ICES Insight

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Communications then and now

During the second half of the nineteenth century, improvements in communication and transportation technology helped create a rising wave of international cooperation in the sciences, resulting in the formation of numerous international scientific organizations, as well as the establishment of international conventions and standards.

The founding of ICES in 1902 epitomized the ideals of international cooperation and exchange that flourished during that time. Mike Sinclair's appreciation of the life and work of Johannes Schmidt, supported by the Carlsberg Foundation in Copenhagen, brings to light the extent of the many, and sometimes surprising, connections that contributed to the success of ICES and its work.

The rise of the Internet, and the exchange of information and data that it facilitates, is analogous to the advancement of international scientific cooperation more than a century ago. Today, although there seems to be a limitless fund of data, the problem is often one of finding it. Following the spirit of ICES founders, ICES Working Group on Operational Oceanographic Products for Fisheries and Environment (WGOOFE) was created to identify the types of data most needed by marine scientists and assemble the links to it, thereby enhancing international exchange.

Distributing data in order to guide consumers in their purchase of seafoods is the idea behind a German programme, supported by the Institute for Baltic Fisheries, and aimed at developing sustainable sourcing policies and communicating stock information to consumers in comprehensible language.

Apropos new ICES groups, ICES Study Group on Recruitment Variability in North Sea Planktivorous Fish (SGRECVAP) was created to address the questions raised by declining herring recruitment. The group's findings have been widely influential, leading to further investigation and publication.

In *Insight* interviews, Ray Hilborn and Elizabeth E. North have kind words to say about fishers and their knowledge of the sea. In addition, new methods of comparing information suggest that fishers and scientists might agree more closely about some matters than we believed.

Finally, communication with undersea vehicles is being revolutionized by recent developments in optical communications, making the dream of untethered remotely operated vehicles a possibility.

We hope that you will find something that interests you in this latest communication from ICES, and if you have any comments or story ideas, please send them to the e-mail address below.

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Marine biodiversity:

ICES, Johannes Schmidt, and the Carlsberg connection

***Michael Sinclair** explains why 2010 – International Year of Biodiversity and the culmination of the first Census of Marine Life – is a great year to celebrate the Carlsberg contribution to our knowledge of marine science.*

On 11 January 2010, the United Nations inaugurated the International Year of Biodiversity in Berlin. Also, by coincidence, 2010 is the final year of the Census of Marine Life, the focus of which has been to provide a global picture of marine biogeography and biodiversity, based on a decade of international research (with major financial support from the Sloan Foundation). The final activities are being held in London in early October.

It is thus fitting that several themes of the ICES Annual Science Conference 2010 in Nantes focus on this field of study, and that a special showing of the film "Oceans", which captures visually the remarkable diversity of life in the sea, will be featured.

I would like to look back at some of the earlier activities of ICES in this broad field of research, which has been revitalized during the past decade or so. Further, I will provide a sketch of the ICES-related work of Johannes Schmidt and the financial support that was provided by the Carlsberg Laboratory and the Carlsberg Foundation. Today, we tend to associate Carlsberg with the Liverpool football team, while giving less attention to their support of science and the arts. I hope to provide a more balanced picture of the influence this brewery has had on society (at least among the ICES community!).

I was stranded in Copenhagen for five days last April, as a result of flight cancellations caused by volcanic ash. After surviving the initial irritation of uncertain travel arrangements and cancellation of commitments in Canada, I realized that the delay provided a good opportunity to follow up an earlier interest in the "racial investigations" led by Schmidt and published in a Carlsberg Foundation journal. Why did a brewery foundation fund research on marine biodiversity so generously? And, more specifically, what were the scientific justifications for what might be considered esoteric questions to the Foundation? At this stage, I do not have the answers, but I hope that this brief summary of Schmidt's remarkable career in marine science (and the support from Carlsberg) will be of interest.

Johannes Schmidt and ICES Committee "A"

Johannes Schmidt was a student and research assistant of Johannes Petersen, Director of the Danish Biological Station at the turn of the 20th century and one of the founders of ICES when it was established in 1902. Petersen promoted a multidisciplinary oceanographic approach to fishery problems and was responsible for the Danish contribution to the work of ICES Committee "A", whose remit was to explain decadal fluctuations in the yield of fisheries.

▲ *RV "Thor" in Icelandic waters in 1903. It is anchored alongside a French fishing schooner.*

Schmidt participated in (or led) six expeditions on the RV "Thor" between 1903 and 1908, conducting early life history surveys (plankton and oceanographic observations) covering the broad area from Iceland to Spain. He was subsequently the principal author of an extensive and influential 1909 ICES report that presented a synthesis of the aggregated results of the Danish expeditions as well as surveys by other ICES Member States.

It is of historical interest that the sampling design and protocols first used by Schmidt to investigate the fluctuations in the yield of fisheries (i.e. plankton and oceanographic observations at a grid of fixed stations) set a precedent for the 1914/1915 Hjort expedition off the Scotian Shelf and in the Gulf of St Lawrence, and for the CalCOFI monitoring programme established by Sverdrup to improve understanding of sardine and anchovy fluctuations in the California Current. Thus, Schmidt, perhaps influenced by Peterson and Hjort, appears to have been the father of large-scale multidisciplinary surveys to investigate population dynamics of fish species.

Key findings of this first basin-scale biogeographic study of fish eggs and larvae in the Northeast Atlantic were: (i) spawning locations differed between gadoid species; (ii) within the distributional range of a species, spawning occurred at several precise locations; and (iii) the geographic areas of spawning were very small compared with the distributional area of the species. These expeditions were an important contribution to Hjort's grand synthesis in 1914, which provided the present interpretation of the causes of temporal trends and variability of fishery landings (i.e. species consist of populations, or "races", which have year classes that vary in abundance). Schmidt was a key player in the work of Committee "A", and the successful completion of the Committee's initial remit was critical to the future existence of the organization. On the other hand, the ICES experience was very influential on the future directions of Schmidt's career with the Carlsberg Laboratory.

During the second expedition on the RV "Thor", in 1904, a single larva of the freshwater eel (*Anguilla* spp.) was caught. This was the first eel larvae observed in the Atlantic Ocean, although eel larvae had been found in the Mediterranean Sea a few years earlier. This observation appears to have turned on a light, as it were, that led Schmidt on a somewhat obsessive odyssey that dominated the rest of his all-too-short life. Thanks to his connection with the Carlsberg family, this single observation of an eel larva led to the first global expedition on marine biodiversity and biogeography. It is a remarkable story that has been well documented.

▲ *Between 1920 and 1922, the 550-tonne, four-masted motor schooner RV "Dana 1", explored the North Atlantic and the West Indies.*

▲ *On the deck of RV "Thor" in 1903. Left to right: Ove Paulsen, Johannes Schmidt, and J. N. Nielsen.*

The Carlsberg Laboratory: engaged in marine biodiversity (1910–1933)

Marine research was a major focus of the Carlsberg Laboratory, and of the Carlsberg Foundation, for 23 years (from 1910 to 1933). During this period, Johannes Schmidt was head of the Physiology Department of the Laboratory. Regrettably, he passed away after a short illness in 1933, at the age of 56 and at the peak of his career. During these two decades, Schmidt carried out a broad programme of research on marine biodiversity and biogeography, with the generous financial support of the Laboratory and the Foundation.

Schmidt was only seven years old when his father died, and he moved to Copenhagen, with his widowed mother and brothers, to live with his uncle, the famous Danish chemist Johan Kjeldahl (head of the Chemistry Department at the Carlsberg Laboratory). He later married Ingeborg Kühle, the daughter of the administrative director of the "Old Carlsberg Brewery". Although these family connections no doubt provided privileged access to funding, he also had warm support from the board (e.g. Professor Johannes Eugenius Bülow Warming and Rudolf Koefoed, the Director of the "Old Carlsberg Brewery"). Koefoed stated at a board meeting that Schmidt should be permitted to continue working on marine biological research and remain a member of ICES. Schmidt used this fortuitous situation of generous research support over two decades to the great benefit of science and society at large.

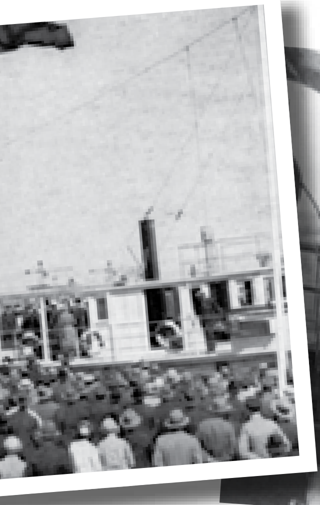
The expeditions led by Schmidt and supported, in whole or in part, by Carlsberg sources include:

- 1910: the "Thor" expedition, in the western Atlantic and Mediterranean
- 1920: the "Dana 1" expedition, in the North Atlantic
- 1928–1930: the "Dana 2" expedition, "The Carlsberg Foundation's Oceanographical Expedition Round the World"

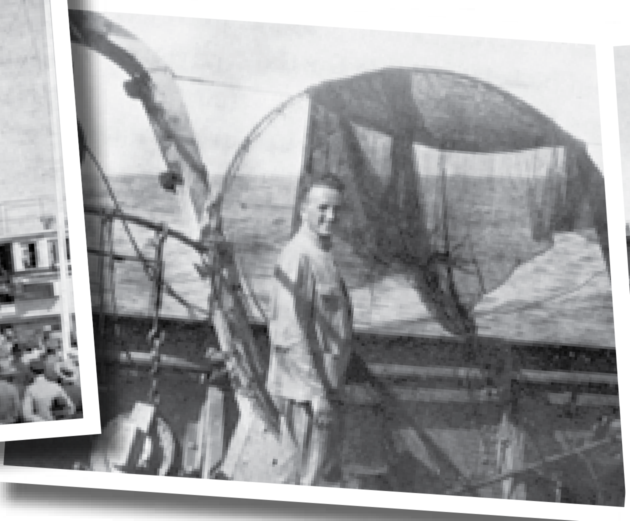
Schmidt's papers were influential beyond the marine science community

The RV "Dana 2" was provided by the Danish government, but all other expenses for the three-year global expedition were provided by the Foundation. The collections from all of Schmidt's expeditions were initially housed at Charlottenlund Castle, the location of the ICES Secretariat at that time. The work of sorting the samples lasted nearly four decades, and the data were published in 83 data reports (also sponsored by the Foundation).

The single eel larva observation in 1904, through a combination of Schmidt's drive and Carlsberg's support, resulted in a global investigation of the biogeography of the genus and family that lasted three decades, and along the way, a rich diversity of other work was undertaken. For example, an incidental discovery of the "Dana 1" expedition was the existence of the Mid-Atlantic Ridge, which led to benthic studies and contributed to fundamental changes in geological interpretations of the seabed.



▲ *RV "Dana 2" on its triumphal return to Copenhagen on 30 June 1930, after completing its circumnavigation of the globe.*



▲ *Schmidt on board the RV "Dana II" with a ringnet of his own construction.*

▲ *The Carlsberg Laboratory, flanked by the two directors' residences.*

Thus, 2010 is the 100th anniversary of the "Thor" expedition on eel early-life history in the Northeast Atlantic, the 90th anniversary of the "Dana 1" expedition on the biogeography of fish eggs and larvae in the North Atlantic, and the 80th anniversary of the completion of the "Dana 2" global expedition on marine biodiversity. As it is also the International Year of Biodiversity and the culmination of the first Census of Marine Life, it is a great year to celebrate and acknowledge the Carlsberg contribution to our knowledge of marine science.

Schmidt's "racial studies"

In addition to his investigations of eel biogeography, Schmidt's second passion was the search for general laws to account for the diversity of spatial patterns in populations of species and their genetic basis (his "racial" studies). I would suggest that both his brewery connection and his experiences with Hjort in Committee "A" were the foundation of this second research theme. Hjort's insights and the ICES fieldwork experience provided the new paradigm on the very nature of species, while the practical breeding work to increase the efficiency of the brewery at the Carlsberg Laboratory provided him with state-of-the-art genetic tools.

Schmidt's early experimental studies at the Carlsberg Laboratory were on the cultivation and crossing of hops, and he established a greenhouse for hops breeding at the laboratory in Copenhagen. The results led to a theoretical understanding of selection and its practical applications to production. No doubt, this practical work on selection and genetics in general, as well as an in-depth knowledge of the literature and tools of applied genetics, contributed to Schmidt's comparative studies on the population richness of marine species.

From his study of the expedition collections, which included a large number of specimens of the European eel (*Anguilla anguilla*), he concluded that there were no "racial" differences in this species. This was an unexpected result, given his observations on other species, both terrestrial and marine, and contrasted with the observations on the common blenny (*Zoarces viviparus*). This pattern, from the panmictic eel to the population-rich blenny, led to an ambitious programme of field and laboratory work, aimed at teasing out the genetic and environmental influences on the morphological characteristics of fish. In addition to these two species, the "million" fish (*Lebistes reticulates*), the common trout (*Salmo trutta*), and the Atlantic cod (*Gadus morhua*) were part of his comparative study. The central thrust of his research was to investigate the relationship between the environment and the genotype. Experimental procedures included traditional measurements of body shape and meristics for fish from different locations and ages, as well as breeding in the laboratory and transplantations of fish from one location to another under natural conditions.

The results of these diverse early studies on the population genetics of marine fish species were published in the "racial investigations" series of the *Comptes-rendus des Travaux du Laboratoire de Carlsberg*. Within the context of the history of ideas, it is of interest to access the Carlsberg archives and investigate the project applications for funding. What were his thoughts on the topical research priorities of his time and on what basis was the work funded?

Schmidt's second passion was the search for general laws to account for the diversity of spatial patterns in populations of species and their genetic basis

Søren Anker Pedersen, Project Coordinator at ICES Secretariat, has received full access to Schmidt's research proposals from the Foundation and is currently studying the material. We do know that Schmidt was seeking general laws to account for the differences between species in their degree of population richness. To my knowledge, he was the first marine ecologist to explicitly state the nature of the problem.

It is noteworthy that Schmidt's research on population genetics between 1910 and 1933 preceded the definition of the "biological species" concept by Ernst Mayr (as part of the "modern synthesis" of evolutionary thought, introduced in his landmark book *Systematics and the Origin of Species* in 1942). In this sense, Schmidt was perhaps thinking outside the box. His papers were influential beyond the marine science community, insofar as Mayr cites Schmidt's work on comparative population patterns in *The Growth of Biological Thought*, published in 1982. I think Schmidt is the only marine fishery ecologist cited by Mayr in his synthesis.

Concluding thoughts

During this International Year of Biodiversity, which also marks the completion of the Census of Marine Life, it is timely to recall the influential and visionary early work of Johannes Schmidt, as he is perhaps not sufficiently recognized today. ICES was a key part of his career, and he, in turn, was instrumental in setting the research directions of our international organization. The ICES flag was flown on the "Dana 2" during the global expedition.

Schmidt was elected a Vice-President of ICES in 1932, but never really took up this role because of his death early the next year. This was a great loss, given that he was in the process of synthesizing the results of the "Dana 2" expedition, and was in full force as a leading thinker of his generation. In addition to the legacy of his ideas, Schmidt mentored many young Danish marine scientists, such as Steemann Nielsen, the creator of the radioactive method of measuring primary production, and Anton Bruun, the scientific leader of the Galathea expedition on the bottom fauna of the deep-sea trenches. Schmidt was a big thinker and encouraged his younger colleagues to take on the difficult scientific challenges of the day.

He contributed knowledge at two levels of biodiversity: population (genetic) and species. It is tempting to conclude that his genetics work on improving beer led in some way to the definition of the biological-species concept, but perhaps this is going too far. Most certainly, the profits of the Carlsberg brewery, through both the Laboratory and the Foundation, have contributed enormously to our present knowledge of marine biogeography and biodiversity. Let's drink to that!

◀ *Johannes Schmidt in 1929 on the island of Koh Chang, Thailand, with Nai Sug. The photograph was taken during RV "Dana II's" circumnavigation of the globe between 1928 and 1930. Nai Sug assisted Schmidt in his studies of the Thai flora during Schmidt's first expedition, thirty years earlier. Schmidt recalled the reunion in his diary entry of 8 May 1929. "I was photographed with my old helper whose name is Sug, now: Nai Sug Sugsai, Koh Chang, Changwad, Chantaburi, Siam, and of course, I will send him the picture. He did not look old and, in spite of being over fifty years old, he had no gray hair, though the hair was somewhat thin on the forehead and his one leg was not strong. Never in all these thirty years has he left Kho Chang! He had several sons. In the village there is now a Wat [a Buddhist monastery]".*

Michael Sinclair is ICES President. His early research was on phytoplankton dynamics in estuaries. This was followed by work on herring stock assessments and fish life histories. He has more recently contributed practical suggestions for the implementation of the ecosystem approach to integrated management of ocean uses. The history of ideas, particularly with respect to marine ecology, is an ongoing hobby.

Acknowledgements

Information about Johannes Schmidt comes from several sources, including the centenary volume of the Foundation (The Carlsberg Laboratory 1876/1976, *edited by H. Holter and K. Max Moller), as well as personal communication with Søren Anker Pedersen, which is very much appreciated.*

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During my few extra days in Copenhagen, I found time to visit the Carlsberg Visitor Centre, hoping to see some reference to Schmidt, "Dana 2", or perhaps even ICES. The Carlsberg contribution to marine science and the associated societal benefits are not on show and perhaps have been forgotten. That said, the visit was of great interest. If you have a couple of hours to spare, I highly recommend the tour. The Visitor Centre provides an interesting introduction to the contribution of the Jacobsen family, through the Foundation, to art in Copenhagen. After the tour, I began to notice marvellous works of art at many different locations. The entrance fee includes a choice of two specialty beers, and my selection was very tasty. It is to be hoped that, in future, we can rekindle the Carlsberg interest in marine biodiversity, in parallel with their support of football teams such as Liverpool.

For information about planning a trip to the Carlsberg Visitor Centre, go to http://www.visitcarlsberg.dk/.

◀ *Visiting Seydisfjord, Iceland, in 1904. Left to right: Captain Søren Jørgensen, J. N. Nielsen, editor Skapti Josephson, Johannes Schmidt, A. Strubberg, Ove Paulsen, and Bjarni Sæmundsson.*

Iceland's first fishery biologist Bjarni Sæmundsson (1867–1940) had been engaged in fishery research on his own initiative since 1895, working voluntarily in his spare time, without any organized support. In 1902, the fishery adviser to the Danish Government asked Sæmundsson to suggest a branch of research that would assist the Icelandic fisheries. In response to Sæmundsson's suggestions, the Danes made a practical contribution by sending an expedition to study the fishing grounds off Iceland, which was part of the kingdom of Denmark at the time. RV "Thor" arrived in Iceland in summer 1903 and spent three summers conducting research.

Sæmundsson participated in the research that laid the foundation for ocean and fishery research off Iceland, as well as for Icelandic international cooperation in this field. Sæmundsson was the only Icelander engaged in ocean and fishery research until 1930, and until 1923, he did it while engaged full-time as a high school teacher.

BACK TO THE FUTURE

Returning to a tried and true method, ICES adopts maximum sustainable yield to guide its advice

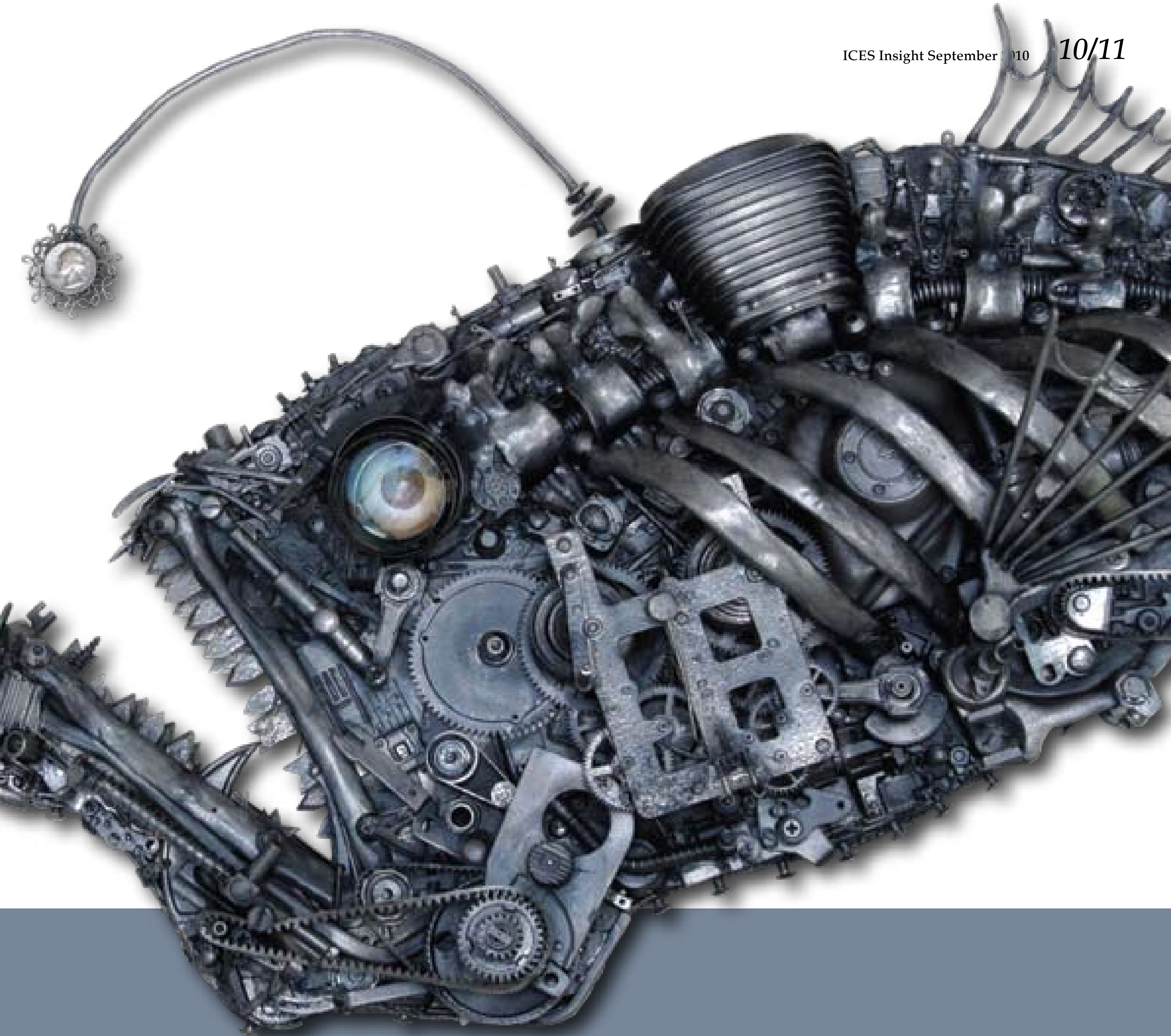
Maximum sustainable yield, a concept nearly as old as fishery science itself, has regained its role in the language of the conventions and agreements that govern fisheries at the international level. ***Ellen Johannesen*** *explains that ICES has begun to implement the renewed concept by moving toward MSY in its advice for fisheries beginning this year.*

Maximum sustainable yield (MSY) is based on the observation that any population attains maximum productivity at an intermediate exploitation level (or fishing pressure in the case of fish stocks). Unharvested fish stocks are thought to be limited to a certain size by density dependence and predation. If by fishing, or natural events, a stock is reduced from its maximum size, production is enhanced and the fishery can take this extra production as sustainable catch. When the population is reduced beyond a certain level, the growth potential of the population will not be fully realized. MSY aims to achieve the long-term maximum production and avoid overfishing resulting in endangered stocks.

The concept of MSY is closely associated with the problem of overfishing. If a stock is fished too intensely, its potential is not fully realized in two ways: the growth potential of individual fish is not fully realized (growth overfishing) and there are too few mature fish to produce enough juveniles (recruitment overfishing).

Growth overfishing occurs when the individual fish are caught too small, before they are past the initial rapid growth phase where growth in weight adds more to the weight of the population than what is lost owing to natural mortality. Recruitment overfishing occurs when the stock is depleted, and the remaining fish cannot produce enough offspring to maintain full productivity. The ICES precautionary approach focused on avoiding recruitment overfishing. ICES interpretation of MSY takes both growth overfishing and recruitment overfishing into account. In this way, ICES approach to MSY embeds the precautionary approach, which from the mid-1990s was the basis for the advice.

The ICES MSY framework aims to inform policy-makers on how they can achieve the goals set out in the various international agreements by advising on how to attain the maximum long-term average catch.



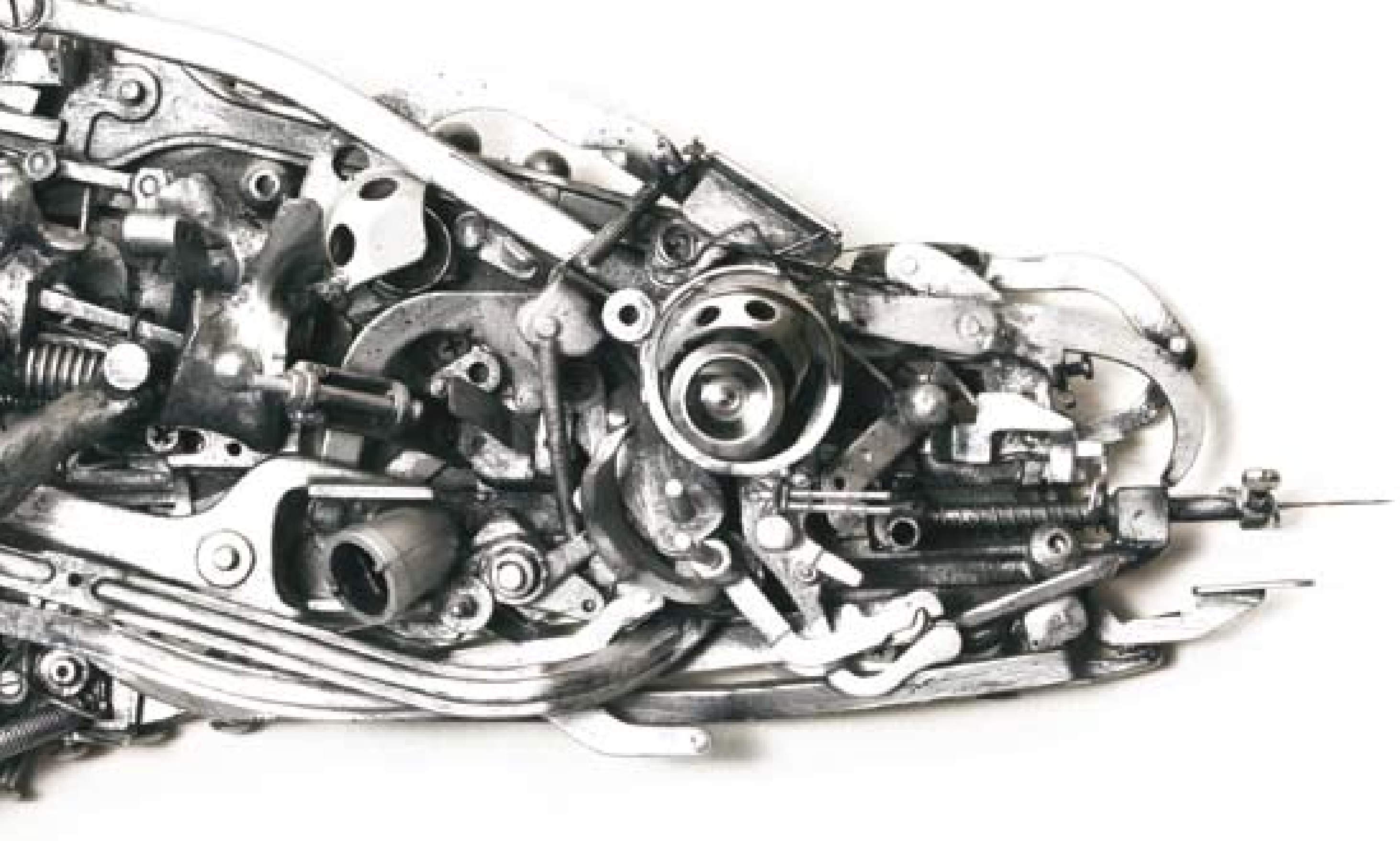
Conventions such as the United Nations Convention on the Law of the Sea (UNCLOS, 1982), the United Nations Conference on Environment and Development (UNCED, 1992), and the Johannesburg Declaration of the World Summit of Sustainable Development (WSSD, 2002) have called for signatories to maintain or restore fish stocks to MSY; the WSSD set a deadline of 2015 for implementation.

Timeline of implementation at ICES

ICES has begun to implement this new approach in response to the objectives of the above agreements and policies that set the context for advice, as well as to provide advice that allows clients to fulfil their international policy obligations.

Hans Lassen, retired Head of the Advisory Programme explains, "One of our main clients, the European Commission, decided how they will interpret these broad political agreements in 2006. During our 2008 annual meeting with all of the clients for fishery advice, we agreed that ICES should operationalize MSY-based advice. In short, we are reflecting general political agreements, which, from an ICES perspective, is nothing new in concept. But the precise way you operationalize the framework differs a bit, of course. It depends on the data you have available: What can you calculate? Implementation of the concept will determine the legal frameworks and political environments under which various management authorities operate".

After the ICES Advisory Committee (ACOM) agreed on an MSY framework in 2009, work on defining how the concept would be implemented began in ICES expert groups. In 2010, ICES hosted a meeting between clients, scientists, and stakeholders to provide some technical guidelines to the expert groups. The Workshop on the Application of Advisory Framework to Data-Poor Stocks (WKFRAME) met in March 2010 to discuss how MSY would be defined in operational advisory terms.



According to WKFRAME's 2010 report, "The concept of MSY is widely interpreted as the maximum long-term average catch that can be achieved under prevailing conditions (including both the state of the ecosystem and size selectivity of the fishery). MSY is considered to be achieved by a fishing mortality (F_{MSY}) that produces a high, long-term average yield, while the stock fluctuates around the stock size where production is at or close to the maximum. A strategy for achieving MSY can be expressed as a harvest control rule where *F* is a fixed target, which may also be a function of stock size. This is the form of the ICES MSY Framework".

The precautionary approach

ICES advice has been based on the precautionary approach since 1998. Advice based on the precautionary approach aims at keeping enough fish in the sea to maintain the full reproductive capacity of the stock. Unfortunately, this goal has not been achieved for all stocks. Implementation of MSY is a more ambitious objective. Maintaining full recruitment potential is necessary for MSY, but it is not sufficient.

Lassen explains, "The point is that the emphasis differs depending on whether recruitment overfishing is the primary issue or both growth overfishing and recruitment overfishing are to be prevented. In general, recruitment overfishing for a fish stock occurs at a higher exploitation rate than growth overfishing. Of course, there are examples where this is not the case, but it is generally the case.

"From the point of view of a fishery biologist, if you have a heavily overfished stock, the first step is to get fishing pressure below recruitment overfishing bounds, and then to balance growth with mortality. You could see this as a shift from the precautionary approach, which is recruitment overfishing, to MSY, which puts more emphasis on growth overfishing".

ICES advice using the MSY approach aims at attaining the objective by controlling fishing mortality. The precautionary approach will continue to be part of ICES advice.

Poul Degnbol, Head of Advisory Programme, notes, "Conservationist stakeholders remind us that MSY is only part of the story. MSY only considers one aspect of fishery management and needs to be framed within an ecosystem approach. When you build a house, you need a roof. A roof won't protect you from the wind, so you need walls, but you still need a roof. MSY does not protect all aspects of the ecosystem but is only one part of management in an ecosystem context. In order to implement an ecosystem approach you must implement MSY but you must also supplement this with specific measures to protect sensitive habitats and species for instance".

How to reach MSY by 2015 is another question, because there are multiple ways of getting there. In general, precautionary approach limits allow higher exploitation limits than the MSY target. Therefore, the general trend where MSY has been implemented is towards lower fishing mortality than has been advised by the precautionary approach. ICES discussed options for changing to the lower fishing mortality rates associated with MSY with the users of fishery advice. Although there was no formal agreement among all the parties, it was generally understood that there should be a gradual transition. "The Johannesburg declaration talks about MSY in 2015, and we are taking five equal steps towards MSY where we have not achieved it", says Lassen.

Model predictions of stock increases may not be realistic, but practical experience indicates that some beneficial increases will usually occur

According to Degnbol, “Some might say that the advice has become more complicated because now there is more than one piece of scientific advice. In the past, there was only one piece of advice, and now the advice presents decision-makers with more options. Each alternative provides them with the choice of how they want to manage the information about what the implications will then be”. This apparent complexity in the advice simply reflects the reality that management decisions are complex.

From theory to practice

In spring 2010, many fish stock assessment advisory working groups began to make the transition to MSY, although not all advice for 150 stocks could be given using MSY in the first year. According to Lassen, “For perhaps a third of fish stocks, we were at or near MSY. For another third, we need some sort of transition plan. For the final third, the information on precisely where we are is rather thin, and we will have to look at those stocks a bit more carefully”.

Degnbol recalls, “It was a tough advisory year because it is always difficult to implement something new. Working groups that already work with sharp time constraints worked under pressure, unforeseen issues arose, and many special cases presented themselves. But in the end, it got done”.

Lassen says, “We have recorded all these issues, and the Advisory Committee will take a closer look when they meet in November, but we managed to get through, and we are completely convinced that the system can be made operational”.

Challenges remain for MSY implementation. Fishery scientists have limited data to work with. Some stocks have been chronically overfished, and no previous data exist from times when they were not overfished, so we do not know what will happen when fishing mortality is reduced. Model predictions of stock increases may not be realistic, but practical experience indicates that some beneficial increases will usually occur. Says Degnbol, “The technical basis is still being developed and, in some cases, the models being used are predicting increases that are hard to believe. So, for some stocks, only observations over time will really reveal how the stocks will react”.

Degnbol concludes, “Industry stakeholders will be concerned with the transition because they are interested in surviving economically in the short term. However, as a concept, MSY is widely accepted because it implies managing at an optimum level over the long term, allowing SSB to reach a certain level, and thus allowing more fish to be harvested”.

North Sea herring is a typical example of a stock that was fished down in the 1970s. After initial closure of the fishery, restricting fishing mortality has resulted in less interannual variability in landings. In recent years, where recruitment was low (probably as a result of environmental factors), restricting fishing mortality to around F_{MSY} through management plans has resulted in a sharp decrease in landings, but stock biomass has remained around levels prior to the collapse in the 1970s. (See “The story of SGRECVAP” starting on page 18.)

About the artist

The sculptures illustrating this article are by sculptor Jud Turner. Working with found objects and welded steel, he creates artworks that are immediately visually engaging, using elements of symmetry, repetition, and intricate detail to balance some of the darker contemporary themes they address. His work has been exhibited all over the world and featured in numerous publications.

About his artistic motivations, Turner says, “Our culture mass produces more consumer goods and pop culture flotsam than any society has at any time in history. I hope to use this abundance created by our culture to provide an artistic critique of that very culture”.

For more information about the artist and his work, visit http://judturner.com/.

An interview with Ray Hilborn

***William Anthony** asks Ray Hilborn about the problems facing fisheries today.*

Ray Hilborn, one of today's leading experts on fisheries, is a professor in the School of Aquatic and Fishery Sciences, University of Washington, specializing in natural resource management and conservation. He serves as an advisor to several international fisheries commissions and agencies as well as teaching graduate and undergraduate courses in conservation, fish stock assessment, and risk analysis. He is the author of *Quantitative Fisheries Stock Assessment*, with Carl Walters, and *The Ecological Detective: Confronting Models with Data*, with Marc Mangel.

Recently, he conducted the course "Introduction to Bayesian Inference in Fisheries Science", with Samu Mäntyniemi, as part of ICES Training Programme.

What is the basis of the problems facing fisheries?

It helps to view fisheries in three dimensions: biological, economic, and social.

Biologically, you want to maintain stock sizes within a range that produces a high sustainable yield. It doesn't have to be optimum, but it has to be within the "good" range.

Economically, you want fisheries to be profitable. Fisheries can be a source of enormous wealth for nations. The Falkland Islands, for example, generate approximately US$10 000 profit per person per year. Iceland's economy is built on fishing, and fishing made the country rich because, particularly in the 1980s and 1990s, the country made its fisheries economically efficient.

In Europe, governments have subsidized their fisheries so much that they are probably a net loss to the national economies. This was certainly true in Canada when I worked for the Canadian government. The budget of the Canadian Department of Fisheries was greater than the value of fish landed in the country!

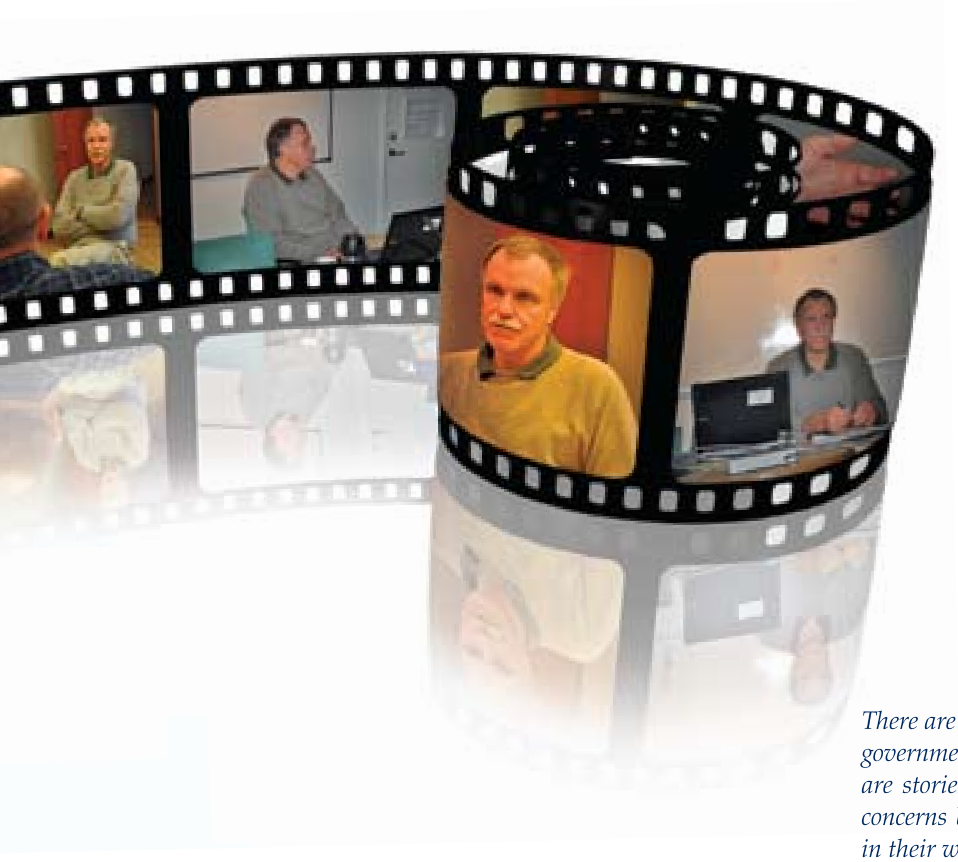
Increasingly, there is a move to what, in the US, they call rationalization: i.e. making fisheries economically efficient. Usually, this means dramatically reducing the number of fishing boats, which means job reduction, so that each boat can catch more fish, and building up the population sizes of the fish so that they are easier to catch. That way, you get good sustainable yield over quite a range of stock sizes. The more fish there are in the ocean, the less time, and the less fuel, it takes to catch them. So generally, you make more money by having more fish than you would if you were just trying to maximize the total catch of fish. It's the difference between maximum economic yield and maximum biological yield.

The social dimension is where things get hard. Fisheries are an important part of community structure. One of the reasons why we are now in trouble is that political pressure to maintain employment in fishing communities has led to the subsidization of fisheries, overcapacity, and too many boats.

The right answer will vary from place to place. Iceland, New Zealand, and Australia, which would usually be cited as three of the best-managed countries in the world, have all explicitly said, "Fisheries are not about creating jobs". They have abandoned any pretence of using fisheries as an employment mechanism and have essentially eliminated from the agenda the idea that you can generate employment from fishing. They certainly don't subsidize the construction of vessels. Their standard answer is, "If you can catch all of the fish with one boat, then do it, instead of using ten boats", but it has caused enormous hardship in the small fishing communities.

So, the metaproblem is: where do we really want to be in these three dimensions? If it's just economics and biology, that's fine because these don't conflict, but it really conflicts with some social objectives, such as the maintenance of small communities and traditional employment.

Economically, there is conflict over where the wealth from very profitable fisheries should go. The trend in Iceland, New Zealand, Australia, and the US, where fisheries are economically efficient and very profitable, is to give money to the people who are currently involved in the fishery and to allocate fishing rights. However, the problem is that those rights are permanent, and if fishermen leave the fishery, they can sell their rights. In Iceland, there are "fish millionaires", i.e. people who don't fish anymore but are millionaires based on the fishing rights that they were granted. Wealth distribution is a complicated issue.



What about other parts of the world?

In many countries, central governments do not have strong control over their fisheries. The high seas are a different case. Actually, stocks are generally not in bad shape biologically, with the exception of bluefin tuna. Few of the large high-seas tuna fisheries, which comprise most of the high-seas fisheries, are overfished severely, if at all.

In fact, we are just doing a project on this. I think our estimate is that the abundance of tuna and billfish in the ocean has probably only been reduced by 20 to 40 per cent since industrial fishing really began in 1950. There is a common misconception, based on a paper published in 2003, that all of these fisheries were depleted long ago; this is totally wrong. However, there is no effective regulation, and the record of self-enforcement is pathetic.

I work on the Commission for the Conservation of Southern Bluefin Tuna, a species whose stocks are severely depleted, and which is probably in the worst state of any of the high-seas fisheries. It turns out that, for ten years, the world catch of these fish has been double or triple the total allowable catch. This illustrates that no international government can assure compliance in the same way as national governments can assure compliance by their own fishermen.

There are similar problems in many countries where national governments are ineffective in the fisheries realm. There are stories coming out of West Africa about foreign fishing concerns bribing senior government officials to let them fish in their waters totally unregulated.

In much of the tropical world, for example Asia, Indonesia, and parts of Africa, you find enormous conflicts between the traditional fishing communities, which usually use small-scale technologies, and the more industrial fleets coming out of their cities.

What are the appropriate mechanisms for managing fisheries in the absence of strong central top–down control? Community-based management can work, but the key is to be able to exclude other people from your area, and this is often not the case, legally or mechanically, in much of the world. Traditional fishermen cannot prevent industrial fleets from taking their fish.

Is it possible to reduce the amount of mistrust that fishers feel towards governments?

Almost everywhere there is a distrust of government because fishery regulations are incredibly intrusive. It's like going to a businessman and telling him exactly when he can open his store and what he can sell.

On one hand, fishermen see and experience much more than average government scientists, who probably spend 90 per cent of their time in offices behind computers. Fishermen spend 90 per cent of their time on the water, sampling marine ecosystems. But an individual fisherman only sees what he sees where he is. Government scientists, through their data-collection programmes and merging of data, see the big picture.

In general, real conflict has occured where there are long-established fisheries, for example in New England or Europe. Governments, which largely used to leave people alone, are becoming more intrusive. On top of that, they are telling fishermen that they're going to make a lot less money and that they're going to catch less. The messages are very bad news.

I like fishermen. They're some of my favourite people. In my experience, fishermen are very cooperative when they're doing well, but when they're doing badly and you're telling them they're going to receive less, they're not going to be happy. I'd always rather work with rich fishermen than poor fishermen.

Part of it has to do with perception. For instance in New England, the amount of allowed fishing time is probably a tenth of what it used to be. Catches are maybe 15 or 20 per cent, certainly well under half, of what they were 20 years ago, but the number of fish in the ocean is increasing substantially. So, fishermen see more fish than they have seen in 30 years, but they're being allowed to catch fewer of them. Part of that is the result of taking too many before, but still, they see fish literally everywhere, and they're being continually restricted. That leads to a problem of perception.

On the other hand, I've done a lot of work with the fishermen in Alaska, and they've seen that it works. They're still in business, and some of the fisheries are doing extremely well. So they know it's working. In Canada, I saw a series of fishing groups go from struggling to doing very well, and become much more cooperative as a result.

Is it correct to say that overfishing leads to overfished stocks?

The US has adopted a specific terminology: "overfishing" is the rate at which the fish are harvested; "overfished" is the total number of fish in a stock in relation to the number that would produce the maximum sustainable yield. So, fishermen can be overfishing if their catch rates are too high, but a stock won't be overfished if its numbers have not yet been depleted. Conversely, an area can be overfished if the fish stocks have been depleted but, if there is no overfishing, the stocks will rebuild.

In the social dimension, we have people who are earning their living as well as people being nourished from fisheries. Are you optimistic that we can sustain a level of protein production sufficient to feed the world?

Yes, I'm optimistic. Certainly, in the parts of the world that I know well, I have no concerns about long-term sustainability of the fishery resources, although climate change and acidification must also be considered.

Fishing is often attacked for its impacts on the ecosystem, and I don't think the fisheries community has made enough of an important point: by any measure of environmental impact, marine capture fisheries are better than agriculture at producing animal protein. Whether it's the CO_2 footprint, the amount of petroleum used, or threats to biodiversity, marine capture fisheries are more efficient than producers of beef, pork, and chicken.

The story of SGRECVAP

...or the group that couldn't pronounce its own name

***Mark Dickey-Collas** tells how North Sea herring kept fishery scientists guessing.*

A cry went up from the herring working group: "Recruitment is down for the third year in a row!", followed closely by "But why?" and "So, what can we do?"

Until 2005, when these facts became apparent, most people thought that, for fishery science, North Sea herring was a "dead" issue, insofar as we had a management plan that appeared to operate well, the assessment was considered high quality, and stock biomass was growing.

Little did we know that herring enjoy challenging fishery scientists (Sinclair, 2009). Also, we didn't predict at the time that recruitment was going to remain low for at least the next eight year classes. What followed was a journey of investigation and discovery.

In typical ICES fashion, we decided to form a study group to address the issue and decided on the catchy name of "Study Group on Recruitment Variability in North Sea Planktivorous Fish". Also in typical ICES fashion, it received the inevitable abbreviation of SGRECVAP. We all know that recruitment variability has been a central topic of study for fishery science for the past 100 years (Houde, 2008) and that, despite all of this study, we often appear to make little progress. So, as appointed Chair, and hoping to limit expectations, I was keen to keep the objectives of the SGRECVAP sensible and the deliverables achievable. The study group met twice (in 2006 and 2007), and we were pleased with what had been found.

The SGRECVAP approach was to investigate likely hypotheses, collect data to test them, and rule out the more unlikely causes of poor recruitment. At the time, many scientists were suggesting that their own favourite research-baby was the cause of the phenomenon. We specifically tried to avoid data mining and multiple correlations across matrices of data and, instead, attempted a reasoned, process-based approach. As the study group was not linked to any specific research project, resources were limited and we had to rely on the goodwill and enthusiasm of SGRECVAP members.

We concluded that environmentally induced change was affecting the recruitment of North Sea herring. Despite the simultaneous occurrence of a large adult population and historically low exploitation, there had been an unprecedented series of years with poor juvenile production. The poor recruitment arose during the larval overwintering phase. Contemporary warming of the North Sea had caused significant changes in the plankton community, and an identified regime shift in around 2000 demonstrated close temporal agreement with the reduced larval survival. Perhaps we were observing the first effects of the planktonic change on higher trophic levels. There was no indication of a recovery in recruitment in the short term. We concluded that, in a dynamic environment, recent management success does not necessarily guarantee future sustainability.

The report was widely read and the work was mentioned in many ICES circles. The findings were incorporated into ICES advice, by adjusting the recruitment signal used in the stock projections. This demonstrated that ICES was taking seriously the effect of environmental variability on one of its "flagship" stocks. However, the members of SGRECVAP and the ICES Secretariat all felt that the findings of SGRECVAP should be publicized to the wider world.

Our next thought was "How and where?" Our investigations had not actually come up with a clear answer, but we did have a story to tell. That story could affect the exploitation of the stock because, by this time, fishing mortality was above the agreed management level. Forecasts demonstrated a high risk of the stock moving outside safe biological limits, potentially precipitating another collapse. We submitted a manuscript telling our story to the journal *Science*, and this got as far as the review stage, which was encouraging. Sadly, it did not progress any further. As we were still keen to tell the story, we approached various editors with a view to finding the most appropriate journal. We discovered, perhaps rather obviously, that the *ICES Journal of Marine Science* was probably the best option. So, we submitted a short manuscript, only to be requested, after the review, to make it longer. Thus, the Payne *et al*. (2009) paper was created directly from the work of our ICES study group.

I was very pleased, especially as it can be frustrating trying to cite work from the ICES community that is never published in the peer-reviewed literature. The paper also led to other spin-offs. Many laboratories initiated investigations into the phenomenon (in Germany, Norway, Denmark, Scotland, and the Netherlands). Also, after a very quiet decade in terms of publications, it appeared that research into North Sea herring was again becoming fashionable (see review by Dickey-Collas *et* *al*., 2010). We enjoyed discussing many of these issues at the ICES/PICES "Linking Herring" symposium in 2008 (Dickey-Collas *et al*., 2009) and the NAUSEA (North Sea 'erring Alliance) group was formed.

We didn't predict at the time that recruitment was going to remain low for at least the next eight year classes

NAUSEA brings us to the present day. NAUSEA is a group of scientists, inspired by SGRECVAP, who are investigating more closely the processes that brought about the poor recruitment. Funding has been secured through the EU projects UNCOVER (Understanding the Mechanisms of Stock Recovery) and RECLAIM (Resolving Climatic Impacts on Fish Stocks) and various national programmes. We are combining the fantastic empirical information (30 years of surveys on many life stages) with newly developed biophysical models of the North Sea. We are paying close attention to the processes governing larval growth and survival. The results obtained by the NAUSEA group are now beginning to be communicated (e.g. at the ICES Annual Science Conference 2009 in Berlin, Germany; the 2009 ICES/PICES/UNCOVER "Rebuilding Depleted Fish Stocks" symposium in Warnemünde, Germany; and the 2010 ICES/PICES/FAO "Climate Change Effects of Fish and Fisheries" symposium in Sendai, Japan), and we have just begun to submit manuscripts.

When I was asked to chair SGRECVAP, I didn't realize how it would affect my research direction. Initially, I thought, "After 100 years of research into recruitment dynamics, how can we do any better?", but I was proven wonderfully wrong. I have enjoyed working on multidisciplinary teams, tackling questions that need a broad range of expertise to answer. I was naïve about the utility of new spatial biophysical models (Hinrichsen *et al*., 2010), which have proven to be very powerful tools when combined with robust understanding of physiology and behaviour of young fish. On the way, I have made many new friends, worked with some incredibly dynamic researchers, and been regularly challenged scientifically. What more could a marine scientist ask for? All as a result of the "failure" of North Sea herring.

Mark Dickey-Collas works at IMARES in the Netherlands as a fishery scientist, having worked in Belfast on Irish Sea fisheries. He is senior advisor to the Dutch Government on pelagic fishery science and has a broad research portfolio (Researcher ID: A-8036-2008). He has been active in ICES since 1994 and is currently the Dutch member of ICES SCICOM and a member of ICES Publications and Communications Group.

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North Sea herring fisheries strongly influenced the economic and social development of northern Europe between 1500 and 1900

The collapse of North Sea herring

North Sea herring fisheries strongly influenced the economic and social development of northern Europe between 1500 and 1900. The trade in herring led to the increasing sophistication of international markets, encouraging the establishment of political alliances between towns and countries. Unfortunately, many international wars were fought over the rights to fish herring. From its beginnings in the 16th century, the herring fleet has introduced new fishing methods and techniques for preserving fish.

The supply of cheap, healthy protein helped to nourish the increasingly urbanized populations of the industrial revolution. The fishery also helped to stir the beginnings of what we now know as fishery science and stimulated the formation of ICES. Therefore, the collapse in the 1970s of one of the "top league" fish stocks caused shock waves across the fishery world.

As with all herring, the productivity of the stock varied over time, but catches were maintained (see Poulsen, 2008). However, at the beginning of the 20th century, when the adult population of North Sea herring was about 5 million tonnes, the fleet became even more mechanized, and catching power was greatly increased. By the mid-1970s, the adult herring population was about 50 000 tonnes (1% of the population size 30 years earlier). After much scientific debate and political wrangling, all targeted fisheries for herring were closed in 1977.

The collapse of the North Sea herring stock had widespread effects: obviously on the fisheries themselves, but also on the markets for herring products, the North Sea ecosystem, fishery science, and our understanding of fish ecology (Dickey-Collas *et al*., 2010). After the closure, the stock recovered, broadly as predicted, and was back at 1 million tonnes by 1990.

The post-collapse fishing fleet was very different: vessels were fewer but larger, and with greater processing power. Some claim that the increase in gadoids or sandeel populations was linked to the decline of herring. It is thought that some species, such as seals, changed their dietary preferences. The disappearance of herring may have led to the loss of bluefin tuna from the North Sea. Fishery scientists were granted a brilliant example of stock collapse and recovery to study, as were the geneticists and ecologists. Managers were given clear evidence that, at small population sizes, the ability to produce the next generation of fish is greatly restricted.

The population of North Sea herring is now closely monitored by ICES and is fished under a management plan agreed between the EU and Norway. Despite changes in productivity (in the mid-1990s and since 2002), this management plan has prevented another collapse and maintained a medium-sized population of herring in the North Sea.

Portraits of famous herring

The genre of fish still life painting developed in the Dutch Republic in the 17th century, reflecting the importance of herring to the country's culture and the economy. The influence of herring on culture is also evident in the portrait paintings.

Sea Fish on a Table 1650
Jan de Bont

Herring play a minor role in this painting, which features six herring placed to one side of the haddock and plaice rather than centrally. They appear to be fresh but, untypically, they are not filleted. Usually, the herring would have been gutted and packed in barrels at sea.

Man with Herring 1655
Christiaen van Couwenbergh

This painting was thought at one time to be a self-portrait, but this is now in question. Painted in a humorous, popular style, the grinning man is depicted wearing the type of clothing associated with common folk. After tobacco was introduced to Holland, the custom quickly developed, at least among the lower classes, of keeping a pipe in the hat or cap, ready for use.

Woman Selling Herring c. 1675–1680
Godfried Schalcken

This painting raises interesting questions about the woman selling herring. Do her pearl earrings and mouche, *the piece of black taffeta applied to her temple to emphasize the fairness of her skin, indicate a status higher than that of fishmonger? And who is the out-of-frame customer with whom she seems to be conversing?*

In Praise of Pickled Herring 1656
Joseph de Bray

This painting takes its title from a poem written by the artist's uncle, the physician and theologian Jacob Westerbaen. Indeed, the poem is the central feature of the painting. The poem itself is a testimony to pickled herring, praising its flavour, appearance, and healing properties. It also describes how it should be consumed with onions, rye bread, and beer, as shown in the foreground.

The Thirsty Eater c. 1625–1630
Gerard van Honthorst

The artist depicted this thirsty eater in a plumed hat with a bare shoulder, a style very different from what the average Dutch burgher was accustomed to wearing, and suggesting a mythological figure. The subject holds a pickled herring in one hand and a tankard, probably filled with beer, in the other. Quenching the thirst with beer was not only pleasurable but also necessary: water at the time was often unfit to drink.

The Merry Drinker c. 1625
Hendrick ter Brugghen

Merry or intoxicated? It has been suggested that the figure with rumpled clothing and a crumpled herring in his left hand is meant to represent a leading character in the Dutch carnival season's burlesque theatre, Pekelharing, literally "pickled herring". The "tough guy" image of our theatrical hero shows the influence of Caravaggio on the artists who gathered in Utrecht.

WGOOFE

HOOKING UP DATA USERS WITH DATA

***Barbara Berx*, *Mark Dickey-Collas*, and *Morten Skogen* describe a disconnect between data producers and data users, and explain how WGOOFE is making new connections.**

In a marine science and management world that increasingly emphasizes a multidisciplinary approach, a world in which large projects often drive collaborations across the fields of oceanography, fishery management, and environmental research, many ICES scientists are under the impression that the data they need are not available. They believe that they have been left to their own devices to find environmental information that supports their research and advisory roles.

In fact, many sources of oceanographic and environmental data are readily available.

ICES Working Group on Operational Oceanographic Products for Fisheries and Environment (WGOOFE) was established in spring 2008 to remedy this gap in awareness. It acts as a two-way link between the producers and users of oceanographic data products, has developed a web portal for oceanographic products, and is working to establish more detailed user requirements. The working group consists of data producers (mostly scientists from meteorological or operational oceanographic backgrounds) and users from a diversity of fields (environmental, oceanographic, ecological modelling, and fisheries).

The magic portal to oceanographic data

The working group is particularly proud of the website created under its guidance, http://www.wgoofe.org, which is currently hosted by Ifremer. It acts as a data portal to various existing oceanographic data products and offers links to empirical (based on physical observations), modelled (based on a computer model or numerical simulations), and integrated (created by combining data residing in different sources) products for forecast, real-time, and time-series research.

> Scientists are under the impression that the data they need are not available

A new development allows users to search for oceanographic data based on parameter type (e.g. temperature, salinity), rather than being limited to searching for data by region.

▲ *Some members of the WGOOFE team at the Aberdeen meeting. Front left to right: R. Forster, H. Klein, E. Dombrowsky, C. Schrum, and M. Payne; back left to right: S. Legrand, Y-H. De Roeck, R. Barciela, B. Berx, M. Skogen, M. Dickey-Collas, and G. Vinay.*

A second development will reward producers of easily accessible products with a prime location on the website and an endorsement indicated by a "WGOOFE traffic light" or quality label. An endorsement will alert users that data are easy to find and ready for download, and that documentation and contact information is easily obtainable. It is hoped that a rewards programme will encourage easy access to data with no broken links, up-to-date data, and will eliminate the countless hurdles encountered when searching for data.

More questions than answers?

Early on, the working group realized that it needed more input from the ICES community about its requirements for oceanographic data products (state variables, frequency, resolution, format, etc.). Many data were available, but how were they needed and in what formats?

Within WGOOFE, the operational data providers (group members who are affiliated with operational oceanographic institutes or organizations with large observational programmes) outnumbered users three to one. Thus, it became clear that the wider ICES community might not be adequately represented by the users around the table. There was an additional danger that producers would drown out the views expressed by the user community. To address these problems, a questionnaire was circulated to gather user views. Events were organized in several research institutes and at ICES Annual Science Conference in support of the questionnaire.

Do you feel like your oceanographic products have been missed by WGOOFE? Do you think WGOOFE is not covering your user needs? Would you like to contribute to one of the most prolific ICES working groups? Why not visit our website (http://www.wgoofe.org), contact our Chairs (Mark Dickey-Collas and Morten Skogen), come to our session at the ICES Annual Science Conference (Theme Session A), or attend the upcoming WGOOFE meeting in Bergen in November?

There was a danger that producers would drown out the views expressed by the user community

The questionnaire elicited responses from 100 marine researchers from environmental and fisheries backgrounds, and from across diverse research institutes. The scientists emphasized the need for information on temperature, transport, primary production, and salinity (see the figure opposite). Their answers also highlighted the gap between researcher requirements identified by data providers and the requirements actually described by the researchers.

For example, although the producers emphasize high-resolution, short-term forecasts, most researchers prefer time-series of annual averages of regional data. Researchers favour absolute values, whereas many producers appear more interested in providing information on the differences from the average (anomalies).

Preferences about the format in which data should be provided likewise diverged, with some lobbying for ASCII files or spreadsheets, while others chose netCDF (network Common Data Form) files, which support the creation, access, and sharing of array-oriented scientific data.

It was clear that almost all of the researchers want access to data (more than 90% of those questioned), whereas only 40% of researchers are interested in graphical presentations.

If not addressed, these diverse perceptions of what is required would slow down research and impede progress towards an integrated ecosystem approach. WGOOFE's next task is to relay this message to the producers of operational oceanographic products.

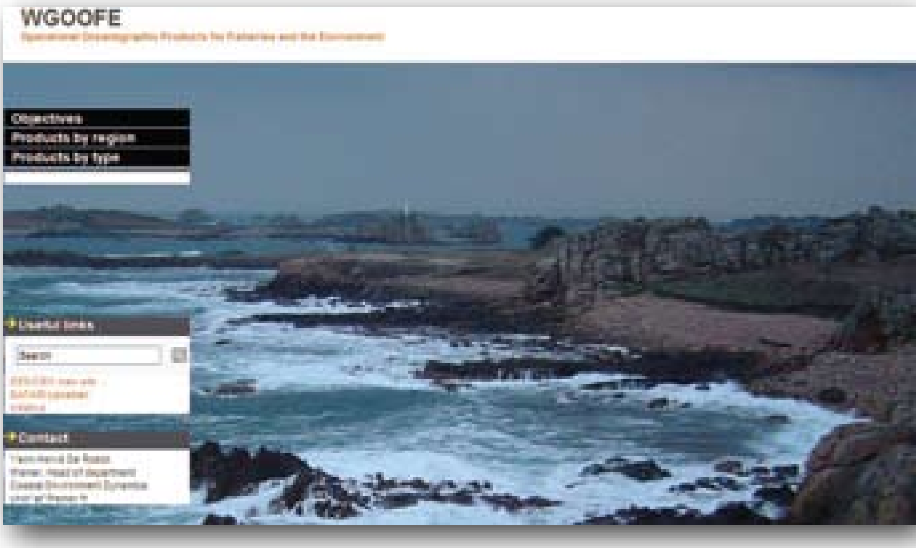
Our autumn spectacle

With support from many ICES expert groups (WGDIM, WGPBI, WGOH, and IGWG), WGOOFE are co-convening one of the theme sessions at the ICES Annual Science Conference 2010. At Theme Session A, "Operational oceanography for fisheries and environmental applications", participants will experience a wide variety of presentations and discussions covering both data products and their development, as well as practical applications. Sob stories about dashed (data) hopes and aspirations will be heard and considered.

Bee Berx is a physical oceanographer working at Marine Scotland Science, UK.

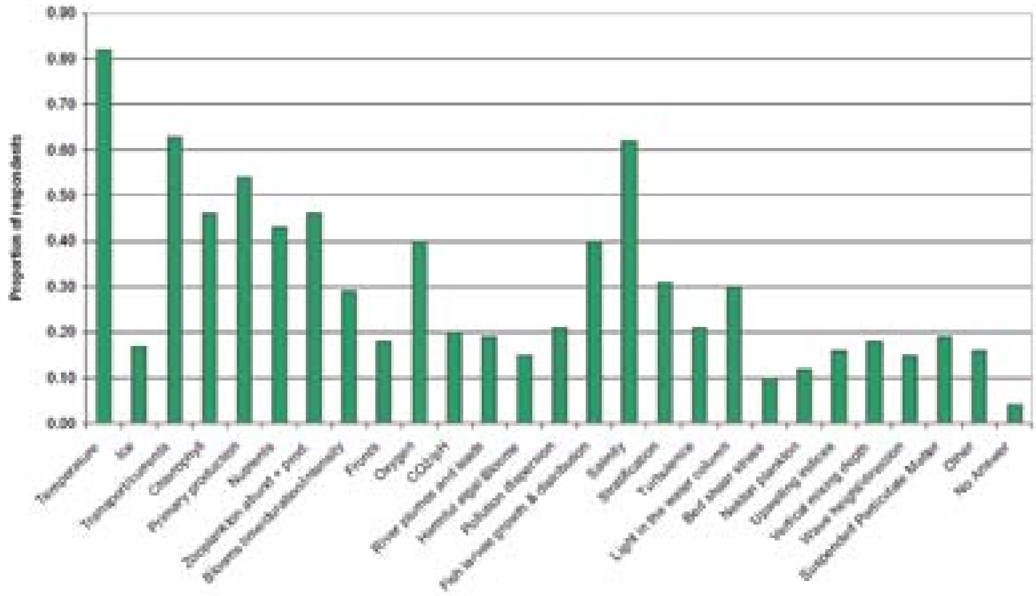
Mark Dickey-Collas is a senior fisheries scientist at IMARES, the Netherlands.

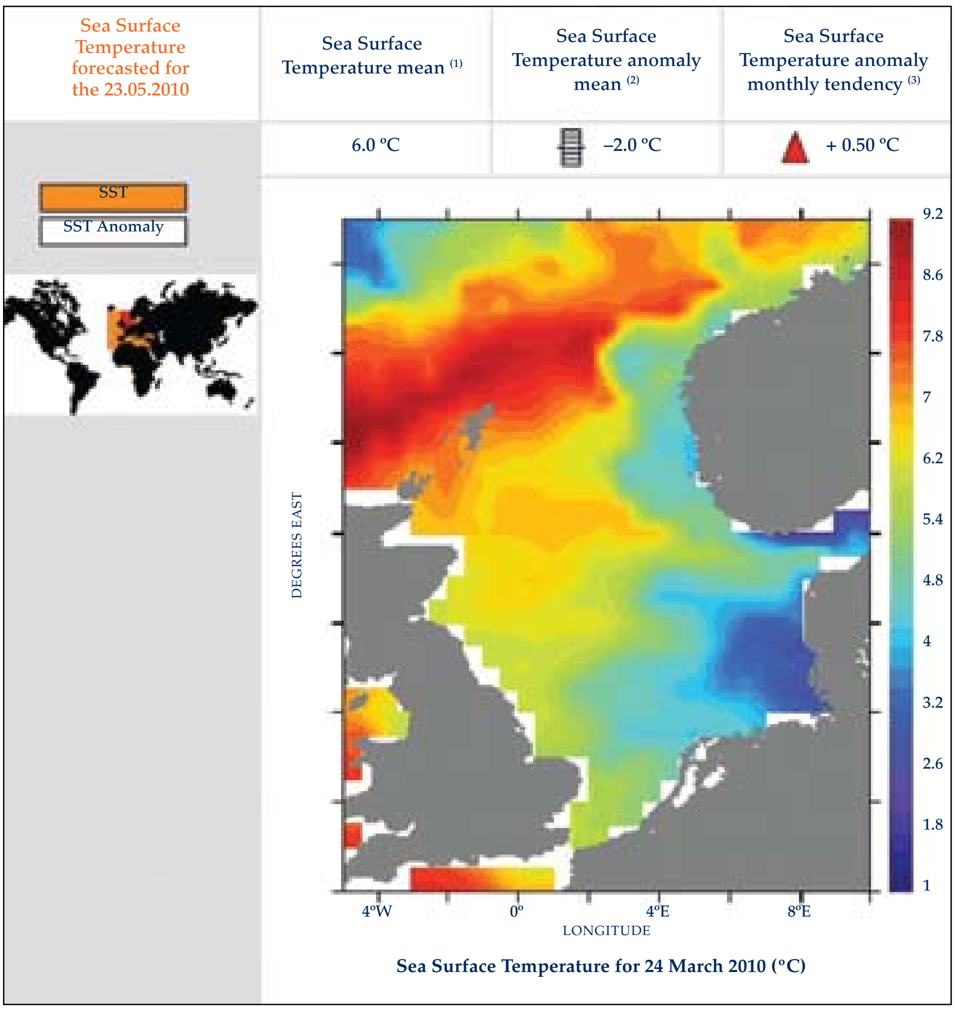
Morten D. Skogen is a senior numerical modeller working at IMR, Norway.



▲ *The WGOOFE portal to oceanographic data products.*

▼ *Variables listed as important to their work by respondents to the WGOOFE survey from the ICES community.*





▲ *Accessed through the WGOOFE website: real-time sea surface temperature for the "Europe" region from the Mercator Ocean website.*

Can we agree to agree?

Fishers and scientists seeing eye to eye

*Cats and dogs. Chalk and cheese. Oil and water. Who would have thought it possible that fishers and scientists might reach the same conclusions? **Ellen Johannesen** reports on new methods of comparing knowledge that suggest fishers and scientists might not be as far apart on some things as we believed.*

Readers might have thought they were dreaming when they read the headline "Fishers and scientists agree on stocks" in the *Fiskeri Tidende* in April this year (see Hansen, 2010). This weekly newspaper of the Danish Fishers' organization was reporting on the results of an analysis conducted by the ICES Secretariat and presented to the February meeting of the North Sea Advisory Council (NSRAC) Executive Committee in Ostend (NSRAC, 2010).

The analysis compared the North Sea Stock Survey (NSSS) time-series of fishers' perceptions of changes in abundance of fish stocks in the North Sea with ICES assessment models of the same fish stocks and found them to be positively correlated, with results from the fishers being slightly more optimistic than those from the assessment models.

Surveys compared

Henrik Sparholt, Professional Officer of the ICES Advisory Programme, compared data from the scientific assessments used to produce ICES advice with eight years of data from the Fishers' NSSS. The two surveys differ from each other in that the ICES assessments use data from the International Bottom Trawl Survey (IBTS) as inputs to the models that influence ICES advice, whereas the NSSS uses fishers' perceptions of changes in stock abundance from year to year.

In February 2010, Sparholt presented the results of the analysis to the NSRAC. (The NSRAC funds the NSSS data analysis and report preparation, which is carried out at the North Atlantic Fisheries College (NAFC) Marine Centre; the costs of conducting the NSSS are borne by the respective national fishers' organizations.)

The results demonstrated that the fishers were slightly more optimistic than the ICES assessments

The NSSS

The NSSS has been collecting data on fishers' perceptions of the status of eight fish stocks in the North Sea since 2003, through a voluntary annual survey in Belgium, Denmark, England, the Netherlands, and Scotland. The aim is to provide a means for fishery scientists and managers to incorporate fishers' knowledge into their assessments.

The NSSS obtains information by means of a questionnaire that asks fishers specific questions, such as "Has the abundance of cod changed since last year?" For analysing abundance, the emphasis is on comparing changes in stocks from one year to the next in specific areas. The respondents can answer "Yes" or "No". If the answer is "Yes", the respondent is then given a choice of five options: "Much less", "Less", "No change", "More", or "Much more". These responses are each assigned a value between –1 and +1, from which a time-series is calculated in order to compare the results of the annual surveys. Sparholt compared this time-series with the ICES assessment of stock abundance.

Using regression analysis (a statistical technique for exploring the relationship between variables), Sparholt demonstrated a positive correlation between the time-series of fishers' perceptions of change in abundance and the stock abundance as assessed by ICES. The results of the analysis demonstrated that the fishers were slightly more optimistic than the ICES assessments about the status of the four main fish stocks: cod, haddock, plaice, and sole.

The method explained

In order to compare the results of previous surveys, time-series for each species in each area, based on an index of fishers' perceptions of abundance, have been calculated for the last eight years of the survey and are presented in the annual report of the NSSS. These time-series are also presented in the annual *ICES Advice* for the relevant stocks, although they are not currently integrated into the advice.

In order to calculate this time-series index, each category of response is assigned a score, i.e.:

Much less = –1
Less = –0.5
No change = 0
More = +0.5
Much more = +1

The score for each category is then multiplied by the percentage of responses for that category and the results for each year, starting with 2001, are then cumulatively summed (Napier, 2009).

$$Index = \sum score_{category} \times percentage\ of\ responses_{category}$$

The dataset from the NSSS now covers a sufficiently long time-series to be usable in this type of comparative analysis. As Sparholt said, "Generally, datasets must contain at least five to ten years worth of observations in order to draw conclusions from the data".

In his comparison of the NSSS time-series with the ICES assessments, Sparholt used a similar approach and applied a score to the responses. (In the ICES comparison, the scores ranged from –2 to +2, whereas in the NSSS time-series the response scores range from –1 to +1.)

Sparholt linked the NSSS time-series to the IBTS and the spatial distribution of the species. He then used the time-series that he developed to obtain an average value for the whole of the North Sea (i.e. not just by area , as in the NSSS). Using regression analysis (a statistical technique for exploring the relationship between variables), Sparholt demonstrated that the NSSS time-series of perceptions of changes in abundance were positively correlated with the ICES assessments of stock.

Integrating fishers' knowledge into ICES assessments

According to Sparholt, this kind of regression analysis could be used in the ICES assessment models in order to allow the results of the NSSS to influence the ICES advice in an integrated way. "It could be used as part of the assessment model as one out of several time-series and, in that way, the ICES estimate of spawning-stock biomass (SSB) will be influenced by the score so it can be an integrated part of the mathematical statistical estimation of the stock sizes of ICES assessments (see the box on previous page for further details).

The current time-series calculated by the NSSS is broken down by subarea of the North Sea. However, if it is to be linked to the ICES assessment models, the NSSS data needs to be aggregated at the level of the North Sea in order to be comparable with the IBTS, which is the current basis for ICES advice.

Although the correlation was established, the analysis is only a starting point and, as Sparholt pointed out, further analysis of the score calculation needs to be considered before the NSSS data can be incorporated into the ICES assessment process.

Fishers' perceptions of changes in stock abundance and ICES assessment models were found to be positively correlated

According to Sparholt, "The main thing is that we need to revise ICES assessment model and the coding of our computer models in order to handle this score value, because it is a score of a change in SSB from one year to the next. It is not just a time-series of estimates of SSB because that is what we normally are used to. It shouldn't be a big thing to change the code and to optimize that as well, using the same statistical approach called the maximum likelihood estimate".

Future considerations

Sparholt suggested some questions for future consideration, for example:

- Should subarea size be included?
- Should subareas be weighted according to stock importance (e.g. based on IBTS data)?
- Should additional information on average size, recruitment, etc., be included?

For the past eight years, these data have been collected and reported by the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), which refers to the time-series produced by the NSSS in its annual stock assessments. However, getting the data to influence the assessment is a more complicated matter. For the ICES assessment model to include the results from the NSSS requires a model developer who can adjust the model to accept this new type of data. Sparholt says that possible candidates are known to the ICES community, but of course, funding and initiative would need to be found at national level.

In 2006, at the request of the European Union, ICES formed the Review Group on Fisheries Surveys of North Sea Stocks (RGFS) to evaluate the information provided by the NSSS. The main conclusions of the report (ICES, 2007) were that the survey should be continued but with the incorporation of recommended changes to the survey design in order to improve its usefulness.

One important aspect of the reliability of the NSSS is the response rate. As reported by the RGFS, one of the main challenges is to improve the response rate and thereby improve the representativeness of the survey. In 2009, only 216 valid questionnaires were returned for the whole of the North Sea. It is the responsibility of the national coordinator to disseminate and encourage participation in this voluntary survey.

Better communication with fishers about the aims and benefits of the survey may encourage a greater response rate, although improving the response rate could also depend on other factors. According to Chevonne Laurenson of the NAFC Marine Centre, who has been involved in the data analyses and report writing since 2006, "It may be time to review the survey and to evaluate how it could be changed to fit the demands of the ICES advisory schedule and to encourage a greater response rate".

Laurenson continues, "At the NAFC Marine Centre, we aim to work closely with industry. Here we have an industry-led survey that has the possibility to be incorporated into the assessment, and with the developing time-series the real potential of the survey is evident, and we are really pleased to be involved".

Fish stock assessments are improved by long-term, reliable, and consistent datasets. Currently the decision to carry out the survey is taken on a year-to-year basis. The survey will be repeated in 2010. Encouraging fishers to participate may depend on demonstrating that the information they provide is used in a way that is meaningful and beneficial to them. Improved data means improved advice, which could be of direct benefit to fishers.

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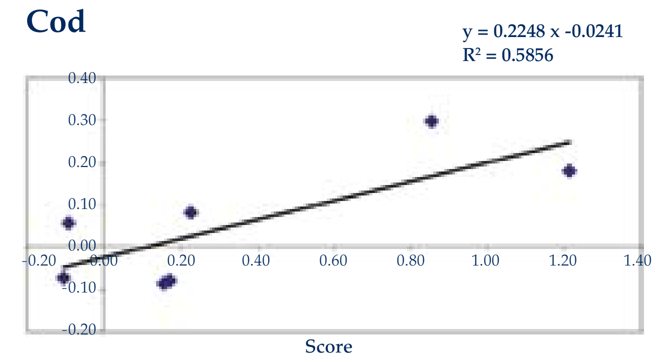
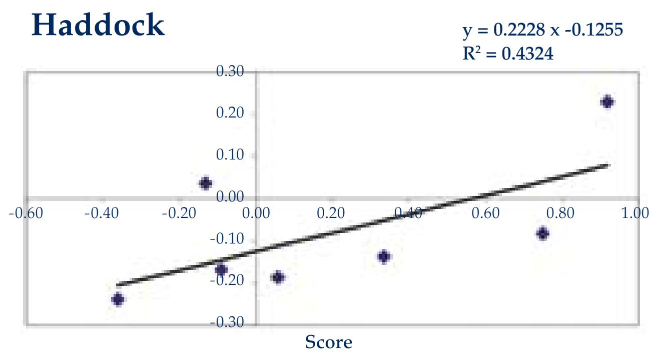
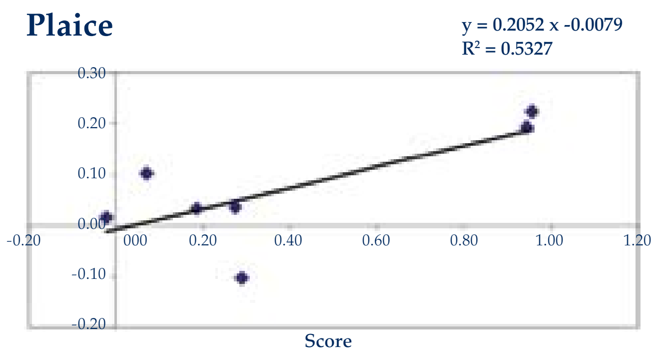
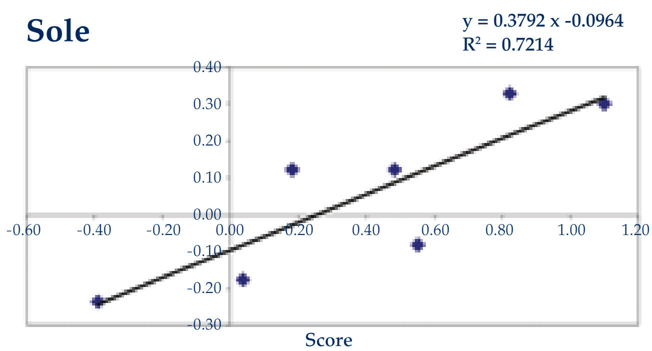
To the right: Regression analysis comparing ICES spawning stock biomass increases in fraction with scores calculated from the NSSS on fishers' perceptions of changes in abundance for four North Sea fish stocks (2002–2008). For each stock there is a positive correlation, not very significant, but the fact that it is consistent across stocks increases the confidence that the relationships are real.









I LIKE YOUR TONE:

COMMUNICATING WITH NON-SCIENTISTS

Kristina Barz *and* ***Christopher Zimmermann*** *tell how a coalition of seafood retailers and processors was the driving force behind the development of an innovative way to communicate with consumers about the seafoods they purchase.*

ICES Advice is the principal source of scientific guidance on marine ecosystems to governments and international regulatory bodies that manage the Northeast Atlantic and adjacent seas. Is it possible, however, to acquaint a wider group – one that includes buyers in the retail and processing sectors, and NGO representatives as well as local fish retailers and their customers – with data on the products that provide their sustenance and livelihood?

This question motivated a group of German seafood retailers and processors to seek support for the development of sustainable sourcing policies, as well as a means of communicating these policies to the consumer in comprehensible language.

As public awareness of our vulnerable environment grows, details about the sources of basic purchases become more important to both consumers and suppliers, whose concerns and backgrounds are very different from the average *ICES Advice* reader. They are particularly interested in receiving up-to-date information about the state of fish stocks, on which they base their purchasing decisions. Without specific scientific knowledge and access to the information published by ICES, this group requires a special source of information that, until recently, has not existed in Germany.

In December 2007, a "round table" was initiated by the German trade and industry associations and the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), at which the Johann Heinrich von Thünen Institute – Institute for Baltic Sea Fisheries (vTI-OSF) offered scientific advice. The Ministry recognized that some of the issues related to sustainable fishing could be solved more effectively if all national stakeholders (including the fisheries and environmental NGOs) were involved from the beginning and were agreed on common initiatives.

The problem of perception had to be addressed

The aims of the round table were to define sourcing policies, which required the identification of the information needed by the public about the state of the fish stocks and the determination of a method to gather the information from sources in addition to *ICES Advice*. Further, the problem of perception had to be addressed. German consumers needed to understand that their concerns had been recognized and a solution had been developed that was intelligible to all concerned.

It was established that compliance with sourcing policies and labelling standards would be absolutely voluntary rather than a legal requirement. There would be no official control but self-regulation and ostracism, in the case of misuse, would be the motivation.

The round table set up three working groups, each devoted to a separate area of concern: (i) minimum criteria for eco-labelling, which forms the basis for German input to the EU legislation process; (ii) the definition of species-specific catch areas for the 19 most important species on the German market; and (iii) the development of a public website "Fischbestände Online" (Fish Stocks Online).

Round-table participants felt that the undifferentiated and partly contradictory information of NGO "fish guides" did not provide the unbiased scientific information that was required. At the same time, the NGOs realized that, although *ICES Advice* was the common source of information, at least for the Northeast Atlantic fish stocks, the NGOs often arrived at different ratings because of divergent interpretations of ICES reports.

All of the participants recognized a vital shared interest in providing scientifically precise, but easily understandable, interpretations. Initially, they defined species-specific fishing areas for the 30 or so most important fish species that dominate 80% of the German market. These areas were far more precise than the legal FAO areas and largely resemble the distribution areas of most, but not all, of the stocks. The industry voluntarily committed itself to display the new fishing areas on all of its products by the end of 2010.

Work on the development of the "Fischbestände Online" website began in October 2009. The site is already online and, by the end of 2012, will provide information about the state of approximately 130 wild-caught marine fish stocks (out of 30+ species) that are of interest to the German market. Unlike many of the other sources of information currently available, it will neither repeat all the information available from scientific bodies (such as ICES) nor make recommendations about what to buy. Instead, the site will seek to provide scientific information in a concise, scientifically correct way, but in language understandable to non-specialists.

The development of the "Fischbestände Online" website is financially supported by two large German retail and processing organizations and, individually, by some of their members. It is hosted by the fishery portal of federal and municipal administrations in order to

▲ *Samples for the use of species-specific catch areas on retail packaging. (Source: Federal Association of German Fish Processors and Fish Wholesalers (BVFisch).)*

▲ *An example of the printable stock summaries available on "Fischbestände Online".*

ensure independence and is available online at http://fischbestaende.portal-fischerei.de/.

Initially, the round table agreed on the structure and type of information that was to be included, and the NGOs (including the World Wide Fund for Nature and Greenpeace) played an active role in developing the structure of the website. Thus, for each species, a one-page species outline gives general information on its biological characteristics, distribution, and use. Three- or four-page stock descriptions are generated for each of the relevant stocks and include specific information on the state of the stock, management, scientific methods and data availability, environmental impact of the fishery, and impact of the environment on stock development (with illustrations on stock development, distribution, and management areas). In addition, the stock descriptions provide all of the relevant statistics on spawning-stock biomass, recruitment, fishing mortality, landings by fleet, bycatch, total allowable catches, and any other relevant information, such as eco-labelled fisheries harvesting these stocks. All stock descriptions are peer reviewed to ensure the quality of the information, which is provided in German and updated as soon as new information becomes available.

Once assembled, this information will enable industry and retailers to develop independent sourcing policies, and NGOs will have easier access to scientific information that is more accurate than before and can update their information leaflets for consumers.

It has also been planned to make this information accessible in other ways: for example, by installing computerized weighing machines, with information displays, in retail outlets. Sales assistants would then be able to provide up-to-date stock-specific, online information to the consumer and thereby demonstrate that the retail organization is adhering to its sourcing policy.

The website's technical requirements, including a content-management system compiled from a database, have already been implemented. This makes it possible to go backwards in time and view the historical development of the information, for example, to provide a snapshot of the state of a herring stock two years previously, when the herring were canned.

German consumers needed to understand that their concerns had been recognized and a solution had been developed that was legible to all concerned

As more than one third of the stocks relevant to "Fischbestände Online" are harvested in the ICES area, the round table considered the *ICES Advice* to be a good starting point for the development of the portal. Many of the ideas discussed in ICES Advisory Committee (ACOM) subgroups over the past two years have been incorporated into the development of the website.

However, it has become apparent that a wider group of users might be attracted if the *ICES Advice* were to include further information, such as the quantity of a stock caught in a sustainable way, details about the fishery, and the social aspects of its activities, as well as additional information about stocks and species.

Stocks that are of economic interest to retailers but come from outside the ICES area are also included (e.g. Alaskan pollock and South Atlantic hake species). Contacts with scientific bodies assessing these stocks are being established.

During the extensive discussions in the planning phase, a great deal was learned about communicating a subject as complex as fish-stock advice to members of the public who are interested but have little scientific background. Clear, jargon-free language that highlights the main message is essential; for example, words such as "demersal" and "discard" should be avoided. The use of colours, symbols, graphs and maps, an easy-to-follow structure and, not least, an attractive layout also make it much easier for users to understand the information.

Based on the work of ICES expert groups, review groups, advice-drafting groups, and ACOM, the additional investment required to attract a wider public appears to be small. However, the impact that this information can have on the public perception of the quality and relevance of this work cannot be overestimated.

Kristina Barz is employed in the industry-financed project "Fischbestände Online" at vTI-OSF.

Christopher Zimmermann is the project leader and German member of the ICES ACOM and deputy director of the vTI-OSF.

Johann Heinrich von Thünen Institute – Federal Research Institute for Rural Areas, Forestry and Fisheries

The Johann Heinrich von Thünen Institute (vTI) is one of four federal research institutes that come under the auspices of the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV). The vTI was created on 1 January 2008 and is an amalgamation of the German Federal Research Centre for Fisheries (BFAFI), the German Federal Research Centre for Forestry and Forest Products (BFH), and part of the German Federal Agricultural Research Centre (FAL). The vTI provides the scientific information on which the policy of the German Federal Government is based, and its applied research thus influences the development of tomorrow's society.

The Institute of Baltic Sea Fishery (OSF) is one of three institutes within the vTI that deal with fish. Apart from monitoring the state of living resources and fisheries in the Baltic Sea, the OSF advises the fish-processing industry and retailers on how to ensure sustainable sourcing.

▶ *The project team at vTI-OSF: Kristina Barz and Christopher Zimmermann (Photo: D. Stepputtis, vTI-OSF).*

▼ *The German RV "Solea" in front of the vTI-OSF building (Photo: C Zimmermann, vTI-OSF).*

Cutting loose:
undersea communication goes cordless

Joel Greenberg *reports on revolutionary developments in optical communications that make untethered remotely operated vehicles possible.*

Whatever you call it, scientists and engineers at the Woods Hole Oceanographic Institution (WHOI) have devised an undersea optical communications system that, complemented by acoustics, heralds a virtual revolution in high-speed undersea data collection and transmission. Combined with a new generation of remotely operated vehicles (ROVs), this emerging combination of undersea technologies is bringing scientists to the verge of the long-sought dream of untethered ROVs (UTROVs).

The ability to transfer real-time video from submerged vehicles to support vessels on the surface "will make it possible to operate self-powered ROVs from surface vessels without requiring a physical connection to the ROV", says WHOI Senior Engineer Norman E. Farr, who led the research that produced the optical system.

A system that heralds a virtual revolution in high-speed undersea data collection and transmission

A key component of this revolutionary system is the "Nereus", a 11 000-metre-rated hybrid remotely operated vehicle (HROV). Engineers at WHOI, led by Andy Bowen, a WHOI research specialist in Applied Ocean Physics and Engineering, recently demonstrated that the new communications system works successfully with the "Nereus".

This summer, Farr and his team followed up this demonstration with the first open-ocean deployment of the system, near the Juan de Fuca Ridge off the west coast of the US, which yielded results that are even more impressive. "The new system", Farr said, "remarkably cut the time it took to unload and transfer data from an undersea well head from hours to minutes".

Both of these demonstrations bring scientists closer to the day when this optical telemetry system (OTS) can be used in concert with UTROVs, literally "cutting the cord" for undersea exploration. According to Farr and Bowen: "This will not only represent a significant technological step forward, but also promises to reduce costs and simplify operations".

Traditional deep-water ROV operations, with long, heavy tether cables, incur high operating costs, driven by their need for ships with specialized positioning systems, large A-frames, and winch systems. In addition, such vehicles are often limited by their tethering systems, for example, making work in ice-covered polar regions too hazardous to attempt.

However, the new micro-thin, fibre-optic tethering system used by the HROV "Nereus" represents a breakthrough in ROV technology and brings untethered technology within reach. The tether of the "Nereus" is free of the requirement to power the vehicle because the vehicle is capable of operating in both autonomous underwater vehicle (AUV) and ROV modes. The tether transmits high-quality, real-time video images and receives commands from skilled pilots on the surface ship to collect samples or to conduct experiments with a manipulator arm. Eventually, with the optical communication system in place, this advanced, lightweight tether is expected to give way to an untethered system capable of real-time communication and data transmission to surface vehicles.

Compared with communication in the air, communication underwater is severely limited because water is essentially opaque to electromagnetic radiation except in the visible band. Even then, light penetrates only a few hundred metres in the clearest waters, and less in sediment-laden or highly populated waters.

With the OTS, the data transmission process took just a couple of minutes

Consequently, acoustic techniques were developed and are now the predominant mode of underwater communications between ships and smaller, autonomous and robotic vehicles. However, acoustic systems – although capable of long-range communication – transmit data at limited speeds and delayed delivery rates because of the relatively slow speed of sound in water.

◀ *Illustration shows how the optical modem could function at a deep-ocean cabled observatory. Autonomous underwater vehicles (AUVs) collect sonar images (downward bands of light) and other data at a hydrothermal vent site and transmit the data through an optical modem to receivers stationed on moorings in the ocean. The moorings are connected to a cabled observatory, and the data are sent back to scientists on shore. Scientists, in turn, can send new instructions to the AUVs via the optical modem as well. (E. Paul Oberlander, Woods Hole Oceanographic Institution.)*

Now, Farr's OTS complements and integrates with existing acoustic systems to permit data rates of up to 10–20 megabits per second (Mbps) over a range of 100 metres using relatively low battery power with small, inexpensive transmitters and receivers.

The advance will allow near-instant data transfer and real-time video from untethered ROVs and AUVs, fitted with sensors, cameras, and other data-collecting devices, to surface ships or laboratories, which would require only a standard cable dangling below the surface for the relaying of data.

When the vehicle goes out of optical range, it will still be within acoustic range, the researchers said, to which Farr adds: "And because it allows communications without the heavy tether-handling equipment required for an ROV, the optical/acoustic system promises to require smaller, less-expensive ships and fewer personnel to perform undersea missions".

Traditional deep-water ROV operations need ships with specialized positioning systems, large A-frames, and winch systems

In Bowen's opinion: "Ongoing advances in control systems and energy storage will serve only to add momentum to a new class of underwater vehicle actively being developed at WHOI".

Farr adds: "The work represents a substantial advance in undersea investigations of anything from the acidity of water to identifying marine life to observing erupting vents and seabed slides to measuring numerous ocean properties. In addition, the optical system would allow direct manoeuvring of the vehicle by a human".

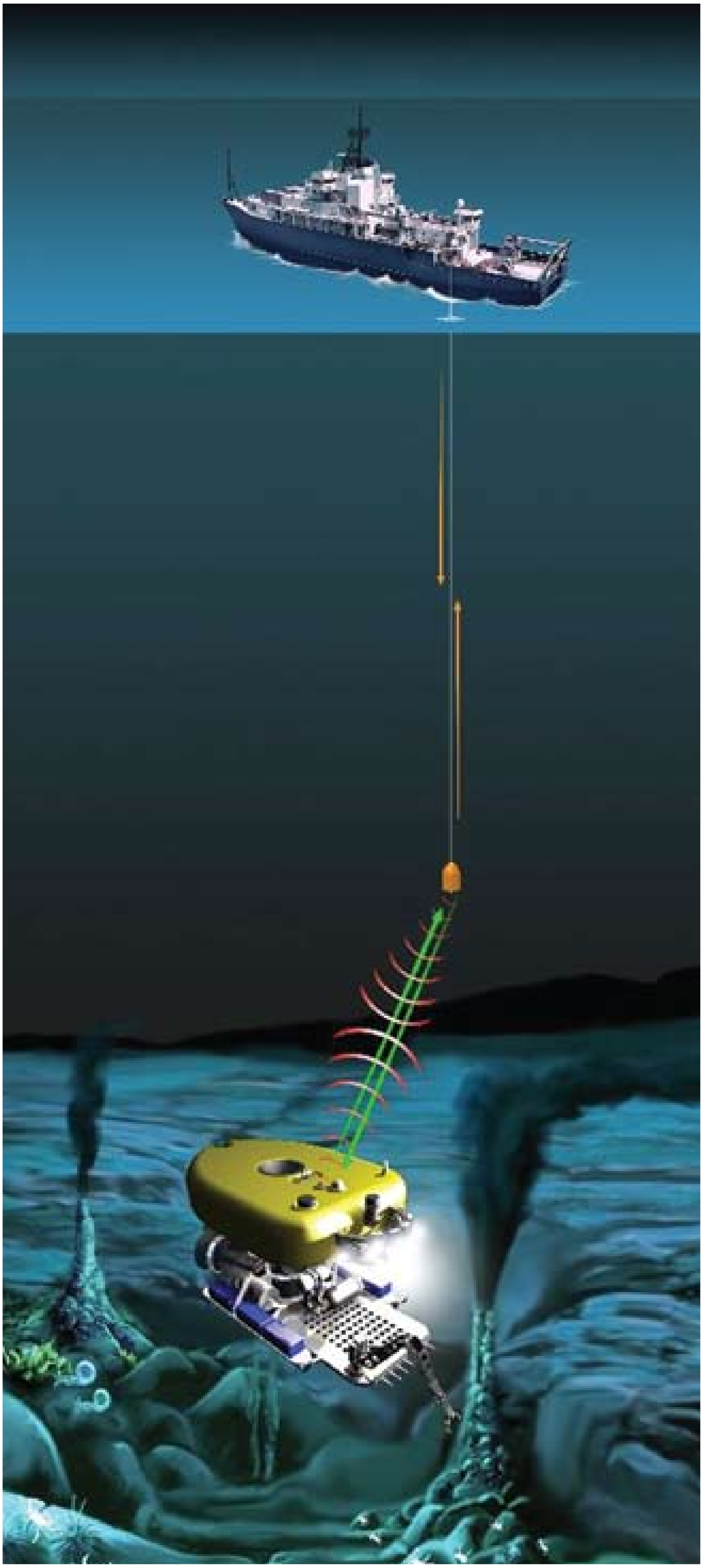
He likens optical/acoustic system possibilities to the world opened up by "your household Wi-Fi".

Co-investigator Maurice Tivey of WHOI adds: "Underwater optical communications is akin to the cell phone revolution…wireless communications. The ability to transfer information and data underwater without wires or plugging cables in is a tremendous capability, allowing vehicles or ships to communicate with sensors on the seabed".

Tivey continues: "Although acoustic communications has been the method of choice in the past, it is limited by bandwidth and the bulkiness of transducers. Today, sensors sample at higher rates and can store lots of data, and so we need to be able to download that data more efficiently. Optical communications allows us to transfer large datasets, like seismic data or tides or hydrothermal vent variations, in a time-efficient manner".

The first deep-water test of the optical communications system was performed on the human-occupied vehicle (HOV) "Alvin" submersible in August 2008. Data were transmitted from a seabed package to a receiver mounted on the submersible. The "Alvin" was moved to a series of stations and error-rate data were collected. The system demonstrated error-free transmissions at 1 Mbps (at a range of more than 100 metres, the researchers reported.

◀ *Norman Farr installs the optical modem on the hybrid remotely operated vehicle "Nereus" for testing off the WHOI dock. (Tom Kleindinst, Woods Hole Oceanographic Institution.)*



▶ *An artist's concept of how the optical modem could function using a battery powered, untethered remotely operated vehicle (UTROV). Using the optical modem, data and real-time video are transferred from the UTROV, outfitted with sensors, cameras, and a manipulator arm, to surface ships. The UTROV receives instructions from a shipboard pilot, who directs it to collect samples, images, video, and other data at a hydrothermal vent site. (E. Paul Oberlander, Woods Hole Oceanographic Institution.)*

A follow-up test was performed at the WHOI dock using "Nereus". This successfully demonstrated that the optical link transferred high-rate video and, with the link, pilots had real-time control of the vehicle, commanding it to perform complex, unstructured manipulations underwater.

In July, the researchers completed the first large-scale deployment of the system at the Juan de Fuca Ridge off shore of the northwestern US. The WHOI team again used "Alvin" to deploy the optical system on a subsea data concentrator to collect and transmit geophysical data from wellheads situated at the undersea ridge.

The researchers performed the test at a CORK (Circulation Obviation Retrofit Kit) borehole observatory in the deep ocean of the Northeast Pacific. (A CORK is a seabed system to seal a borehole from the overlying ocean.)

CORKs are typically visited by submersibles on a semi-regular basis for downloading data and for collecting physical samples of subsurface fluids. Using "Alvin", Farr and his colleagues deployed the OTS in water 2420 metres deep.

In the future, autonomous vehicles could interrogate such seabed observatories in a data-mule configuration and then dock at a seabed-cabled node to download data

The OTS was plugged into the existing underwater connector on the CORK to provide not only an optical and acoustic communication interface, but also additional data storage and battery power for the CORK to sample at an increased data rate. Using an OTS mounted on a conductivity, temperature, and depth (CTD) recorder, the scientists were able to establish an optical communication link at a range of 100 metres and at rates of 1, 5, and 10 Mbps with no bit errors. After one week, they repeated the CTD-OTS experiment and downloaded 20 Mb of data over a 5-Mpbs link at a range of 80 metres. According to Farr: "The CORK-OTS will remain installed at the CORK for a year".

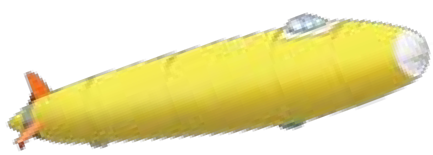
"Normally, the data transmission process would take around two hours, with three people waiting in 'Alvin'", Farr said. "With the OTS, it took just a couple of minutes".

"Our optical telemetry system enables faster data rates to be employed for *in situ* measurements that were previously limited by data-download times from a submersible", Farr says in a report to be presented in October 2010 at the Marine Technology Society/Institute of Electrical and Electronic Engineers "Oceans" conference in Seattle." The OTS also permits non-submersible-equipped vessels to extract data from the CORK borehole observatory on a more frequent basis using a receiver lowered by wire from a ship", he adds.

The optical system would allow direct manoeuvring of the vehicle by a human

Farr goes on to say: "In the future, autonomous vehicles could interrogate such seabed observatories in a 'data-mule' configuration and then dock at a seabed-cabled node to download data. While borehole observatories may ultimately be linked into undersea cables relaying real-time data back to shore, they represent a superb opportunity to test free-water optical communication methods".

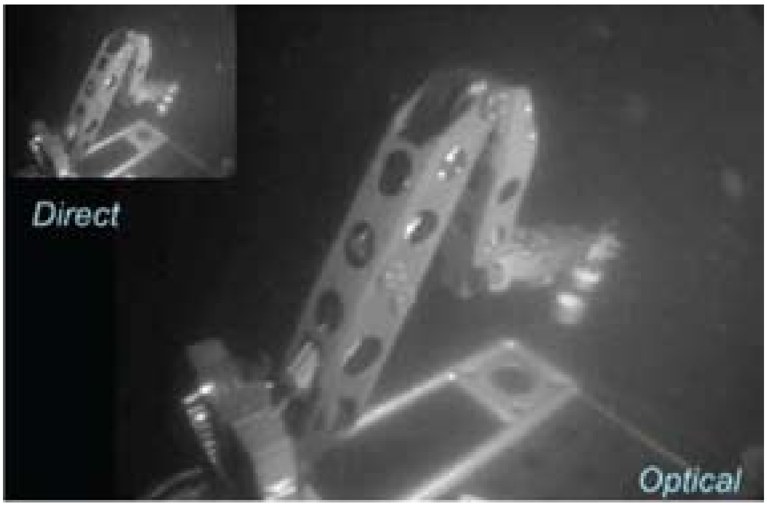
"This application of seabed optical communication could be used for a number of other types of seabed sensors that may not be linked into a cabled network. The lessons learned from our CORK development efforts will go a long way towards establishing the viability of underwater optical communications for a host of autonomous seabed sensor systems in the future".



Bowen comments: "The recent development and successful testing of the HROV 'Nereus' paves the way for a derivative vehicle-type able to perform a variety of useful tasks such as rapid event response, deployment from ships of opportunity, time-series ocean observatory maintenance, and exploration at increasingly high latitudes, including beneath polar ice".

The test results clearly demonstrate that next-generation, battery-powered vehicles like the "Nereus", are capable of replacing conventional tethered vehicles in performing an increasing range of tasks, the researchers say. "The unique, integrated combination of advancements in both acoustic and optical communications, coupled with the successful realization of a battery-powered ROV, positions Woods Hole Oceanographic scientists and engineers to make broad and important contributions to the evolution of undersea robotic vehicles in the years to come", says Bowen.

"Ultimately," says Farr, "the system will allow us to have vehicles [at specific undersea locations] waiting to respond to an event. It's a game-changer".



▲ *In recent dock trials of the optical modem system, the "Nereus" vehicle performed manipulative tasks while virtually tethered to its surface control station, demonstrating the ability of such a link to support tetherless ROV activities. The image above is a composite of real-time video frame captures showing the direct image (upper left) relayed to the surface via a traditional hard-wire tether compared with the video transmitted wirelessly through water via the optical modem. (Woods Hole Oceanographic Institution.)*

The Woods Hole Oceanographic Institution is a private, independent organization in Falmouth, Massachusetts, dedicated to marine research, engineering, and higher education. Established in 1930 on a recommendation from the National Academy of Sciences, its primary mission is to understand the oceans and their interaction with the Earth as a whole, and to communicate a basic understanding of the oceans' role in the changing global environment.

▲ *The prototype optical modem is comprised of a small LED transmitter (left) with a photo-multiplier receiver, providing low-power, multipoint bi-directional communications over distances of up to 200 metres. (Woods Hole Oceanographic Institution.)*

Joel Greenberg is a writer and publicist with the Woods Hole Oceanographic Institution (WHOI). Before joining WHOI, he was science and medicine editor at the Los Angeles Times*. He has also been the editor of* Science News Magazine *in Washington, DC, as well as a science writer at the* New York Times *and the* Miami Herald *in Florida.*

Q&A Elizabeth W. North

In her plenary lecture, "What Can Science Tell Us That Fishermen Don't Already Know?", at ICES Annual Science Conference 2009, Elizabeth W. North made the case that a process-level understanding of recruitment for individual species is an achievable and important goal for fishery science.

Dr North is an Associate Professor at the University of Maryland Center for Environmental Science. She works to advance basic principles of fishery oceanography, support fishery management, and enhance ecosystem restoration. Her research integrates field and numerical approaches and focuses on physical–biological interactions during the early life of fish and shellfish.

She is currently Co-Chair of the Working Group on Modelling of Physical–Biological Interactions (WGPBI) and a co-convenor of the ICES Workshop on Understanding and Quantifying Mortality in Fish Early Life Stages: Experiments, Observations, and Models (WKMOR).

You said that the ocean is not a big blue box anymore. Can you explain the idea of the big blue box?

We use mathematical formulae to assess how many fish are in the sea and to help us decide how many we can remove without jeopardizing the health of the population and the sustainability of the fishery. Our mathematical tools have been limited by the assumption that the ocean is like a big blue box: that the fish are spread out uniformly, that there are no decadal warming or cooling trends, and that ocean circulation patterns and ecosystems don't vary. Although we certainly have known for millennia that fish school and the ocean changes, it is only recently, with the advent of sophisticated computer technology and three-dimensional biophysical models, that we have the opportunity to include a quantitative understanding of the sea's variability into the formal tools which we use for fishery management.

What are we learning about the sea from biophysical models?

Biophysical models help us understand how circulation patterns influence the early life of fish and shellfish as well as the prey upon which they depend for survival. The location of spawning areas, the transport of larvae to, or retention within, their nursery areas, and the timing of prey production are affected by changes in the sea. These changes influence the number of young fish and shellfish that survive from year to year. Biophysical models help us locate prime spawning and nursery areas and transport pathways that must be protected to ensure population sustainability. In addition, the models help us understand the links between variation in the sea and variation in the survival of young fish and shellfish. This knowledge is necessary for identifying how changes in climate could influence future populations and for mitigating the impacts of climate change.

Can you give an example from your current work where this comes in handy?

We are using biophysical models to help select the best locations for oyster restoration in Chesapeake Bay. With limited public funding to support oyster enhancement, it is an ongoing effort to balance and meet the many objectives of oyster restoration. These objectives include improving water quality, enhancing oyster populations, and supporting harvest. Our biophysical models allow us to combine the biology of the oyster, the physics of water motion, and the economics of oyster restoration to select optimum locations to build or enhance oyster reefs. These "sweet spots" differ depending on the objectives of the restoration efforts. For example, the model predicts that reefs located in water of low salinity would maximize harvest. In contrast, reefs placed in locations with moderate salinity and with high larval transport success would maximize the enhancement of oyster populations. Regions that promote the positive effects of oyster filtration would maximize improvements in water quality.

In your lecture, you talked about the benefits of oysters to the ecosystem. What role do they play in Chesapeake Bay?

Oysters provide multiple ecosystem services in shallow, sandy, and muddy estuaries such as Chesapeake Bay. They provide hard substrata and build reefs that many other organisms utilize as habitat. They provide nursery habitat and food for a suite of fish species that humans like to eat. They also enhance water quality and promote transfer of energy into the fish food chain. Oysters have a huge capacity to filter suspended matter from the water, leaving it clearer. They ingest some of the suspended matter and repackage the rest as biodeposits (faeces and pseudo-faeces), which can sink to the bottom. Tiny creatures called amphipods eat the biodeposits and are, in turn, eaten by fish, transferring energy to the fish food chain.

What is the biggest problem facing Chesapeake Bay?

Eutrophication is the biggest problem facing Chesapeake Bay. This over-fertilization causes algal blooms, some of which can be harmful. In addition, algae are so abundant in the Bay that when they die and sink, the bacteria that decompose the algae remove oxygen from the water and create "dead zones". The algae also block the light needed by seagrasses, which results in reduced seagrass growth and survival, and the degradation of this important fish and shellfish nursery habitat.

Are oysters useful in counteracting pollution?

Historically, oysters were so abundant that their reefs were navigation hazards, and they likely had an effect on water quality and clarity, especially in the tributaries of Chesapeake Bay. Now, the abundance of oysters in the Bay has declined to such an extent that they, at best, can only have local impacts on water quality. The efforts underway to restore oyster populations could improve water quality if they are large enough in scale, if oysters are protected long enough to establish thriving populations, and if they are located in sweet spots that maximize the effects of oyster filtration. Our computer simulations can help us understand how many oysters are needed and where to put them to achieve water quality goals, even as the climate changes.

What can science tell us that fishermen don't already know?

Fishermen have an intimate, first-hand understanding of the sea and the fish and shellfish within it. They experience the tides, winds, and waves, and feel the water temperatures shift on their skin. They know where and when fish can be found, and certainly how best to catch them. The dynamic nature of the sea is a truth evident to all those whose living depends upon it. Complementary to this knowledge, what science offers is the ability to understand the "big picture" impacts of human activities on marine systems; it offers a long-term vision of the consequences of collective action. It is that kind of vision, in my opinion, that can help the fishing industry ensure a sustainable future.

Biophysical modelling offers fishery science the ability to incorporate the changing nature of the sea into our formal process of fishery management and ecosystem restoration. If we can demonstrate to the fishermen that our science captures what they already know to be true about the sea, and explains the processes, then perhaps they will be more interested in accepting and applying what science recommends to their industry. If we honour their vision, perhaps they will honour ours.

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