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ICES contributions to marine science – an overview

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The indirect and direct contributions by ICES to marine science are manifold. ICES serves as a forum for scientific discussions and as an initiator, coordinator, and facilitator of multi-national programmes in marine research and monitoring. It is midwife to other organizations, producer of standards and technical tables, data manager, and publisher. It bridges the gaps between academia and governmental institutes and administrations and provides on-the-job training to young scientists. Moreover, ICES contributed to marine science by opening up new ways of thinking and methodology which often went beyond its immediate applied objectives. ICES benefits from the unique diversity and high concentration of marine science institutions in Europe and North America and from the fact that Europe is particularly blessed by the ocean although it is also threatened by climate change. This paper deals with the services of ICES to marine science and management and with its direct contributions to hydrography, biological oceanography, fisheries, and fish biology.

Keywords: fish biology, fishery hydrography, marine science history, overfishing.

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Introduction

According to its name, ICES is "for the exploration of the sea". The name has not changed in the course of the century in spite of the Council's early emphasis on fish, fisheries, and mariculture and later on marine environmental protection. A council itself cannot explore the seas, but just consider that ICES has served as an initiator, promoter, coordinator, facilitator, and publisher of marine science in particular. ICES served the development and standardization of methods and instruments; data storage and retrieval; joint research projects from the early planning stage through to the final publication of results. ICES meetings of various kinds provided the platform for scientific discussions bridging gaps between nationalities, generations, and disciplines, as well as between governmental research institutions and academics. ICES publication series helped scientific communication at various levels from ephemeral notes and data lists to top-class scientific papers. The ICES role as a recognized adviser on fisheries management and environmental protection provided a favourable climate for the further development of marine science in general. In this paper, I provide an overview covering the highlights of the Council's contributions to marine science in the areas of hydrography, biology, and the overfishing problem.

ICES as a forum and service for marine scientists

ICES has always been a place for international and interdisciplinary discussions on new ideas and methods. Its symposia attract scientists from many parts of the world. The former *Rapports et Procès-Verbaux,* the *Journal du Conseil*[1], and the enormous greyish literature were important contributions to marine science. At various kinds of ICES meetings, international and interdisciplinary experiments were planned. Those cooperative programmes helped us on our home fronts to get ship time, more staff, or a new research vessel.

For the first sixty years of its existence, ICES was the world's leading authority in the development of methods and instruments for much of physical, chemical, and biological oceanography. The International Laboratory (Central Laboratory) was already planned by F. Nansen in 1899 and later replaced by the Service Hydrographique. The water sampling and temperature measurements were standardized. The Nansen bottle combined with the reversing thermometer by Richter became the globally accepted instruments. But most important were Knudsen's method of chlorinity determination and the

[1] Now published as respectively *ICES Marine Science Symposia* and *ICES Journal of Marine Science.*

definition of chlorinity and salinity together with the distribution of the Copenhagen *eau normale*. According to S. Morcos (2002), the various hydrographical services "made ICES a household word in many laboratories particularly in developing countries, where for generations students of oceanography regarded ICES as their link to the scientific world." In the 1950s, electrical conductivity measurements replaced the titration methods. Very early, ICES approached UNESCO to join forces in providing a universally accepted new system of oceanographic tables and standards.

Another less-known example of ICES services is the production of fish catalogues and identification sheets. Already in 1904, the Council published Hoek's "Catalogue of the Fishes of Northern Europe" (in French with vernacular names in all major languages of the region), and from 1929 to 1938, 18 *cahie*rs of the *Faune Ichthyologique* were compiled. It was not until the 1970s that FAO picked up this activity on a worldwide basis, which is now followed by the electronic FISHBASE.

A great help to zooplankton workers and fishery biologists are the *Fiches d'Identification*, or *Identification Leaflets*, on zooplankton, fish eggs, and larvae, as well as those on diseases and parasites of marine organisms. Over the years, it became increasingly difficult to find authors for those sheets. But under the buzz word "biodiversity", those taxonomic services should become more popular again.

ICES as a data centre

ICES pioneered international data collection and data handling. *Bulletin Statistique des Pêches Maritimes* was started in 1903 and *Bulletin Hydrographique* in 1909. When FAO and UNESCO/IOC established global networks, ICES became the regional oceanographic data centre for the North Atlantic. The data sets of long time-series of routine observations taken in a standardized manner have become increasingly important for ground-truthing of advanced modelling. Countries and laboratories worldwide try to live up to the ICES standards of continuity and accuracy even when money is very scarce and scientific interest shifts towards short-term experiments, modelling, and theoretical studies.

ICES as a midwife for other organizations

Being the first international organization for the exploration of the sea, it is natural that ICES had great influence on those organizations which followed. Examples include the International Council for the Exploration of the Mediterranean and – more recently – the North Pacific Marine Science Organization (PICES).

After World War II, Member Country governments felt that the responsibility for decision-making should be separated from the advisory functions of ICES. Therefore, regional fishery commissions and global and regional pollution commissions were created. But the methodological advice by ICES remained a crucial element both in fisheries and pollution assessments worldwide.

Scientists of ICES became involved in the creation of SCOR (1957) and IOC (1961); others greatly helped to make the Fishery Division of FAO a world authority in fishery research and management in the 1960s and 1970s. Joint working groups of ICES with those organizations were very productive and helped to overcome political obstacles, e.g., in the Baltic.

On the other hand, there have been scientists who felt excluded as they did not belong to a national fisheries institute affiliated with ICES or who did not like the *modus operandi* of the ICES Statutory Meetings at times when the advisory functions tended to distract ICES from doing genuine science and ICES became somewhat separated from the mainstream of oceanography.

ICES as a scientific advisory body

The advisory functions of ICES are intimately linked with its scientific work. The need for advice prompted Member governments to provide the necessary infrastructure for marine science, often beyond the immediate requirements of fisheries research. Collective scientific work, early warnings, and practical recommendations were typical for ICES, particularly in its early years. Its committees each consisted originally of a small handful of dedicated scientists and fishery administrators. Whales and whaling may serve as an example. Already in the 1920s, ICES was highly interested in whale research, and the exploration of the Southern Ocean was largely motivated and financed by the revenues of the whaling industry. In 1929, the ICES Whaling Committee under Johan Hjort concluded: "the Committee feels strongly that the enormous expansion of the whaling industry in recent years constitutes a real menace to the maintenance of the stocks of whales, and if the expansion continues at the present rate there is a real risk of those being so reduced as to cause serious detriment to the industry" and "While admitting that until the scientific researches have reached a definite conclusion it will be impossible to devise any measures of protection of a permanent nature, the Committee is of the opinion that the Governments of the countries interested in whaling should, as a matter of urgency, give serious consideration to the question of taking immediately temporary measures for dealing with the situation." Furthermore, ICES asked the Norwegian government to establish "a central institution to collect statistics from the whaling industry throughout the world, on the understanding that a report be laid before the Committee yearly" (quotations from Thomasson, 1981).

Training by ICES

From time to time, ICES ran training courses in modern fields of fisheries research. Very productive were the two Lowestoft courses in 1956 and 1957 on population dynamics with Beverton, Holt, Gulland, Parrish, Jones, and Cushing as instructors. Afterwards and largely under the auspices of FAO, former professors and students of the courses disseminated the model of Beverton and Holt (1957) worldwide, even in areas where its monospecific, growth-oriented version did not fit. Later on, Norway took the lead in training on acoustic methods.

ICES working groups became training centres for many hundreds of young scientists. They learned how to compile and analyse data and how to phrase assessment reports and recommendations. Much of the homogeneity in the thinking of fisheries biologists in the North Atlantic stems from the unifying and inspiring atmosphere of the ICES working groups. Governments and directors of institutes should make far more use of those training opportunities for their junior staff members in addition to sending the old hands.

ICES has done very little directly for the developing and newly industrialized countries. Even the impact of the ICES/FAO CINECA programme on the coastal states of the Canary upwelling region was rather limited. Individual ICES scientists, however, served in UN or national projects for capacity building and implanted the belief in international cooperation in developing regions.

Direct contributions of ICES to marine science

Marine science *per se* is not the primary objective of ICES. In 1905, the President (Herwig), Vice-President (Pettersson), and General Secretary (Hoek) of ICES stated: "The aim of the international cooperation for the study of the sea is: to prepare for a rational exploitation of the sea on a scientific basis." They called for "a comprehensive study ... which strives to arrive at practical ends by common international work along scientific lines" (quoted from Thomasson, 1981).

Physical oceanography, biology of fish and plankton, and the rational basis for fisheries were named as the three endeavours for ICES. In the early years, the national committees of the nine participating states were well-defined bodies which agreed on joint activities and afterwards reported on their outcome and on the state of the fish stocks, hydrography, and plankton in the various areas. Research was conducted in a few national institutes for fisheries and marine research. In the last third of the century, ICES became a partner in international programmes which had been initiated largely by US scientists and organized by UN and ICSU organizations.

I will mainly concentrate on the old days and leave it to the younger generation to decide which of their activities they attribute to ICES. For the sake of brevity, I will keep to northern European waters and stocks, leaving out the contributions, particularly from The Netherlands, Belgium, France, Spain, Portugal, and Ireland featuring mariculture, shellfish, and "southern" fish species. Also, the Baltic will be unduly neglected and hence many of the activities by the Member Countries bordering the Baltic. Similarly, pollution and eutrophication as well as the research on fishing techniques, including acoustic fish location and censuses, will not be dealt with.

Hydrographical investigations

How can hydrography assist in preparing predictions of value in fisheries problems (Sverdrup, 1952)? Wooster (1999), in his jubilee lecture, has described the long way ICES went in its attempt to answer this question. Hydrography in relation to fisheries was the strongest argument put forward by Pettersson when pushing for the creation of ICES. He succeeded in getting the ongoing Norwegian surveys broadened by international cooperation. Seasonal hydrographic surveys were initiated and coordinated by ICES for the Baltic, North Sea, and Norwegian Sea (Pettersson, 1923). The regular surveys at the Kola Meridian followed the same pattern. In addition to the routine observations, ICES, after World War II, organized various multi-ship programmes. The first large one was the participation in the International Geophysical Year 1957/1958 through organization of ICES Polar Front surveys in summer and winter. A series of multi-ship studies of large-scale processes subsequently followed, particularly on the exchange of water masses across the Iceland–Faroe–Shetland Ridge, but also on the Canary Current upwelling system. Circulation, diffusion, and flux experiments followed in the North Sea and the Baltic. Observations and modelling were intimately linked in those studies. Applicability in terms of fishery oceanography was the key to obtaining fishery research vessels for those projects. Plankton workers participated in those oceanographic cruises. In recent decades, fishery oceanography, including remote sensing, faded somewhat in Europe compared to the US, where some physical and chemical oceanographers developed great interest in fisheries biology and ecosystem research (e.g., Wooster, 1983; Bakun, 1996).

Biological investigations

The second endeavour was the investigation of "the biological conditions of the plant and animal world in these seas with special regard to food, reproduction, growth, and migration of the different food fishes" (Thomasson, 1981).

Plankton and benthos

Right from the beginning, plankton sampling was part of the seasonal hydrographic surveys. Hensen nets and Nansen nets were the standard gears, later replaced by two nets for zooplankton and microplankton developed by the Council. Ostenfeldt (1913), the initiator of the international plankton programme, was aware of the fact that any conclusions regarding plankton as the food base for fish required prior detailed knowledge about the spatial and seasonal distribution of the various species of zooplankton.

Twenty years later, Alister Hardy tried a short cut with his fisherman's Plankton Indicator assessing the concentration of copepods and the greenishness of the water as hints where to find herring shoals. The Hardy Continuous Plankton Recorder is still in routine use worldwide in combination with principal component analysis of the massive data sets. ICES now has a stake in it, although Hardy has never directly associated with the Council, ressembling Victor Hensen before and Steemann Nielsen after him. Another line of plankton research dealt with the use of specific plankton organisms as indicators of water movements and water masses. Countless fish egg and larval surveys have been carried out in an attempt to forecast recruitment or to hindcast spawning-stock size (e.g., Saville, 1981).

Over many decades, European planktologists in ICES saw much of their justification in the attempt to be useful to fishery biologists or oceanographers. Although biological oceanography in its own right has not been strong in ICES, safeguarding and full analysis of observational programmes has been and should be an important contribution of ICES to the development of biological oceanography.

Benthos was studied as food for fish (Petersen, 1918). Denmark became the leader in the surveying of zoobenthos in northern Europe. As with plankton, the benthos monitoring programmes introduced by ICES have provided long time-series which are now invaluable sources of information on long-term trends as well as on regular and irregular fluctuations in benthos in relation to various external forcings by climate, eutrophication, pollution, and bottom trawling.

Fish biology

Studies of the life history and populations of plaice, herring, cod, and salmon ranked highest on the ICES agenda. Those species are now among the best studied in the world. Over the decades, basic biological knowledge was assembled about growth, reproduction, feeding, and migrations as well as about fluctuations in recruitment and abundance. Some of the findings obtained "under the direction of ICES" are now found in most textbooks of marine ecology.

The founding fathers of ICES chose migrations and overfishing of herring and cod as its central themes (Thomasson, 1981). Lowestoft became the Mecca for stock assessment (Graham, 1956; Lee, 1992), Helgoland featured plaice research as well as plankton and benthos studies, while Bergen was the centre for life history studies on Arcto-Norwegian cod and Atlanto-Scandian herring, often combined with fishery oceanography.

One of the great breakthroughs was the recognition of the strong 1904 year class of herring by Hjort (1914). It led him to recognize the importance of year-class strength for fluctuations in the abundance of fish on given fishing grounds. Those fluctuations had previously been interpreted as failures and shifts in the migrations. The general adoption of Lea's age readings (Lea, 1929) was much delayed by D'Arcy Thompson who believed more in his statistician Miss Sherriff than in his Norwegian colleague. The dispute was finally resolved by what we now call an ICES intercalibration workshop (Ruud, 1971). Similar scientific disputes between strong personalities in ICES, e.g., by Devold and Höglund on Bohuslän herring, persisted for years, often to the amusement of young observers.

The Icelandic–Norwegian herring tagging experiment off central Norway and north of Iceland by Fridriksson and Aasen (1952) unveiled the migration pattern of Norwegian spring spawners. The first set of internal tags was imported by Fridriksson from California (Fridriksson, 1951). Much further research, including many years of acoustic surveys, was needed to reach the present knowledge on the long-term expansion and retraction in the range of distribution and migration of Atlanto-Scandian spring spawners. The same internal tags to be detected in fishmeal factories were also used in two tagging experiments on young North Sea herring on Blöden Ground in 1957 and 1958. Those experiments were rather unique as they were financed directly by ICES (Went, 1972).

Of similar importance was the work on the Arcto-Norwegian cod. Norwegian (most prominently Rollefsen, e.g., 1933) and British scientists as well as Russians and Germans participated in those investigations, which shed light on the life history, population dynamics, ecology, and eco-physiology of this long-lived species feeding near the Polar Front, but spawning in the warm Norwegian Current. The warming of Greenland waters in the 1920s and 1930s resulted in the temporary establishment of a strong cod population off West Greenland, connected with the Icelandic cod stock by larval drift and spawning migrations between Iceland and Greenland (see summary in Harden Jones, 1967). Those populations were of great interest not only to the Icelanders and Greenlanders, but also to the distant-water fleets of several European countries which, therefore, joined Iceland and Denmark in the studies of those stocks. One hundred years of northern cod research under ICES has provided some of the most fascinating stories in marine ecology.

Since about 1936, the German fishery developed a preference for redfish (*Sebastes* spp.) in Icelandic waters. Species and stock separation and age reading became matters of lively discussion in ICES. Redfish proved to be long lived, spawning in the deeper layers of the open ocean. Vast numbers of its larvae were found by the RV "Dana" expeditions to the northern North Atlantic (Tåning, 1949), which were partly motivated by the search for further clues on the migrations of the European eel and its larvae.

In the North Sea, plaice and herring were the most important target species in ICES, shared by fisheries of all bordering states. In the early decades, the study of plaice was done by the Biologische Anstalt Helgoland under the direction of ICES. Two highlights of the results presented to ICES in a long series of papers from Heincke's General Report (Heincke, 1913) to Bückmann (1944) were: 1) the closing of the fishery in World War I provided the proof on the effect of fishing on stock size, age composition, and growth, and 2) growth is limited by poor feeding conditions, *inter alia* caused by overcrowding on the young fish grounds by strong year classes.

C. G. J. Petersen's successful transplantation of plaice from poor to rich feeding grounds in the Limfjord (Petersen, 1909) gave rise to ICES transplantation of plaice in the North Sea and Baltic.

During their life, fish pass through a series of trophic relations both as predator and as prey. This statement is based on countless stomach analyses carried out under the aegis of ICES.

The question of races in herring was studied by Heincke (1878, 1881, 1889) by means of statistical analysis of meristic and morphometric characters. This method was adopted by ICES for stock identification and separation and was carried on almost *ad infinitum*. After a meeting of the Herring Committee, David Cushing sighed, "Millions and millions of vertebrae can't be wrong." Later on, stock identification was largely based on patterns in scales and otoliths as means of certifying origin and specific life history. The problems created when one management unit consisted of several stocks were particularly pressing in North Sea herring.

Genetic fixation versus response to environmental conditions became an issue of heated debate among herring workers in the North Sea. Observations on the distribution of larvae and their meristic characters were followed by rearing experiments done jointly in Aberdeen, Helgoland, and Bergen (Hempel and Blaxter, 1961). Nowadays, one would do it more elegantly by population genetics. A by-product of the rearing experiments was the detection of striking differences in the number and size of eggs in winter/spring versus summer/autumn spawners as adaptations to seasonal differences in food supply and predation (Blaxter and Hempel, 1966).

The old question of how nature regulates recruitment puzzled fishery biologists in ICES all the time. Hjort's "critical period" (Hjort, 1914), my "larval gate" (Hempel, 1965), Iles's "retention area" (Iles and Sinclair, 1982), Rosenthal's "feeding tunnel" (Rosenthal and Hempel, 1970), and Cushing's "match/mismatch" hypothesis (Cushing, 1978) were eagerly discussed in ICES. Bakun's triad of enrichment, concentration, and retention puts those concepts into the context of large-scale oceanographic features and their long-term changes (Bakun, 1996). But that was done outside ICES.

The overfishing problem

The third ICES endeavour of 1905 reads as follows: "The solution of the problem, how far the deep sea fishery as a commercial industry stands in general on a rational basis, whether the quantities and the consumption of fish, taken from the seas mentioned, are in proper proportion to the production occurring under the prevailing conditions, and whether any disproportion between production and consumption arises from general or local overfishing, or from an injudicious employment of the fishing apparatus present in use" (quoted from Thomasson, 1981).

It was a long way from Petersen's (1903) account of the "overfishing problem" to today's precautionary measures and ecosystem management. Hjort, Jahn, and Ottestad (1933) in Bergen and Graham (1939) in Lowestoft translated the sigmoid curve of population growth into advice for fishery management, and Bückmann (1938) on Helgoland introduced the von Bertalanffy growth curve to fisheries science. After World War II, Beverton and Holt (1957) developed those concepts into a complex yield model which, in its advanced form, also included recruitment overfishing. Single-species stock assessments linked with new methods for stock separation and with recruitment studies remained domains of ICES. Some pioneering papers had been forgotten for a long time because Baranov (1912) and Bückmann (1938) had published their key papers in Russian and German, respectively. In later years, Nikolsky (1969) made great efforts to acquaint his western colleagues in ICES with Russian literature on fishery biology.

Of course, ICES was not the only player in the evolution of theories and methods for stock assessment and fishery regulation. Ricker's stock-recruitment curve (Ricker, 1954) is just as old as the model by Beverton and Holt. Murphy (1965) developed the virtual population analysis in parallel to Gulland (1965). FAO and ICNAF became strongholds in the theory of population dynamics, and Pauly and his co-workers in ICLARM added further methods (e.g., Pauly, 1982, 1984).

In the 1960s and early 1970s in the North Sea, positive changes in demersal fish stocks took place which could not be interpreted in the traditional way. The yields in the fisheries for gadoid fish increased drastically thanks to better growth and a series of excellent year classes. New industrial fisheries on small fish like sandeel, Norway pout, and sprat were very productive, while the stocks of herring and mackerel had gone down owing to overexploitation. In search of explanations, the 1975 ICES Symposium in Århus tried to distinguish between the effects of climatic change and reduced pelagic stocks (Hempel, 1978a, 1978b). Cushing postulated that the high frequency of good year classes was a consequence of a better match in space and time between the hatching of the fish larvae and the spring bloom of the small zooplankton which serve as food for the larvae. A shift in the composition as well as in the timing of the phytoplankton and zooplankton had been observed in the Hardy Plankton Recorder surveys (Cushing, 1978). Andersen and Ursin (1978) postulated indirect man-made causes and developed a multispecies model incorporating the trophic interaction of 11 species of fish at the larval, juvenile, and adult stages. The model suggested that the decline of the herring and mackerel due to heavy fishing meant less predation on larval and juvenile gadoids and other North Sea fish.

The term "ecosystem overfishing" was born at the Århus Symposium. About the same time on the other side of the Atlantic, the comprehensive, long-term study of Georges Bank resulted in the concept of Large Marine Ecosystems (Sherman, 1994), which became a powerful tool for the organization and fundraising for large-scale projects worldwide.

Final comments

Is ICES like an old man full of good memories and grateful for being still somewhat useful in an ever-changing world? Or is ICES rather like a well-established old firm which steadily reacts to new demands of the market?

ICES has been (and possibly still is) Number 1 in fisheries science and related fields of oceanography. It picked up the pollution question very early and contributed successfully to marine research on climate change. It has developed strong links to other international organizations. But is that enough for the decades to come?

The marine science community worldwide has to respond to the changing needs of society. One hundred years ago, Pettersson and Herwig were even proactive regarding the needs of their clients in fisheries. ICES will have to decide which of the new challenges it will take on: 1) the dialogue between society and science on coastal zone management, particularly in the overcrowded tropical regions of the world; 2) biodiversity; 3) biotechnology; and 4) the use of the seabed as source and sink of minerals, industrial waste, and greenhouse gases. ICES also has to take into account the demands of young scientists in terms of scientific communication and meetings.

ICES has always been a home in which generations of marine scientists and administrators enjoyed scientific discussion and developed plans with fellow scientists who sometimes became close friends, and everybody was served by an excellent Secretariat. Under the shelter of ICES, people also met who were otherwise isolated. In the hot period of the Cold War, the USSR, Poland, and the GDR were welcomed as new members. In 1944, Hjort stressed the need for keeping ICES alive as a foothold for international cooperation after the war (Hjort, 1945). But in November 1944, the Administrative Secretary Wilhelm Nellemose, a member of the Danish Resistance, died in a German concentration camp. Nevertheless, Scandinavians were among the first to pave the way for Germans to re-enter the international science community.

An intergovernmental body like ICES, dealing with matters of major economic importance, is not free of political tensions. However, "the goodwill which exists between representatives of all member nations, despite their different politics and creeds, is perhaps the one characteristic of the Council, which has enabled it to prosper in the past" (Went, 1972). Over the almost five decades of my acquaintance with ICES, I have always noticed the good human relations. This is the spirit in which marine science freely developed under ICES for a full century.

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