfish fisheries will be managed and what kind of science will be carried out. Traditionally, research has been funded by government with public money on the grounds that it was directed at a common-property resource and was therefore to the public good. The tendency to define stakeholders narrowly as those directly involved in the fishing industry may undermine the substantive basis for the public-good argument and strengthen support for shifting responsibility and cost of science and management to those profiting directly from the fishery. Under this model, DFO would play a much less costly supporting role, in the form of programme management and quality control to a largely self-regulating fishing industry intent on addressing economic objectives.

These developments need to be considered in a societal context. Both government and industry placed more confidence on scientific advice before the stock collapses, and stakeholder involvement was minimal. The creation of FRCC after the collapses reflected a widespread view that more use should be made of traditional knowledge and that stakeholders should have a more direct say in the decision-making process. Although the fishing industry had greater input through FRCC, government retained its central role. Shared stewardship suggests a more decentralized approach for the future. How much science and what type of science will be required under a decentralized system, and who will provide it, will be influenced by national legislation, international agreements, and societal pressure. Under existing national legislation, fisheries management is not always consistent with scientific advice on sustainability, and this is likely to continue under decentralized governance through shared stewardship. However, international agreements such as the United Nations Fish Stocks Agreement require decisions to be consistent with the PA and to be based on the best available scientific information. Additionally, Canada has agreed in terms of the Johannesburg Accord (2002), to "maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015". There is no public checklist of the status of Canadian fish stocks with respect to PA reference points and sustainability criteria, but most east coast groundfish stocks are assessed to be well below B_{msy}. To evaluate progress towards recovery and sustainability targets, peer-reviewed science-based single-species stock assessments are required. More directly, society, perceiving diminished opportunities from capture fisheries, is increasingly requiring scientific evidence through an eco-labelling certification process that fisheries are being managed in a sustainable manner. Although ecosystem sustainability is a laudable objective, progress with respect to sustainability can be best made in the medium term by enhancing quantitative single-species stock assessments and strengthening the role of peer-reviewed science through structured decision-making within a PA framework.

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