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On the importance of clarity in scientific advice for fisheries management

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ABSTRACT

Fisheries management is a difficult process that requires policymakers and scientists to work in concert with one another to set quotas or other management actions that conserve fisheries resources for long-term use. Policymakers take such actions based on advice from their scientists, who serve as independent knowledge providers. There are many examples, however, of policymakers allowing short-term financial or political objectives to drive their decision making rather than strictly adhering to the advice of their scientists. Throughout the histories of the International Commission for Conservation of Atlantic Tunas and the Western and Central Pacific Fisheries Commission, policymakers have followed the advice of their scientists only 39% and 17% of the time, respectively. There are also a number of cases where a lack of clarity in the scientific advice leads to undesirable management actions, either a result of simple misinterpretation by policymakers or imprecision in the advice allowing for a range of actions not intended by the scientists. To improve the likelihood that managers and scientists interpret language in the same way, it is important that scientists provide advice that is explicit and precise and clearly states the appropriate management measures to be applied. Here, a set of guidelines that may help scientists to achieve the necessary clarity is presented. Following these steps would allow scientists to clearly describe stock assessment results and other complex scientific processes and provide their expert advice in a manner that is most useful for policymakers but without sacrificing their reputation of independent knowledge provision.

1. Introduction

Most marine governance decisions are made only after policymakers consider (and ideally follow) the advice of their government scientists or scientific organizations contracted to provide such advice, a process intended to prevent politically motivated decision making so that adopted management options are grounded in good science [1,2]. This is particularly true for the management of highly migratory fishes, which typically fall within the jurisdiction of one or more regional fisheries management organizations (RFMOs). RFMOs are groups of governments, usually founded by treaty or other international agreement, charged with managing transboundary stocks through multi-government cooperation. In an idealized system, the member governments of each RFMO represent all stakeholders in their constituency (i.e., fishing, trade, and conservation interests), allowing RFMOs to address issues associated with the high seas commons and with multinational conservation and resource management.

Most RFMOs have subsidiary bodies for science and/or research that provide regular advice to the organization's annual plenary meeting. The subsidiary bodies typically comprise government scientists, along with academic researchers, representatives of industry and environmental nongovernmental organizations with relevant expertise, and invited or contracted external individuals. This is the case for all of the five RFMOs that manage fisheries for tuna and tuna-like species around the world (tRFMOs; Table 1). These five organizations manage major commercial tuna fisheries worth approximately US$10 billion per year, dockside, and more than US$42 billion at the final point of sale [3], along with highly migratory stocks of small tunas, billfishes, swordfish, and pelagic sharks whose fisheries values have not been estimated. Many of the stocks under tRFMO jurisdiction are overfished or severely depleted [4–9]. The RFMO model was originally derived, in the 1940s–'50s, to address fisheries allocation and economic gain [10], with little intention that science would play a role in actively reducing catches. As fisheries stocks have been depleted, the advice provided by scientists has become the focus of intensifying examination. Given the financial and conservation stakes, and the reality that tRFMO policymakers are rarely technical experts in the intricacies of stock assessment [11], it is essential that the scientific advice be both clear and explicit, to reduce the likelihood that the advice could be misinterpreted – willfully or otherwise – in a way that threatens the sustainability of

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Table 1
The regional fisheries management organizations that manage fisheries for tuna and tuna-like species (tRFMOs) and their subsidiary bodies charged with producing scientific advice.

Organization	Scientific subsidiary body	Stock assessment body
Commission for the Conservation of Southern Bluefin Tuna [13]	Scientific Committee	Internal working group
Indian Ocean Tuna Commission [14]	Scientific Committee	Internal working groups
Inter-American Tropical Tuna Commission [16]	Scientific Advisory Committee	Secretariat scientists/International Scientific Committee for Tuna and Tuna-like Species in the North Pacific
International Commission for the Conservation of Atlantic Tunas [15]	Standing Committee for Research and Statistics	Internal working groups
Western and Central Pacific Fisheries Commission [17]	Scientific Committee	Secretariat of the Pacific Community/International Scientific Committee for Tuna and Tuna-like Species in the North Pacific

stocks or fisheries.

2. Production of advice

Fisheries management decisions, including the setting of catch limits, implementation of size limits, and designation of spatiotemporal closures, are generally made after a group of scientists has assessed the status of the stock in question and developed estimates of how many individuals can be safely removed from the population and by what means [12]. Though each RFMO has subtle differences in the way it goes about running the actual stock assessment models, they all follow a general pattern. Fisheries scientists run one or often several assessment models and agree on a best estimate of the current stock status, along with an approximation of the uncertainty associated with the estimate. Three of the five tRFMOs have internal working groups that conduct this science directly [13–15], while the Inter-American Tropical Tuna Commission (IATTC [16]) tasks either its own Secretariat scientists or asks the members of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific (ISC) to run its stock assessment models and the Western and Central Pacific Fisheries Commission (WCFPC [17]) contracts with the Secretariat of the Pacific Community (SPC) or works with the ISC to run its models (Table 1). The practice of working with external bodies to conduct stock assessments is not unique to tRFMOs. The North-East Atlantic Fisheries Commission has a formal working relationship with the International Council for the Exploration of the Seas, which conducts many of their assessments.

The results of the stock assessments are passed on to the RFMO's full subsidiary science body, where they are used to develop official scientific advice about the catch limit and any other aspects of the management process that require scientific input. This advice is not completely free of influence from policymakers and other stakeholders. In fact, management objectives are often required to frame the advice that the technical experts provide, and those objectives are defined with input from the fishing industry and other interested parties (e.g., [18]). If a stock meets the RFMO's definition of being overfished, then the advice should reflect catch limits that adhere to the policymakers' objectives, including preferred timelines and probabilities of success for recovery. If a stock does not meet the RFMO's definition of being overfished, then the advice should reflect the policymakers' preferred probability of maintaining stock levels above those that are considered overfished. Other management objectives beyond those tied to reference stock levels can be defined and also help scientists know how to provide advice [19]. Without pre-agreed objectives or definitions of how management should proceed, scientists do not have clear guidance on which to develop their advice.

Scientists also often have the difficult task of incorporating the scientific uncertainty inherent in stock assessments into the management advice that they provide to policymakers [20,21]. Running multiple assessment models or incorporating different sets of assumptions and data inputs can provide a range of stock size estimates and targets and therefore a range of catch levels that would meet the management objectives [22]. Scientists are also often asked to assess the likelihood that management measures outside of a simple catch limit system (e.g., closed areas, gear modification, etc.) will shorten (or lengthen) timelines to recovery, increase (or decrease) the probability of successfully recovering overfished stocks within those timelines, or increase (or decrease) the probability of preventing currently healthy stocks from becoming overfished [23,24]. This can be difficult. The language used by scientists to communicate the uncertainty inherent in stock assessment models and to describe the interactions among several management options has serious implications for the decisions taken by the RFMOs. Oftentimes this process results in the scientific advice including a wide range of "acceptable" catch limits, without a clear picture of the risks associated with following the upper and lower bounds of the range and no clear path forward for the policymakers. Similarly, the additive benefit of applying more than one of the management options is typically not quantified and thus creates a situation where the policymakers may guess or gamble with options outside of the advice.

3. When managers fail to follow the advice

Policymakers can and sometimes do purposefully choose to not follow the available scientific advice. They may take no management action despite advice to do so, or they may adopt management actions that only partially implement the advice. To explore the prevalence and consequences of these two practices, the entire history of scientific advice and management decisions for the International Commission for the Conservation of Atlantic Tunas (ICCAT) and for the WCPFC was examined and the frequency with which the actions adopted by the policymakers were exactly aligned with the scientists' recommendations was determined (methods provided in Supplementary information). Since ICCAT's scientific subsidiary body began providing scientific advice in 1970, the policymakers have chosen to take no management actions 40.4% of the time and have adopted management actions that do not adhere to the advice another 20.6% of the time. This leaves only 39.0% of the time that the policymakers have followed through and implemented regulations in line with the advice.

Since WCPFC's scientific subsidiary body began providing management advice in 2005, policymakers have chosen to take no management action more often than not (59.6% of the times scientists provided advice). When WCPFC has adopted measures, more than half of those measures are not fully in line with the scientific advice. WCPFC managers follow the advice of their scientists only 17.0% of the time (excluding north Pacific stocks; see Supplementary information).

In some of the reviewed cases, policymakers and scientists seemingly interpreted the language provided in the advice differently, risking the fate of multi-billion dollar fisheries and the health of marine populations, due to misunderstandings or vagueness in the provided advice. In other instances, inexplicit advice led to a situation where a broad range of potential policy decisions, and an equally broad set of impacts on the managed stock, could be reasonably determined to be in line with the advice. While these two categories of actions were scored as such, it became clear that the advice could be improved in order to increase the likelihood that policymakers and scientists interpret the

language in the same way.

When management policies follow the recommendations of the scientists, fisheries stocks do better than when policies ignore or do not fully implement those recommendations [21,25]. No matter how explicit the advice, scientists cannot prevent managers from choosing to ignore them. They can, on the other hand, recognize the possibility that their technical language may be misinterpreted or may be too imprecise, and they can preemptively address common questions that they determine might arise from policymakers or non-experts.

4. When the advice is not sufficiently clear

A lack of clarity in scientific advice is not simply a hypothetical problem. Several recent ICCAT management decisions exemplify this broader issue. After the 2014 stock assessment of bluefin tuna in the eastern Atlantic and Mediterranean Sea, scientists drafted advice on the catch limit that was misinterpreted by a number of stakeholders. The language reads: “a gradual increase (in steps over e.g. 2 or 3 years) of the catch to the level of the most precautionary [maximum sustainable yield (MSY)] estimate would allow the population to increase even in the most conservative scenario” [26]. Several policymakers and stakeholders interpreted this to mean that the precautionary MSY level could be reached in two to three years via a series of annual steps, and that is precisely what ICCAT adopted [27]. The assessment group's co-chair, however, expressed to us that he intended for each gradual step to last two to three years before the catch limit was increased, to allow sufficient time to observe and evaluate the impact of each increase (S. Bonhommeau, November 2014, pers. comm.). The lack of clear language meant that there was room within the advice to allow for the catch limit to increase much more quickly than the stock assessment's co-chair intended, even while adhering to one interpretation of the advice.

The scientific advice for western Atlantic bluefin tuna has also been fraught with ambiguity, largely due to widely dichotomous assumptions about the growth potential of the stock. For example, when a stock rebuilding plan was adopted in 1998 for this overfished population, the scientists recommended a catch limit between 1500 and 2500 metric tons [28]. Language that provides such a broad range of options is not helpful in developing science-based fisheries management strategies, since politics can influence the outcome. Indeed, managers adopted a catch limit at the very top end of the range – 2500 mt [29]. Clear, explicit advice is a vital tool in the fisheries management process. A decade later the western bluefin tuna scientists gave an even broader range of advice: “the Commission is faced with [total allowable catch (TAC)] options that range between 2400 t and zero…” However, on this occasion, they went on to say that “the Committee strongly advises against an increase in TAC” [30]. The outcome based on that explicit advice was much different than in 1998: the Commission maintained the then existing catch limit and even lowered it for the following year [31].

Another example from ICCAT occurred in 2015. That year's stock assessment of Atlantic bigeye tuna projected recovery timelines for the overfished bigeye. The last year in the projected timelines was 2028, arbitrarily chosen as fifteen years from the terminal year of the assessment [32]. Policymakers interpreted this to mean that 2028 would be an appropriate recovery target, as advised by the scientists. In reality, that year was an artifact of the model chosen by scientists and was not intended by the authors to represent a target (C. Brown, October 2015, pers. comm.). In fact, a thirteen year recovery timeline is longer than necessary for a highly fecund, early to mature species like the bigeye tuna. The lack of clear language explaining the reasons for presenting the lengthy recovery timelines almost certainly contributed to delayed recovery for this highly valuable tuna stock, when ICCAT adopted a recovery plan with only a 49% chance of recovering the stock by the end of the projected timeline [24]. In discussion on the negotiation floor, policymakers often incorrectly cited the recovery target of 2028 as being based on the scientific advice (G. Galland, R. Hopkins, and S. Miller, November 2015, pers. obs.). In order to avoid such confusion, the scientists should have explicitly stated the biologically appropriate recovery timeline.

The lack of clear scientific advice, coupled with the policymakers ignoring some advice, can lead to situations where fisheries under RFMO jurisdiction experience steep declines and where effective recovery plans are not implemented until a stock's status reaches a state of emergency. In the case of the Mediterranean swordfish – a highly depleted species with a long history of overfishing – ICCAT policymakers disregarded the scientific advice for several years in a row, to the point where scientists gave up providing any advice in some years (1996, 1997, 1999, 2005, 2006; see methods in Supplementary information). The consequent lack of clear advice (or any advice at all) provided the policymakers with a means to continue rolling over a failing management plan. Only when scientists provided new advice after the 2016 stock assessment was new management action considered. Unfortunately, the advice was provided in a confusing, inexplicit manner (i.e., provided in a series of difficult to understand tables; [5]), and the newly adopted management plan ignored it once again, setting catch limits more than 50% above the scientifically advised level and allowing overfishing to continue [33]. The interaction between policymakers ignoring the advice and the lack of clarity in the language provided by scientists has prevented recovery of a previously extremely important and valuable stock to fishermen in the region. The current Mediterranean swordfish spawning biomass stands at just 12% of the biomass capable of supporting MSY [5].

These examples share a common thread. A lack of clarity in scientific advice leads to situations that are seemingly good for the fishermen and bad for the fish – at least in the short term. In the longer term, they are bad for fishermen too, as stocks fail to recover or even continue to decline, leading to sometimes sudden decreases in catch limit. In other words, the lack of clear, explicit scientific advice almost always leads to higher catches today or longer timelines for recovery, almost never the reverse.

5. Solutions

As stated above, stock assessment modelling is an inexact science, with the technical experts accepting a certain degree of statistical error and uncertainty surrounding the results. Incorporating this uncertainty into the management advice is one of the more difficult tasks facing fisheries scientists. Furthermore, scientists are often fiercely protective of their reputation as independent, unbiased experts and careful to not give the impression that they are being too prescriptive or influenced by the political process of fisheries management. Finally, policymakers do not always provide their scientists with clear guidance in terms of their specific objectives for the fishery or ask their scientists the most relevant questions (e.g., on how proposed management actions would contribute to or inhibit efforts to recover overfished species), leading to gaps in the advice that may confound pending management decisions. The combination of these issues often leads to the vague advice described above, opening the door for misinterpretation, willful or otherwise.

Given this reality, writing scientific advice would benefit from a clear set of guidelines that help scientists to ensure that they are as clear and explicit as possible. When management objectives have been stated, scientists should provide advice on catch limits and other management measures that may be necessary to achieve the objectives, with an appropriate buffer that accounts for uncertainty in stock assessment (or other scientific) results. Scientists should recognize that a range of possible catch limits based on stock assessment uncertainty is rarely treated as such and is typically interpreted as evidence that a catch limit at the top end of the range is scientifically sound and/or equally as risk-prone as a catch limit at the lower end of the range. Authors of scientific advice should be willing to preempt any potential

Table 2
Guidelines to produce robust management advice by avoiding common pitfalls that can lead to undesirable and ineffective management decisions.

Issues leading to scientifically undesirable management	Guidelines to avoid undesirable management
Ranges of potential catch limits are given in the advice, often leading to managers simply choosing the highest catch limit in the range	Avoid giving ranges of potential catch limits whenever possible and report the probabilities of achieving the management objectives associated with different catch limits when a range is absolutely necessary
Scientists avoid providing the expected qualitative impact that proposed management measures may have on a stock until the relative success of such measures can be quantitatively confirmed	Directly and succinctly describe how additional management measures beyond simple catch limit manipulation may or may not be expected to change the reported probabilities of success and/or timelines, recognizing that simply stating that the impact of additional measures cannot yet be confirmed does not provide policymakers with the necessary information to make the most informed management decision
Scientists avoid providing information beyond what was specifically asked of them by policymakers	Preemptively ask and answer relevant management questions in order to shorten the timeline between identification of a problem and implementation of a management plan
The advice refers to one or a range of reference years when recommending future catch limits	Avoid only referring to reference years when discussing necessary reductions from historical catch and instead also explicitly report the recommended future catch levels
The advice may include the results of several different stock assessment models, often with slightly different scientific interpretations that can be confusing for non-technical experts	Avoid reporting assessment model results that were not chosen by the scientists as the most likely to represent the current stock status and aim to provide at least a qualitative position on which of the assessment outputs is most plausible
Projections resulting from stock assessments may include arbitrary timelines based on the assessment model chosen as opposed to biological constraints	Provide advice not just on what to do but also when to do it, including biologically appropriate rebuilding timelines
The advice includes long, potentially confusing, discussions of the uncertainty involved with stock assessment results	Account for uncertainty in the stock assessment results by building appropriate, precautionary buffers into the advice but avoid long, confusing discussions on this topic

follow-up questions that policymakers may have in response to the advice by providing answers ahead of time rather than waiting for explicit instruction from managers. This practice does not cross any line of scientific independence but instead provides a service to the fisheries management process by mitigating the need for scientists and policymakers to undertake a series of questions and answers that may take years to resolve, risking the success of their management efforts.

It is easy for scientists to be explicit when they conclude that no changes should be made. For example, policymakers are not likely to misinterpret statements like, “our analysis continues to indicate that increases in allowable catch are not advisable at this time” [34], “the Committee does not recommend an increase of the TAC” [5], or “limit catches to no more than 15,000 t” [35]. It is not as easy to craft advice when the scientists conclude that the catch limit could be increased or should be decreased, but it is possible to achieve clarity. WCPFC scientists recently provided explicit advice on the highly overfished Pacific bigeye tuna stock that read, “a 36% reduction in fishing mortality from the average levels for 2008–2011 would be expected to return the fishing mortality rate to [the rate that produces] MSY” [6]. Scientists at the Indian Ocean Tuna Commission (IOTC) provide a single summary table for the management advice of all stocks under IOTC management, simplifying the guidance for managers and forcing the scientists to give clear and concise advice (e.g., [7]). The IOTC tables provide both the quantitative advice (i.e., a specific catch limit) and the justification. Unfortunately, such clear advice in cases where management changes are required is the exception rather than the rule across fisheries management, and the process in such cases can benefit from a standard set of guidelines for providing scientific advice (Table 2). Again, such guidelines do not cross a line of scientific independency but instead bolster a tradition of scientific advisement by reducing the likelihood that advice can be misinterpreted and increasing precision.

6. Conclusions

Fisheries management is a difficult process that relies on inexact science and forecasting to develop policies that represent a breadth of stakeholders, often with different ideas of what ideal management should be. The development of scientific advice, under these circumstances, can be complex, particularly as scientists strive to protect their reputations as independent providers. This situation leads to advice that may be either vague or inexplicit or may be clear to the authors but misinterpreted by policymakers. There are multiple reasons why policymakers already can and do choose to ignore the scientific advice when making fisheries management decisions. It is important that scientists do not unwittingly enable this practice by providing advice that can be willfully or unintentionally misinterpreted, thus resulting in undesirable management decisions and negative consequences for the relevant stocks. This reality places the burden on scientists to author advice that can be easily deciphered by a non-scientific audience. To enable them to comprehensively deliver the clearest possible advice to policymakers – without risking their reputation as independent knowledge providers – new best practices are needed. A set of guidelines are provided here to help achieve the required clarity.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.marpol.2017.10.029.

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