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Ocean travellers

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When ICES was established at the beginning of the 20th century, fish migrations were considered to be one of the most important problems to be addressed by the new organization. This is reflected in the fact that one of the three committees established in 1902 was Committee A, the Committee on Migration of Food Fishes. In order to elucidate the life histories of the most important fish species, the Committee initiated extended egg and larval surveys covering the Northeast Atlantic and its marginal seas. This was followed by large-scale tagging of several fish species. Owing to the coordinated international effort, light was cast on the annual larval drift from spawning grounds to nursery areas; the migration of adult fish between wintering, feeding, and spawning areas; and how the distribution of most species was limited to the continental shelf areas, with the dramatic exception of a few species like the eel. Subsequent investigations revealed that some other species, such as herring, salmon, and tunas, were also real ocean travellers with extensive migrations, far beyond the continental shelves. When discussing these migrations, it is important to distinguish between categories of ocean travelling, e.g., massive annual migrations between feeding and spawning grounds, and long-distance migrations of a few strays. The former is of great economic interest for the fisheries, while the latter is primarily of an academic nature.

Keywords: bluefin tuna, cod, eel, fish migration, herring, Johannes Schmidt.

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Introduction

It is well known that fluctuations in landings of marine fish have caused severe economic problems in the coastal communities of northern Europe from the earliest times. This is, for instance, pointed out by Hjort (1914). Perhaps the most striking fluctuations in historical yields are those of the herring fisheries in the Scandinavian countries. Although the Icelandic sagas are not much concerned with aspects of everyday life like fishing, it is clear from at least one of them, Egils Saga, that herring fishing was conducted at the west coast of Norway in the ninth century and that the fishermen were using quite extensive nets, each of which required "many" men to handle them. These were probably large beach seines that were used for centuries in the Norwegian winter herring fishery. It is mentioned in *Heimskringla* [The History of the Norwegian Kings, written by Snorri Sturluson (1178–1241)] that the herring fishery flourished during the reign of King Hákon the Good (933–960), but to the contrary, there was a famine on the west coast of Norway during the reign of his nephew and successor, Haraldur Eiriksson, because of the failure of the herring fishery. In fact, the famine was so severe just after 970 that the king had great difficulty in feeding his court, but in 975, the herring returned and brought prosperity to the coastal areas of western Norway. This prosperity continued into the 11th century, and one of the Norwegian chieftains, Erlingur Skjálgson, encouraged his slaves to make enough (silver) money from the herring fishery to buy their own freedom.

Another herring fishery, the so-called Scanian fishery at the southwest coast of Sweden, also showed great periodic fluctuations. This is sometimes referred to as the first great herring fishery (Jenkins, 1927). It flourished in the 12th, 13th, and 14th centuries. However, in the 16th century, the herring left Scania on account of the sins of the people! The alternating herring periods between the west coast of Norway and Bohuslän (Sweden) during the 18th and 19th centuries have, for example, been reviewed by Anderson (1960) and Devold (1963).

An important feature of the herring fisheries of northwestern Europe was their seasonality. Thus, the herring season usually started at the west coast of Norway during winter, followed by the spring and summer fisheries at Shetland and Scotland, the autumn fishery at England, and finally the fishery in the English Channel at the end of the year. These apparently successive her-

Figure 1. Johannes Schmidt (around 1910).

Figure 2. Distribution of pelagic stations taken on the "Thor", 1903–1905 (from Schmidt, 1906).

ring seasons as well as the periodicity of the herring fisheries in Scandinavia were probably the main motivation for the formulation of the so-called polar migration theory which was very popular in the 18th and early 19th centuries and was most comprehensively presented by Anderson (1746). It has recently been reviewed and summarized by Wegner (1993) and Sinclair (1997).

The theory or better-named "fantasia" postulates that the home of the herring was under the northern polar ice at great depths. From this peaceful home, the herring made annual runs all the way to the Channel, as illustrated by the seasonal fisheries mentioned earlier. The theory was later modified to include transatlantic migrations from the southern end of the European migration to the United States. It was also expanded to include species other than herring. Although this theory had been criticized by Heincke (1898) and others towards the end of the 19th century, the migration of fishes was still a very important question when ICES was established. This is reflected in the fact that one of the three committees established in 1902 was Committee A, the Committee on Migration of Food Fishes, with Johan Hjort from Norway as Chair. Since fish migrations were thought, at that time, to be the cause of fluctuations in landings of the great European fisheries, Committee A dealt not only with migration as such but also with fluctuations of the fisheries in general.

At its first meeting in 1902, the Committee initiated extensive egg and larval surveys covering the North Sea as well as the Northeast Atlantic from the Bay of Biscay to northern Norway, including Iceland and the Faroes. The main emphasis was on the study of the biology of gadoids and herring (ICES, 1909). The participating research vessels, some of which had been specially constructed for this task, came from at least five countries. These research surveys led directly or indirectly to the discovery of several ocean travellers, especially when the egg and larval investigations were supplemented by tagging.

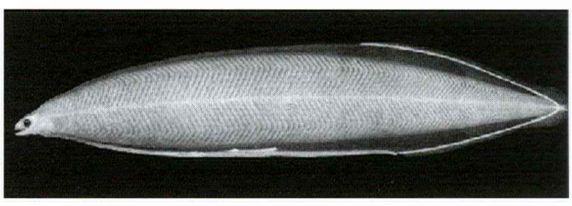

Figure 3. *Leptocephales brevirostris*, an eel larva (from Schmidt, 1906).

Figure 4. The research steamer "Thor" in Seidisfjördur (East Iceland) in 1903: 200 BRT, maximum speed of 8 knots, coal fuel for 11–12 days (from Strubberg, 1947).

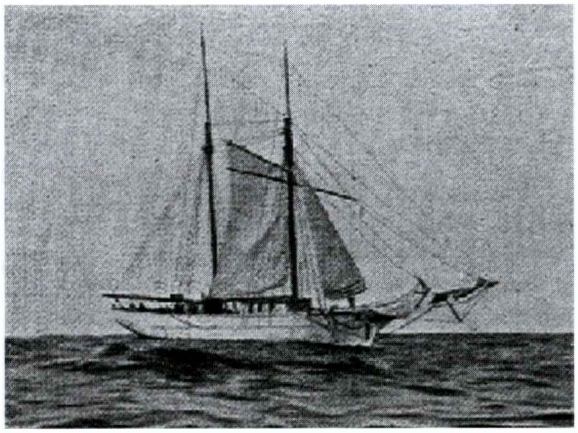

Figure 5. Motor schooner "Margrethe", only 90 BRT (from Schmidt, 1928).

The Danish fisheries investigations in the "Atlantic and adjacent seas" were of particular interest and were led by a brilliant young scientist, Johannes Schmidt (Figure 1). Judging from the distribution of stations, the Danish research steamer "Thor" appears to have covered a very large part of the total area of investigation proposed by ICES (Figure 2). During these surveys in 1903–1905, Schmidt succeeded in charting the distribution of the pelagic fry of almost all of the major food fishes in what later was known within ICES as the Northwestern Area as well as the area west of Great Britain and France. However, owing to the discovery of a single so-called leptocephali larva where none should have been, the investigations took an unexpected turn (Figure 3).

The eel problem

The biology of the eel had been the cause of headaches for centuries. Catches of other common food fishes usually contained various size and age groups, depending on fishing area or season. As a result, it was relatively easy to observe the size at which fish became sexually mature and then follow the sexual maturation cycle to find the spawning season and places. As an example, it had been known for centuries that the area around the Lofoten archipelago (Norway) was an important spawning ground for cod and that the main season was in late winter or early spring. However, the fishery for the eel did not disclose any such information because the eel disappeared from the traditional inland fishing areas before the gonads were properly developed. Since no offshore fishery for eel existed, the reproductive phase of eel biology remained unsolved, and presented a great challenge to marine biologists. The common belief was that the eel bred in many localities near the coast in deep waters as, for example, postulated by Grassi (1896).

A. C. Strubberg (1947), an assistant and colleague of Schmidt, has described the event when the first leptocephali eel larva was detected on board the research steamer "Thor" (Figure 4) in the Atlantic ocean west of the Faroes at 61°21'N and 10°59'W the evening of 22 May 1904:

> It was a dramatic moment when I spotted the transparent eel larva undulating in the bowl and the silvery eyes shining in the lamplight [Figure 3]. As fast as the heavy rubber boots permitted, I rushed downstairs and described the phenomenon to Dr. Schmidt who was enjoying his Chibuk cigar in the cabin. The survey for more larvae was immediately continued, but for the time being, we had to be content with the one example, the first one outside the Mediterranean. (Author's translation from Danish.)

This discovery caused considerable interest, not only in Denmark, but also internationally, including the rapidly growing ICES community.

In the following year (1905), the month of June was allocated on the "Thor" to further investigation of the "eel problem". The area of investigation stretched from the Hebrides to Brittany and was extended westward to cover the continental slope down to a depth of at least 1500 m (Figure 2). During this survey, Johannes Schmidt and his crew succeeded in catching a total of 265 eel larvae at 13 out of 19 stations located at or outside the 1000-m depth contour. Following these results, Schmidt (1906) published a 136-page treatise, *Contributions to the Life History of the Eel*. On the basis of these data, chiefly from the 1905 survey, he concluded that the spawning place of the European eel was outside the 1000-m depth contour west of Great Britain and France and that this was the common breeding area for the entire stock, with the possible exception of the Mediterranean component. Schmidt realized that these results were of great practical value for the fisheries in

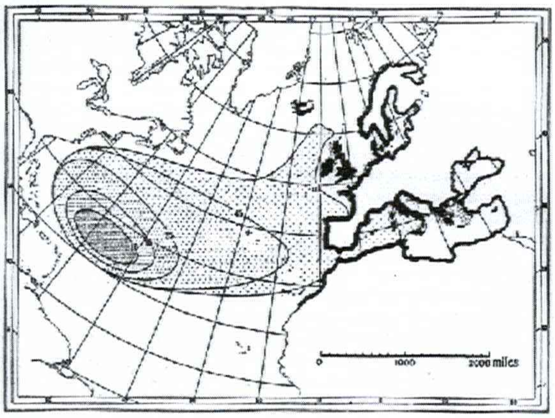

Figure 6. Size distribution of the *Leptocephales* larvae of the European eel (dotted areas) and of adults (black areas) (from Schmidt, 1928).

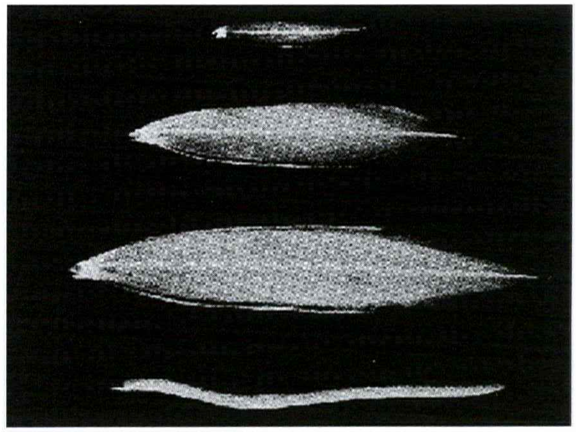

Figure 7. The four youngest year classes of the European eel (from Winge and Tåning, 1947).

Denmark, where the fishery was highly developed despite relatively small eel runs, compared with those in the Atlantic coastal areas where the fishery was negligible. Having one common spawning centre instead of many small ones would greatly reduce the danger of any local or fractional overfishing.

In order to obtain further information on this important "spawning centre" at the oceanic continental slope, Schmidt led another expedition on the "Thor" to the area in May–June and September 1906. The results were unexpected because the farther west he went from the continental slope the more abundant were the smaller and presumably younger larvae. Thus, it became clear that the spawning centre of the European eel was not located at the continental slope, but somewhere much farther west in the Atlantic Ocean beyond the range of the small 200-BRT "Thor" that had served so well at the Faroes and Iceland (Figure 4).

As the eel problem was becoming more and more complex, Johannes Schmidt became more and more determined to solve it. One of his colleagues, Åge Vedel Tåning (1947), has described how Johannes worked day and night and gradually became obsessed with the problem. When he realized that the "Thor" could not be used in the mid-Atlantic, he took her during the winters of 1908/1909 and 1910 to the Mediterranean and concluded, contrary to existing belief, that the Mediterranean eel, like the northern European eel, originated from the common spawning centre in the Atlantic Ocean.

The eel larvae that had been caught during the "Thor" expeditions in 1905 and 1906 were 6–9 cm in length. In 1910, Johan Hjort (1910), working on the Norwegian research steamer "Michael Sars", caught a few smaller larvae (4–5 cm) in the area southwest of the Azores. In addition, some similar larvae were discovered in old collections (Zoological Museum in Copenhagen) from almost the same part of the Atlantic, as far as 32°W (Schmidt, 1928). Encouraged by these discoveries, Schmidt suggested that the spawning centre lay between the Azores and Bermuda (Harden Jones, 1968).

In the absence of a suitable research steamer to work in the Western Atlantic, Schmidt managed to organize a pelagic fishery on the Danish transatlantic shipping routes. During the first two years, the collection by these vessels brought virtually nothing new. However, in 1913, a small sailing schooner, "Margrethe" (Figure 5), was made available and was sent on a cruise across the Atlantic. On this cruise, a collection was made for the first time, at 73 stations, of a large number of eel larvae from the open ocean (over 700 larvae of the common eel and about 10 000 larvae of other eel species). Of special importance was the fact that the number of larvae increased, but the individual size decreased from east to west within a zone between 24°N and 40°N, thus giving a much better clue to the likely position of the spawning centre than had been obtained in earlier surveys. Unfortunately, the "Margrethe" stranded in the West Indies on 21 December 1913 and was lost, but all the scientific material was fortunately rescued from the wreck. Using the results from the "Margrethe" collections, the pelagic sampling on board transatlantic steamers was reorganized and, as a result, in May–June 1914, tiny eel larvae (as small as 14 and 18 mm) were found at 26°N and 55°W.

During the cruises of the "Dana" in 1920–1922, the main emphasis, based on the knowledge obtained before World War I, was on locating the yolk sac larvae as well as the distribution of eggs in the Sargasso Sea. The yolk sac larvae were located and collected, but the eggs were not found. On the basis of the distribution of the yolk sac larvae and their seasonal occurrence, Johannes Schmidt (1928) stated that:

> The spawning places of the European eel lie in a restricted area in the west Atlantic between 22° and

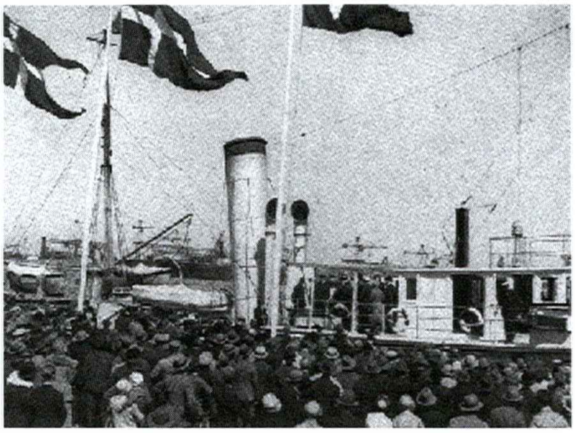

Figure 8. The "Dana" returns on 30 June 1930 after having circumnavigated the globe with Professor Johannes Schmidt as leader.

30°N and between about 65° and 48°W [Figure 6]. The spawning begins late in the winter and is continued to the beginning of summer. The average size of the larvae was ca. 12 mm in April and 25 mm in June. Whilst the *pre larvae* were found in depths from 200 to 500 metres the *youngest larvae* (7–15 mm) occurred as a rule ca. 100–75 m. below the surface, the slightly older higher, all over depths over 6000 m. The great mass of the fry of the year remain in June over or near the spawning places. At this period of the year, the investigations of the "Thor" had shown that the full grown larvae (75 mm) occurred off the coastal banks west of Europe. These larvae represent II-group and are on the average 2 years older than the 25 mm larvae in the western Atlantic. The intermediate age group – I-group – is found in the early summer in the central Atlantic with an average length of 50–60 mm. What gives the eel a special position among the marine organisms, is its *enormously extensive wanderings* in the larval stage, such great distances have to be encompassed that the larvae of the one age group do not reach the goal, the fresh waters of Europe, before the second and third age group are on the way. (Figure 7).

The spawning places of the American eel were also successfully located during the cruises of the 'Dana'. They lie in the ocean to the north of the West Indies somewhat farther to the west and south than those of the *Anguilla vulgaris*, perhaps overlapping to some extent. The smallest larvae of the American eel, 7–8 mm, were taken in February, they grow rapidly and are fully grown by the end of the year, 60–65 mm. The metamorphosis is completed in the winter months and the glass-eels run up into fresh water in the spring. The American eel, thus reaches its full development from egg to glass-eel in about one year while the European eel as mentioned takes about 3 years.

Throughout the 20 years of investigation, solving the eel problem was very much an ICES project. Thus, it is clear from the records of the annual meetings that the participants were always eager to hear the latest reports from Johannes Schmidt. In 1913, ICES decided that he should be the leader and reporter of the ICES eel investigations. During the period 1928–1930, Schmidt continued his eel research worldwide on the research vessel "Dana" and circumnavigated the globe at that time. His absence due to these long voyages was specially noted in the records from the annual meetings and when he returned he was received by a large crowd, as well as the King of Denmark, as a national and international hero (Figure 8).

The migrations of cod at Iceland and Greenland

Although a fishery for cod had been conducted all around Iceland in all seasons, the most important one took place at the south and west coasts during late winter and early spring. For several centuries, it had been of an international nature and based on spawning concentrations of very large cod.

The ICES programme of investigating the distribution of pelagic young fry of the main food fishes in the Icelandic area was undertaken by the Danish Marine Institute in 1903, with active participation by the first Icelandic marine biologist, Dr Bjarni Sæmundsson. During the first two years of the investigations, it proved possible to chart the distribution of eggs and larvae of most of the major food fishes during the spring and summer months at Iceland. This was done by circumnavigating the island country a few times. In 1904, such egg and larval surveys were carried out four times, and the results regarding the all-important cod were summarized in the report of Committee A (ICES, 1909) as follows (Figure 9):

In April the cod eggs were found from the 'Horns' (SE-Iceland) as far as Cape North (NW-Iceland). Most were on the south coast, but on the north coast numerous hauls gave not a single egg.

In the period from May 27th to June 2nd there were still no eggs on the north and east coasts, on the other hand the eggs and pelagic fry were now more numerous on the west than on the south coast.

In July there was still nothing to be found on the east coast but the pelagic fry were in abundance on the north coast as far as Cape Langanes.

In August all the pelagic fry had disappeared from the south and west coasts; on the other hand, they were very numerous on the north coast and northernmost part of the east coast, most numerous in the neighbourhood of Cape Langanes.

Based on these findings, Schmidt (1909) concluded that the spawning grounds were found only in the warm

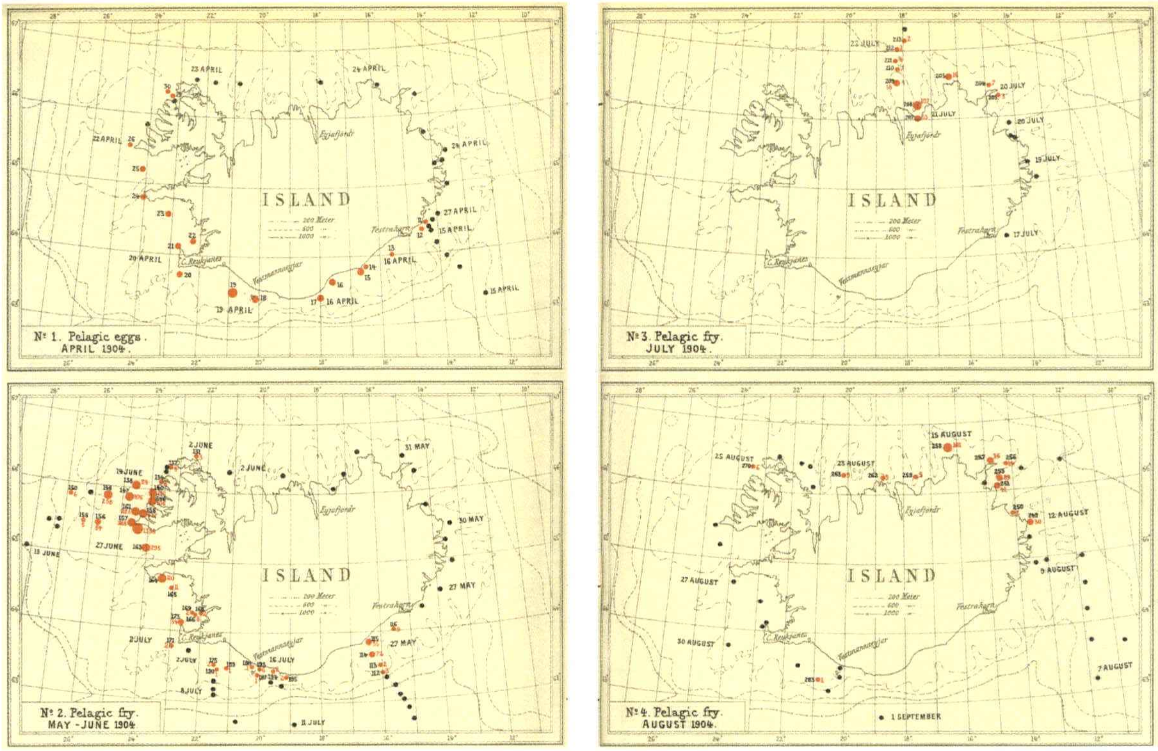

Figure 9. Distribution of cod eggs in April (upper left) and cod fry (larvae and 0-group) in May–August 1904 (from Schmidt, 1909 and rearranged by Jónsson, 1988).

water at South and West Iceland, while the nursery grounds were in much colder waters at the north and east coasts, and that the cod remained on the nursery grounds until they became mature and returned to the spawning grounds at South and West Iceland. He based these conclusions not only on the drifting of the young stages, but he also studied the bottom stages of the young cod occurring in shallow water and noted that the distribution was very unequal on the coast of Iceland. Thus, relatively few of the bottom stages were obtained at the southwest coast. On the other hand, these occurred in such enormous quantities on the eastern and northern coasts, i.e., where no or very few cod spawn, that there is perhaps no other place in the world where they occur in such numbers as here (Schmidt, 1909). In addition, he initiated tagging of cod in 1903. The results from these experiments showed and supported the conclusion that cod stay on the nursery grounds north and east of Iceland until they reach maturity and then migrate to the spawning grounds at Southwest Iceland. The conclusion of these early investigations was that Iceland had its own indigenous stock of cod which consequently can only be maintained by self renewal. In other words, Iceland is a self-contained area (Schmidt, 1928).

It is common practice to separate the cod at Greenland into two categories: the coastal cod, which is indigenous to the fjords in Greenland, and the bank stock, which undergoes many more fluctuations and can be very abundant under favourable conditions. During the first two decades of the 20th century, the latter type, or offshore cod, was practically absent from Greenland waters. However, soon after 1920, reports of increasing abundance of cod on the West Greenland banks became more and more frequent. During the "Dana" survey in Icelandic waters in 1924, the reports of great abundance of cod on the west coast of Greenland were so intensive that Johannes Schmidt decided to send his co-worker, Vedel Tåning, as an observer on the Danish inspection vessel "Islandsfalk", which was on its way from Iceland to Greenland at that time. One of the objectives was to tag some cod at West Greenland.

Since there was no fishing gear on board the inspection vessel, Tåning (1947) asked the native Greenlanders to catch cod on handlines and paid them half a Danish crown for each cod. The fishermen had a good laugh at the expense of this young but "crazy" scientist who, almost as soon as he had paid for the fish, threw them overboard. One of these tagged cod was captured in Faxaflói (Southwest Iceland) on 23 March 1927, about two and a half years after being tagged at West Greenland. This was so unexpected that it was suspected that there was something mysterious about this return until a vast number of cod were returned at Iceland from subsequent taggings in Greenland waters during the years 1927–1937 (Figure 10).

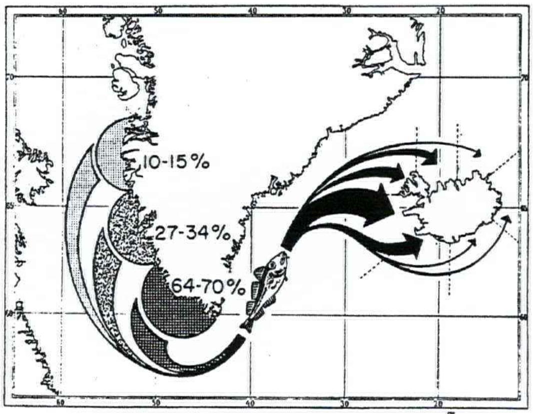

Figure 10. Migrations of cod from Greenland to Iceland, 1927–1939. The numbers show the % returns at Iceland (from Hansen and Hermann, 1953).

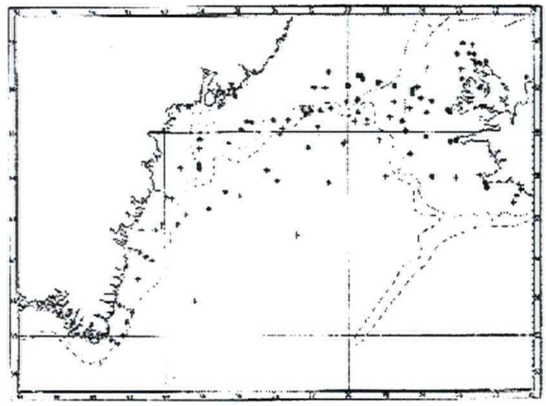

Figure 11. Drift of cod larvae in the Greenland Sound Investigations, 1931–1934. • Larvae present, + No larvae (from Tåning, 1937).

Investigations on the distribution of the cod fry showed (Tåning, 1937) that all the 0-group did not drift to the nursery grounds off the north and east coasts of Iceland as had been assumed after the first investigations in 1903 and 1904. Instead, in some years, they drifted with the western branch of the Irminger Current to East Greenland (Figure 11) and from there they were carried by the East Greenland Current to the west coast of Greenland. This drift of 0-group cod across the Denmark Strait has been observed intermittently in later years (Jakobsson, 1993; Schopka, 1994), and in some years has been associated with a tongue of cold water branching off from the East Greenland Current towards Northwest Iceland and thus temporarily blocking the flow of Atlantic water to the north coast of Iceland. This process usually started in June or July, and by October, the cod fry had reached the nursery grounds at Southwest Greenland, a distance of more than 1000 nautical miles.

During the ICES programme at the beginning of the 20th century, considerable numbers of cod were tagged on the nursery grounds at North and East Iceland. When tagging was resumed in 1924, most of the fish were tagged on the spawning grounds at the southwest coast. The cod tagged on the nursery grounds at Iceland had only been recaptured in the Icelandic area, while the cod tagged on the spawning grounds at the beginning of the 1930s had a wider distribution (Figure 12). However, it should be noted that at least 95% of these tagged cod were recaptured in the Icelandic area, while about 5% were captured elsewhere (Tåning, 1934, 1937). Thus, during the period 1925–1935, 23 individuals were caught outside the Icelandic area. Of these 23 individuals, no fewer than 16 were marked in the same year at South Iceland (1931), most of them even on the same ground during the same day. Of the 16, there were 13 that proceeded to the West Greenland banks, one went to Newfoundland, one to Norway, and one to the Faroes. The cod migrating to West Greenland evidently belonged to a school, keeping together when crossing from Iceland to Greenland (Tåning, 1934). Thus, it is clear that during the late 1920s and the first half of the 1930s, there were real ocean travellers belonging to the spawning stock at Iceland. These ocean travellers have, however, been very few and far between in later years. Thus, Jón Jónsson (1996) and his colleagues tagged 84 576 cod during the period 1948–1986. The returns amounted to 11 019 tags. Of these, 38 or only 0.34% were recaptured outside the Icelandic area. Considering that 18 of the 38 "long-distance travellers" were caught at East Greenland, mainly on Dohrn Bank, which is about halfway between Greenland and Iceland, the number of the real long-distance ocean travellers is reduced to 20 strays.

In 1991, a new tagging project was started at Iceland and during the period 1991–1999, no fewer than 24 134 cod were tagged, of which about half (12 453) were on the spawning grounds at the south and southwest coasts. Until July 1999, the returns had totalled 6892. Of these, 3 were caught at the mid-line between the Faroes and Iceland, while the remaining 6889 were caught at Iceland (Thorsteinsson, 2000). Judging by this information, the cod at Iceland have given up long-distance ocean travelling at the close of the 20th century, behaving in this respect just as Johannes Schmidt found at the very beginning of the ICES programme almost 100 years ago.

It remains to be noted, however, that real massive migrations between Iceland and Greenland occur periodically through the drift of cod fry over 1000 miles to West Greenland and a corresponding return migration of mature fish to the spawning grounds at Southwest Iceland 7–10 years later (Figure 10).

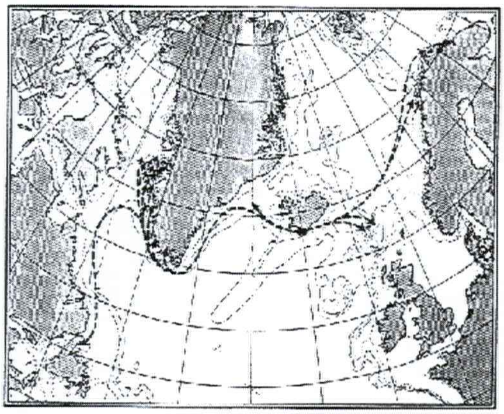

Figure 12. Long-distance migrations of cod tagged on the spawning grounds at Southwest Iceland, 1924–1936. About 95% of the returns from these tagging experiments have been reported from Icelandic waters inside the 200-m depth contour (from Tåning, 1937).

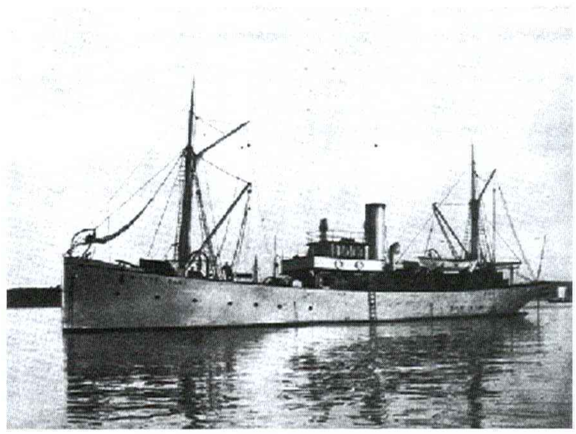

Figure 13. The Norwegian research vessel "Michael Sars" commissioned in 1900 (from Hjort, 1928).

The Northeast Arctic cod

Traditionally, there were two major Norwegian coastal cod fisheries (Nakken, 1994) which took place for centuries, i.e., the fishery for spawning cod (the *skrei* fishery) during late winter and early spring on the spawning grounds, and the fishery for immature cod (the spring cod fishery) which followed the capelin to its spawning grounds along the northern coasts (Finnmark and Murmansk) from March to June.

As pointed out by Sinclair (1997), the extensive egg and larval surveys in the North Atlantic organized by ICES were, in fact, enlarged research activities that had independently been initiated by Norway just prior to the foundation of ICES. Thus, in the year 1900, a new ocean-going research vessel, the "Michael Sars " (Figure 13) was commissioned and used extensively in carrying out the Norwegian part of the ICES programme (Figure 14). When this work continued during the first years of the 20th century, it was evident that cod spawned along the entire west coast of Norway and that the most intensive spawning took place at the Lofoten Islands. The egg and larval surveys further illustrated how the young cod fry drifted with the Atlantic Current northwards into the Barents Sea. Subsequent taggings (e.g., Hjort, 1926; Idelson, 1931; and Trout, 1958) have shown that the cod stay in the Barents Sea until they reach maturity and start ocean travelling towards the spawning grounds at the west coast of Norway several hundreds, if not a thousand, miles away (Figure 15). Harden Jones (1968) has summarized the results from these experiments:

> In August and September the mature and the immature fish are at the northern limit of their summer feeding migration at Spitsbergen and the northeasterly parts of the Barents Sea. In October they turn south and west towards Bear Island and the Norwegian and Murman coasts. The area over which the cod are found in winter is much smaller than that over which they are found in summer.

Then towards the end of the year, the large mature cod continue their winter travel towards the spawning grounds. However, not all the cod which participated in this winter ocean travelling down the Norwegian coastline are mature fish. They are sometimes accompanied by a number of the larger immatures which are believed to be making a "dummy run" towards the spawning grounds. Another group of the immature fish, perhaps not so sporty, but more realistic, follow the capelin run to their spawning grounds at the coasts of northern Norway and Murmansk, feeding intensively during this winter travel.

After spawning in March–April, the cod disappeared from the spawning grounds at western Norway. During the second half of the 19th century, the Norwegians started fishing for cod at the Svalbard Banks in the northwestern Barents Sea in the summer. In 1878, the Norwegian scientist Georg Ossian Sars received a longline hook which had been removed from a cod caught off Svalbard. The hook was of the type used in the winter fishery for spawning cod at the Norwegian coast and was quite different from the hooks used in the summer fishery (Nakken, 1998). This was probably the first clear sign that the cod returned to the Barents Sea after spawning. Subsequent tagging on the spawning grounds during the 20th century has repeatedly confirmed these post-spawning migrations (Hjort, 1914, 1926; Iversen, 1934; and Dannevig, 1953). Thus, the potentially largest cod stock in the world's oce ans uses the Barents Sea as its main, if not the only, feeding area throughout its lifespan (Figure 16).

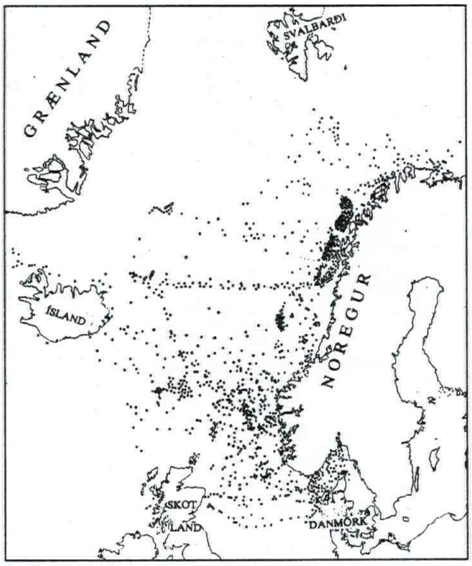

Figure 14. Research stations taken on the "Michael Sars", 1900–1904 (from Hjort, 1909).

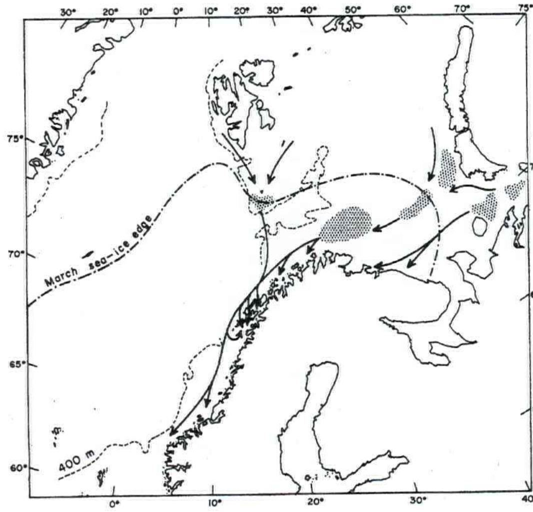

Figure 15. Migrations (contranatant) of the Arcto-Norwegian cod in autumn and early winter (from Harden Jones, 1968).

Bluefin tuna

The tuna species are commonly considered warm-water or tropical species. The largest of them, the bluefin tuna, is an exception because it travels to temperate and even boreal areas during the feeding migrations. This was especially true during the warm oceanic period 1920–1964 when they were frequently observed in Icelandic and Norwegian waters as well as in the North Sea and the Skagerrak.

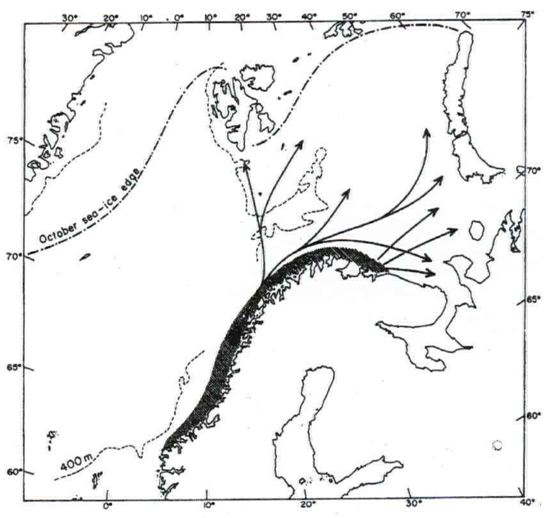

Figure 16. Post-spawning migrations (denatant) of the Arcto-Norwegian cod in late spring and early summer (from Harden Jones, 1968).

These magnificent ocean travellers spawn in two areas, to the east in the Mediterranean Sea and to the west in the Gulf of Mexico (Cury *et al.*, 1998). After spawning in the Gulf of Mexico, large fish migrate through the Florida Strait and north along the coast of the United States. The main feeding grounds are along the edge of the continental shelf between Georges Bank and the Grand Banks off Newfoundland and into the Gulf of St Lawrence. The wintering grounds are considered to be in the central North Atlantic between 60°N and 40°N east of the main track of the Gulf Stream (Figure 17).

After spawning in the Mediterranean, the eastern branch of the stock of bluefin tuna returns to the Atlantic and joins the northward migration to the feeding grounds. The large fish can endure colder waters than the smaller fish, sometimes entering the North Sea and the Norwegian coastal waters as far north as Cape North. Tagging experiments indicate a low level of exchange between the Eastern and the Western Atlantic branches of these ocean travellers. Moreover, the pattern of the transatlantic migrations seems irregular. As an example, 14 tagged age 2 and 3 bluefin were recovered in the inner Bay of Biscay in 1966. These fish had been tagged one year earlier in the New York Bight (Mather *et al.*, 1967). Large numbers of such young bluefin had been tagged in the years immediately prior to and after

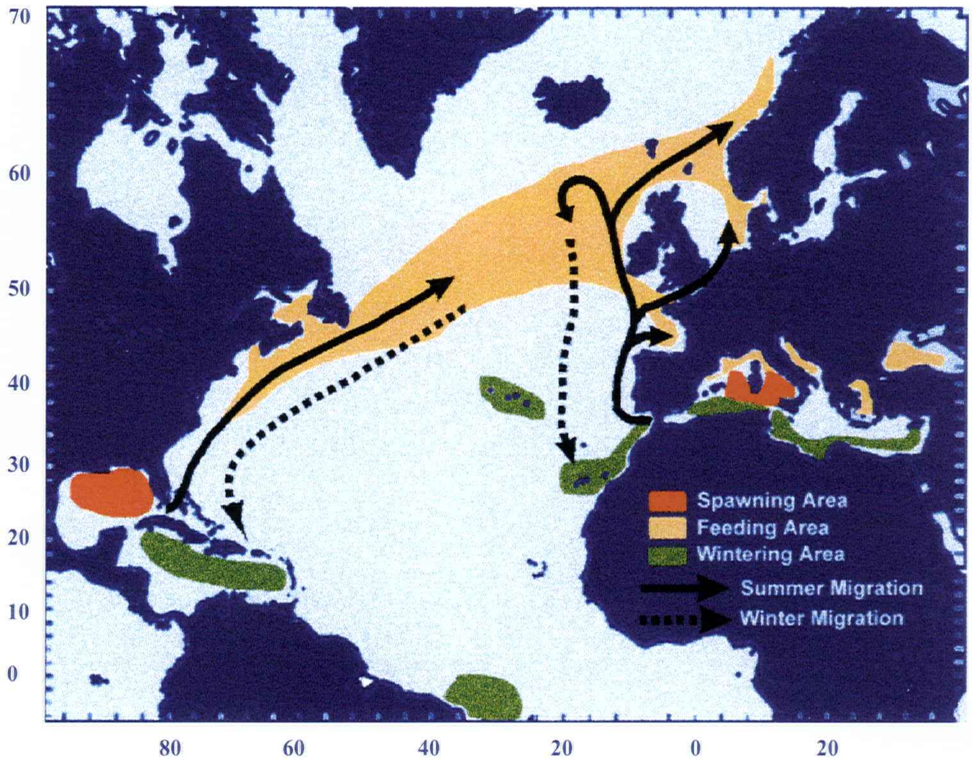

Figure 17. Spawning centres and migration routes of bluefin tuna (redrawn from Cury *et al.*, 1998).

the 1965 season, but this cluster of transatlantic recaptures is the only one observed. Such irregularity of transatlantic recoveries suggests random movements by strays, perhaps guided by unusual oceanographic features.

On the other hand, when populations on both sides of the Atlantic were abundant, a feeding area where western and eastern bluefin tuna seemed to have mixed regularly was the southern part of the North Sea and off the west coast of Norway. Fishermen harvesting herring in these areas observed, during the 1930s, large bluefin feeding on herring schools. This led to a directed bluefin tuna fishery using specially designed purse seines from 1950 to 1964. Hamre (1960, 1961, 1962, and 1963) described this major Norwegian fishery, which at times extended nearly as far north as Cape North and yielded an annual average catch of 3300 t of bluefin between 1950 and 1962. He reported the recovery of bluefin that had been tagged off the United States as well as fish tagged close to the Strait of Gibraltar. In addition, Mather (1962) reported the capture of two large bluefin tagged off the United States and recovered less than four months later off Norway.

Recognizing the importance of these feeding migrations, ICES, acting on the recommendation of the Scombriform Fish Committee in 1961, established a Bluefin Tuna Working Group that met for the first time in 1962 and met throughout most of the 1960s until the International Commission for the Conservation of Atlantic Tunas (ICCAT) became functional in about 1970. The most important task of the Working Group was to identify the various runs of bluefin to the feeding grounds and divide them into size categories. By comparing data from the Norwegian purse seine fishery and the German line fishery in the southern and central North Sea, the Working Group concluded that the largest tunas, after having visited the northwest coast of Norway, returned southwards towards the North Sea where they were subjected to a German fishery a few weeks after they had been subjected to a Norwegian fishery much farther north. Since the great oceanic climatic change that started in 1965, bluefin tuna have not visited the boreal feeding grounds described above. However, in recent years since 1995, Japanese tuna fishermen have followed the feeding migrations of the bluefin into Icelandic and Faroese waters, indicating that these long-distance travellers are penetrating further north again. This could possibly be a first indication of a reversal of the ocean climate in the Nordic seas. The contraction of the migration area in the 1960s could, of course, also be connected with decreasing stock size and

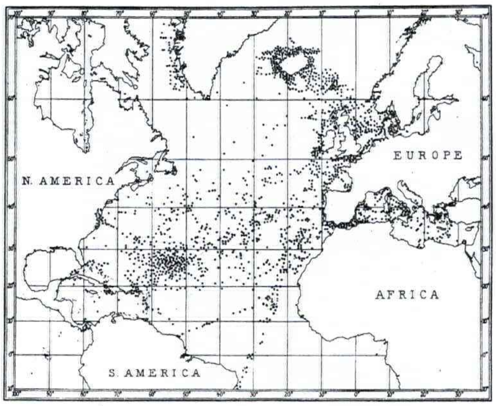

Figure 18. Selection of Danish research stations, 1903–1927 (from Schmidt, 1928).

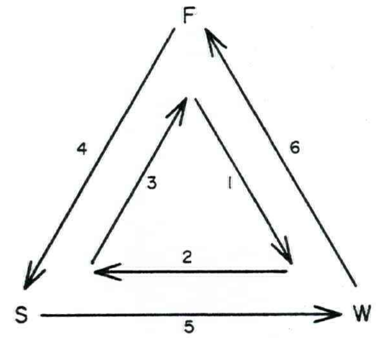

Figure 19. Annual migrations of adult fish stocks represented by triangles, where the corners are spawning areas (S), feeding areas (F), and wintering areas (W) (from Harden Jones, 1968).

decreasing numbers of the largest size category of the bluefin that came to the northern waters until 1964.

Discussion

In this paper, a few ocean travellers have been selected that have been of great interest to ICES and are not dealt with in other papers contributed to this symposium. The importance of the egg and larval surveys initiated by ICES at the beginning of the 20th century can hardly be overestimated with regard to their contribution to the status of fisheries biology at that time. Traditionally, most of the fishing took place in coastal waters. Two important and very practical questions that the ICES surveys were expected to answer were how far out in the Atlantic on the whole did food fishes extend, and whether there was any possibility of extending the area of fishing farther out to sea. Schmidt (1928), on the occasion of the ICES 25th jubilee, answered the question with his unfailing clarity:

> A glance at the Chart [Figure 18] with the stations extending right across the Atlantic from the shallowest to the deepest regions will show, that we have had very good opportunities for answering these questions. At all these stations we have worked with apparatus adapted to the capture of our food-fishes.
>
> The answer to the question can thus be given in a quite definite manner. Our northern food-fishes are restricted to the continental shelf and the Atlantic slope or its immediate neighbourhood. Within this – relative to the enormous extent of the ocean – narrow belt these fishes live the whole of their lives from egg to adult fish. Yet we have two marked exceptions to this rule, the *eel* (*Anguilla vulgaris*) and the *conger eel (Conger vulgaris)*, whose divergent life-histories will be specially discussed in the following.
>
> This main result that the great areas of the ocean are empty of food-fishes agrees with the fact that most of the species so far closely investigated have proved to be divisible into several distinct races or populations, each living its life separate from the others. As the species are gradually taken up one after another for finer, racial analysis there becomes less and less room for the extended migrations earlier believed in. Here again, however, we must make exceptions of the eel and the conger, especially the former.

It is of interest to note the next to last sentence where Schmidt clearly expressed the death sentence over the extended migration theory earlier believed in, as he put it. At the same time, the results of the early ICES research programmes showed that there was important denatant migration of fish fry from the spawning grounds to the nursery grounds and then annual migrations of the mature fish between the nursery grounds and the spawning grounds (Figure 19). The ocean travelling of the two most abundant cod stocks in the Northeast Atlantic, i.e., the Arcto-Norwegian and the Icelandic, are two clear examples of fish stocks undertaking such a migration pattern. It should be noted that the founders of ICES were careful to collect hydrographic data along with the biological data, with the former being used with great enthusiasm to explain the ocean travelling taking or not taking place.

Thus, the 1909 report in Committee A, after having described the denatant migration of cod fry from the spawning grounds at Southwest Iceland to the nursery grounds at North and East Iceland, pointed out that this was a striking example of how the current carries enormous quantities of eggs and young fish from the south coast to the west coast to the north coast and again to the east coast. The report continued:

In this case however the influence of the current does not tend to carry the young fish away from land, the movement follows the coast much more in contrast to what occurs on the eastern side of the Norwegian sea.

Although the annual migration between the feeding and spawning grounds of, for example, cod, herring, and salmon can be quite extensive and of great interest, the solution to the mysterious "eel problem" was the most dramatic ICES discovery or achievement in relation to ocean travellers. When discussing ocean travellers, it is important to distinguish between the various categories. In addition to the annual migrations between the feeding and spawning grounds, there are the long-distance strays which often cause excitement and curiosity. The massive migration of several million tonnes of herring to faraway feeding grounds is not only an interesting biological phenomenon, but also economically very important for the fisheries concerned. In some cases, such massive ocean travelling occurs annually for a number of years, as is known for bluefin tuna and the Atlanto-Scandian herring, but then, owing to some external changes, these are given up or reduced, at least temporarily. In other cases, these occur intermittently, the ocean travelling of cod between Iceland and Greenland being a good example.

The annual migrations of adult fish are sometimes represented by a triangle, as shown in Figure 19. The clockwise sequence of 1, 2, and 3 is typical for winter–spring spawners, while the counter-clockwise sequence of 4, 5, and 6 is typical for summer–autumn spawners. The sequence for the summer-spawning herring at Iceland is exceptional, being 4, 3, 1, and 6.

References

Anderson, J. 1746. Nachrichten von Island, Grönland, und der Strasse Davis, zum wahren Nutzen der Wissenschaften und der Handlung (News from Iceland, Greenland, and Davis Strait to be used in science and commerce). Georg Christian Grund, Hamburg. 328 pp. (In German).

Anderson, K. A. 1960. On the causes of the great fluctuations in the herring fishery on the west coast of Sweden. Report of the Institute of Marine Research, Lysekil, Series Biology, 5. 53 pp.

Cury, P., Anneville, O., Bard, F. X., Fonteneau, A., and Claude, R. 1998. Obstinate North Atlantic bluefin tuna (*Thunnus thynnus thynnus*): An evolutionary perspective to consider spawning migration. International Commission for the Conservation of Atlantic Tunas, Tuna Symposium, 50(1): 239–247.

Dannevig, G. 1953. Tagging experiments of cod, Lofoten 1947–1952: some preliminary results. Journal du Conseil International pour l'Exploration de la Mer, 19: 195–203.

Devold, F. 1963. The life history of the Atlanto-Scandian herring. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 154: 98–108.

Grassi, G. B. 1896. The reproduction and metamorphosis of the common eel (*Anguilla vulgaris*). Quarterly Journal of Microscopical Science, 39: 371–385.

Hamre, J. 1960. Tuna investigation in Norwegian coastal waters 1954–1958. Annales Biologiques, 15: 197–211.

Hamre, J. 1961–1963. The Norwegian tuna investigations 1959–1962. Annales Biologiques, 16–18.

Hansen, P. M., and Hermann, F. 1953. Fisken og Havet ved Grønland (The fish and the sea at Greenland). Kommissionen for Danmarks Fiskeri- og Havundersøgelser Skrifter, 15: 1–128. (In Danish).

Harden Jones, F. R. 1968. Fish Migration. Edward Arnold, London. 325 pp.

Heincke, F. 1898. Naturgeschichte des Herings I. Die Localformen und die Wanderungen des Herings in den europäishen Meeren (The life history of the herring I. The local features and migration pattern of the herring in the European seas). Abhandlungen des Deutschen Seefischereivereins (Transactions of the German Fishing Industry), Ver. 2. 128 pp. (In German).

Hjort, J. 1909. Oversigt over norsk fiskeri- og havforskning 1900–1908 (Overview on the Norwegian fishery and oceanographic research 1900–1908). Reports of the Norwegian Fisheries and Marine Investigations, 2(1): 1–202.

Hjort, J. 1910. Eel-larvae (*Leptocephalus brevirostris*) from the central north Atlantic. Nature, 85: 104–106.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe viewed in the light of biological research. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 20: 228 pp.

Hjort, J. 1926. Fluctuations in the year classes of important food fishes. Journal du Conseil International pour l'Exploration de la Mer, 1: 5–38.

Hjort, J. 1928. The first cruises with the steam ship Michael Sars. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 47: 188–195.

ICES. 1909. Rapport sur les travaux de la Commission A dans la période 1902–1907. A. General Part. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 10: 1–159.

Idelson, M. 1931. Fish marking in the Barents Sea. Journal du Conseil International pour l'Exploration de la Mer, 6: 432–433.

Iversen, T. 1934. Some observations on cod in northern waters. Fiskeri Direktoratets Skrifter, Serie Havundersøgelser, 4(8). 35 pp.

Jakobsson, J. 1970. On fish tags and taggings. Oceanography and Marine Biology Annual Review, 8: 457–500.

Jakobsson, J. 1993. Recent variability in the fisheries of the North Atlantic. ICES Marine Science Symposia, 195: 291–315.

Jenkins, J. T. 1927. The herring and the herring fisheries. P. S. King & Son, Ltd, London. 175 pp.

Jónsson, J. 1988. Hafrannsóknir vid Ísland I (Marine research at Iceland I). Reykjavík. 340 pp. (In Icelandic with extended English summary).

Jónsson, J.1996. Tagging of cod in Icelandic waters 1948–1986. Rit Fiskideildar, 14(1). 82 pp.

Mather, F. J. 1962. Transatlantic migration of two large bluefin tuna. Journal du Conseil International pour l'Exploration de la Mer, 27: 325–327.

Mather, F. J., Bartlett, M. R., and Beckett, J. S. 1967. Transatlantic migrations of young bluefin tuna (*Thunnus thynnus*). Journal of the Fisheries Research Board of Canada, 24(9): 1991–1997.

Nakken, O. 1994. Causes of trends and fluctuations in the Arcto-Norwegian cod stock. ICES Marine Science Symposia, 198: 212–228.

Nakken, O. 1998. Past, present and future exploitation and management of marine resources in the Barents Sea and adjacent waters. Fisheries Research, 37: 23–35.

Schmidt, J. 1906. Contributions to the life-history of the eel (*Anguilla vulgaris*, Flem.). Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 5: 137–264.

Schmidt, J. 1909. The distribution of the pelagic fry and the spawning regions of the gadoids in the North Atlantic from Iceland to Spain. *In* Rapport sur les travaux de la Commission A dans la période 1902–1907. B. Special Part. 229 pp. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 10. 844 pp.

Schmidt, J. 1928. Danish fisheries investigations in the Atlantic and adjacent seas. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 47: 103–122.

Sinclair, M. 1997. Prologue. Recruitment in fish populations: the paradigm shift generated by ICES Committee A. *In* Early Life History and Recruitment in Fish Populations, pp. 1–25. Ed. by R. Christopher Chambers and Edward A. Trippel. Chapman & Hall, London. 596 pp.

Schopka, S. A. 1994. Fluctuations in the cod stock off Iceland during the twentieth century in relation to changes in the fisheries and environment. ICES Marine Science Symposia, 198: 175–193.

Strubberg, A. C. 1947. Nyttefiskenes Livshistorie studeres i Nordatlanten og sydpå til Biscaya (The study of the life history of the food fishes in the North Atlantic extending south to the Bay of Biscay). *In* Naturforskeren Johannes Schmidt, hans liv og ekspeditioner skildret af venner og medarbejdere (The nature researcher Johannes Schmidt, his life and expeditions described by friends and colleagues), pp. 26–36. Ed. by Øjvind Winge and Å. Vedel Tåning. Gyldendal, Copenhagen. 187 pp. (In Danish).

Tåning, Å. Vedel. 1934. Survey of long distance migrations of cod in the North Western Atlantic according to marking experiments. Rapports et Procès-Verbaux des Réunions du Conseil International pour l'Exploration de la Mer, 89: 35–11.

Tåning, Å. Vedel. 1937. Some features in the migration of cod. Journal du Conseil International pour l'Exploration de la Mer, 12: 1–35.

Tåning, Å. Vedel. 1947. Aaleundersøgelserne begynder for alvor (The start of the intensive eel investigations). *In* Naturforskeren Johannes Schmidt, hans liv og ekspeditioner skildret af venner og medarbejdere (The nature researcher Johannes Schmidt, his life and expeditions described by friends and colleagues), pp. 37–44. Ed. by Øjvind Winge and Å. Vedel Tåning. Gyldendal, Copenhagen. 187 pp. (In Danish).

Trout, G. C. 1958. Results of the English cod tagging in the Barents Sea. Journal du Conseil International pour l'Exploration de la Mer, 23: 371–80.

Wegner, G. 1993. Ein Hamburger Burgermeister und eine heringstheorie (1746) [A mayor of Hamburg and a herring theory (1746)]. Deutsche Hydrographische Zeitschrift Ergänzungschaft, Reihe E, No. 25. 14 pp.