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Stockholm 1999 Centenary Lectures

International Council for the Exploration of the Sea

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Foreword

The 1999 Annual Science Conference held in Stockholm included an Open Lecture and a special programme of four Centenary Lectures on subjects relating to the history of ICES. One lecture, by Alasdair D. McIntyre, was revised and included in "100 Years of Science under ICES" (*ICES Marine Science Symposia,* Volume 215). The four papers published in *ICES Cooperative Research Report*, No. 260, comprise the manuscripts for the lectures subsequently revised by publication, by David de G. Griffith, Jakob Jakobsson, Artur Svansson, and Warren S. Wooster.

The evolution of ICES

David de G. Griffith

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Present address: International Council for the Exploration of the Sea, Copenhagen, Denmark

"What shall we tell you? Tales, marvellous tales
Of ships and stars and isles where good men rest."

James Elroy Flecker: The Golden Journey to Samarkand

"Et que vous raconter? Sinon des contes féeriques
De navires et d'étoiles et d'îles magiques
Où dorment les hommes de bonne volonté"

[Freely translated by Michèle Bo Bramsen]

The foundation and early years

It all began in earnest at the Sixth International Geographical Congress, 1895. On the proposal of Otto Pettersson of Sweden, a resolution was passed that the Congress:

> "recognises the scientific and economic importance of the results of recent research in the Baltic, the North Sea and the North Atlantic especially with regard to fishing interests and records its opinion that the survey of the areas should be continued and extended by the co-operation of the different nationalities concerned on the lines of the Scheme presented to the Congress by Prof. Pettersson" (Went, 1972).

Resulting from further initiatives by Otto Pettersson, Fridtjof Nansen, Gustaf Ekman, Johan Hjort, Sir John Murray and others, and on the invitation of the King of Sweden and Norway, Oscar II, the first International Conference for the Exploration of the Sea was held in Stockholm in 1899. Participation consisted of representatives of Denmark, Germany, the Netherlands, Norway, Russia, Sweden, and the United Kingdom of Great Britain and Ireland (Went, 1972).

The birth process of ICES was blessed with midwives and sponsors possessed of outstanding scientific talent and a tenacious sense of purpose. The most outstanding scientists of their day—and the passage of a century has not diminished their brilliance—they moulded the shape of an idea whose time had come. They were men who would not easily be diverted from the achievement of a goal. They had the requisite broad experience, scientific astuteness, and political foresight, and they had another essential ingredient: influential backing—in this case, from the sovereign head of state himself.

Among the nations which eventually set up the International Council for the Exploration of the Sea, I believe it is fair to say, without in any way downgrading the parts played by other participants, that the Scandinavian countries were *primus inter pares*—first among equals.

First, King Oscar II, who was King Carl Gustav's grandfather's grandfather, enthusiastically supported the idea of an international conference in Stockholm. Throughout his life Oscar II demonstrated a keen and committed interest in research and exploration, and gave his patronage and his financial support (totalling almost 0.25 million Swedish kroner) to many geographic expeditions over a 40-year period from the 1860s onwards (Nathurst, 1907). His descendants have maintained strong commitments to science and the arts.

Otto Pettersson, who launched the concept in 1895, was outstanding in the fields of chemistry, physics, and oceanography. He was a gold medallist of the Swedish Academy, and Professor of Chemistry at Stockholm's Technical High School. Pettersson was also the supreme gadget-man, and as such he invented the eponymous water bottle to which Nansen's name is also attached (in his obituary of Otto Pettersson, D'Arcy Thompson claimed that the invention was really Pettersson's). Concerning Pettersson's role in the founding of ICES, D'Arcy Thompson wrote that "*to him, more than any other man, its first inception was due; no man worked harder or longer for it than he did. It stands as his great and worthy monument"* (Thompson, 1948).

And the redoubtable Fridtjof Nansen—what an extraordinary man: outstanding polar explorer, adept innovator of survival field-craft under the most hostile conditions (Gjelsvik; and Christopherson, 1961). Nansen was primarily a zoologist, but one whose intellectual capabilities were never to be constrained by just one scientific discipline, and above all a person who could never resist a challenge. For Nansen, once a venture was commenced there was to be no way back; only forward, to the achievement of the goal. His philosophy regarding expeditions into the Arctic wilderness—such as his crossing of Greenland from east to west in 1888 and again in his 1895 dash towards the pole by dog-sled, ski, and kayak from his ship "Fram"—was to cut off, at the beginning, all possible lines of retreat. Thus the only way to achieve his and his colleagues' very survival was to press ever onwards; no turning back; no option. Later in his career, Nansen's outstanding qualities were to be given wide international recognition in other spheres. To name only some of them:

- Norwegian ambassador to Great Britain, 1906–1908;
- Norwegian delegate to the League of Nations, 1920–1930;
- League of Nations High Commissioner for Prisoners of War, 1920–1921;
- First League of Nations High Commissioner for Refugees, 1921;
- In charge of International Red Cross famine relief in Russia, 1921–1922;
- Nobel Peace Prize, 1922.

On the establishment of the ICES Central Laboratory in Christiania in 1902 with Nansen as its Director, Walfrid Ekman was appointed assistant. There is a nice link here with Nansen's scientific findings during his "Fram" expedition to the Arctic in 1893–1896 and with the development of one of the fundamentals of ocean physics. While "Fram" was locked in the ice, Nansen had recorded that the line of drift was between 20º and 40º to the right of the wind direction. A few years later, in a discussion with Professor Bjerknes of Stockholm, Nansen proposed a theoretical study of the influence of the earth's rotation on wind-induced currents (Kullenberg, 1954). Bjerknes volunteered the information that one of his most promising students, one Walfrid Ekman, was just the person for the job. So it was that Ekman made this the subject of his thesis and developed the theory (which he extended in 1905) which bears his name—the spiral deviation of wind-induced current pattern with increasing depth, resulting from interaction with the earth's rotation. Walfrid Ekman was another gadget-man *par excellence:* in the obituary for him written in 1954, his current meter was described as "an instrument of rare perfection" (Kullenberg, 1954), and his reversing water bottle achieved similar recognition.

At the 1899 Stockholm Conference, the Danish hydrographer Martin Knudsen was invited to continue his work on the development of a set of standard tables for the determination of seawater constants. The Knudsen Tables duly appeared in 1903, but Knudsen's work produced another early landmark of vital importance in the evolution of ICES—the provision of standard seawater.

In 1899, Knudsen had proposed the creation of "an international institution for processing standard water…in order to secure homogeneity in the determinations of halogen done by the different nations". Although this logical and far-sighted suggestion was not fully adopted by the Conference—and one can sense Knudsen's disappointment in his 1903 account of his standard water initiative—he continued to develop it anyway through 1900–1903, side by side with his work on the Hydrographical Tables. His justifications were (among others) that the Conference had not expressly turned it down, and that, furthermore, he was convinced that sooner or later the availability of standard seawater would be seen as an essential requirement for international cooperative hydrographical work (Knudsen, 1903).

Nansen, however (who seems likely to have been a more forceful character than Knudsen), persuaded the Conference to establish a Central Laboratory, and in his proposal for its work programme at Christiania he took over Martin Knudsen's idea for the provision of standard seawater. This work continued at Christiania until 1908, when the Central Laboratory closed and the Council passed the responsibility for the standard seawater service to Knudsen (Thomsen, 1950).

Martin Knudsen served ICES as Head of the Service Hydrographique from 1902 to 1948. His sustained contribution to the success of the Council, particularly during its first half-century, was without parallel.

By looking at the status and personal characteristics of the founding figures of ICES, as I have attempted to summarise above, we can sense the driving force of those early years. Once the preliminary groundwork had been covered, ICES had no slow beginning—the Big Bang is a much closer analogy.

Analysis

In examining archival material for trends and innovations to map out the evolutionary landmarks of ICES, I have looked at changing perceptions and priorities as represented by

- alterations in the structure and diversity of scientific committees;
- definitive resolutions and conferences;
- keynote papers;
- the general coverage of annual meeting documents.

Looking at this material in general, one is struck by the extent to which the same problems arise repeatedly throughout the Council's history. Although they may differ in detail, or in the nature of their manifestation, and even though the ICES response varied in accordance with the solutions available at the time—themselves reflecting the evolutionary process, which I shall be describing—one sees recurrent expressions of the need for improvements in:

- fisheries statistics;
- research funds in the Member Countries;
- resource conservation measures;
- interdisciplinary communications between ICES scientists.

More positively, there are also clear and repeated examples of how the ICES programme has stimulated and supported national and international action, at government level, in relation to the sustainable use of the sea's biological and environmental resources.

Structure of the Scientific Committees

It is important to note that the original aims and objectives of the organisation were primarily directed towards "the interests of the fisheries" and "rational exploitation of the sea by way of scientific enquiry" through international co-operation and intergovernmental agreements (Anon., 1901). The *practical* application of science to matters of immediate concern to the member states was stressed, specifically:

- migrations of herring and cod;
- influence of these migrations on the fisheries;
- biology of herring, cod, and other fish species;
- overfishing, especially with regard to flatfish.

To these ends, three scientific committees were established in 1902 (ICES, 1903):

Committee A	Migration of Food Fishes	Johan Hjort (Norway)
Committee B	Overfishing	W. Garstang (UK)
Committee C	Baltic	O. Nordquist (Finland)

Hydrographic investigations were given importance too, of course, hence the establishment of the Standard Sea Water Service, the production of Martin Knudsen's Standard Tables, and the organisation of innovative oceanographic surveys in the first coordinated international programmes.

Given the central role of hydrography throughout the first century of ICES activities, it might be considered surprising that the subject did not get a committee to itself. Annual meetings provided for scientific discussion in Sections, however, in much the same way that Theme Sessions are organised today; thus a Hydrographical Section, a Biological Section, and a Statistics Section appear in the records of the first years.

While the *stated* priorities were definitely fisheries-oriented, it is clear that the Council's approach was emphatically a holistic one. With world-class oceanographers at the core of ICES, things could not have been otherwise. In those days, the scientific tradition was much less compartmentalised than it became in subsequent decades; the Kepler philosophy was very much to the fore: if you cannot see the whole, you cannot understand the parts. Borrowing a style of nomenclature from geology, I call this period the *1st Holistic era* of ICES. It was a period characterised by a cross-disciplinary fertilisation in which constructive criticism and innovative ideas were encouraged and facilitated. The international data-gathering programmes at sea were not the only manifestation of this; here, for example, is the oceanographer-inventor supreme, Otto Pettersson, castigating his fishery science colleagues in 1909:

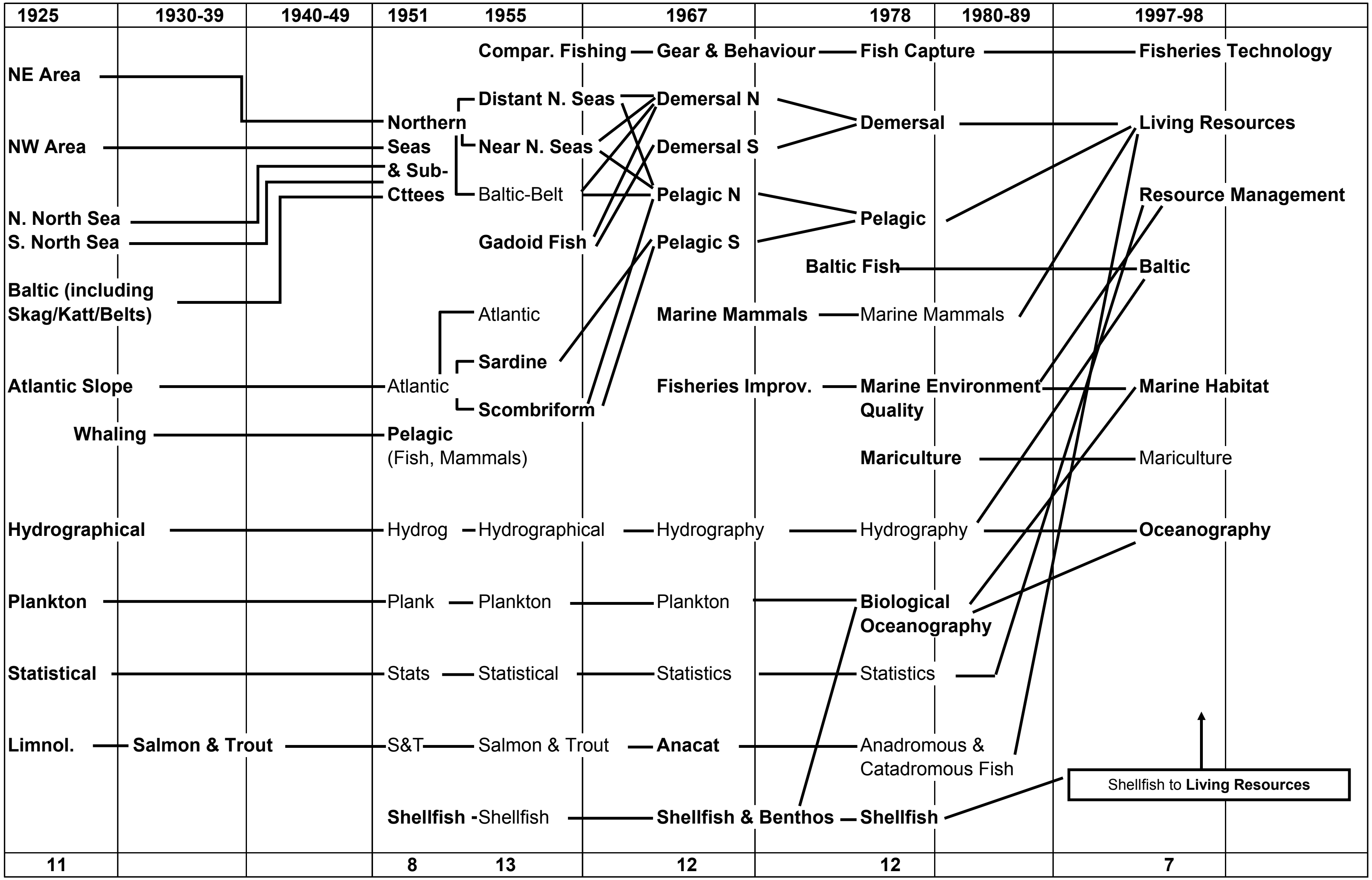
> "Nowhere in the International Study of the Sea were there made greater advances during the last seven years than with regard to the subtlety of the analytic methods and to the perfection of the apparatus. At present we have an "*embarras de richesse*" of new constructions of water bottles, current meters, Plankton-nets etc. But all these inventions only mean progress with regard to the technics [sic] of the scientific study. In our annals not a single progress in the development of the technics of the practical fishery is recorded. And still an improvement of the nets used for the high-sea-fishery to the end that they might counteract the annihilation of the young fishes would be of far greater interest than the invention of new scientific apparatus. I have asked myself why the specialists of the International Study of the Sea have not at all worked at the improvement of these apparatus which already at the beginning were on our programme" (ICES, 1910)

Pettersson went on to suggest that lack of funds might have been a deterrent to potential inventors of such improved fishing gear, and generously offered 2,000 kroner of his own money as a financial inducement.

Such opportunities for multidisciplinary debate and consequent "hybrid vigour" of thought were to become severely reduced in later years as the committee structure became more complex, reflecting the growth of scientific specialisation within the marine sphere as throughout science generally.

This trend in committee organisation does not seem to have hindered the sustained development of ICES as the leading international marine science body, nor its status as the source of advice to governments and regional Commissions. It came to be recognised within ICES, however, first in 1950 and again in the 1970s, 1980s, and 1990s, that the complexity of the committee structure was a severe constraint on productive scientific discussion, requiring significant changes to be made.

In the years up to 1925, the practice had been for the Bureau to decide, before the start of the annual meeting, what Committees and Sections would be convened. The President used to announce the sessions and their conveners on the first day of the meeting, although some Sections—particularly in the earliest years—seem to have had a measure of constancy as indicated above. The system appears to have had similarities to the procedures followed in the early 1980s when at least some of the Theme Sessions were created on the basis of abstracts submitted in advance of the annual meeting. In 1925, however, the procedure was radically revised and a committee arrangement—very much along the lines of the modern system—was instigated. Apart from some relatively minor adjustments, this remained in place until 1951 (Figure 1).



New committees in bold
Sub-committees not shown

Evolutionary lines are simplified & do not show extra responsibilities. For example, Fisheries Technology includes physical effects of fishing operations on the seabed.

Figure 1. Changes in the ICES Scientific Committee structure since 1925.

In 1950, the Council went through a process of reflection virtually identical to that which was to recur during the late 1970s and early 1980s, questioning the appropriateness of the committee structure and procedures as they then stood (Andersson, 1949). The arguments advanced in favour of change included the need to

- reduce the separation of participants at Council sessions caused by many committees;
- bring matters of general interest before somewhat larger meetings than at present.

The number of days allocated to the whole Council Meeting should not be extended, it was felt; "the longer the meeting, the harder it is to spare active people to attend it". Meetings on the Sunday should be considered.

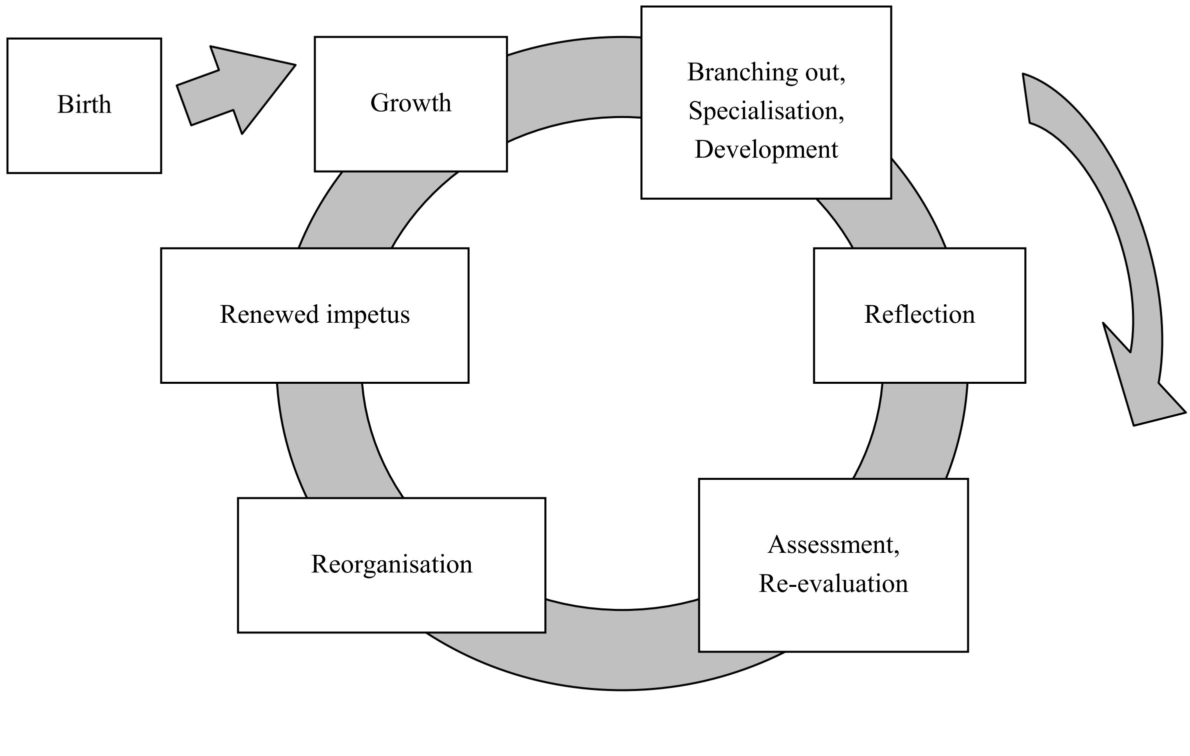
With effect from the 1951 annual meeting, the Council re-graded the five northern area fish committees as subcommittees under a single Northern Seas Committee. Marine mammals were grouped with herring in a Pelagic Committee, and the Shellfish Committee was created (Figure 1).

Very shortly afterwards, in 1955, the fish committees were again reorganised (ICES, 1955). The subcommittees of the Northern Seas Committee were reconstituted as a new series of area-based committees. Two new Committees were established: Comparative Fishing and Gadoid Fish. The two subcommittees of the Atlantic Committee—Sardine and Scombriform—each became a full Committee. The Pelagic Committee (pelagic fish and marine mammals) was abolished.

The records do not explain the underlying reasons for these changes, nor why they came so soon after the 1951 reorganisation. Perhaps the 1950–1951 operation did not achieve its objectives, or maybe the Council was seeking to develop the best structure to handle the science of fisheries management, for input to the Liaison Committee (established in 1953) and subsequent transmission to the Permanent Commission. A third possibility worth considering is that increasing availability of research funding in post-war Europe may have begun to produce a greater flow of information, with a consequent need for rapid adaption of internal procedures within ICES to handle this.

As Arthur Went describes in his history of ICES (Went, 1972), action was initiated in 1961 to draw up a formal ICES Convention. This was concluded in 1964, and entered into force in 1968 following ratification by the Contracting Parties. In association with this major development, a Host Agreement was concluded with the Danish Government and new Rules of Procedure were agreed by the Delegates. The Council established a Working Group on Committee Structure, and subsequently adopted revisions (mainly in the Fish Committees), which took effect from 1 November 1966 (i.e., at the 1967 Annual Meeting). In the words of the President (Dr Jöran Hult) at the opening session of the 1966 ICES meeting, the changes in Committee structure and in the Rules of Procedure were aimed at "making the work of the Council more effective both now and when the Convention of 1964 has entered into force, and thus to strengthen the position of ICES as an advisory body in fishery matters in the North Atlantic" (ICES, 1966).

Evolutionary trends, as represented by movements in the committee structure of ICES, took place in a cyclical fashion:



This cyclical progression (which of course is actually a spiral since it has a considerable forward-moving component) was interrupted by two "glaciations" represented by the two World Wars.

Cycle	Years		Duration	Events	Reasons for cycle completion
1	1902–1924		23 years	WW1	
2	1925–1950		26 years	WW2	Improve scientific communication
3	1951–1954		4 years	Perm. Commission, Liaison Committee	
4	1955–1966	27 years	12 years	ICES Convention	Make the work of ICES more effective; strengthen ICES' position as a fishery advisory body in North Atlantic
5	1967–1977		11 years	200 miles	
6	1978–1997		20 years		Improve scientific communication

This suggests that the natural cycle period, when no external forces appear to be operating, is around 25 years.

Evidence from Scientific Committee papers

Consistency of coding, by which papers were allocated to the various committees, allows an examination of trends only during the years 1955 through 1982. (From 1983 onwards, the reports of Assessment Working Groups were included in the annual Council Meeting documentation, and from 1987 onwards papers were often presented at more than one committee.)

The total number of papers presented to the annual meeting rose from fewer than 100 in the mid-1950s, expanding gradually through the 1960s and more rapidly during the 1970s to reach a peak of 500 in the early 1980s (Figure 2). Increasing numbers of papers presented to the Hydrography Committee made a greater contribution to this trend than did the papers for the fish committees. Between them, these two areas (hydrography and fisheries) accounted for around 90% of the total annual meeting documentation, falling to about 70% during the 1970s and early 1980s when the environment and mariculture papers submitted to the two new committees were making an increasing impact (Figure 3).

It has been generally recognised, however, that the priorities of national marine laboratories, the scientific orientation of a committee Chair and the amount of time which he or she is able to devote to intersessional committee work, have all had a strong bearing on the number and scope of the papers submitted to the Standing Committees each year. The significance of the frequency distribution of scientific papers summarised in the preceding paragraph, and their internal trends, is thus unclear. What is certain, however, is that from time to time individual laboratories and even committee Chairs through their own energy and initiatives have had a direct positive impact on the evolution of ICES. Two examples of such institutional concentration have been the Lowestoft population dynamics school and the pioneering hydroacoustic work at Bergen. Committee Chairs, by identifying gaps and opportunities through their committee's activities, have acted as focus points for ICES to develop new areas of knowledge for the benefit of marine science, and ultimately also of those who depend on the sea for their livelihood.

ICES developments in scientific thought, and international impacts

Fish stock assessment

Scientific developments. In his history paper delivered during the 1994 ICES Annual Science Conference, Mike Sinclair describes the contribution of Johan Hjort, Friedrich Heincke, and others to the evolutionary leap in scientific thought concerning the causes of year-to-year fluctuations in fisheries (Sinclair, 1997). The seminal publication in this regard was Hjort's paper "Fluctuations in the great fisheries of Northern Europe" (Hjort, 1914).

It had been widely believed that these inter-annual variations in the fisheries were due to large-scale alterations in the migration pattern of fish, and that the effects were exercised at the species level. Sinclair points out that Hjort's interpretation of the available data, however (obtained through the work of ICES Committee A, from Heincke's observations on eels and herring, and from Hjort's own data on Norwegian cod), attributed fluctuations in fisheries to changes in year-class abundance at the population level.

While the hypotheses put forward by Hjort attracted widespread recognition, the testing of them was undoubtedly hindered by the dispute about the validity of age reading from herring scales. At the ICES meeting in 1910, Hjort had delivered an account by Einar Lea, "On the methods used in the herring investigations", in which Lea demonstrated the annual nature of the scale rings. Not everybody was convinced, however, and the opposition to scale reading—led chiefly by D'Arcy Thompson—was sufficient to delay the full acceptance of Lea's age-reading methods until 1923 (Went, 1972).

The basic principles of fisheries science continued to undergo development through the ensuing decades, and by the 1960s widespread quantification and forecasting of fish stocks had been made possible. This achievement was the product of a steady evolutionary trend, founded mainly on the work of Hjort, Heincke, Lea, and others (as described above), followed by E. S. Russell and Michael Graham in the 1930s, Ray Beverton and Sidney Holt in the 1940s and 1950s, and John Gulland and others in the 1960s. (The first exposition of the mainstay of fish stock assessment methodology, the Virtual Population Analysis, is tucked away as an annex, written by

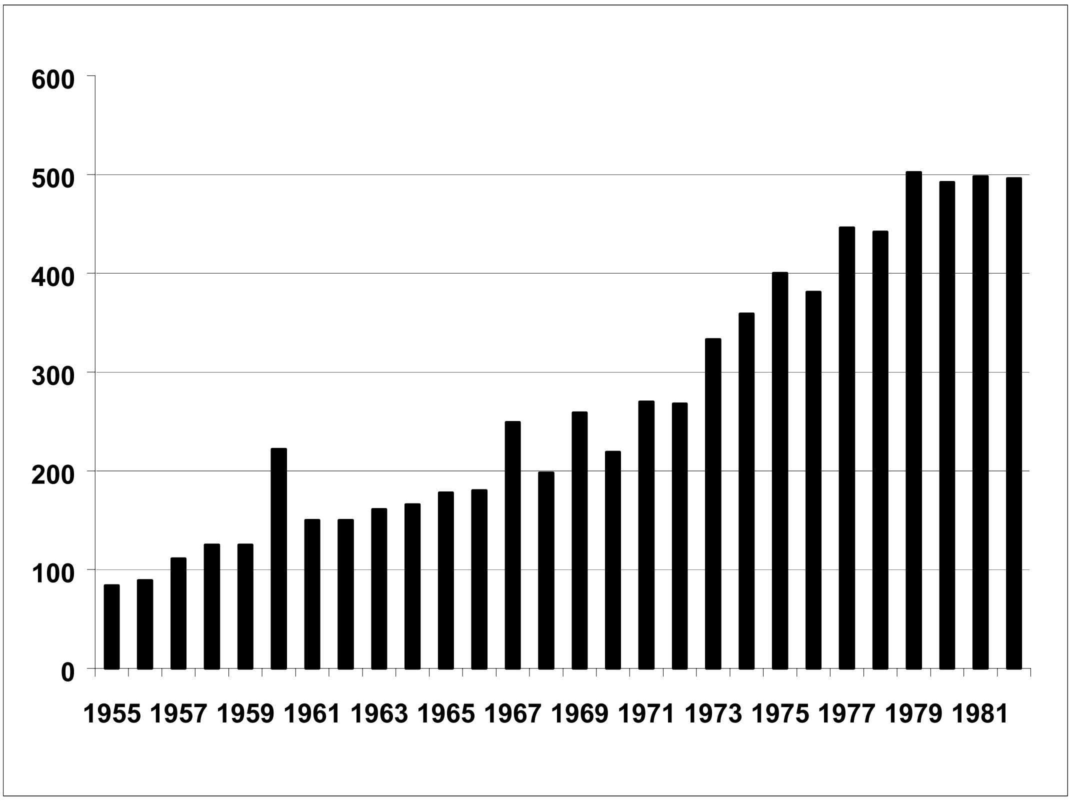


Figure 2. Numbers of papers contributed to the Scientific Committees, 1955–1982.

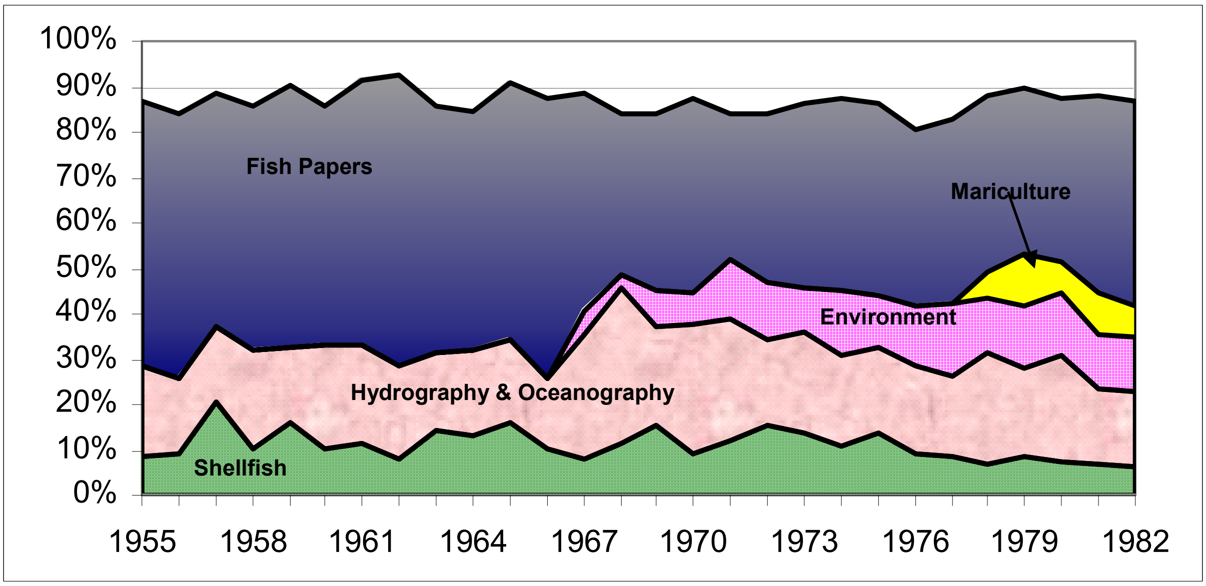


Figure 3. Percentage of papers according to Committee categories, 1955–1982.

John Gulland, attached to the 1965 report of the North-East Arctic Fisheries Working Group.) These developments enabled ICES, during the 1960s, to set up the first fully analytical Fish Stock Assessment Working Groups. Also by the 1960s, echosounders were being increasingly used as a scientific tool in the measurement of fish abundance, reflecting technical developments since their first application in fisheries science in the 1930s.

The origin of the specific evolutionary process leading to modern fish stock assessment techniques and related scientific advice can be traced back to the work of Petersen in 1894. This trend (as described in 1952 by Michael Graham) is summarised in Figure 4. (Petersen, 1894; Baranov, 1918; Russell, 1931; Hjort *et al.,* 1933; Graham, 1935; Graham, 1952; Beverton and Holt, 1957).

Through the 1970s, multispecies modelling—particularly exemplified in the work of "Jydefar" Andersen and Erik Ursin at Charlottenlund (Denmark)—enabled ICES to take a further big evolutionary step forward in population studies into the multispecies approach. An extensive ICES-coordinated biological programme, with accompanying Working Groups, was established to investigate and quantify interspecies relationships by monitoring the stomach contents of fish. The first "Year of the Stomach" was organised in 1981, followed by a second in 1991.

International impacts. In response to the concerns expressed by ICES member governments concerning overfishing, the Council's recommendations included—virtually every year from 1902 onwards—warnings about the continued landings of immature fish. Frequent statements on the importance of accurate and standardised statistics on catch and fishing effort were also made, and during the 1920s these were supplemented by proposals for closed areas, transplanting of plaice, and minimum size regulations. ICES continued to provide similar advice through the 1930s, and convened a series of Special Scientific Meetings to focus on specific aspects of fisheries biology and technology in relation to conservation (see text table). The 1934 Special Meeting drew up definitive recommendations concerning what, today, would be called technical conservation measures (ICES, 1934). These actions came to fruition in the *International Convention for the Regulation of the Meshes of Fishing Nets and Size Limits for Fish*, adopted at London in 1937. The President of ICES, Henry Maurice, commented that this "might be said to have set the seal of administrative achievement on the scientific work directed by the Council" (ICES, 1937).

Regional Conventions covering parts of the Baltic, as well as the Skagerrak, had already been adopted in 1928 and 1930 respectively.

In 1946, the 1937 Convention was replaced by a more comprehensive Convention, also signed in London. The Permanent Commission which was established under the terms of the 1946 Convention held its first meeting in 1953, with ICES as its source of scientific advice. This was provided through the Liaison Committee, which commenced in the same year.

ICES Special Scientific Meetings

1932	The Effect upon the Stock of Fish of the Capture of Undersized Fish (ICES, 1932)
1934	Size Limits for Fish and Regulation of the Meshes of Fishing Nets (ICES, 1934)
1938	Rate of Growth (ICES, 1938)
1939	Overfishing Problems (ICES, 1939)
1948	Effect of the War on the Stocks of Commercial Food Fishes (ICES, 1948)
1949	The Comparative Efficiency of Fishing Craft, Their Gear and Modification of Gear (ICES, 1949)

The 1946 Convention and its Permanent Commission was replaced by the North-East Atlantic Fisheries Convention in 1963. This Convention had to be rewritten following the widespread extension of fishery limits to 200 miles during the 1970s, and so the "new" NEAFC came into effect in 1982 (NEAFC, 1995). The Advisory Committee on Fishery Management (ACFM) replaced the old Liaison Committee in 1978, with a new structure, which guaranteed all ICES countries full participation in the advisory process.

ICES was equally active in providing advice on the status of whale stocks, and at its 1928 meeting the Whaling Committee drew up a comprehensive set of proposals for urgent action to protect whales, addressed to member governments. At the same meeting the Committee examined, at the request of the Norwegian government, draft Norwegian legislation aimed at whale conservation (ICES, 1928). In stressing the need for uniform whaling legislation in each country, ICES was sowing the seed of the international Convention, which was still some years away.

Also in 1928, ICES agreed to provide scientific advice to the League of Nations, in response to the League's proposal for mutual cooperation "in regard to the question of the rational exploitation of the resources of the sea" (ICES, 1928). It would be reasonable to assume that this League of Nations initiative was facilitated through Fridtjof Nansen, Norwegian delegate to the League from 1920 to 1930. In 1930 the Whaling Committee undertook to review a League of Nations draft Convention on the regulation of whaling.

Thus there can be no doubt that the scientific support and advice of ICES facilitated the establishment of the International Whaling Convention in 1946, following the London Whaling Conference of 1937.

Figure 5 summarises the impact of ICES on the creation of, and support to, some intergovernmental Conventions.

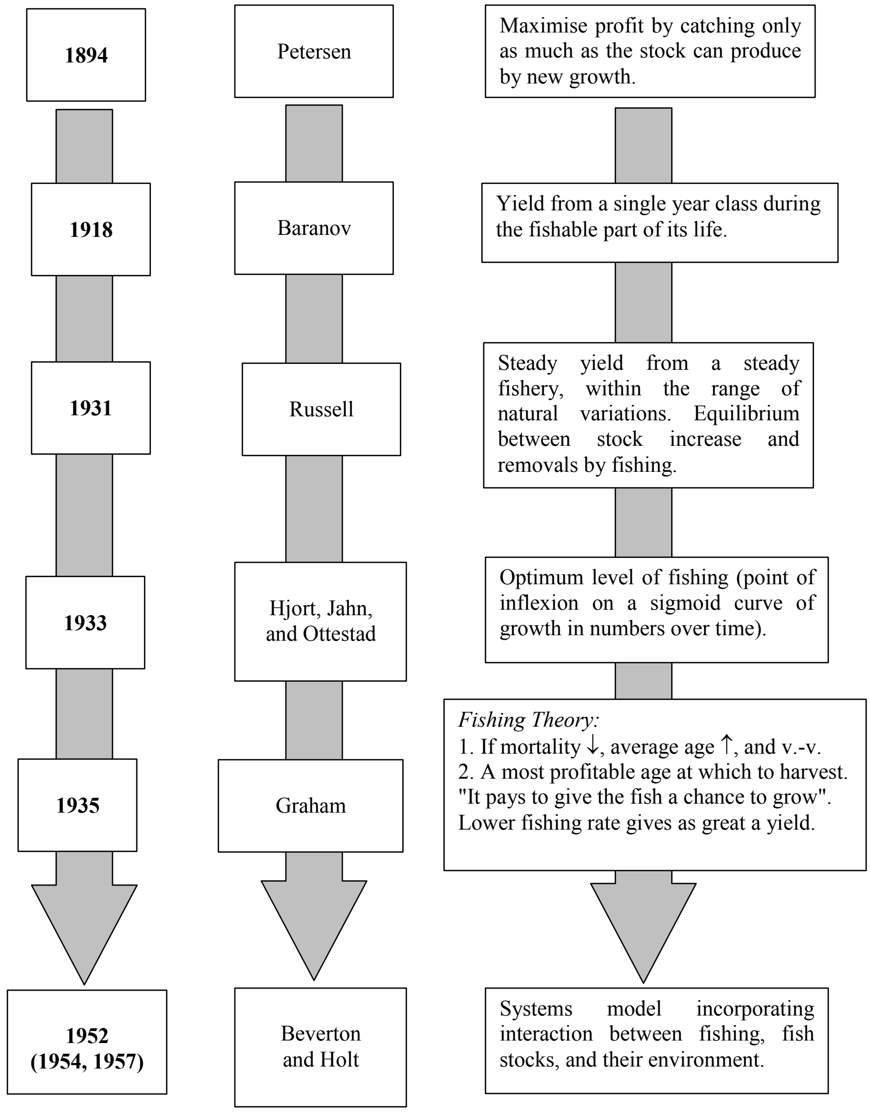


Figure 4. Evolution of modern fish stock assessment techniques; adapted from Graham (1952).

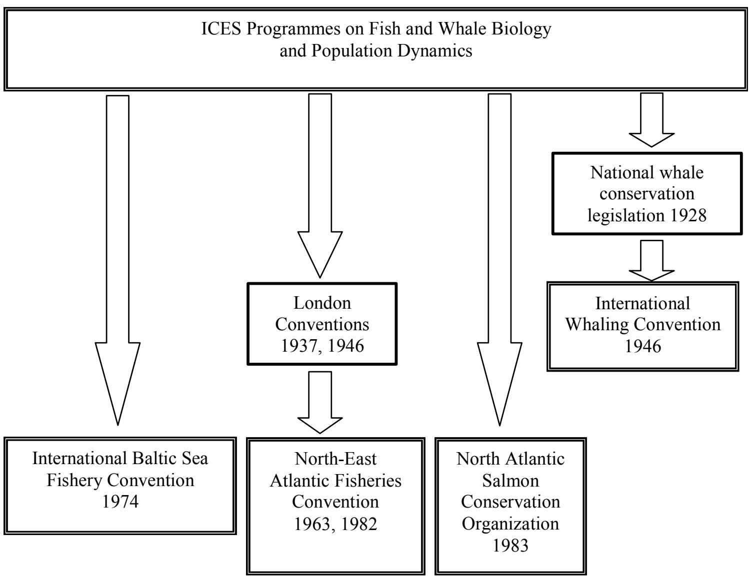


Figure 5. Impact of ICES on the creation of, and support to, intergovernmental Conventions.

Fisheries economics

The subject of cooperation between biologists, technologists, and economists in analysing and interpreting catch and effort statistics first came up at the Statistics Committee in 1971, when the General Secretary reported on responses to enquiries among ICES members concerning the extent of such three-way collaboration at the national level (ICES, 1971). Of the four countries that replied, only Belgium reported positively. Matters rested there until 1982, when Dr C. Clarke (Dept. of Mathematics, University of British Columbia, Canada) accepted ICES' invitation to deliver the Open Lecture entitled "Economic Effects of National and International Management of Marine Resources" (ICES, 1983).

In the following year, 1983, a joint session of the Statistics Committee and the Fish Committees considered, among other topics, the interrelation between biological and economical aspects of fish stock assessment. This event reflected previous statements, at various levels within ICES, concerning the desirability of "entering into a dialogue with fisheries economists". The expressed aim was to consider the need to "tailor" the biological advice so that it could be taken further by fishery economists for assessing the economic consequences of specific pieces of biological advice. The meeting generated considerable interest. The participants—notable economists among them—strongly supported the need for cooperation between economists and biologists, although no clear agreement emerged as to how this might best be achieved (ICES, 1984).

ICES took a further evolutionary step into the area of economics and sociology in 1994, when Professor Jackie McGlade (UK) gave the Open Lecture entitled "Putting Fishermen into Fishery Models". There followed a Theme Session on "Improving the Link between Fisheries Sciences and Management: Biological, Social and Economic Considerations" (ICES, 1995a). Aspects of these matters were taken further at the Annual Science Conference in 1995, in a Theme Session entitled "Improving the Link between Fisheries Sciences and Management 2: Can We Manage Fisheries by Technical Measures Alone?"

Hydrography

The orientation of the hydrography programme planned by the 1899 Stockholm Conference reflected the "broad approach" thinking which characterised the *1st Holistic era* of ICES:

> "The hydrographical researches shall have for their object:
>
> The distinction of different water strata, according to their geographical distribution, their depths, their temperature, salinity, gas-contents, plankton and currents,
>
> In order to find the fundamental principles not only for the determination of the external conditions of the useful marine animals, but also for weather forecasts for extended periods in the interests of agriculture ….
>
> It is desirable that the observations should be made as far as possible simultaneously in the four typical months, February, May, August and November, at definite points along the same determined lines (Conférence Internationale pour l'Exploration de la Mer Réunie à Stockholm, 1899)."

In addition to extensive research-vessel activities, the "Ships of Opportunity" programme designed and coordinated by ICES produced valuable data from samples of surface water taken by commercial steamships while under way; ICES published temperature and salinity data from these samples every three months. This programme continued into the 1970s; from the 1960s, additional data were provided by the Ocean Weather Ship programme, which was strongly supported by ICES.

On the biological side, the information flow to marine scientists was considerably boosted by Sir Alister Hardy's invention of the Continuous Plankton Recorder, which he described in a paper (Hardy, 1936) presented to the ICES Special Plankton Meeting in 1935. At that stage Hardy's experiments in the North Sea had been running for three years, using an improved version of his original CPR, which had been given its first trials in the Antarctic in 1925.

By the 1950s and 1960s the hydrographers, no less than their fisheries colleagues, were also breaking new ground in the scientific quantification of marine phenomena. Reflecting advances in mathematical modelling, along with increased understanding of physical and chemical processes and improved technology, ICES organised and coordinated several international hydrographic programmes.

As a contribution to the International Geophysical Year, the Polar Front Survey 1957–1958 was carried out under the aegis of ICES, co-sponsored by ICNAF. The results were published by ICES in 1969 as the "Atlas of the Hydrography of the Northern North Atlantic Ocean", compiled by Gunther Dietrich, Kiel (Figure 6).

In 1960, as a corollary to the Polar Front Survey, OVERFLOW 60 mapped and quantified the overspill of cold, sub-arctic deep water from the Norwegian Sea into the North Atlantic, in order to investigate how the North Atlantic gets its supply of nutrients. This is a vital issue in regard to the ultimate sustainability of resources, which is now—almost 40 years later—high on the list of political priorities. Planned and managed by ICES, OVERFLOW 60 has been described as perhaps the most intensive multi-ship scientific exercise ever undertaken (Figure 7).

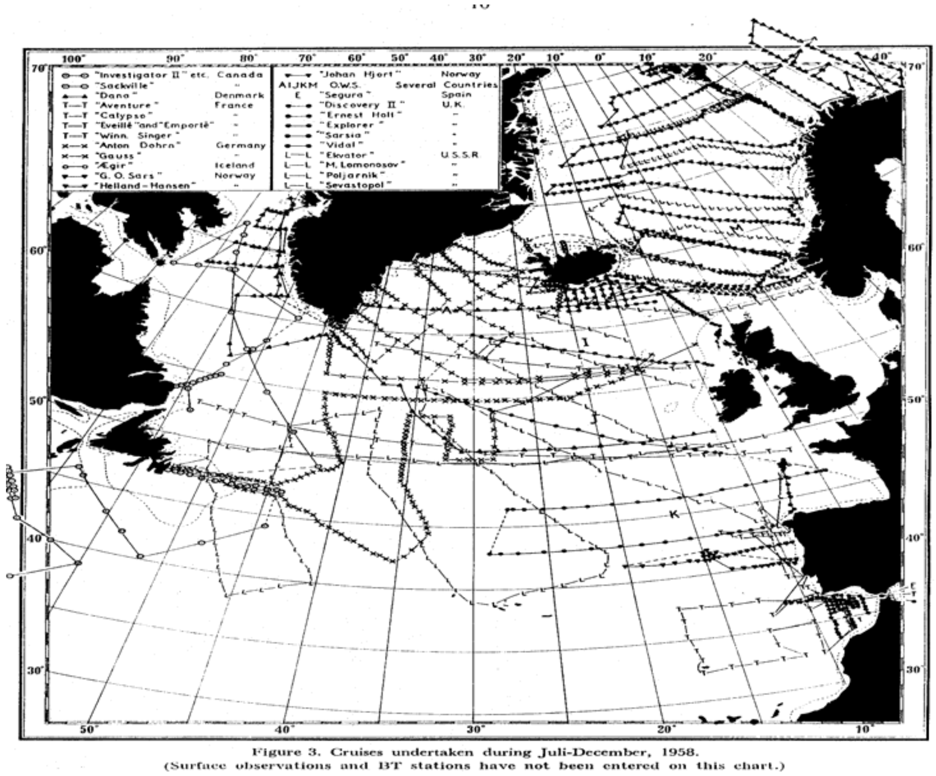


Figure 6. International Geophysical Year Polar Front Survey, 1957–1958.

Technological advances through the 1960s and 1970s saw the development of modern recording current meters (RCMs) and conductivity/temperature/depth equipment (CTDs).

Thus OVERFLOW 60 was followed up by OVERFLOW 73 using the improved equipment, which had become available by that time. Three years later, in 1976, ICES organised JONSDAP, the first coordinated international hydrographic survey of the North Sea. A component of the JONSDAP programme included the deployment of 400 RCMs in a 100-km square (10 000 km^2) in the North Sea over a three-month period in 1976, to complement the work of the modellers. The data from that experiment are still producing valuable information.

Ambitious and successful international projects continued to be carried out under the ICES flag throughout the 1970s and 1980s, such as PEX (the Patchiness Experiment) and NANSEN (North Atlantic and Norwegian Sea Exchange). The SKAGEX programme (Skagerrak Experiment) of 1990 may turn out to be the last in this notable 40-year programme of international ICES hydrographic survey work. Figure 8 shows the 21,266 data points in the ICES oceanographic database for 1990 (all stations, including SKAGEX). Constraints in national research budgets, exacerbated by increasing costs, have contributed to reduced availability of the necessary ship-time. The resurgence of international global programmes such as JGOFS (Joint Global Ocean Flux Study), WOCE (World Ocean Circulation Experiment), and GLOBEC (Global Ocean Ecosystem Dynamics Programme) have also increased the competition for financial resources. Consequently there is a view that we are unlikely to see exclusively ICES-organised international hydrographical investigations on the scale of those carried out during previous decades.

The general revival of a more holistic orientation within ICES in recent years was already being spearheaded in the hydrography area during the late 1970s. In 1979 the outgoing Chair of the Hydrography Committee, Harry Hill, drew attention to:

- the growing trend (in the Hydrography Committee) away from a predominantly North Sea focus towards a broader consideration of problems over a wider area, including the deep ocean and across the Atlantic from the Arctic to the Antarctic;
- broader coverage of the scientific disciplines, through meteorology, remote sensing, air–sea interaction, the physics and chemistry of water and sediments, the effects of studies in these areas on biological processes and on fish egg, larval and adult fish distributions;
- improved integration within ICES, as demonstrated by the joint session that year between the Marine Environmental Quality Committee and the Hydrography Committee.

"Overall", Harry Hill concluded, "in this (1979) meeting we seem to have achieved a much broader presentation of problems across geographical areas and across scientific disciplines, such that we may be able to appreciate, learn from, and exchange ideas, techniques and information across a broad geographical and scientific spectrum". (ICES, 1980).

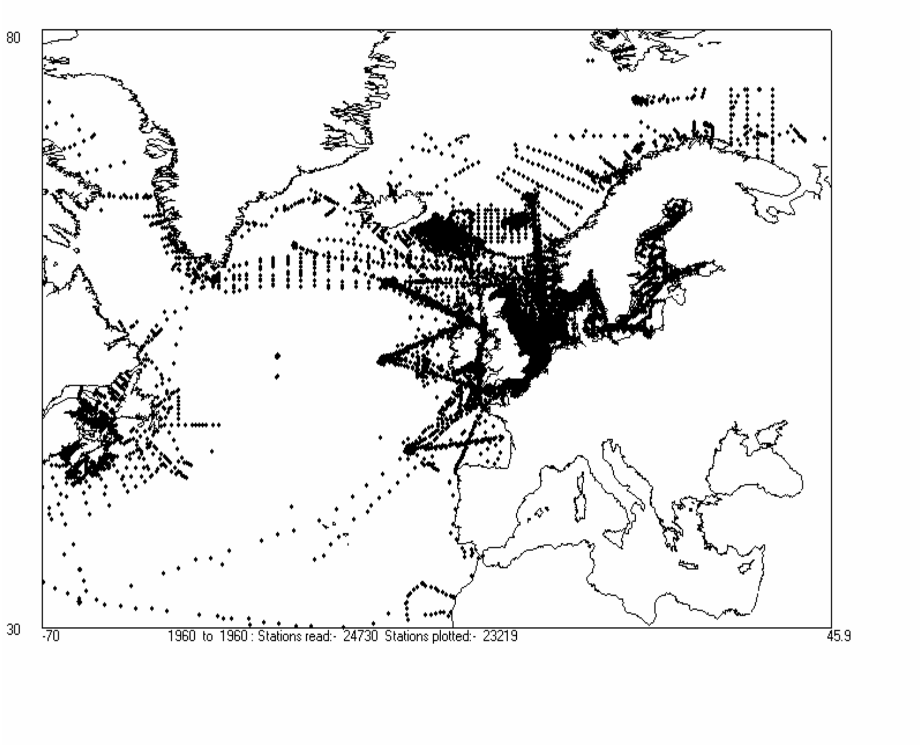


Figure 7. ICES oceanographic database: data points for 1960. Total number of stations: 23 219.

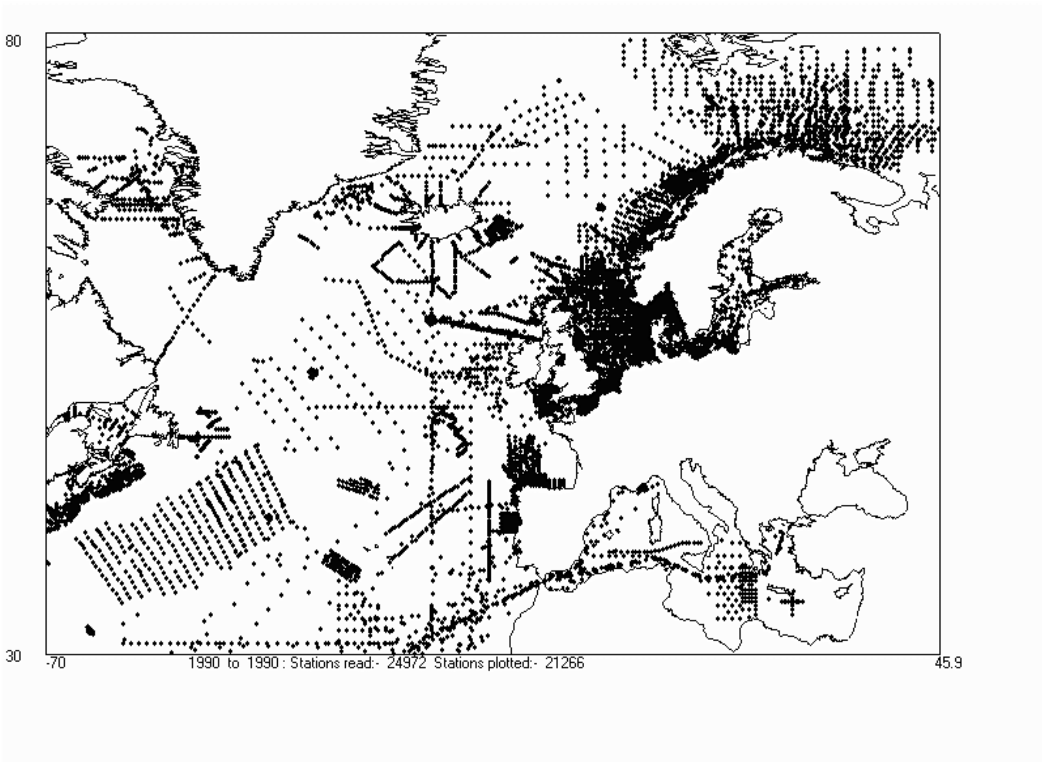


Figure 8. ICES oceanographic database: data points for 1990. Total number of stations: 21 266.

Marine environment

The 1970s were undoubtedly the Decade of the Environment. The idea that contaminants could accumulate in fish was a novel one when global awareness was suddenly alerted by the discovery, during the 1960s, of concentrations of mercury in tuna and swordfish. Also during the 1960s, widespread publicity was given to the serious neurological disorders observed in a localised, fish-eating, human population in Minamata, Japan, whose main food source had been exposed to 30 years of chronic methyl mercury pollution from a nearby industrial waste discharge to the sea.

While these matters made newspaper headlines around the world, growing awareness and concern about marine contaminants in the North Atlantic led ICES to establish the Fisheries Improvement Committee (whose remit included marine pollution issues) in 1967. It became the Marine Environment Quality Committee in 1978.

The ICES Working Group on Pollution of the North Sea was first convened in 1968, and the ICES/SCOR Working Group on Pollution of the Baltic was established a year later. In 1972 ICES commenced the programme on baseline studies in the North Sea to look at trace contaminants in fish and shellfish. This groundbreaking ICES initiative was the foundation of international marine pollution investigations, and in 1975 it was expanded to include the Northwest Atlantic, Northeast Atlantic, and the Baltic in a cooperative programme.

By a process akin to parallel evolution, growing concern in the scientific and political sectors about contaminants in the marine environment (including oil pollution and the dumping of industrial waste at sea) led to the convening, in Stockholm in 1972, of the UN Conference on the Human Environment, and the adoption of a range of international Conventions throughout the early 1970s:

Oslo	1972	OSCOM	Later merged as OSPARCOM, subsequently (1992) OSPAR
Paris	1974	PARCOM	
Helsinki	1974	HELCOM	
London	1972	LDC	London Dumping Convention (now London Convention)
Paris	1974	MARPOL	Oil and other pollution from ships

ICES has formal advisory links only with OSPAR and HELCOM.

In order to provide advice on environmental issues, but with particular regard to marine pollution *vis-à-vis* the formal provision of scientific advice to the newly created Oslo Commission, ICES established the Advisory Committee on Marine Pollution (ACMP) in 1973. In 1992, ICES changed the ACMP structure and altered its title to ACME—the Advisory Committee on the Marine Environment.

By the early 1990s, the ICES emphasis on the pollution aspects of environmental matters was rapidly shifting to broader ecological concerns, such as ecosystem effects of fishing activities. Where such matters had been addressed in the past, the approach had tended to be in the opposite direction: the impact of pollution (or sand and gravel extraction) on fisheries, for example.

ICES has provided the essential scientific input for international reviews of the quality of the marine environment, particularly in the Baltic and in the North Sea. The first ("Preliminary") Baltic Assessment was made in 1980, since when four more have been undertaken.

In 1987, as an outcome of the Ministerial Declaration of the Second International Conference on the Protection of the North Sea, an intergovernmental North Sea Task Force was established, to act under the co-sponsorship of OSPARCOM and ICES and with the following terms of reference:

> "to carry out work leading, in a reasonable time scale, to a dependable and comprehensive statement of circulation patterns, inputs and dispersion of contaminants, ecological conditions and effects of human activities in the North Sea. (North Sea Task Force, 1993)."

The North Sea Quality Status Report (QSR) was published in 1993.

At OSPAR's request, ICES will peer review the holistic QSR 2000, which covers the whole Northeast Atlantic. The regional assessments on which QSR 2000 will be based are nearing completion, under the aegis of OSPAR (ICES, 2000).

In 1971, ICES commenced the development of a Code of Practice on the Introductions and Transfers of Marine Organisms. The first version was adopted in 1973, followed by a revision in 1979. An updated version, taking account of new developments, appeared in 1994 (ICES, 1995b).

Summary of evolutionary progress

In Table 1, I summarise what I consider to have been the main evolutionary highlights since the foundation of ICES in 1902. I have split up the century into calendar decades, which may blur some of the underlying trends, but I believe it is a time-scale which is generally suitable for the purpose.

As I suggested above, the early years of ICES were characterised by a holistic approach to marine science, even though there was an overt fisheries orientation to the ICES programme. I have therefore applied the term *1st Holistic era* to the years 1902 to 1919.

During the 1920s and 1930s much diversification took place. The flowering of new ideas during this period achieved significant advances in knowledge, although it stretched the ICES system to the point where the science disciplines tended to lose contact with one another. By 1950 the Council realised that the situation needed to be tackled, and a wholesale reorganisation of the committee structure ensued in order to bring ICES scientists closer together. I call this 1920–1959 period the *Growth and Specialisation era.*

The 1960s and 1970s represented the *Quantification era*, in which developments across the fisheries and environmental areas of ICES moved, broadly speaking, from a predominantly qualitative mode into a generally quantitative one.

The Hydrography Committee showed the way in the late 1970s, and in the 1980s and 1990s ICES re-ordered its internal arrangements to effectively remove the barriers to interdisciplinary deliberations. The development of Theme Sessions in the early 1980s got off to a rather slow start (the scope of the first ones was not much broader than the committee sessions they were designed to replace), but in recent years we have been much more successful in setting up Theme Sessions which have a much higher and therefore healthier diversity index. That improvement, together with the new committee structure, demonstrates that ICES—at the end of its first century—has returned to the holistic approach which was such a dominant feature at its beginning.

Thus at the end of the 20th century in general terms, or at the culmination of the 1st century for ICES, we find ourselves in the *2nd Holistic era*. We see a genuinely cross-discipline committee structure, scientific emphasis on ecosystem interactions and the precautionary approach, the inclusion of human ecology as represented by fisheries economics and sociological considerations, and the central involvement of ICES in the assessment of marine environmental quality.

Long may this latest evolutionary trend continue, spanning and uniting marine science disciplines so that the whole is greater than the sum of its parts. May ICES flourish during its second century as auspiciously as it has during its first.

Table 1. ICES evolutionary markers, arranged by decade. Notional "eras" indicated.

<table>
<tr><td rowspan="2">1st Holistic era</td><td>1902–1909</td><td>Overfishing concerns. Hydrographic conditions in relation to fisheries.
Migration thinking on fisheries fluctuations re-examined.
Innovative equipment developed at Central Laboratory.
Standard Seawater production commenced.
Knudsen's Tables of physical constants of seawater.</td></tr>
<tr><td>1910–1919</td><td>Overfishing concerns continue: various programmes.
Fisheries fluctuations: Paradigm shift from migration thinking to population thinking; Hjort's paper, 1914.</td></tr>
<tr><td rowspan="4">Growth and Specialisation era</td><td>1920–1929</td><td>Overfishing: ICES continues to recommend conservation measures.
Resolution of herring scale reading controversy.
Mesh selectivity investigations intensify.</td></tr>
<tr><td>1930–1939</td><td>E. S. Russell, M. Graham develop population thinking: Fishing Theory.
Johan Hjort et al.: Optimum fishing.
First application of echosounders in fisheries science.
Hardy's Continuous Plankton Recorder.</td></tr>
<tr><td>1940–1949</td><td>Comparative fishing: the search for equivalence.
Further development of Fishing Theory, principally by Beverton and Holt.
Cod, herring shoals monitored by echosounder and ASDIC.</td></tr>
<tr><td>1950–1959</td><td>Importance of Comparative Fishing continues (new Committee).
Beverton and Holt "On the Dynamics of Exploited Fish Populations".</td></tr>
<tr><td rowspan="2">Quantification era</td><td>1960–1969</td><td>Quantification (hydrography, fish stocks). VPA. Stock Assessment WGs.
Increasing use of echosounders for measuring fish stock abundance.</td></tr>
<tr><td>1970–1979</td><td>The environment.
Biological, physical, chemical quantification continues.
Mariculture Committee. Code of Practice on Introductions.</td></tr>
<tr><td rowspan="2">2nd Holistic era</td><td>1980–1989</td><td>Multispecies approach; first Year of the Stomach.
Dialogue meetings start. Theme Sessions organised.
Environmental stocktaking commences; Baltic Assessment.</td></tr>
<tr><td>1990–1999</td><td>Further maturation through holistic developments:
Study of fisheries/environment interactions,
Precautionary Approach, Fisheries Economics.
Environmental stocktaking continues: Assessments and QSRs.</td></tr>
</table>

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ICES and the problem of overfishing

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Introduction

The fear of overfishing was one of the reasons for establishing ICES. As time has passed, other problems have come and gone but the problem of overfishing has persisted within the organization for one hundred years and shows little sign of disappearing. However, a few years before the foundation of ICES there was a firm belief that the living resources of the seas were inexhaustible, as so clearly expressed by one of the leading naturalists of that time, T. H. Huxley (1884): "Cod live in a layer of 120–180 feet thick off the Lofoten Islands and they live one yard apart, so there are twelve hundred million cod below one square mile. The area is much more than one square mile and the total catch is only 300 millions". And he continues: "Facts of this kind seem to me to justify the belief that the take of all the cod and herring fisheries put together does not amount to 5% of the total number of the fish. I believe then that the cod fishery, the herring fishery, the pilchard fishery, the mackerel fishery and probably all the great fisheries are inexhaustible. That is to say that nothing we do seriously affects the numbers of the fish."

Although we find this statement short-sighted today we should remember that the author probably had the very primitive sailing smacks in mind, which were the most advanced fishing vessels at that time (Figure 1).

Fluctuations in landings of marine fish were in the past as they are today characteristic of most fisheries, causing severe economic problems in coastal communities. These fluctuations in yield gave rise to the theory of migrations, which were supposed to be of great extent. Little was known as to where the fish were to be found during a considerable part of the year, and a plausible explanation for failure of the fisheries was furnished by the suggestion that the fish in such poor years neglected wholly or in part to visit the usual grounds. Thus the belief was that fishing had nothing to do with fluctuations in the fisheries, and varying migrational patterns were the cause.

With the expansion in the trawler fleet and the introduction of steam power the efficiency of the fishing fleet was rapidly changing towards the end of the 19th century, and many thinking scientists were changing their views. In fact some were satisfied that overfishing was actually taking place already about one hundred years ago. Bearing this in mind we should not be surprised to learn that among the first committees formed by ICES were Committee A, the Committee on Migration of Food Fishes, and Committee B, the Committee on Overfishing.

Before going any further I think it is necessary to reflect on what we mean by overfishing. It is usual to draw a distinction between two types of problem, i.e., recruitment overfishing and growth overfishing. By recruitment overfishing we mean that the mature fish have been reduced to such an extent by fishing that the production of eggs and larvae by the spawning stock has been so reduced that the strength of the incoming year classes is affected; that is to say, the recruitment declines as the spawning stock is reduced. By growth overfishing we mean that the weight of the catch is reduced because fish are caught before they have had a chance to grow and put on weight.

The most dramatic example of recruitment overfishing shown by any major fish stock is that of the Atlanto-Scandian herring, which is potentially the most abundant herring stock in the world. As shown in Figure 2 (ICES, 2000), it collapsed in the late 1960s and did not recover until 25 years later. The so-called demersal fish such as cod, haddock, plaice, and many others increase in weight as much as ten times during their adult lives, and the stocks are therefore vulnerable to growth overfishing as a consequence (Figure 3). But because of their great fertility they tend to resist recruitment overfishing. It is of interest to note that this distinction between the two types of overfishing is not new, because as early as 1903 the Danish marine biologist Johannes Petersen (1903) made a similar distinction.

Considering the vast fishing power of the modern fishing fleet with high-tech electronic equipment in navigational and fish-finding aids as well as very efficient fishing gear we find it easy to understand that no fish stock in the world can withstand the impact of this type of fishing fleet (Figures 4 and 5). When on the other hand reflecting on the fishing fleet at the beginning of this century (Figure 6)—a fleet with no fish-finding equipment, very few navigational aids, small steam engines, and correspondingly small trawls—we ask the question whether the fear of overfishing at that time was substantiated. The fear was probably closely connected with the change from passive fishing gear like hooks or setnets to acting gear like the trawl, which is actively dragged along the bottom of the sea.

The first Chair of the Overfishing Committee was Walter Garstang (Figure 7). As a young British scientist working at Lowestoft he was one of the very first to use average annual catch per unit of effort as an index of stock before the turn of the century. For example, he estimated (Garstang, 1900) that the fishing power of the Grimby fleet had more than doubled during the period 1889 to 1898,

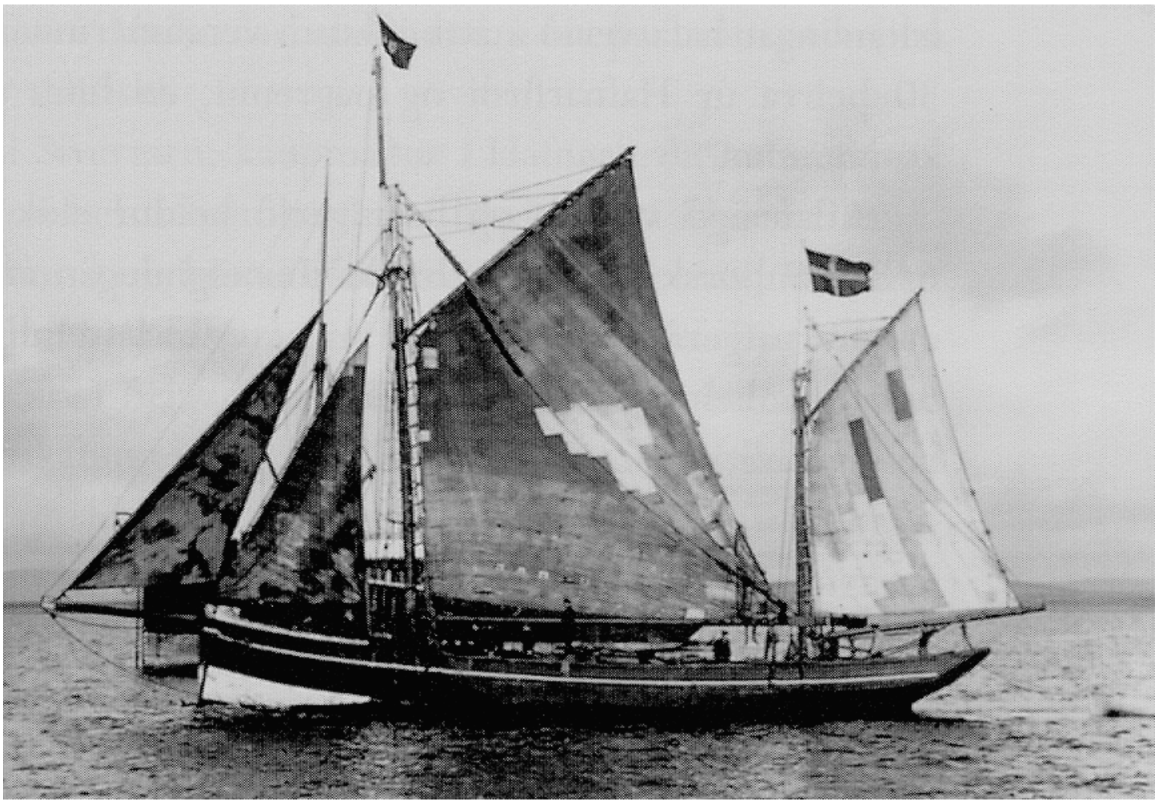

Figure 1. Fishing smacks like this were the mainstay of the North Sea fishing fleet during the latter half of the 19th century. (J. Th. Thor, 1997).

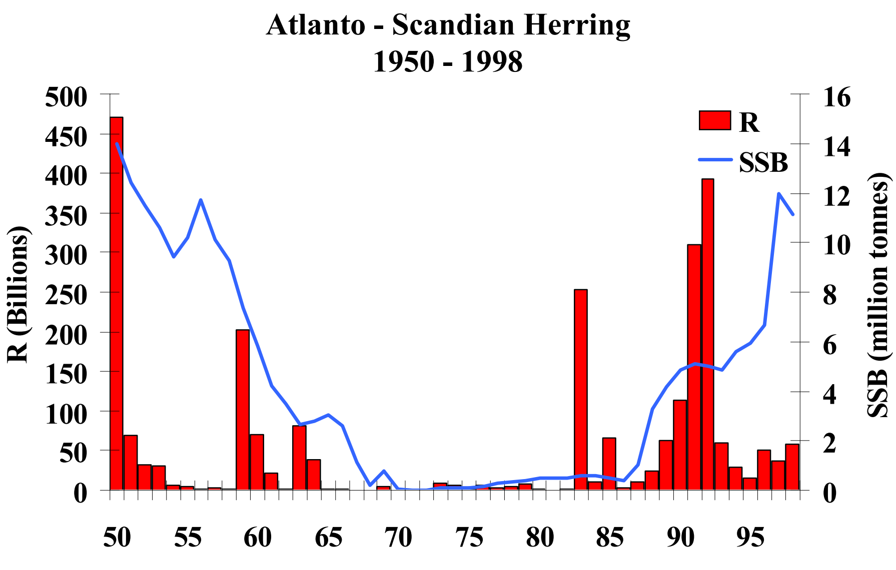

Figure 2. Stock abundance and recruitment of the Atlanto-Scandian herring, 1950–1998 (ICES, 2000).

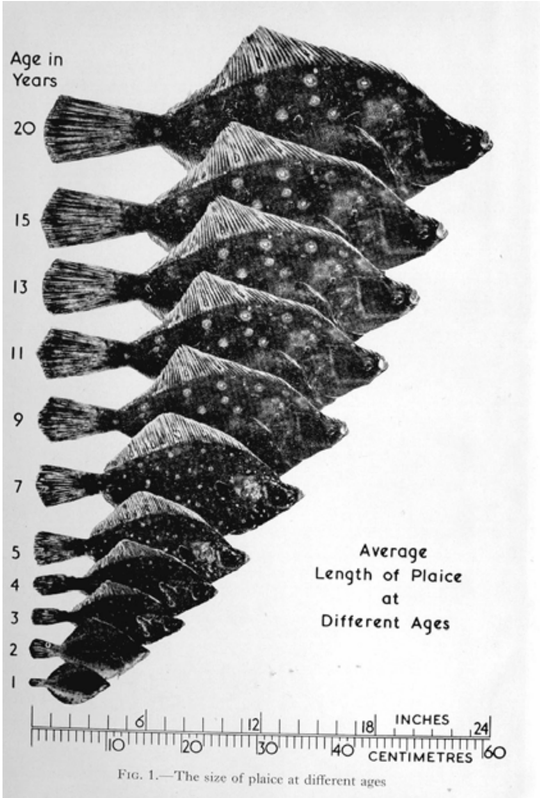

Figure 3. Average length of plaice at different ages (Wimpenny, 1953).

Figure 4. A modern trawler. (Photo by G. Thordarson, Reykjavík).

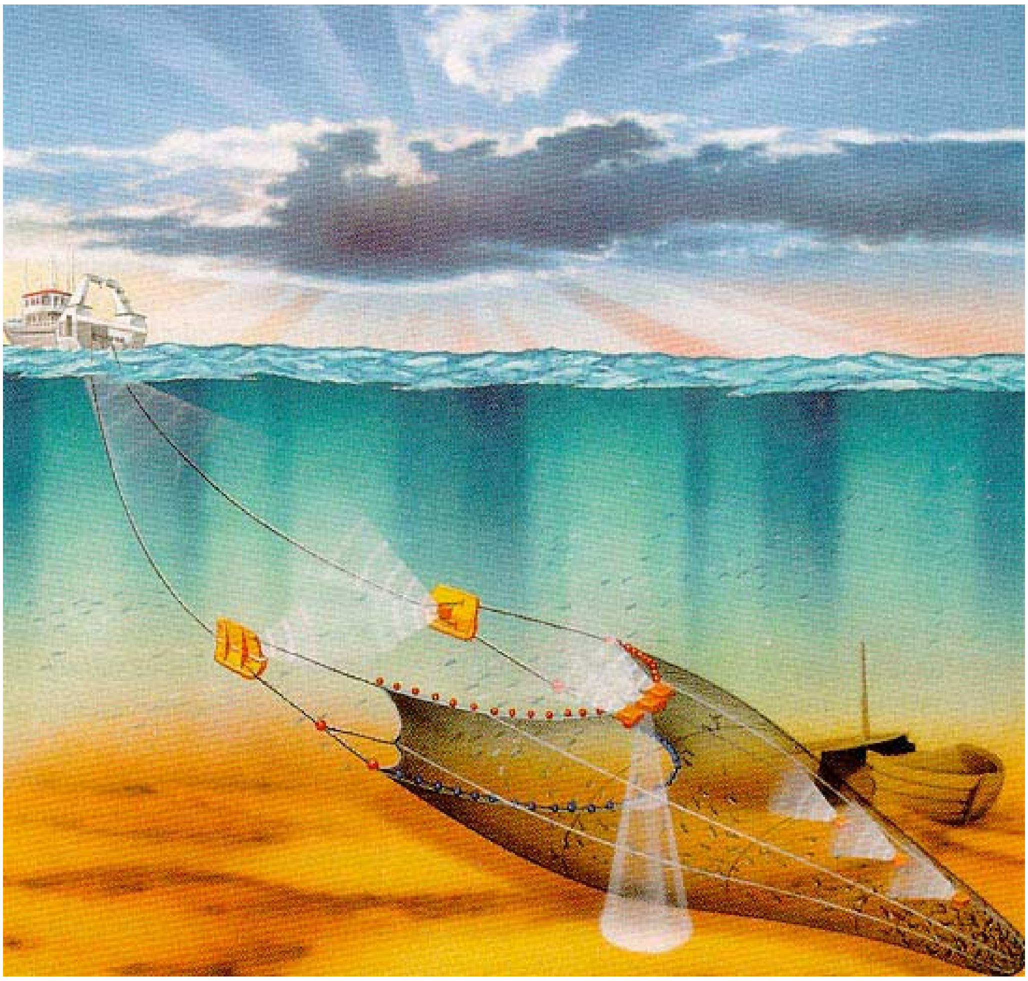

Figure 5. High-technology electronic devices are used to monitor the behaviour of the fish in relation to the fishing gear. (Drawing by S. A. Kárason, Reykjavík).

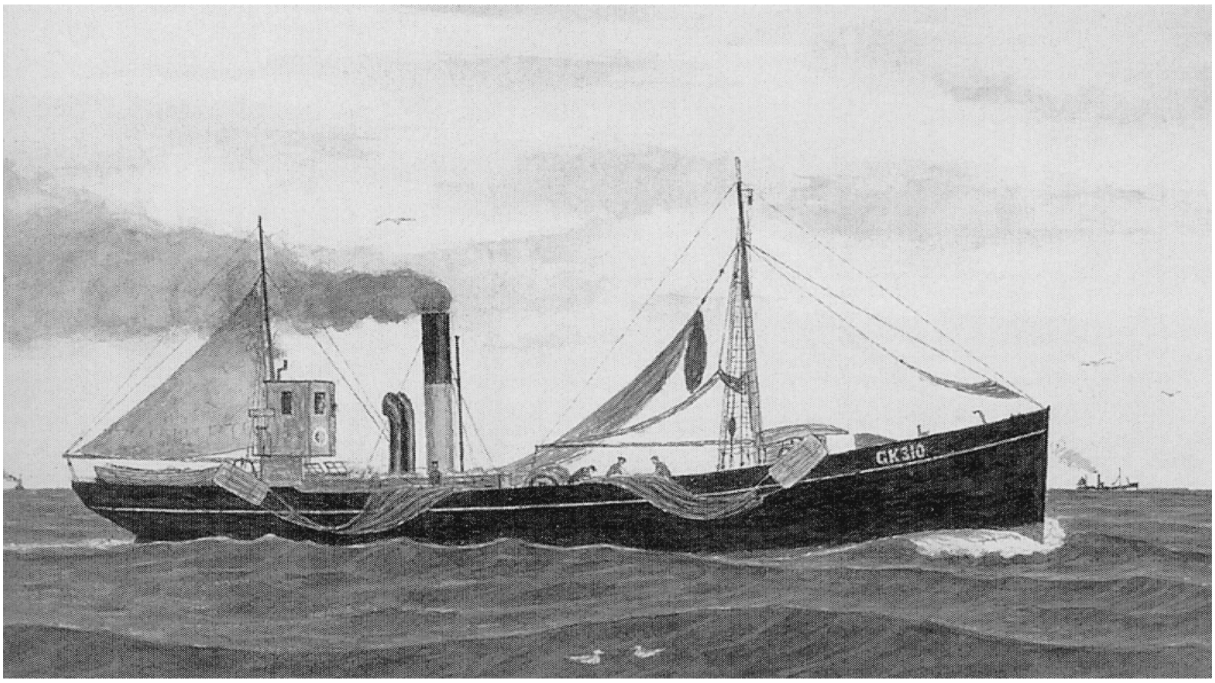

Figure 6. The first Icelandic steam trawler, 1905. (Drawing by Bjarni Saemundsson; J. Th. Thor, 1997).

and taking the catch per unit of fishing effort as indicative of stock density, the trawled fish was reduced to nearly half in the last decade of the 19th century as steam trawlers began to dominate in the fishery (Figure 8).

The "Plaice Problem" and ICES

The Overfishing Committee initiated the collection of catch statistics and market measurements. Since fishery for plaice was the main concern in relation to overfishing the committee concentrated its effort on the plaice fishery in the North Sea, and accordingly its name was changed to "The Plaice Committee". Collecting market measurements of the landings was one thing. Working up the data was another even more time-consuming task in those days when data processing had to be done entirely by hand. This was further complicated because the methods used to collect the statistics in each country were all different and therefore combining them in order to get an overall picture was a difficult and slow process.

Research-vessel trawl surveys were organized. Combining the data from several research vessels proved to be very difficult because the research vessels available at that time were very different in size and power and construction, and all used different nets. It was considered too expensive to fit them out with a standard gear. Despite these differences valuable information was obtained, such as that collected on the distribution of the various size groups (Figure 9).

Large-scale marking of plaice was organized using the new Petersen discs initially made from cattle bone and held together by silver wire (Figure 10). No fewer than 69 000 plaice were tagged before the outbreak of the First World War (Jakobsson, 1970). The results of the large-scale tagging of plaice illustrated the migration pattern of the North Sea plaice to and from the spawning grounds, nursery grounds, and feeding areas. But the tagging experiments revealed more than that. Recalling Huxley's (1884) argument for the inexhaustibility of the sea as depending on fish catches being only a very small fraction of the total number of fish in the sea: if this were true, correspondingly only a small fraction of the tagged fish could be expected to be caught by the fishermen. But this was certainly not the case because the fishermen returned more than 30% of the tagged or marked fish already within the first year of liberation.

Walter Garstang had to leave the Plaice Committee in 1908 owing to a change in his career. His successor was Friedrich Heincke (Figure 11), Director of the Marine Biological Station in Helgoland and the father of the theory of herring stocks. Based on these tagging experiments, Heincke (1913) concluded in an extensive and brilliant report that the plaice suffered an annual mortality of 30–50%, and the decrease in large plaice and the increased proportion of small fish in the landings were direct results of intensive fishing. Heincke estimated that about 203 million plaice were landed annually and about 300 million small fish of 10–24 cm were uselessly destroyed and discarded. Of these 500 million, three-quarters of the numbers were under 25 cm and only 2% were over 35 cm and five years of age (Figure 3).

He also stated that the plaice fishery in the North Sea presented a picture not only of too intensive but also of imprudent fishing owing to the useless destruction of enormous quantities of young plaice. Based on Heincke's report (Heincke, 1913) the Plaice Committee recommended that a minimum landing size limit of 20 cm, rising to 22 cm from April to September, should be introduced as a first step. This was accepted by the Council, and subsequently conveyed through the Danish Foreign Office to the governments concerned in 1913. Thus after intensive work for more than 10 years the very first fishery management recommendation of the Council was submitted to ICES Member Countries. However, the governments of the ICES countries could not agree, and the political and economic arguments began. They were cut short, in this case being interrupted in August 1914 by the outbreak of the First World War.

By the time of the Council Meeting in July 1921 the Plaice Committee had changed its policy and recommended a closed area to protect the young immature fish instead of a minimum landing size limit (Figure 12). It was also recommended that a review of these regulations be carried out three years after their inception. The Council accepted this proposal at its meeting in September 1922.

The President congratulated the Council upon the fact that at length they had reached a definite conclusion on this basic subject, which had taken so much of their time and attention during the preceding 20 years. Professor Johan Hjort said that there was a general feeling in the Bureau that a few words of congratulation should be addressed to the Plaice Committee, which he proceeded to do, recording his thanks to those who had contributed most to the work, including Walter Garstang, Friedrich Heincke, Johannes Petersen and the President, Henry Maurice. The proposal was then channelled through the Danish Foreign Office to the member states. The Belgian, Danish, French, Swedish, and Dutch governments were in favour of an international convention on the closure in nearshore waters to protect the small plaice, while the answer from the British government was delayed for four years. It must have been a painful duty for the President, Henry Maurice (Figure 13), who also was a British Delegate, when he had to read a statement at the September 1926 meeting from the British authorities vetoing any closure of the sea. I say this because Maurice, who had been elected President in 1920 and remained in that office until 1938—or much longer than any other person—was an ardent fighter against overfishing and any misuse of the sea.

A few years later the plaice problem was at least partially solved through the development of the Danish seine fishery in the eastern North Sea using a large mesh size. This was backed by a Danish regulation setting a minimum landing size of 23 cm. At the same time the English trawl fleet retreated from the eastern nursery grounds to deeper waters where they caught older fish (Figure 9).

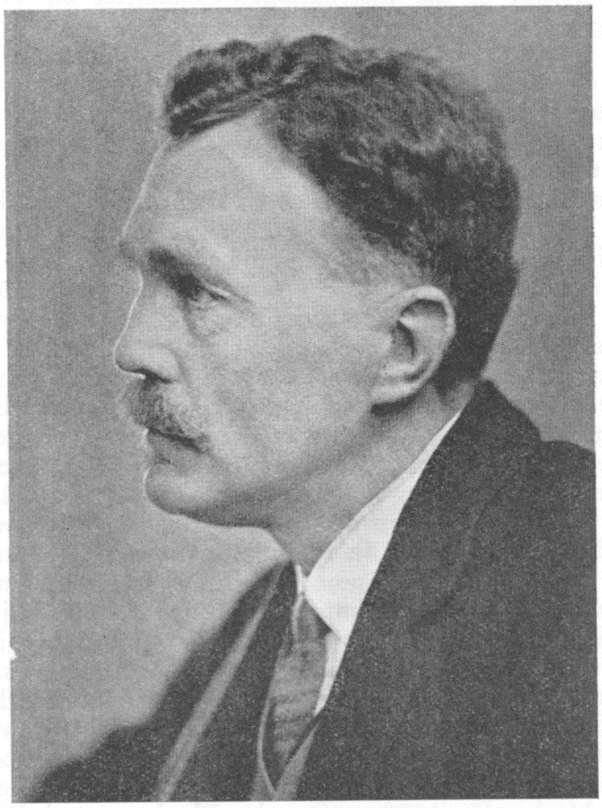

Figure 7. Walter Garstang, the first Chair of the ICES Overfishing Committee, 1902–1908. (Lee, 1992).

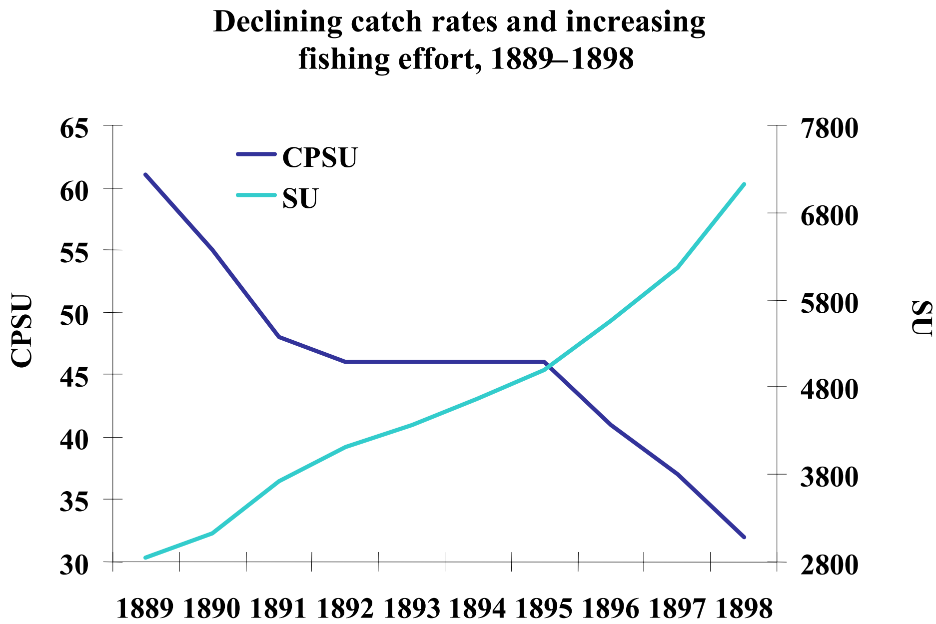

Figure 8. Catch rates and fishing effort, 1889–1898, calculated by Garstang (1900). SU:smack units, CPSU:catch per smack unit. (Redrawn from Smith, 1994).

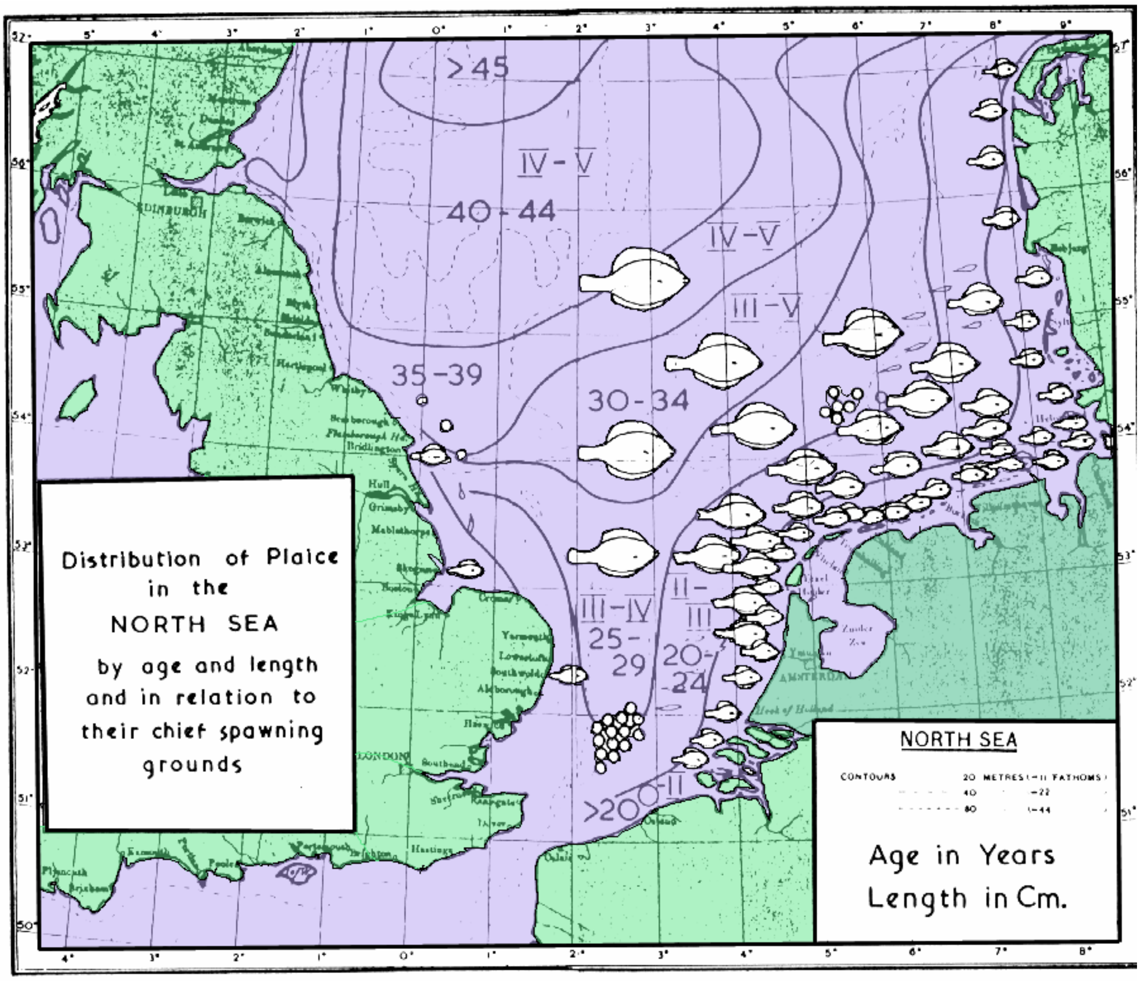

Figure 9. Size distribution of North Sea plaice (Wimpenny, 1953).

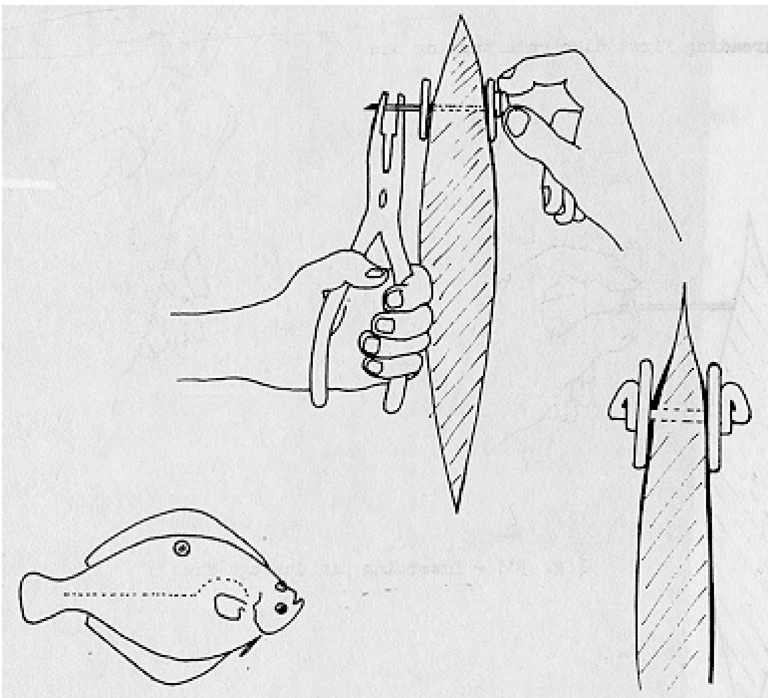

Figure 10. Attaching Petersen disc to flatfish (Jones, 1979).

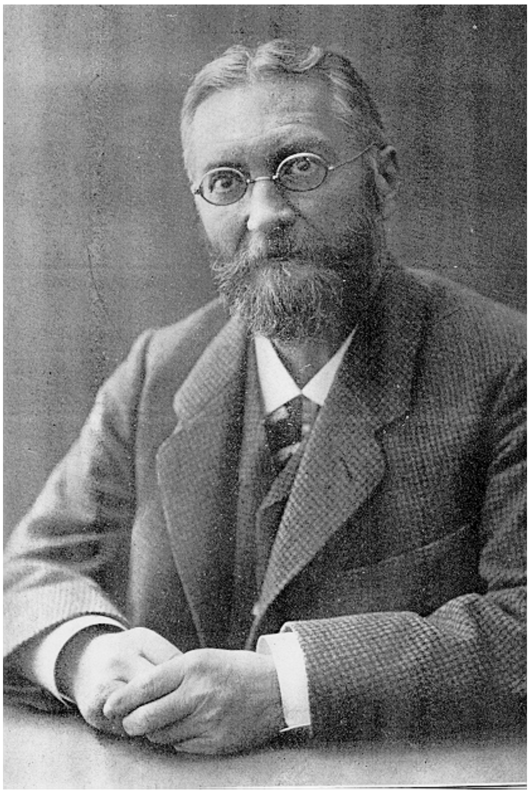

Figure 11. Friedrich Heincke, second Chair of the ICES Overfishing Committee, 1908–1913. (Photo from the Sea Fish Institute Hamburg).

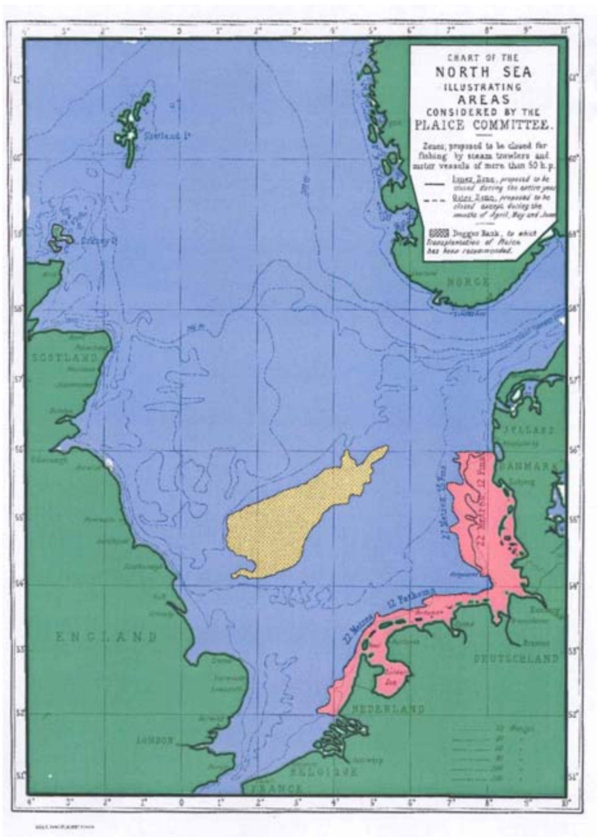

Figure 12. The proposed "Plaice Box" in 1922. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 27: 50–72.

Immediately after the Second World War minefields prevented excessive fishing on the nursery grounds and in 1987 they were partially closed to fishing with the introduction of a new "plaice box" when the 65-year-old idea of the ICES Plaice Committee was revived.

The Great Fishing Experiment

The First World War led to a great reduction in the fishing activity in the North Sea, often called "the Great Fishing Experiment". The effect of this was eloquently summarized by Basil Engholm (1961), English Fishery Secretary: "Up to the first world war it could reasonably have been argued that those who were advocating the necessity for taking action to conserve fish stocks were speaking largely on the basis of theory and conjecture. There was no proof at that time of the need to regulate fishing in the interests of the conservation of fish stocks but the war of 1914–1918 brought about a radical change in this position. The very substantial restriction in fishing, which inevitably occurred between 1914–1918, provided indisputable proof that in some of the more heavily fished areas such as the North Sea, the abundance of fish stocks had in fact been seriously depleted by the increasing fishing effort. After four years of greatly reduced fishing the fish had been able to survive and grow to such an extent that in 1919 the average landing per day's absence of an English trawler from the North Sea was 30,6 cwts compared with 14,3 cwts in 1913. In other words the landings had more than doubled." In addition the relative frequencies of the size categories of the plaice catches were reversed in 1919 compared with 1913 (Figure 14).

However, it was not long before fish stocks lost the benefit arising from the reduction in fishing effort during the First World War. Within a few years the fishing fleet had become more effective than ever and the catch rates were brought down to the pre-war level as shown so well in Figure 15 by Russell (1942).

Fluctuations in the fisheries

In 1904 the German scientist Friedrich Heincke presented at a meeting of the International Council in Amsterdam the results of investigations directed towards determining age in the case of cod and plaice based on a study of the bones of the fish. Norwegian marine biologists led by Johan Hjort (Figure 16) who had been working in a similar direction became interested, and this resulted in a revolutionary step forward in the investigation of the fisheries, that is, large-scale age determination of fish (Figure 17). Prior to this, various scientists had tried to divide fish into age groups according to lengths, usually resulting in dividing the catches into three or at the most four age groups. And as Johan Hjort (1914) put it in his classic work, "Fluctuations in the great fisheries of Northern Europe": "These measurements led me to suppose that the Finmark cod were fish of rapid growth, the stock consisting of only a few year classes. These results proved to be entirely wrong once the new technique of reading age from scales of cod and herring had been applied for a few years. This new technique revealed that the stock of cod and herring included a far greater number of year classes than had previously been supposed and that the relative numerical values of these year classes exhibited great fluctuations from year to year". Based on these findings Johan Hjort elucidated that fluctuations in fisheries were not only due to variation in migration or overfishing but were often due to great variation in the number of fish that entered the fishery from year to year, i.e., owing to variation in year-class strength (Figure 18). These results induced many fishery biologists to start programmes for monitoring the varying age distribution of landings of several important fish stocks. These age distributions were then used to predict future catches by monitoring the entrance of very strong or very poor year classes to the fishery. However, this had to be based primarily on relative strength of year classes within the age distribution, and this approach achieved moderate success for, e.g., the North Sea haddock and the East Anglian herring.

Mesh selection experiments

During the first 30 years of the 20th century it was a common belief within the fishing industry that the meshes of a trawl, including those of the codend, were pulled tight when the net was being towed, thus forming an impervious bag through which fish could not be released until the meshes opened up while the net was being hauled on board. Based on this view any increase in the mesh size would therefore be entirely useless as a means of sparing the lives of small fish. It is of interest to note in this connection that Otto Pettersson at a Council Meeting in 1909 compared the great advance being made in developing new instruments in hydrography while nothing was done in developing trawls to reduce their harmful effects on juvenile fish. He offered a prize of 2000 Danish kroner to those who found a solution to this problem.

Following this intervention, one of his countrymen, G. Ridderstad, constructed a trawl net with ridged or semi-rigid meshes (Ridderstad, 1915) in order to spare undersized fish. This was followed by the Dutch construction of the so-called Gelder codend, which was expanded by ridged frames. Neither of these saving gears, as they were called at the time, proved popular. However, the modern techniques of conveying unwanted size groups of fish out of the trawl are based on related ideas, i.e., devices made of metal grids inserted in the trawl.

ICES convened a meeting (symposium) in Copenhagen in June 1934 on the size limits for fish and regulations of the meshes of fishnets, which turned out to be a turning point for conservation methods in fisheries during the two or three decades that followed. At that meeting a British scientist (Davis, 1934) presented the results of very careful experimentation proving that fish were released through ordinary codends of 75 mm when the net was being towed (Figure 19). The results also strongly suggested that a mesh of about 85 or 90 mm was advantageous. ICES approved these findings and recom-

Figure 13. Henry G. Maurice, ICES President, 1920–1938, who was also a British Delegate.

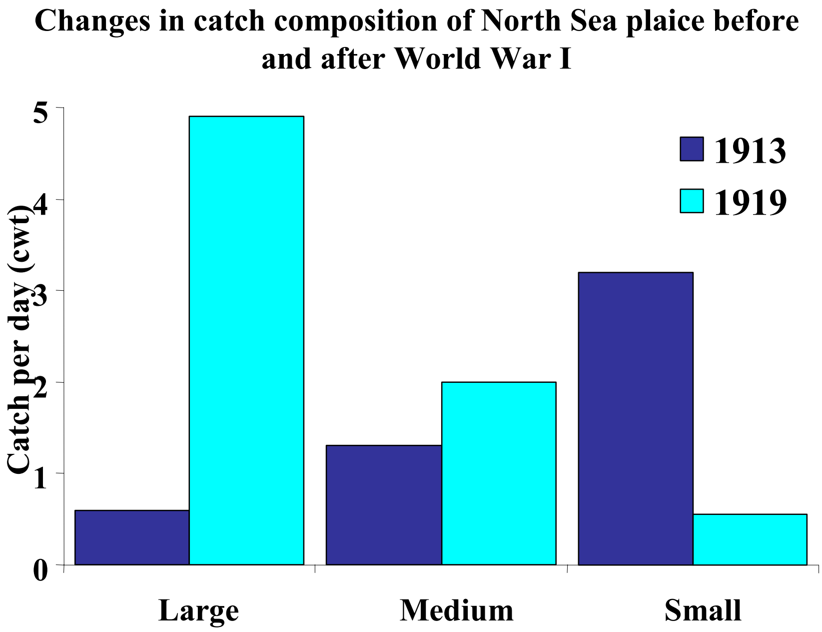

Figure 14. Changes in catch composition of North Sea plaice before and after World War I (Borley *et al.,* 1923).

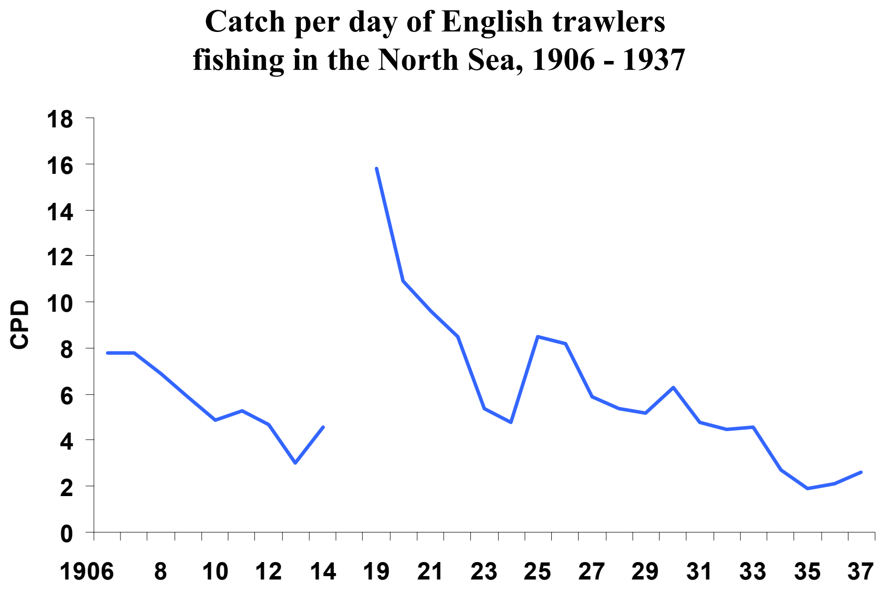

Figure 15. Catch per day of English trawls fishing in the North Sea, 1906–1937 (Russell, 1942).

Figure 16. Johan Hjort, first Chair of the Consultative Committee, 1925–1938, and ICES President, 1938–1948.

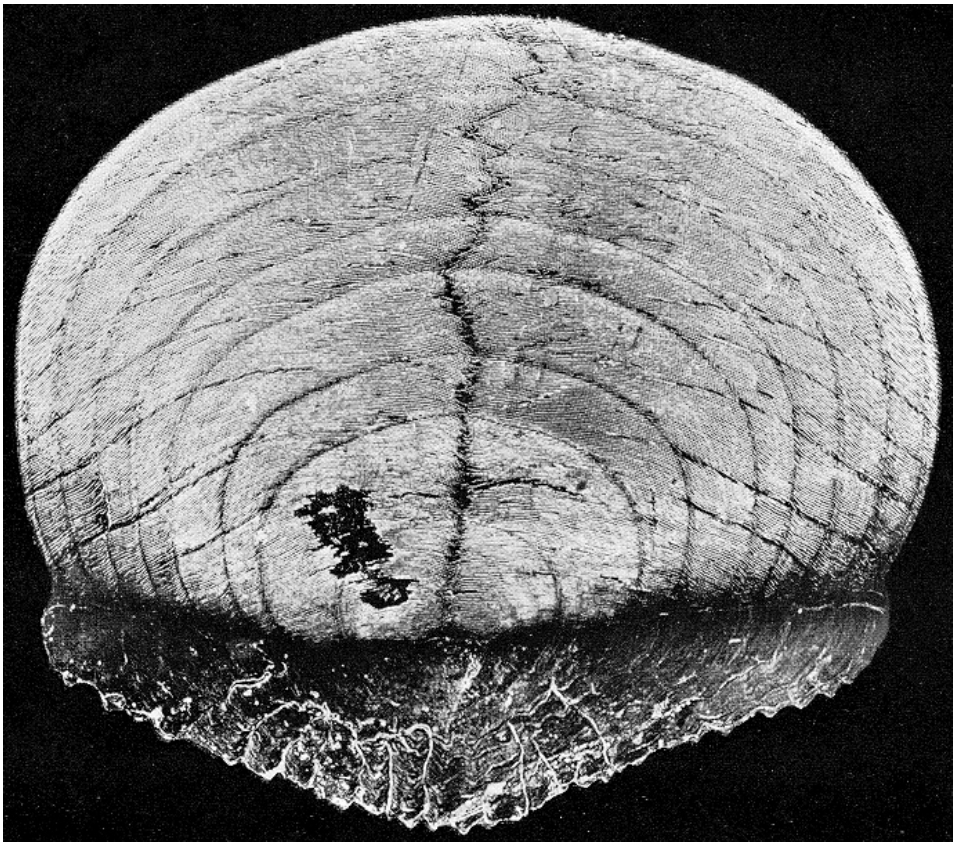

Figure 17. Herring scale with eight winter rings (Hjort, 1914).

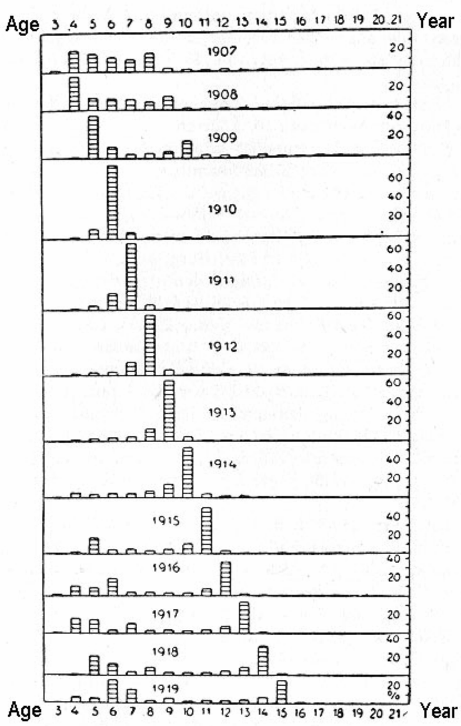

Figure 18. Age distribution of the Norwegian herring (Hjort, 1926).

mended the 75-mm mesh size as a minimum, recognizing that larger mesh were advantageous and were being implemented in the Arctic cod fisheries.

When President Henry Maurice was presenting the conclusion and the report of the special scientific biological meeting to the Council (Maurice, 1934) he said: "The report represents the considered opinion of the biological experts of the Council and as such I assume that you accept it without discussion. What is proposed is no hasty lead in the dark but a deliberated advance over territory already explored and mapped, an advance which can be made in the confidence that we can safely go so far and having consolidated our achievement, prepare for further exploration and a further well considered advance. I hope you will allow me as a President of the Council to give myself the pleasure of being the first to congratulate you on these conclusions and these recommendations to the participating governments. I confess that I take pride in the fact that the British government has been the first to take of its initiative the important step of endeavouring to promote true economy of fishing by regulation of the mesh of nets. In the matter of the imposition of size limit for fish others of you have led the way"[1]. And the President also stated: "And now the Council has reached the point at which it can with confidence make certain definite recommendation to the governments with a view to the maintenance of an adequate stock of food fishes in the sea and the most economical use of that stock. It need hardly be said that the occasion for such advice would not have arisen unless there were evidence not merely of wasteful fishing but of fishing so wasteful that it was beginning to have a detrimental effect upon the stock. Fishing has especially since the war increased in intensity and has been carried out by increasingly efficient ships and fishing gears. One result of this has been the destruction of increasingly large number of fish so small that they are either unmarketable or are marketable only at prices which are barely if at all remunerative."

Fisheries conservation conventions

Following the results of the mesh-selection experiments which clearly showed that it was possible through increased mesh size to prevent the destruction of the vast number of very small fish, ICES scientists under the leadership of Henry Maurice brought pressure on the governments especially around the North Sea to respond to these new findings. The result was a conference that was held in London in the autumn of 1936 and a meeting in March 1937 with Maurice in the chair. The objective was to reach international agreement on the mesh size to be used in the seas of western Europe and on minimum landing sizes of the most important species of whitefish. Although a convention was drawn up and signed by ten countries it was never ratified because of the outbreak of war in 1939. However, the International Conference on Overfishing was held in London in March 1946, and this conference not only discussed the regulation of mesh sizes but also possible methods of limiting the amount of fishing to be conducted at least in the North Sea. No agreement was reached on these latter issues and it is easy to see in retrospect why this was too much to hope for, because food shortages were still serious in many of the countries concerned. The conference did, however, result in the signing of the convention for the regulation of the meshes of fishnets and the minimum landing size of fish. The minimum mesh in the North Sea should be not less than 75 mm, while 110 was accepted for Iceland and other northern waters This convention came into effective operation in 1954. It included the foundation of the so-called Permanent Commission, which was to execute the decision of the conference and reconsider any new issue for fish conservation (Engholm, 1961).

The Permanent Commission decided to rely upon ICES to provide the international scientific advice, and as a result a Liaison Committee was set up by ICES, becoming in fact the forerunner to the present Advisory Committee on Fishery Management. The work of the Permanent Commission was later taken over by the North-East Atlantic Fisheries Commission in 1959. The statutes of its convention clearly stated that the commission was required to seek the scientific advice of ICES and its cooperation in carrying out any necessary investigation on the state of stocks. This consolidated the procedure adopted following the introduction of the 1946 convention.

ICES responded to the requests from these international conventions by establishing a great number of stock assessment working groups that were tailor-made to answer the different questions asked by the fisheries conventions. The assessments made by working groups were then channelled to the Liaison Committee until 1977; in 1978 the Advisory Committee for Fishery Management took over the task of the Liaison Committee. Following the results of the 1934 ICES conference on the effects of mesh selection, the main concern of the fisheries conventions immediately following the Second World War was seeking advice on varying mesh sizes of trawls and seines in the fisheries. International comparative fishing trials with different trawls and mesh sizes were therefore a very important part of the ICES advisory work during the first two decades after the Second World War. However, questions on the effects of other methods gradually crept in from the fisheries conventions, such as the effects of closed areas, closed seasons, and reduced effort. Therefore a great demand for a precise theoretical formulation of the effect of fishing on fish stocks was building up. Throughout the 1930s and 1940s, developing a mathematical formulation expressing the relation between stocks and fisheries was the objective of several fisheries scientists.

In 1931, E. S. Russell tried to explain the effect of natural growth increments and recruits versus natural mortality and catch, which he put into a simple equation as

[1] Here the President is referring to the 1929 convention on minimum landing size for plaice in the southwestern Baltic.

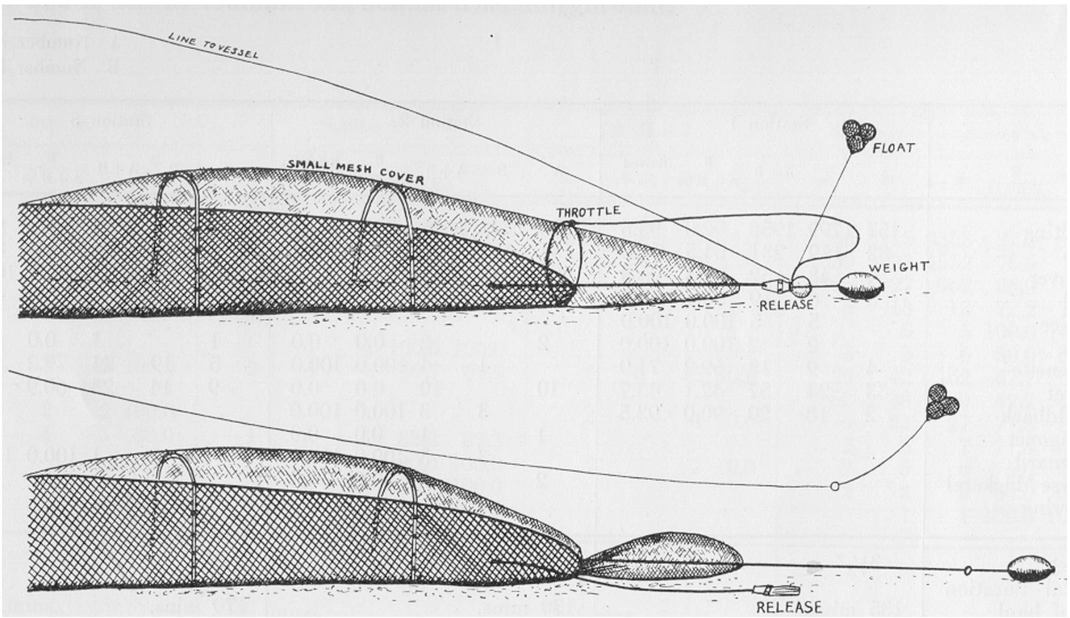

Figure 19. The mesh selection experiment (Davis, 1934).

The Russell Equation

Stock in equilibrium if

$$R + G = M + C$$

$$S_2 = S_1 + (R+G) - (M+C)$$

R = Recruitment
G = Individual growth
M = Natural mortality
C = Catch
S = Stock

Figure 20. The Russell Equation (Russell, 1931).

shown in Figure 20 (Russell, 1931). As another example, Michael Graham calculated in 1938 that the North Sea fishermen used a quarter of their time at sea to reduce their catch by 15% (Graham, 1938).

The breakthrough came when Beverton and Holt developed their yield equation at the beginning of the 1950s (Graham, 1952; Beverton and Holt, 1957). This famous equation is shown in Figure 21. If we insert both fisheries and biological data from a given fish stock into this equation we obtain a yield curve which for most fish stocks has the shape shown in Figure 22. Here we observe that if there is no fishing effort then there is no yield, but as we increase the fishing intensity the yield increases, at first very rapidly and then gradually slowing as we move to the right on the X-axis. With further intensity of fishing the yield does not increase but often decreases.

I am not going to explain how this mathematical equation was developed, but I propose to explain in a simplified way how the various points on this curve are calculated. This is shown in Table 1. We start with one thousand individuals at the age of one year and follow their destiny throughout the life cycle if we remove about 50% each year. In the other case we reduce the fishing effort and remove about 25% annually from the stock of one thousand fish throughout their lifespan. We see that in the first case the removals or the catch consists mainly of a large number of small fish while in the other case we get a much bigger percentage of older and heavier fish. There may not be a great difference in the yield, but there is a great difference in the fishing effort, with one case being less than half of what it took to catch all the small fish. There is also a great difference in the resulting spawning stock. The one resulting from the high exploitation rate is only a small fraction of the one resulting from removing about 25% each year. The yield curve and the present position of each fishery is now considered a necessary part of any stock assessment carried out by ICES. In fact it was considered so important that ICES asked the Lowestoft laboratory to organize certain courses in fish population dynamics, the first one of which was held in 1957.

Traditionally, ICES scientists have only attached weight of fish to the yield curve. However, by associating a certain price with the weight the "yield" curve illustrates a potential income from a fishery. This is shown in Figure 23. In addition the running cost of the fishery is assumed to be proportional to the fishing mortality coefficient F and is shown as a straight diagonal line. The profit is then indicated by the difference between the "yield" curve of income and the straight line of running cost. The so-called maximum economic rent of the resource is usually achieved at a fishing effort level a little less than the one giving the maximum yield (income). When the running cost exceeds the income, the fishermen demand subsidies to cover their loss. These are generally granted for "social reasons". Thus subsidies are the greatest and the most effective fuel that generates overfishing and are responsible for the collapse of many fish stocks and other wild marine populations.

Another important method of stock assessment was the innovation of the so-called virtual population or cohort analysis. This was introduced in the late 1960s by John Gulland and first applied in the ICES forum at a meeting of the North East Arctic Working Group in 1972. The basic requirement is to know the number of fish that are caught at each age in a given stock each year. An example is shown in Table 2. Following one year class we see how the fish enter the fishery at the age of 3 years and gradually the number increases as the year class is fully recruited and then drops off as the fish grow older and the number in the sea decreases. By adding the numbers caught each year and at the same time taking account of those fish that were not caught but died from disease or other natural causes we can calculate how many fish of that particular year class were in the sea each year (Pope, 1972). If this is done for all year classes in the stock then we can by summing up vertically get the number of fish at any given year in the past, and by applying the mean weight to each age group we get the abundance of the stock at any given time. It was with these two new tools, i.e., the yield equation and the method of virtual population analysis (VPA), that the Liaison Committee on behalf of ICES set out to assess the state of the stocks in the Northeast Atlantic. In addition, quantitative acoustic assessment methods were developed and used in the assessment of pelagic fish like herring. In the course of time since these methods were introduced they have been constantly improved. In recent years, assessment of uncertainties and risk analyses have become very important in the advisory function of ICES.

The objectives of conservation and ICES management advice

The purpose of conservation in fisheries was not only to benefit the fish but to benefit man. Unlike conservation in many other fields, fishery conservation was not aimed at preserving the rare species from extinction or at keeping the natural flora and fauna of a place from changing. Its purpose was quite simply to preserve both the productivity of the resources and the profitability of fishing for the fishermen of all countries. In other words the purpose of conservation in fisheries was usually said to be to enable fishermen to obtain from a stock of fish the highest possible yield consistent with that yield being maintained in future. This was what was usually called or became known as the "maximum sustainable yield".

Until the immediate post-war period it was thought that through regulating mesh sizes we would be able to achieve this objective.

Despite the increased mesh sizes it became clear during the 1950s and 1960s that the fishing power of the international fleet was being increased to such an extent that if it were not regulated in some way, fishing profitability and eventually total fish catches would inevitably decline. The first sign would be the same as that which was

Table 1. Two examples of yield per recruit calculations, one showing the results of removing 25% per year and the other when 50% are removed. The positions of these examples are shown as two vertical lines on the yield curve shown in Figure 22.

50%				**25%**			
Age	**N**	**Cn**	**Cw**	**Age**	**N**	**Cn**	**Cw**
1	1000	506	506	1	1000	250	249.5
2	368	186	372	2	595	148	296.7
3	135	68	205	3	353	88	264.6
4	50	25	101	4	210	52	209.7
5	18	9	46	5	125	31	155.9
6	6.7	3	20	6	74	19	111.2
7	2.5	1	9	7	44	11	77.1
8	0.9	0.5	5	8	26	7	65.5
9	0.3	0.2	2	9	16	4	42.8
Total catch		800	1266	Total catch		610	1473
SSB = 1503				**SSB = 4904**			

Table 2. Virtual population analyses are based on catch in number of each year class over its lifespan in the fishery. The 1983 year class in the Icelandic cod stock is taken as an example. The numbers are in millions.

Catch

Age	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
3	**21.0**	11.0	6.7	2.6	5.8	8.6
4	20.0	**62.0**	39.3	28.0	12.3	25.1
5	26.6	27.2	**55.9**	50.1	27.2	15.5
6	30.8	15.2	18.7	**31.5**	44.5	21.5
7	11.4	15.7	6.4	6.0	**17.0**	25.0
8	4.4	4.2	5.9	1.9	2.6	**6.4**

Stock abundance

Age	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
3	**335.0**	278.0	169.0	83.0	133.0	123.0
4	112.0	**256.0**	217.0	132.0	65.8	104.0
5	66.0	73.0	**154.0**	143.0	82.9	43.0
6	67.0	30.0	36.0	**76.0**	102.9	43.0
7	21.0	27.0	11.0	12.7	**34.0**	45.0
8	8.0	7.0	8.5	3.6	5.0	**13.0**

The Beverton and Holt yield equation

$$Y = FRe^{-M(t_{q'} - t_q)} W_{\infty} \sum \frac{\Omega_n e^{-nK(t_{q'} - t_0)}}{F + M + nK} \left(1 - e^{-(F+M+nK)\lambda}\right)$$

Figure 21. The Beverton and Holt yield equation. (Graham, 1952).

Yield per recruit and spawning stock

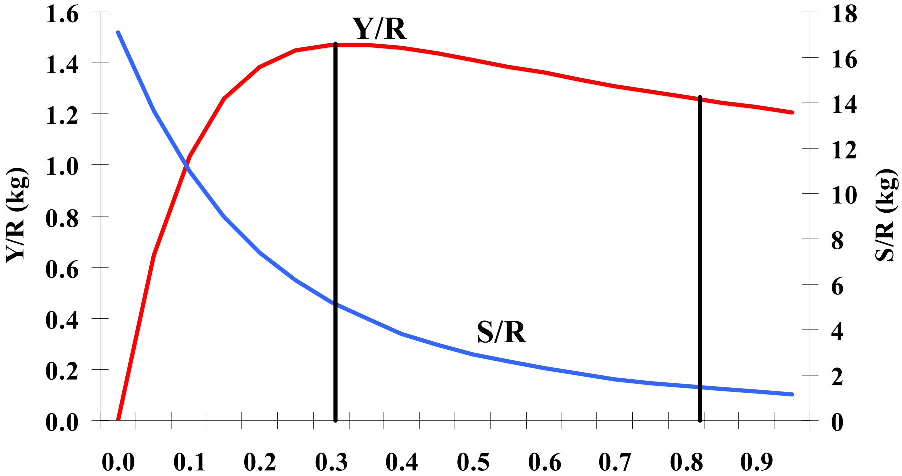

Figure 22. Yield per recruitment curve and spawning stock. (Data corresponding to Table 1.)

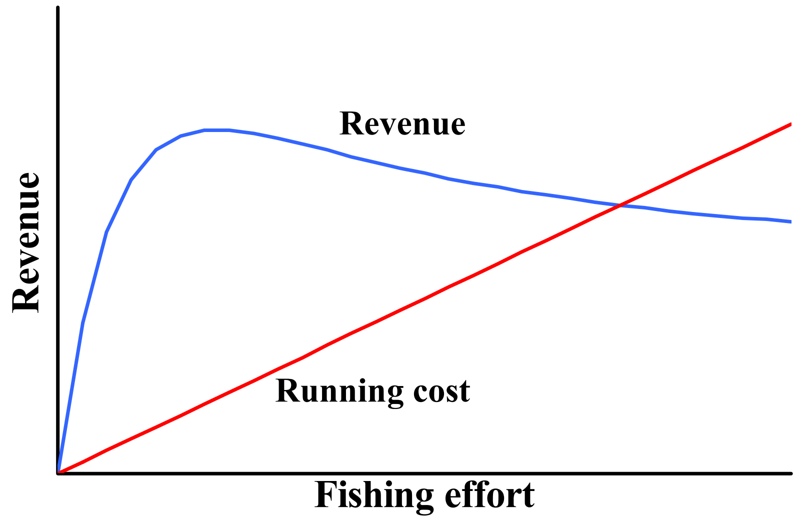

Figure 23. Revenue, fishing effort, and corresponding running cost of fishing.

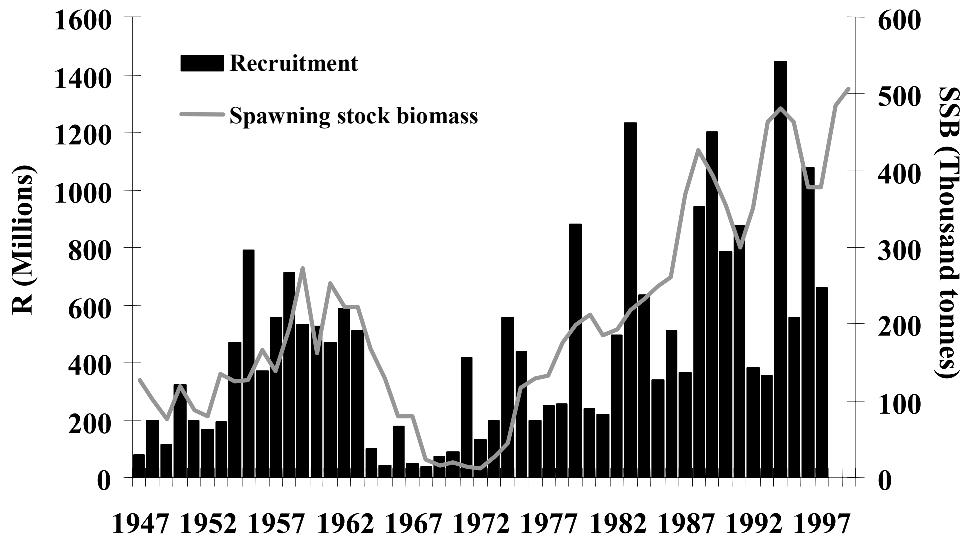

Figure 24. Spawning-stock biomass and recruitment of the Icelandic summer-spawning herring, 1947–1999.

already noticed at the beginning of the century: the fishing effort required for a given catch would increase; in other words, it would take fishermen longer and longer to catch the same weight of fish. At the same time managers were anxiously asking ICES for advice without ever formulating their management objectives.

In the absence of any objectives from the managing authorities ICES decided in 1975 to set up an *ad hoc* group of scientists to define proper objectives in fisheries management based on biological terms. Gunnar Sætersdal (Norway), then the Chair of the Consultative and the Liaison Committees of ICES, was appointed Chair, while the other 16 committee members were leading international experts in fisheries assessment and management advice. In the report from the *ad hoc* meeting that was held in January 1976 it was pointed out that the term "maximum sustainable yield" had attained wide and general use. It was explained that there was considerable danger in assuming that a fishing mortality rate associated with the greatest yield on a yield-per-recruit basis would also give the maximum sustainable yield in absolute terms. The prime danger is the assumption that the recruitment is independent of the parent stock. In yield-per-recruit curves of the flat-topped variety, fishing at F max may result in serious depletion of the stock with a consequent danger of reducing recruitment, and it will certainly reduce the catch per unit effort to rather low levels, with little resulting increase in yield per recruit from the increased input of fishing (ICES, 1977).

Against the background of this critical review of concepts and objectives of management and their past and present uses, an attempt was made in the report to outline a new comprehensive objective for fishery management, with the aim of ensuring the optimum long-term utilization of the resources. This new approach in principle establishes the exploitation not at the maximum point of the yield curve but at a lower level on the left-hand side of the maximum. This will at least in theory give a little less tonnage than the maximum on the yield curve, but other benefits would be generated. Furthermore, this comprehensive objective for management should also take into account:

a) exploitation pattern, which should as far as practicable be optimized;

b) the spawning stock, which should be maintained within the range that would produce the most desirable level of recruitment;

c) a buffer stock, which implies that the stock size should be maintained at a sufficiently high level so that its variations due to recruitment are reduced; and

d) catch per effort which implies that fishable stock densities should be maintained at high enough levels to ensure harvesting without excessive costs.

The application of the optimal sustainable yield as opposed to the maximum sustainable yield concept would require that for each stock there should be a need to:

a) define an optimal range of spawning-stock size;

b) define an agreed minimum fishable biomass level;

c) assess the characteristics of the fishing pattern in relation to an optimized pattern.

The advantages of adopting these integrated objectives in the management of the fisheries were expected to include reduced fluctuations of TACs from year to year, increased catch rates, reduced risks of stock depletion, and increased reliability of scientific advice.

Thirty-three of the major fish stocks in the Northeast Atlantic were classified according to the level of exploitation. Two stocks, blue whiting and Icelandic capelin, were considered underexploited; fully exploited was one stock, the Barents Sea capelin. One stock was considered recruitment overfished, the North Sea mackerel; and one was depleted, Atlanto-Scandian herring. The North Sea herring was considered recruitment overfished or depleted. All the other 27 stocks were considered growth overfished, and of these four were on the verge of being recruitment overfished: Arctic cod, North Sea sole, Icelandic cod, and Icelandic haddock.

The summary of this report was presented to the 14th annual meeting of the North-East Atlantic Fisheries Commission in 1976. This was the last meeting of what is now considered the old NEAFC, just before the extension of the Exclusive Economic Zones, and there was no effective discussion of these new comprehensive management objectives recommended by ICES. However, ICES working groups and the Liaison Committee in 1977, and the Advisory Committee for Fishery Management during the period 1978 to 1980, were greatly influenced by the new formulation of management objectives. It was clear that in the absence of any objectives from the management authorities ICES had taken the lead in the fight against overfishing. But ICES was coming into new management regimes after the extension of the Exclusive Economic Zones to 200 nautical miles.

In order to make up for the lack of dialogue that had taken place during the NEAFC meetings prior to 1976, ICES started to invite managers to so-called Dialogue Meetings, the first two of which were held in 1980. There the formulation of the advice of ACFM was criticized, this being considered far too deterministic, leaving too little scope for the managers to take into account other factors than those based on purely biological considerations. According to this line of reasoning it was not the role of ICES to recommend a certain figure for the total allowable catch but to calculate a wide range of options for the managers to choose from.

Responding to this criticism, the formulation of ICES advice was changed and the objectives in the 1976 report became the best-kept secret within ICES. Instead five categories of stocks were defined, depending on the rate of exploitation. ICES was only to make a firm recommendation if the stock concerned was on the verge of being heavily reduced or depleted. If not, ICES either gave a preference for a certain exploitation rate or none at all if the stock was not heavily exploited. This attitude went even further when the concept of "minimum biologically acceptable level" (MBAL) was developed at the beginning of the 1990s. In line with this concept recommendations were made only if the stocks were exploited outside safe biological limits (i.e., where stocks were below the MBAL, or expected to fall below this level in the near future. For stocks in this category, ACFM only gave advice on what measures were needed to rectify the situation; when stocks were exploited within safe biological limits, ACFM provided options without indicating a preference.

In this latter situation, the choice of a particular option was left to the managers. In the absence of recommendations the managers were tempted to decide on the exploitation rate which very often drove the stocks very near or below the MBAL state, and the overfishing continued. Thus of the almost 90 stocks dealt with by ICES in 1998, 30% were within safe biological limits, 38% were close to or outside safe biological limits. For 32% of the stocks the status was either not known or uncertain.

However, the 1976 objectives were applied in the management of the summer-spawning herring stock at Iceland. This stock had collapsed during the late 1960s. After a few years' fishing ban in the early 1970s, fishing was resumed in 1975, and in subsequent years the comprehensive objectives formulated by ICES in 1976 were adopted, e.g., with respect to fishing pattern by establishing a minimum landing size of 27 cm, and with respect to spawning stock by allowing it to increase to almost twice the abundance level observed prior to the collapse. Thus the idea of a buffer stock to reduce variations due to recruitment fluctuations was taken care of. The target fishing mortality has been $F = F_{0.1}$ which corresponds to about a 20% harvesting rate, which is in accordance with the 1976 comprehensive management objectives as described by Jakobsson and Stefánsson (1999). The results are shown in Figure 24. Thus the summer-spawning herring at Iceland was one of the first stocks to be recognized as being managed according to the precautionary approach, which in all major aspects corresponds to the ICES 1976 comprehensive management objectives. By rejecting them in 1980, rational harvesting of the fish stocks in the NE Atlantic was delayed by two decades.

The precautionary approach

In the most recent years a new philosophy or a new attitude to utilization of wild natural living resources has been emerging. Terms like biodiversity, sustainability, and precautionary approach have become the mainstay of the vocabulary used in the discussion on overfishing today. Thus the advisory sector of ICES quickly took advantage of the fact that the recipients of the fishery management advice had signed international treaties such as the Rio Declaration of 1992, the UN Declaration on Straddling Stocks of 1995, and the FAO Code of Conduct, where these new ideas were emphasized. As a result ICES now incorporates the basic philosophy of the precautionary approach in the formulation of fishery advice. Consequently stocks fall into two main categories, determined by whether they are harvested according to the precautionary approach or not. An important feature of this policy is that certain signposts or warning signals are flashed in order to help managers take steps in time to prevent or halt the decline of a stock before it reaches a depleted stage or is outside safe biological limits. To me this simply means that ICES has reverted to an earlier policy of giving much firmer advice to help solve the problem of overfishing—backed by a new attitude among the general public, which no longer tolerates irresponsible exploitation of natural living marine resources.

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ICES and the problem of overfishing

Summary

During the 19th century it was generally believed that the resources of the seas were so great that man could hardly make any impression on them. However, with the expansion in the trawling fleet and the introduction of steam power and otter trawls the efficiency of the fishing fleet was rapidly changing towards the end of the last century, and many thinking scientists were changing their views. In fact some were satisfied that overfishing was actually taking place already about one hundred years ago. This belief was in fact one of the reasons why ICES was established and this problem has lived with ICES for the last one hundred years.

During the first quarter of this century the problem of overfishing was mainly limited to the plaice fishery in the North Sea, where great quantities of very small unmarketable plaice were thrown back into the sea or taken to reduction factories for animal feed. During the 1930s ICES diverted its attention to the exploitation of the haddock and cod stocks in the North Sea. This led to the discovery of the possibility of releasing small fish from the trawl by increasing the mesh size of the gear in order to allow the young fish to grow to a larger size and thus eventually increasing the yield from the fishery. This led to the establishment of the overfishing convention in 1946, which was later replaced by the North-East Atlantic Fisheries Commission in 1963. From the early 1930s to the mid-1970s the conservation measures in the NE Atlantic were mainly restricted to the establishment of minimum mesh sizes and minimum landing sizes of fish, and to some extent to closed-area regulations. Throughout this period ICES was involved in evaluating the various technical developments and became the principal advisory organization in marine science.

Despite these measures, overfishing continued and it became clear that the problem could not be solved by technical measures alone. This could only be done by

restricting fishing operations in some way either by limiting fishing effort or by limiting catches.

Great advances in the science of fish population dynamics in the 1950s and 1960s made it possible for ICES to evaluate the effect of such measures and assess the abundance of the various marine resources as well as the yield that they could sustain. This led to a new phase in the advisory role of ICES which is still developing, with the introduction of new attitudes to the wild animal population in the world oceans.

Bitter experience has taught those who wish to harvest the resources of the marine ecosystem to appreciate how vulnerable at least some of them are to overexploitation.

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Otto Pettersson and the birth of ICES

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Introduction

ICES was initiated in 1899 in Stockholm. Three persons composing the Swedish Hydrographic Commission instigated it, but there is no doubt that Otto Pettersson, one of the three, was the driving force. So I find it very appropriate to call him the Father of ICES. Of course, as a Swedish hydrographer I am disposed to be biased, but David Griffith, citing D'Arcy Thompson (Thompson, 1948) hinted at a similar conclusion in his Open Lecture (Griffith, 1999). Thompson wrote that "to him, more than any other man, its first inception was due; no man worked harder or longer for it than he did. It stands as his great and worthy monument".

Much of the ensuing information is more elaborately recounted in my unpublished monograph (Svansson, 2000). I will use the word "hydrography" for physical and chemical oceanography of seawater, as it has been used for very many years in ICES. "Oceanography" is then understood as embracing all studies pertaining to the sea, including, for instance, marine biology and bottom sediments.

Otto Pettersson was born in 1848 and died 93 years later, in 1941 soon after the start of the Second World War. He took his Doctor's Degree in Uppsala with a thesis in chemistry. In 1881 he moved from Uppsala to the new Stockholms Högskola, today Stockholm University. Here he was soon appointed its first chair of chemistry, a position he left in 1909 at the age of 61. So, Otto Pettersson was primarily a chemist, whereas oceanography became his hobby.

Another member of the Swedish Hydrographic Commission, Gustaf Ekman, played the role of first arousing Otto Pettersson's interest in oceanography. The two, who were destined to be lifelong friends, met in Uppsala in 1874, where Gustaf Ekman also had the ambition of becoming a chemist. He was a distant relative of F. L. Ekman, whom we regard as our first Swedish hydrographer. F. L. Ekman was, moreover, the father of Walfrid Ekman, also well known to hydrographers. When F. L. Ekman organised a major survey about Sweden in 1877, Gustaf was one of its participants. A little later, in the winter of 1877/1878, there appeared in the Swedish archipelago of the Skagerrak for the first time since 1810, an invasion of wintering herring. Gustaf had the opportunity to take measurements of temperature and salinity among the schools of herring. He learned that the herring seemed to disappear when the low saline water of Baltic origin dominated. Instead, the herring returned with what was later called the Bank Water.

This relation between fisheries and hydrography made an indelible impression upon Otto Pettersson. He took over the concept from his friend. Gustaf himself soon left Uppsala to work for a Gothenburg company releated to his family. Otto Pettersson exploited the idea to its extreme, but as I shall show, he did not succeed at convincing the ICES founders. It was mostly in scientific articles that he continued to seek new evidence of his conviction that fisheries and hydrography were closely related.

It is of note that Otto Pettersson had his roots in the Swedish West Coast archipelago. His grandfather had worked at a herring oil factory. At the end of the last period, 1755–1810, when the herring fishery failed, he made a profitable investment when he could buy cheaply what was left from bankruptcies. Possibly Otto Pettersson concluded from his family's experience the importance of solving the puzzle of fish fluctuations.

F. L. Ekman's health was poor during a great part of his life, an unfortunate fact that seems to have opened doors for Otto Pettersson into his new field. We may safely assume that Gustaf Ekman acted as an intermediary. So while family history might explain Otto Pettersson's interest in fisheries fluctuations, his early involvement in oceanography was due to the Ekmans. Otto Pettersson's first oceanographic work involved the processing of data collected during Nordenskiöld's "Vega" Expedition of 1878–1880 along the Siberian coast.

The first step: five ships in February 1890

Otto Pettersson, in letters to Gustaf Ekman, worried that the hydrographic investigations of the late 1870s had not been continued. No doubt a new "herring period" was present, because the catches increased every year. At last in the autumn of 1889 the two friends could begin. They organised five ships to take samples simultaneously during one week in February 1890. This method simply copied the meteorologists' method of producing weather maps, now in order to obtain information about the state of the sea. Owing to generous sponsorship the enterprise became larger than Otto and Gustaf had expected.

During the following year the results of the February 1890 camaign were published in Swedish with a long English summary. Translated into English the title reads "The features of Skagerrak and Kattegat hydrography". The authors included comprehensive research that outlined the hydrography of the region, as background for the snapshot of 1890. If not before, at this time Otto learned about the expeditions of the British "Challenger" around the world, the Norwegian "Vøringen" in the Norwegian Sea, the German cruises on board "Pommerania", and many others.

Otto Pettersson presented these results at a meeting of the Scandinavian Naturalists in Copenhagen in July 1892. He boldly suggested that a Commission be formed to promote cooperative investigations. The group, however, considered a resolution to be sufficient action.

One month later Otto Pettersson attended a meeting of the British Association in Edinburgh. He may have met several British scientists here for the first time, especially the famous Sir John Murray of the "Challenger" Expedition.

Five countries cooperate in 1893–1894: The London Geographical Congress in 1895

In early 1893, the Swedish government allotted means for Swedish participation in a Scandinavian cooperative venture of four seasonal cruises. At the same time Otto Pettersson contacted the Fishery Board of Scotland to encourage participation. Otto Krümmel from Kiel preferred to keep German involvement unofficial. The ultimate outcome was a Swedish-led collaboration of ships from all five countries. This arrangement of seasonal cruises was later included in the first scientific programme of ICES.

Once again in the summer of 1895 Otto Pettersson travelled to spread the word of the hydrographic cooperation. At the Sixth International Geographical Congress in London, he reported on the collaborative work. Again, the result was a formal resolution. This was later appended to what I have called the ICES Conception Letter addressed to King Oscar II, dated two years later in October 1897.

Royal audience: ICES Conception Letter proposes a meeting in Stockholm

Otto Pettersson was convinced that the collaboration should be sanctioned at the government level. The Conception Letter was handed over to the Swedish government at a Royal Audience. We may guess that Otto Pettersson and his partners in the Swedish Hydrographic Commission did not find it worth their while to deliver the letter without such an Audience. The long time elapsed between the London meeting and October 1897 may have been necessary to prepare the ground, in other words to gain sanction beforehand.

I have made very great use of Jens Smed's recently completed manuscript "On the foundation of ICES" (Smed, 1998). It is partly based on archival material, which we have in Stockholm and which I was happy to hand over to him. I was rather surprised to learn that we have archived documents not only of the Stockholm meeting in 1899 but also of the Christiania (now Oslo) meeting in 1901 as well. The reason is that Norway and Sweden were in union with each other (until 1905) with a common King and a common Ministry for Foreign Affairs. This Swedish/Norwegian Foreign Ministry, situated in Stockholm, was to hold the responsibility of creating ICES all the way up to Copenhagen 1902.

There were parts of the foreign policy that were preferably handled by King Oscar personally, as most European countries had powerful monarchs at the time. Otto Pettersson probably felt the Audience to be a Royal Open Sesame when he met with much more compliance from the Foreign Ministry than he had expected. Otto Pettersson was at the right place to visit this and other ministries often and easily.

Contemporaneous approaches

Otto Pettersson may have suspected that Sir John Murray planned to take a similar step in Great Britain. In a letter from the Norwegian Johan Hjort in 1896, Otto Pettersson had been told just that. Later, after the Royal Audience, Otto Pettersson learned that Murray had, in the summer of 1897, asked Fridtjof Nansen to take the initiative.

However, Otto Pettersson quite certainly did not know of a meeting between German and Dutch fisheries experts in the spring of 1897, suggesting a North Sea cooperation. Otto Pettersson had good contacts with Otto Krümmel in Kiel, and he also knew of the plankton experts there. But he was not necessarily in a position to know about actions taken by German fisheries experts.

The Swedish/Norwegian Foreign Ministry reconnoitres

The ICES Conception Letter suggested that Denmark, Great Britain, and Norway should be approached as a start. Before the Swedish/Norwegian Ministry put this plan into effect in April 1898, Germany had been incorporated at the suggestion of Otto Pettersson. The Conception Letter included Otto Pettersson's favourite hypothesis, "All the fisheries of the Nordic Seas and particularly the behaviour of migrating fishes are, as we know, related to the great movements of the upper layers of the sea."

Already in July 1898 an answer arrived from Lord Salisbury, Prime and Foreign Minister of Great Britain. He was sceptical of the meeting described in the Conception Letter, which he felt to be of little apparent practical use for the fisheries.

The Stockholm meeting and its report

Later, in November, after diplomatic contacts, Great Britain agreed to a meeting at which any suggestions for the benefit of fisheries were welcome. Therefore, after the Netherlands and Russia had been contacted as well, a preliminary invitation for a meeting in Stockholm in June 1899 was sent out together with a Draft Programme. A final invitation for 15–23 June was dated 21 April 1899.

The Draft Programme suggested, among other things, an investigation of the North Atlantic current system "on which depends the appearance of the migrating fishes"; in other words, Otto Pettersson's favourite hypothesis.

The Stockholm meeting produced a report containing sections on hydrography, biology, and organisational matters. The governments of the participating countries were thereafter asked to comment on the Stockholm resolutions. The meeting had decided that France and Belgium should be informed. When approached by the S/N Ministry for Foreign Affairs about participating, Belgium answered in the affirmative; France, however, in the negative.

A second preparatory conference necessary. Christiania, however, postponed

Great Britain, answering in May 1900, was even more sceptical than before, believing that the Stockholm resolutions dealt mostly with scientific investigations. More discussion was clearly needed, and Otto Pettersson found the time was ripe to call a meeting of the Interim Committee, which had been set up during the Stockholm meeting. An invitation to Christiania for October 1900 was issued, but following a prompt reply from Germany the meeting had to be postponed; Germany's head delegate, Walther Herwig, could not attend owing to illness.

Appended to the Christiania invitation was again a Programme, definitely written by Otto Pettersson. His pet idea was here reduced to "closer specify the connection between the biological works and the fisheries investigations and the seasonal investigations of hydrographical and meteorological character decided upon in Stockholm."

Informal gathering in Gothenburg

Otto Pettersson now took a step that frightened the Norwegians. He called a meeting of Scandinavian scientists in Gothenburg. Johan Hjort absolutely refused to come; Fridtjof Nansen hesitated. It did not help that Otto Pettersson revised the character of the meeting to one appearing to be quite innocent. No Norwegians came to Gothenburg on 20 November 1900. The Norwegians feared that the Gothenburg meeting might lead to cancellation of the postponed Christiania meeting. There were rumours that Herwig's illness was of a political character: a way for Germany to withdraw. Thank heavens, this appeared to be a false rumour. Already at the end of November 1900 Herwig informed Otto Pettersson by letter that he was ready for a Christiania meeting.

Christiania meeting at last

In Norway they concluded that it would be advantageous to postpone the meeting until the spring of 1901. This would allow the countries more time to vote on costs first. Norway had already voted for its own marine research organisation, including a research vessel. Now the Parliament added a sum of 10 000 Norwegian kroner per year, hoping to attract the Central Institute, consisting of the Bureau plus a Central Laboratory, to Norway. Already right after the Stockholm Conference Johan Hjort had met King Oscar, who informed him that Sweden would not compete with Norway for this Institute. Otto Pettersson had found the requirements too unrealistic in Gothenburg. Stockholm, standing on the Baltic, was out of the question.

The Christiania meeting took place 6–11 May 1901. The hydrographic programme from Stockholm was very little changed, whereas the fishery programme was enlarged considerably. Much concern was devoted to organisational matters. It became clear that there would be no majority for both Bureau and Laboratory to be located in Norway. The Norwegian parliament had therefore to revote the 10 000 Norwegian kroner. This fact may be the reason that the chief delegates produced a special document on the organisation of ICES. Special, because it was not included in the printed report. Most of the proposals, both the printed and the "not printed", were later endorsed by the ICES constitution meeting.

The Christiania report

The Norwegian Prime Minister sent a comprehensive report to Stockholm in August. At this point the common Foreign Ministry had again to ask the participating governments to react. Sweden, Germany, and the Netherlands answered in the affirmative already in late 1901.

Great Britain, consistently the most hesitant country, answered rather positively in January 1902, only adding that after three years she would consider whether to continue. In March the Norwegian Parliament voted the 10 000 Norwegian kroner to be offered to the Central Laboratory in Norway. In the same month Russia followed suit, though granting only two years. At long last Denmark, the future host country of the Bureau, decided in May to comply fully with the Christiania resolutions calling for five years of cooperation.

Copenhagen 1902: achievements

When on 22 July 1902 ICES was constituted in Copenhagen, Otto Pettersson must have been very pleased. The Swedes had vaguely suggested an association; they got an International Council with a permanent Central Bureau. Nansen's proposal for an International Laboratory could only be applauded. It was a guarantee for procuring the suggested standardisation of methods. The Swedish proposals were more than fulfilled in Christiania, when Martin Knudsen presented his elaborate investigations in the shape of the now classic Hydrographical Tables. The introduction of standard seawater supplied the finishing touch.

The Swedish plankton expert Per Cleve was not a member of the Swedish Hydrographic Commission, but he did not protest when at the 1899 meeting plankton was included in the hydrographic programme. In Christiania it was still mentioned in this programme but with a reference to the biological programme, where the details were to be found. Cleve had every reason to be satisfied when his branch was given high status by the authorities from Kiel, especially Victor Hensen.

Copenhagen 1902: disappointments

When it came to fisheries, Otto Pettersson's main interest was in what he considered the fundamental influence of hydrography on fisheries. Here, however, he received almost no response from the two meetings.

Otto Pettersson must have been disappointed when reading the two programmes in this respect. In both the hydrographic programmes of 1899 and 1901 there was just a sentence mentioning "fundamental principles of the external conditions of the useful marine animals". Much worse were the biological programmes: in Stockholm not one word, in Christiania only "with constant reference to the hydrographic conditions of life". Otto Pettersson does not seem to have tried to advocate a discussion of this matter, which might conveniently have been taken up in plenary.

So we must agree with the American Tim Smith when he wrote recently: "The linkage between hydrography and fisheries was not immediately evident in the early research programmes of ICES, where the Biological and the Hydrographical Programmes were pursued separately" (Smith, 1999). I was somewhat shocked when I read these words for the first time. Up to then I had not been aware of the fact that the probable incentive for establishing ICES, the relation between fisheries and hydrography, was practically absent from the first scientific programme of ICES.

Copenhagen 1902: future consequences?

Would the future relations between the two branches have been different if there had been a special unifying paragraph in the programme? No doubt the tendency toward isolation developed between the two. Soon the fisheries biologists became annoyed with all the compulsory hydrographic measurements, which took too much time from their own investigations. Johan Hjort, a close friend of Otto Pettersson, was for a long time one of the displeased. In 1938, however, he wrote to Otto Pettersson,

> "It is remarkable that we biologists are more interested in the vast hydrographic challenges of the variations in the sea than the hydrographers themselves. I have the feeling that the hydrographers mostly seek a connection between mathematics and hydrographic observations, a connection they are not able to effect" (Hjort, 1938).

We might expect that Otto Pettersson felt happy at the moment he read this, realising that at last one sceptical biologist had understood his great vision.

Otto Pettersson was a member of the ICES Bureau all his life. In particular he again played a crucial role late in his career as President during the First World War, and in 1932 was named Honorary President. He attended every annual statutory meeting through 1934.

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Ocean exploration and marine science

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I first heard about ICES from Harald Sverdrup, in 1947 when I took his introductory course in physical oceanography. Sverdrup, who later (1955–1957) became ICES President, spoke enthusiastically of what he considered to be THE international oceanographic organization. It was only much later, in 1961, that I had my first opportunity to attend an ICES meeting and to appreciate that INTERNATIONAL was in a regional, rather than a global, context and that EXPLORATION OF THE SEA could mean something other than endless voyages on the boundless main.

For me, as a Pacific oceanographer, to understand ICES took some redefinition of terms as well as some years of apprenticeship. What I thought of as physical oceanography was called hydrography, and biological oceanography was handled by the Plankton Committee. *Oceanography* was not a term in common use, the *Sea* was principally the North Sea, and *exploration* seemed mostly to concern the location and assessment of fish stocks.

When ICES was established, northern Europe was the principal locus of marine science in the world, and well-known oceanographers pushed for creating an international forum whereby science could be brought to bear on overfishing and other fishery-related problems. This emphasis is obvious in the ICES charter, which speaks of "research and investigations for the study of the sea, particularly those related to the living resources thereof."

The fishery link was clearly stated by D'Arcy Thompson during a preparatory conference here in Stockholm in 1899 when he proposed:

> "That in all researches, whether hydrographical or biological, … it be recognized as a primary object to estimate the quantity of fish available for the use of man, to record the variation in its amount from place to place and from time to time, to ascribe natural variations to their natural causes, and to determine whether or how far variations in the available stock are caused by the operations of man, and, if so, whether, when, or how, measures of restriction and protection should be applied." (Went, 1972).

Of course, at that time the threats to the quality of the marine environment were not recognized or were not so evident, or there might have been additional comments on the application of researches to the understanding and control of that potential human impact. While I shall focus on ICES oceanography in the context of marine living resources, obviously the comments should not be restricted solely to that application.

Although modern oceanographers tend to think of their field as pure science, fifty years ago when I started my studies it was seen primarily as an application of physics, chemistry, biology, and geology to the study of the oceans. At that time, there was only one major university in the United States that granted a PhD in oceanography. Now such programs are legion, and the application of oceanographic understanding to practical problems, not only in fisheries and pollution control but in coastal development and protection, military matters, and climate forecasting, to mention a few, is commonplace. In the ICES context, ocean studies have always had a practical, or applied, flavor, yet contributions of major scientific importance have been made under the ICES flag. Thus I shall not try too hard to disentangle "oceanography" from the subjects to be discussed by other speakers.

How do you evaluate the contribution to oceanography of an ancient organization such as ICES—and there is no other of its vintage—when it was in some ways the birthplace of oceanography? Of course, one can argue about where and when oceanography began—and who was its father?—but a plausible case could be made that oceanography as we know it today was born when ICES was created!

Characteristics of the field as it has become evident over the century of ICES operation include the following (from Wooster, 1993):

- Many marine problems are intrinsically multidisciplinary, or even interdisciplinary;
- Space and time scales extend over an enormous range, from near molecular to the breadth of the earth and from less than seconds to the lifetime of the planet;
- Cooperative efforts of many field observers are needed because of the wide range of scales involved;
- Comparable quality is required for data compiled from a variety of sources and used to describe processes and phenomena of larger scale; and
- Controlled experiments are seldom practicable, their place being taken by natural experiments that necessitate careful field observations and ingenious interpretations.

It should be noted that oceanography is essentially characterized by cooperation among nations. The ocean one hundred years ago was not so constrained by national jurisdictions as it is today, but still today the ocean and its fish and other contents mix freely and largely ignore the man-made boundaries. At the same time, as noted above, the scientific understanding of the ocean and its contents is inherently interdisciplinary. The international and interdisciplinary character of oceanography has always been evident in the programs of ICES.

A task from the beginning, in fact perhaps a cause for the beginning, was the coordination of hydrographic surveys in the North Sea. This capability has served ICES, and the broader scientific community, well during subsequent years. An American tends to see the fishery-related community and the more academic earth science community as somewhat alien and unlikely to work together fruitfully. Evidence to the contrary is the performance of ICES during the International Geophysical Year, 1957–1958, when its North Atlantic Polar Front Survey mobilized ships throughout the 18-month "year" including an impressive 24 ships in the July – December 1958 period (ICES, 1961). A decade later, the ICES Symposium on the living resources of the African Atlantic continental shelf (ICES, 1970) led to organization by the Intergovernmental Oceanographic Commission of the Cooperative Investigations of the Eastern Central Atlantic and a central role for ICES in coordination of this international venture. The breadth of scientific interest and involvement of laboratories in different countries, along with the professional skills of the Secretariat, made ICES a natural resource to be called on in such an enterprise even though it went far beyond the traditional area of operation.

In addition to its role in promoting and coordinating marine scientific investigations, ICES has made important contributions to the nuts and bolts of the field. This is particularly true in the case of methodology and data management. In the first years, there was established a Central Laboratory in Christiania (now Oslo), under Nansen's directorship and with the job of developing and providing instruments and standards for use in coordinated surveys (Went, 1972). Only in this way, could the data be compiled and merged for analysis. Best known of the products was standard seawater that made possible uniform chlorinity measurements and salinity estimations. When I started as a chemical oceanographer at the Scripps Institution in California, we treasured the ampoules of Copenhagen water that controlled our chlorinity measurements in the eastern North Pacific. Although the Central Laboratory closed after only six years, the standard seawater continued to be produced by ICES in Copenhagen until 1975 when responsibility was transferred to the International Association of Physical Oceanography (now IAPSO) and to the Institute of Oceanographic Sciences in England. ICES was the originator of a continuing cooperation with UNESCO, the Scientific Committee on Oceanic Research, and the International Association for the Physical Sciences of the Ocean in a Joint Panel on Oceanographic Tables and Standards which keeps an eye on such matters on behalf of the world scientific community.

Of course, these are not the only kinds of oceanographic measurements that have required standardization or intercalibration. There have been a myriad of working groups over the years that have agonized over a variety of physical, chemical, and biological measurements whose determination requires a common approach by participants in cooperative investigations. This need arises not only because of the collective analysis of the observations in any given investigation, but also so that the resulting data can be compiled in a database for use by other investigators. ICES has pioneered in its data management practices, with a Hydrographic Department, later Service, being established in the first years of operation.

I leave to the other speakers mention of parallel work on methods and data management for fisheries, and later pollution, investigations.

Twenty years ago, I gave a General Assembly lecture on "The Contribution of Exploration to Marine Sciences" in which I defined exploration as creative observation in an uncontrolled environment that allows one to see what has not been seen before. I showed the interaction of exploratory research with that needed for fishery and other applications and concluded that attempts to distinguish between them are no more useful than those which divide oceanographers from fishery scientists. The annual record of lectures, symposia, and publications demonstrates the nature of exploration in the ICES context, as the following case study illustrates.

Thirty years ago, ICES held a symposium in Dublin on the subject of physical variability in the North Atlantic (ICES, 1972). Two-thirds of the papers were devoted to longer period fluctuations, but within the constraints of the assigned subject, there were none that dealt with biological consequences. This intrigued me to looking into the subsequent development in the ICES scientific program of interest in the interactions between longer period physical fluctuations, interannual, interdecadal, and beyond, and the biota of the ICES geographical realm. I chose the period of my own involvement in ICES, from 1973, for review.

In 1975, the Aarhus symposium on recent changes in North Sea fish stocks and their causes (ICES, 1978a), there were many papers on fish-stock changes, but only a few that were focused on hydrographic and nutrient changes that might have been the primal causes. The next year, however, at the Joint Oceanographic Assembly in Edinburgh, there were four symposia co-sponsored (ICES, 1978b) on the subject of marine ecosystems and fisheries oceanography, one of which dealt explicitly with the biological effects of ocean variability—even El Niño reared its ugly head! In this case, however, the author discounted the importance of such interannual events in favor of overfishing and the storm scale of variability as the principal causes of biotic change.

The subject was not highlighted again until 1982 with a mini-symposium on climatic variations in the North Atlantic and their effects on biota and fisheries. Longer period physical variability was emphasized and linked to that of plankton, although the association with fish stocks was deemed largely circumstantial.

The pace quickened during the next two years, starting with Alan Longhurst's 1983 lecture on heterogeneity of the oceans and its implications for fisheries. The following year saw publication (ICES, 1984) of a collection of papers on hydrobiological variability in the North Atlantic and adjacent seas. The papers were mostly physical, in honour of the retiring Hydrographer, Jens Smed, but in addition to the Longhurst lecture, there were several other papers on climate–biota links. The 1984 meeting also included a mini-symposium on the mid-1970s anomaly, which was devoted to a major temperature–salinity anomaly in the North Atlantic and accompanying changes in the biota. This large-scale change was linked to climate and to effects on plankton and fish stocks, although the latter effects were not clear cut, perhaps because the event was examined in isolation from longer period changes.

The subject came of age in 1991, with the symposium on hydrobiological variability in the ICES Area. In the publication (ICES, 1992), more than half the 500 pages were devoted to variations in plankton and fisheries in relation to the environment. One should note that the study of variations depends on the availability of data over an adequate period of time. In an introduction to the volume, Dickson quotes Duarte *et al.* (1992): despite the importance for such studies of long-term monitoring programs, they are "among the shortest projects in marine sciences: many are initiated, but few survive a decade." It is the goal of an international program, the Global Ocean Observing Program (GOOS) of the IOC, eventually to provide the data on which studies of the effect of climate variations on marine ecosystems depend.

The next year saw Ken Mann's lecture on the impact of physical oceanography in understanding marine ecosystems, followed in 1993 by the symposium on cod and climate change (ICES, 1994). Here the subject matter came particularly close to the ICES mission of bringing science to management, in a case where it was difficult to sort out the effects of climate variations from those of extended overfishing. Nonetheless, the importance of climate variability in this case was made clear, as also evidenced by establishment of the ICES/GLOBEC program on Cod and Climate Change earlier in 1993.

Subsequent years have kept the topic to the forefront: in 1995, the symposium on changes in the North Sea ecosystem and their causes (ICES, 1996); in 1996, Dickson's lecture on physical and biological effects of the North Atlantic Oscillation; in 1997 the symposium on emporal variability of plankton and their physical–chemical environment (ICES, 1998). By this time, it is clear that a new paradigm has emerged—changes in marine ecosystems, including the higher trophic levels, are influenced by climate variations as well as human activity, and the effective conservation of living marine resources depends on recognition and evaluation of both of these forcing functions.

How has our knowledge of the ocean and its biota changed during the century that ICES has been in existence? Needless to say, I can't project my memory back that far, but perhaps you will settle for the half century that I have been paying attention.

Even fifty years ago, we knew that the ocean circulation was largely driven by the wind and modulated by density differences and by the rotation of the earth. We were mostly ignorant of small-scale spatial differences in temperature and salinity because of the crudity of the available instruments, and the velocity field was mostly estimated indirectly. We couldn't measure many variables of known importance, such as nitrate-nitrogen, and we tended to think that seasonality was the most important time scale. The deep ocean was considered to be largely inert, and therefore boring. I remember, after a particularly rough cruise in the 1950s, giving a lecture with the title "The Mean Ocean." Of course, my point was not that the ocean was nasty but that we missed most of the interesting features when we dealt only with average conditions.

We also had a first-order knowledge of ecosystem structure, with the primary producers at the bottom and the large fish, birds, and mammals (including man) at the top, and even a descriptive knowledge of much that was in between, but modelling was in its infancy.

A quick look through recent issues of the *ICES Journal of Marine Science* and its symposium editions suggests that the questions are not vastly different, but the base of knowledge has grown tremendously. Many of the advances in the last several decades have resulted from improved instruments and methods. Instruments have been developed whereby ocean currents can be directly measured, and aerospace remote sensing permits the observation over large space scales of surface currents and temperature and of ocean colour, a measure of phytoplankton standing stock. Towed instruments have evolved from the Continuous Plankton Recorder, in use for more than 50 years, to a variety of optical, acoustic, and other recorders that provide spatial continuity between stations. Such instruments can also be mounted on moorings permitting temporal continuity at selected locations and useful sampling intervals.

Despite the difficulty of controlling the ocean environment, some experiments have become possible, for example in mesocosms where controlled ecosystem experiments have been done. The increased power of computers has made simulation model experiments possible as well as vastly increasing the capability for handling data of all sorts, physical, chemical, and biological. This has been essential as the observing power, hence data-generating capability, of the marine science community has been vastly increased.

The advances in ocean understanding are not just the product of improved methodology, but reflect the application of scientific findings in many fields, marine and otherwise. Of course, these advances have not been confined to the participants in ICES, nor have they all arisen or been reported there. ICES attention has been directed to a part, not the whole of, the world ocean, and to a part, not the whole, of the science of the sea. I am convinced, however, that ICES has made a major contribution to the development of oceanography, in broadening the meaning and approach of the field to include the application of all the fields of natural science to the study of marine ecosystems, to the forces that transform them, and to the consequences for their future condition and the uses to which they are put. ICES has provided a fertile environment within which this transformation has taken place.

Summary

From its inception, ICES was concerned with evaluating variations in the quantity of fish and ascribing these to natural causes and to the operations of man. Yet while ocean studies associated with the organization have always had a practical flavor, major scientific contributions have been made under the ICES flag. Marine science is inherently interdisciplinary and is characterized by cooperation among nations. The ICES role in promoting exploration of the interaction between climate variations and marine fisheries is examined. In this and other fields, ICES has made a major contribution to the development of oceanography, in broadening the meaning and approach of the field to include the application of all the fields of natural science to the study of marine ecosystems, to the forces that transform them, and to the consequences for their future condition and the uses to which they are put.

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