Learning From Our Oceans – Listening to Our Scientists!

Chris Garrett
University of Victoria

Introduction

The protection of the oceans for the benefit and enjoyment of present and future generations requires the traditional knowledge of native people, the experience of those who gain their livelihood from the sea or who use it for recreation, and the input of amateur and professional scientists. This brief essay will be concerned with the role of the latter group.

The main points to be discussed are:

• Key issues as seen by scientists sometimes differ significantly from the perceptions of the public or portrayals by the media, as well as from priorities implied by government regulation.

• Scientific results should not be distorted to make them appear to support decisions that are really based on economic, legal, social and political considerations.

• Scientific assessment and prediction should include estimation of uncertainty, and this uncertainty should be allowed for in decision-making.

• We must allow for the possibility of "unknown unknowns" and try to assess the likelihood that they will occur.

• The "precautionary principle" is particularly important if it stresses precaution against irreversible changes.

• In spite of the existence of both known and unknown unknowns, there are many situations in which we can be confident of our understanding and in saying that major surprises are unlikely.

• Scientific understanding, and assessment of missing knowledge, can be usefully provided to the public and government through the use of "expert panels" established through organisations such as the Royal Society of Canada.

• The application of existing knowledge and the improvement of scientific understanding require the involvement of strong government laboratories.

• For scientific research at government laboratories to be credible, scientists there must be permitted to speak out freely as individuals as well as collectively.

• Universities need to be involved in independent oceanographic research and in educating the experts of tomorrow.

• In particular, there should be at least one east coast and one west coast university with a serious commitment to the oceans, and we should not forget the importance of our Arctic coast and ocean.

The Perception of Key Issues

Decisions on the use and protection of the oceans are not purely scientific. The role of scientists is to provide the information, assessment and predictions that can help society to quantify risks and benefits and optimise its actions within the context of accepted goals.

Unfortunately, public perception and portrayals in the media of the consequences of various uses of the marine environment sometimes differ significantly from the views of the scientific community. This is clearly unfortunate if warnings from the scientific community about some new threat to the oceans are not heeded, but it is also regrettable if the threat of a particular practice is exaggerated. This can lead to government regulation followed by the unnecessary consumption of significant financial resources to the detriment of other societal needs. More importantly, perhaps, preoccupation with unimportant issues can lead to insufficient attention being paid to serious threats to the marine environment.

This seems to have been particularly true for various forms of waste disposal in the oceans. To be sure, some discharges of sewage and other wastes in many parts of the world do pose a significant threat to the health of humans and marine biota, but there have been other high-profile examples of ocean dumping in which the consequences observed or predicted by marine scientists were much less than implied by media portrayals.

One example of this concerned the disposal of the Brent Spar, a large offshore oil storage structure in the North Sea. At the end of its useful life, Shell Oil proposed to dispose of it in 1995 by sinking it in 2,300 metres of water in the North Atlantic to the west of Scotland. This received government approval, but was strongly opposed by Greenpeace and other organisations and the structure was towed back to shore and moored in a Norwegian fjord. A report (NERC, 1996; available from http://www.nerc.ac.uk/oilrpt.htm) commissioned by the UK government stressed the negligible nature of the risk posed by deepwater disposal, but considerable resources were nonetheless expended in exploring other options. In the end, much of the structure was cut into sections and used in a quay extension at Mekjarvik in Norway. As discussed in a report (NERC, 1998; available from http://www.nerc.ac.uk/decommissioning/report2.pdf), this disposal option could be deemed preferable to deep sea disposal if one were to place a high value on reuse and recycling, but did involve greater cost and greater risk to the workforce involved. The second report again stressed the very small potential harm associated with deepwater disposal and advised that this issue was distracting attention from other more serious threats such as habitat destruction, overfishing, the invasion of non-indigenous species of marine organisms, and various types of pollution.

In spite of this, subsequent oceanic disposal of structures from the North Sea oil fields has been generally prohibited (see OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations, available from http://www.ospar.org/eng/html/dra/welcome.html), but the other much more harmful but less easily regulated impacts of human activity continue to be inadequately addressed. It seems that governments sometimes like to appear to be doing something to protect the marine environment rather than making the difficult decisions that would really lead to effective protection.

Another even less widely recognised example of exaggerated fears concerns the disposal of radioactive waste in the oceans. This was carried out by a number of nations from 1946 until 1982, but has since been banned. The scientific issues and some of the politics were reviewed by Bewers and Garrett (1987) who try to present both sides of the issues (i.e. government/industry on the one hand and environmental groups on the other) as well as their own analysis. It suffices

to say here that the risk to individuals, to the human population as a whole, and to marine biota, was assessed by various groups of scientists as being very small. More recently, there have been concerns about the dumping of radioactive wastes in the Arctic by the former Soviet Union. The disposal of large amounts of liquid and solid wastes was not admitted until 1992 but has since been assessed by a number of groups; one report is summarised at http://www.iaea.or.at/worldatom/Periodicals/Bulletin/Bull391/specialreport.html . The overall conclusion is that, again, the risk to the general public and to marine life is very small indeed, certainly much less than sometimes portrayed, and much less than the risk associated with other forms of Arctic contamination reviewed by Macdonald et al. (2000).

The examples given are by no means intended to suggest that marine scientists are in favour of casual dumping at sea of any form of waste. The oceanographic community can, however, provide assessments of the impact of various activities so that the environmental consequences of oceanic disposal can be compared with those of other forms of disposal (which may be more environmentally damaging) and so that priorities can be set for the protection of the marine environment. The dumping at sea of many forms of waste is, in fact, prohibited or tightly regulated by national and international organisations. One danger of introducing regulations that seem not to have a scientific basis is that governments and industry will use this as an excuse to ignore regulations that are well founded.

Distortion of Scientific Results

The examples above lead to my next point. Decisions in marine environmental protection are based on social, economic, legal, and political considerations as well as on purely scientific ones. This can sometimes lead to a reordering of priorities and may lead to either weaker or stronger regulation. One senses, for example, that excessive fishing activity is often permitted for short term, and usually shortsighted, economic or political reasons, while waste disposal can be either under-regulated, as for some types of chemical discharge, or, as in the example of the Brent Spar, over-regulated from a purely scientific standpoint.

Decisions that appear to be inconsistent from a scientific viewpoint might be more acceptable if the full reasons were given, but these reasons need to be stated clearly and honestly. Frequently, however, scientific findings are distorted or misrepresented in order to make them appear to justify a decision reached on other grounds. Such a process does a disservice to the public as a whole as well as to the scientific community.

It might be considered rash to present examples of this deliberate distortion, but in the Canadian context it is perhaps appropriate to mention possible examples connected with our fisheries. Hutchings et al. (1997) suggest that actions stemming from managerial distortion of the findings of fisheries scientists in the Department of Fisheries and Oceans played a significant role in the collapse of the cod fishery. They also review the effect on salmonid production in the Nechako River, B.C., of reduced flow caused by discharge through an ALCAN dam, commenting on the difficulties faced by government scientists instructed to support the minister's position, even when this was in conflict with scientific evidence. Doubleday et al. (1997) presented a reply, and accounts in the press (e.g. http://www.ottawacitizen.com/national/970704/942652.html) illustrate the positions of both sides of this dispute.

Scientific Uncertainty

Any scientific assessment or prediction clearly involves uncertainty, and it makes sense to take this into account in the regulatory process. Allowing for uncertainties involves common sense and judgement based on probabilities, insofar as these can be assessed. For example, if fisheries scientists estimate a range of possible allowable catches, taking into account uncertainties in the data and models, it might be dangerous to use the average rather than the lower end of the range. More elaborate statistical treatment could, of course, set catch levels based on acceptance of some low level of the possibility of serious consequences. A similar approach, using the pessimistic end of uncertain estimates, could be used in the regulation of ocean dumping.

In some situations, "trial and error" is an adequate way of dealing with uncertainty. This clearly only works if the consequences of error are acceptable. More importantly, however, there are situations where the consequences of some action will not occur until many years, or decades later. By the time serious consequences begin to appear in response to some continuing practice, it may be too late to prevent major damage that could have been forestalled if the practice had been stopped earlier. In such cases we rely heavily on scientific models and it is particularly important to know the uncertainties in the predictions that come from them. Global warming is clearly one such issue. The deep-ocean disposal of some types of waste is another, given the time (a few centuries) that it would take for effects to be felt in the upper ocean.

An examination of uncertainty is also critical for the identification of topics where improvement in our scientific measurements or understanding is most required.

Unknown Unknowns

One of the most important aspects of scientific uncertainty arises from the possibility that there are factors we have not even thought of yet. These are sometimes called “unknown unknowns” to contrast them with the “known unknowns” which are just error bars on things we do know to some extent. By definition we cannot say at any instant what the “unknown unknowns” are, but we can look back at situations in which we were caught by surprise as some new scientific process was discovered.

One important environmental example of this was the ozone hole over Antarctica. While ozone destruction by chlorofluorocarbons (CFCs) in the stratosphere had been expected, the strong reactions that could occur on the surfaces of ice crystals high over Antarctica had not been anticipated until the discovery of the ozone hole and urgent investigation of the processes responsible. Clearly if this process had been anticipated, the phase-out of the use of CFCs would have been legislated earlier and the ozone hole problem would now be less severe.

A marine example concerned the apparent endocrine-disrupting properties of the tributyl tin (TBT) used in marine antifouling paints since the mid 1960s. Unpredicted, serious and persistent effects on whole populations of molluscs were linked to TBT in the 1980s, and this has led to partial, if still inadequate, regulation. (See http://www.royalsoc.ac.uk/files/statfiles/document-111.pdf for an account of the effects of TBT and other endocrine-disrupting chemicals. This report also discusses the complexity of dealing with all the human-made chemicals that find their way into the environment.)

Examples of this kind provide salutary lessons for scientists in their efforts to provide scientific input to wise use of the oceans. There may be nasty surprises in store in many situations and we should always try to anticipate what they might be. At the very least, we can try to assess the probability that we are missing important processes or effects and factor this into some sort of comparison of benefits and potential costs.

The "Precautionary Principle"

One way of taking uncertainty into account in the use of the oceans is through application of the so-called "precautionary principle" which urges caution in the face of scientific uncertainty. Given that this uncertainty is always present, in the form of both known and unknown unknowns, the precautionary principle can be a recipe for paralysis. I think it is most useful if it is modified to stress avoidance of long-lived or even irreversible harm. We can, perhaps, afford to make mistakes if they are readily corrected, but in general we need to avoid permanent damage. This is, after all, how we proceed in many aspects of our daily lives.

It could, of course, be argued that, in the face of "unknown unknowns", there is always the possibility that some human activity might lead to irreversible changes in the ocean and should thus be prohibited, but this seems to me to be too pessimistic and too restrictive. There are some parts of science that we really do understand well enough to be confident. To give a simple terrestrial example, if I fall off my bicycle on my way home from work, it will not be because I suddenly find that Newton's laws of motion do not apply on some particular street corner! Similarly, in the ocean there are some aspects of the ocean's physics, chemistry and biology that are robustly understood. This is particularly relevant in the context of marine pollution if the material being discharged into the ocean is something that also occurs naturally, with pathways, concentration factors and consequences reasonably well established.

Expert Panels

There are very many issues in modern society that rest to some extent on scientific understanding. The marine realm is no exception. If the background science were completely understood and precise, then statements and predictions would be accurate and could, in principle, easily be factored into decision making and regulation along with other non-scientific considerations.

With many modern issues, however, such as those of climate change, fishing, marine pollution and so on, our scientific understanding is incomplete. In these cases it is important that the knowledge we do possess, as well as expert assessment of uncertainties, be provided in the most up-to-date, objective and comprehensible manner to the government and the public. This is not easy, as many people or organisations that speak out on scientific matters are often perceived to have conflicts of interest which bias their stated views.

It will probably never be possible to avoid this problem altogether. Even apparently objective scientists, perhaps from academic institutions, may be subtly, even unconsciously, influenced by dreams of glory if not monetary reward! Nonetheless, I believe that excellent reports to provide advice to governments and information to the public can be prepared by expert panels set up by professional organisations. In the United Kingdom, the Royal Society of London plays this role; its reports can be found at http://www.royalsoc.ac.uk/templates/statements/index.cfm . In the United States, the National

Research Council represents the National Academies of Science and Engineering in establishing panels to address a variety of issues of public concern (see http://nationalacademies.org). The Royal Society of Canada has recently adopted similar mechanisms to establish expert panels in response to outside requests. Examples of recent reports, together with a Manual of Procedural Guidelines, may be found through http://www.rsc.ca .

It is important to stress that, in the establishment of these panels, an effort is made to avoid conflict of interest. Differing points of view in panel members are probably inevitable, but an attempt is made to balance these. It should also be mentioned that such panels are not "elitist" committees made up only of members of the appointing academies, but draw on the best expertise available.

This recommendation for the establishment of expert panels under the auspices of an independent body at arm's length from other sectors of society is not meant to imply that panels established by other means are ineffective. For example, in waters local to me, a British Columbia/Washington State Marine Science Panel was appointed by the province and state, but drew on broad inputs from scientists, environmental groups and others in preparing its report. A summary of the report and its recommendations is available at http://www.wa.gov/puget_sound/shared/bcwaswl.html.

It seems worthwhile mentioning here that the BC/WA Marine Science Panel ascribed considerable importance to recovery time in assessing the threats to the marine environment. In this respect, they were particularly concerned about the largely irreversible consequences of things like habitat destruction and the introduction of non-indigenous species. The cumulative harm of these, to present and future generations, could easily exceed the transient, if severe, impact of something like an oil spill.

Incidentally, the panel did not regard Victoria's contentious sewage discharge as a serious issue. The argument was that continued surveillance will reveal if there is some component of the sewage that is causing unexpected and unacceptable damage, but that it is very unlikely that any harm is irreversible if we eliminate the cause.

It must be admitted, however, that panels established more or less directly by government agencies do run the risk that their membership will be chosen to promote government objectives rather than to present an impartial review. At the very least, the suspicion that this might have been the case is apt to diminish the credibility of the panel report. Equally, the public might be concerned about any possibility that corporations or environmental groups unduly influence panels or organisations.

A global organisation that seems to me to have a good record of addressing marine issues is the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP, see http://gesamp.imo.org). While its reports are generally technical in nature, a recent brief summary "Ocean at Risk" http://gesamp.imo.org/ocean.htm and a report entitled "A Sea of Troubles" http://gesamp.imo.org/no70/index.htm are presented in a form that is suitable for a general audience, even if some generalisations really require qualification.

This raises another key issue hinted at earlier. For reports to be useful to the general public, they must be comprehensible or at least have a comprehensible "executive summary". I fear that in many cases not enough effort is put into this, thus greatly diminishing the value and impact of the report. The consequences of poor communication of scientific results can be huge, as illustrated, for example, by the case studies reviewed by Powell and Leiss (1997).

Finally, it has to be admitted that expert panel reports, while potentially extremely valuable in providing advice to the government and information for the public (which is also the electorate!), need to be followed by regulatory action in order to be effective. This is often missing.

Government Laboratories

I have mentioned scientific uncertainty with respect to both known and unknown factors. Reduction of this requires continued scientific research. Some of this needs to be conducted in government oceanographic laboratories, particularly for the many essential tasks of long term monitoring and associated research that are not carried out effectively within universities or the private sector.

On the other hand, the best way to maintain a surveillance program is seldom well defined. It requires continued attention to the improvement of observational techniques and vigilance to ensure that the appropriate variables are being observed. This can only be done if the laboratories are themselves engaged in basic scientific research, collaborating freely internationally and participating in international projects.

Oceanographic laboratories in Canada have a great international reputation for having in the past achieved a balance between basic and applied research, with the former feeding into the latter. In the last decade, however, it has to be admitted that reduced funding, and what the scientists regard as unimaginative and unsupportive management, have greatly reduced their capabilities. The laboratories need to be strengthened again. They also need to be freed from excessive concentration on purely regional issues, and allowed to function in the full national, and international, interest. Canada needs to contribute to global oceanographic projects and would then benefit from the acquisition of international experience and expertise that can be brought to bear on local problems.

Another important issue with respect to government departments involved in science-based activities concerns the latitude given to scientists to speak out as individuals as well as collectively. I suspect that at present in Canada the official pronouncements of these departments are not believed by most of the public precisely because of a perception that government scientists are muzzled and that the official statements on scientific issues have been distorted by other considerations. This perception is reinforced by episodes like the ones discussed earlier in this essay. Managers will claim that of course scientists may speak freely on purely scientific matters, but may not do so on questions of policy arising from the science. But the line between science and policy is not well defined, so many government scientists find it easier to keep quiet in general. Even those who do speak to the media are probably rather guarded. I suggest that it would be preferable to give as much freedom to government scientists as to those at universities. Any confusion arising from disagreement between the views of different scientists, and between their views and the collective statement of the government, is more than compensated for by increased credibility when there is a consensus. Taxpayers also have the right to be told directly what is being discovered at the laboratories for which they pay, without any managerial or political filter unless the national interest is at stake.

Universities

As an academic, I hope that I will be forgiven for concluding with a plug for universities. These need to be involved in oceanographic research every bit as much as in other fields of science, and also in educating the young scientists who can bring fresh ideas and help society manage the oceans wisely in the future.

This is not as straightforward as it sounds. The main difficulty is that oceanography is largely a topic for graduate education as it must rest on a firm foundation of basic science – physics, chemistry, biology and mathematics. This presents a difficulty for some universities driven by undergraduate enrollment. There are a variety of possible solutions.

One, adopted successfully by Dalhousie University in Halifax, is to accept the special nature of oceanography and establish a graduate Department of Oceanography, maybe teaching a few undergraduate courses but not offering an undergraduate degree. There are dangers in this, however. One is that such a department can become detached from the rest of the university (though I am not saying that this is the case at Dalhousie). Another is that the department can be vulnerable if its enrolment of graduate students declines for any reason.

What I believe to be the most sensible solution is to have faculty in particular areas of oceanography jointly appointed between an appropriate undergraduate science department and a graduate centre of oceanography. The faculty would then do most of their undergraduate teaching in basic science, but also offer a few general undergraduate courses and several specialist graduate courses. In such a model the ocean scientists are not only seen to pull their weight in undergraduate teaching, but also, through inspiring digressions in basic science classes as well as through general ocean science courses, can help to inspire good undergraduates to consider ocean science as a field for graduate studies and a career.

This model may not be easy to adopt, as any vigorous basic science department will have many other areas in which it would like to make faculty appointments. It may require significant direction from senior levels of a university to make it happen.

Whatever the solution, it is clear that, when it comes to ocean science, Canada as a whole is currently not well served by its universities. The east coast has oceanographic strength at the Memorial University of Newfoundland, and particularly at Dalhousie University, but the west coast of Canada does not at present have a university with an equivalent serious commitment to ocean sciences. This shortcoming must be addressed. A focus on Canada's north, Arctic, coast, might be split between universities and government laboratories on the other coasts or could be a priority for an inland institution.

Conclusions

Learning from our oceans needs to be followed by careful application of that knowledge. Much of the knowledge is scientific, and part of this knowledge consists of estimates of uncertainty in the things we do understand and awareness of how much we need to know. We also need to be fully aware that surprises await us, and that some of the things we think we know may need to be unlearned as we discover more about the oceans.

In spite of all this uncertainty, the cautious and honest incorporation of scientific advice into management and policy is surely better than ignoring it, and strong support for further scientific research is surely better than continuing in ignorance with policies based on wishful thinking.

This may all sound like a pitch for more funding for ocean scientists. To some extent it is; to quote an anonymous sage: "If you think that education is expensive, try ignorance!" But I am also suggesting that, at any level of scientific funding, society needs to listen to its scientists.

Acknowledgements

I thank Mike Bewers, Robin Brown, Ken Denman, Howard Freeland, Tetjana Ross, Mary-Louise Timmermans, Verena Tunnicliffe and Bob Wilson for comments.

References (additional to the web references included in the text)

Bewers, J. M. and C. J. R. Garrett, 1987: Analysis of the issues related to sea dumping of radioactive wastes. *Marine Policy* **11**, 105-124.

Doubleday, W. G., D. B. Atkinson and J. Baird, 1997: Comment: Scientific inquiry and fish stock assessment in the Canadian Department of Fisheries and Oceans. *Canadian Journal of Fisheries and Aquatic Science*, **54**, 1422-1426.

Hutchings, J. A., C. Walters and R. L. Haedrich, 1997: Is scientific inquiry incompatible with government information control? *Canadian Journal of Fisheries and Aquatic Science*, **54**, 1198-1210.

Macdonald, R. W. and 28 others, 2000: Contaminants in the Canadian Arctic: 5 years of progress in understanding sources, occurrence and pathways. *The Science of the Total Environment*, **254**, 93-234.

Powell, D. and W. Leiss, 1997: *Mad Cows and Mother's Milk: The Perils of Poor Risk Communication.* McGill Queens University Press, 336 pp.