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Capelin – What are they good for? Introduction

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The ICES Symposium entitled "Capelin – What Are They Good For? Biology, Management, and the Ecological Role of Capelin", was held 23–27 July, 2001, in Reykjavík, Iceland. The co-conveners were Jim Carscadden, Canada, and Hjálmar Vilhjálmsson, Iceland, and 50 scientists from Canada, Denmark, Finland, Greenland, Iceland, Norway, Russia, the United Kingdom, and the United States registered. In this introduction, a brief overview focusing on capelin biology, the role of capelin as a forage species and commercial capelin fisheries is presented. Most of the information is gleaned from studies on Atlantic stocks, reflecting the extensive research activities initiated during the 1970s to support management of the large commercial fisheries. The 44 symposium papers were grouped into five themes: biology and ecology, multispecies interactions, abundance estimation, management, and capelin as an experimental animal. There were 17 poster presentations. Four recommendations for future activities are listed.

Keywords: capelin, *Mallotus villosus* (Müller).

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Introduction

The ICES Symposium "Capelin – What Are They Good For? Biology, Management, and the Ecological Role of Capelin", was held from 23 to 27 July 2001, in Reykjavík, Iceland, co-convened by the authors of this Introduction (which was not subject to peer-review). In all, 50 scientists from Canada, Denmark, Finland, Greenland, Iceland, Norway, Russia, the United Kingdom, and the United States registered, and 44 papers and 17 posters were presented. This volume contains the papers submitted, reviewed, and accepted for publication. The idea of a symposium was first mooted by the Northern Pelagic and Blue Whiting Fisheries Working Group of ICES in 1997, and ICES gave its endorsement in 1999. The sponsorship by ICES of a symposium centred on one species was viewed as unusual, but it emphasized the important dual role of capelin, *Mallotus villosus* (Müller), as both forage and commercial species, not only within the ICES jurisdiction, but throughout the northern hemisphere. In addition, it was noted that no international symposium at which capelin played a prominent role had been held since 1966, when the ICES Symposium on "The Ecology of Pelagic Fish Species in Arctic Waters and Adjacent Seas" was held at the ICES headquarters in Charlottenlund, Denmark (Blacker, 1968).

There has been considerable research on capelin conducted by Russian-speaking scientists (a recent search of Russian literature identified 389 papers on capelin published in Russian between 1892 and 2000; O. and L. Karamushko, unpublished data), but for the most part, those papers are not accessible to scientists who do not read Russian. Although not explicitly stated in the pre-symposium advertising, one of the main aims of the conference was to attract Russian scientists to present their research results to an English-speaking audience.

Overview of capelin

The capelin is a small, silvery, pelagic schooling species and a member of the family Osmeridae (McAllister,

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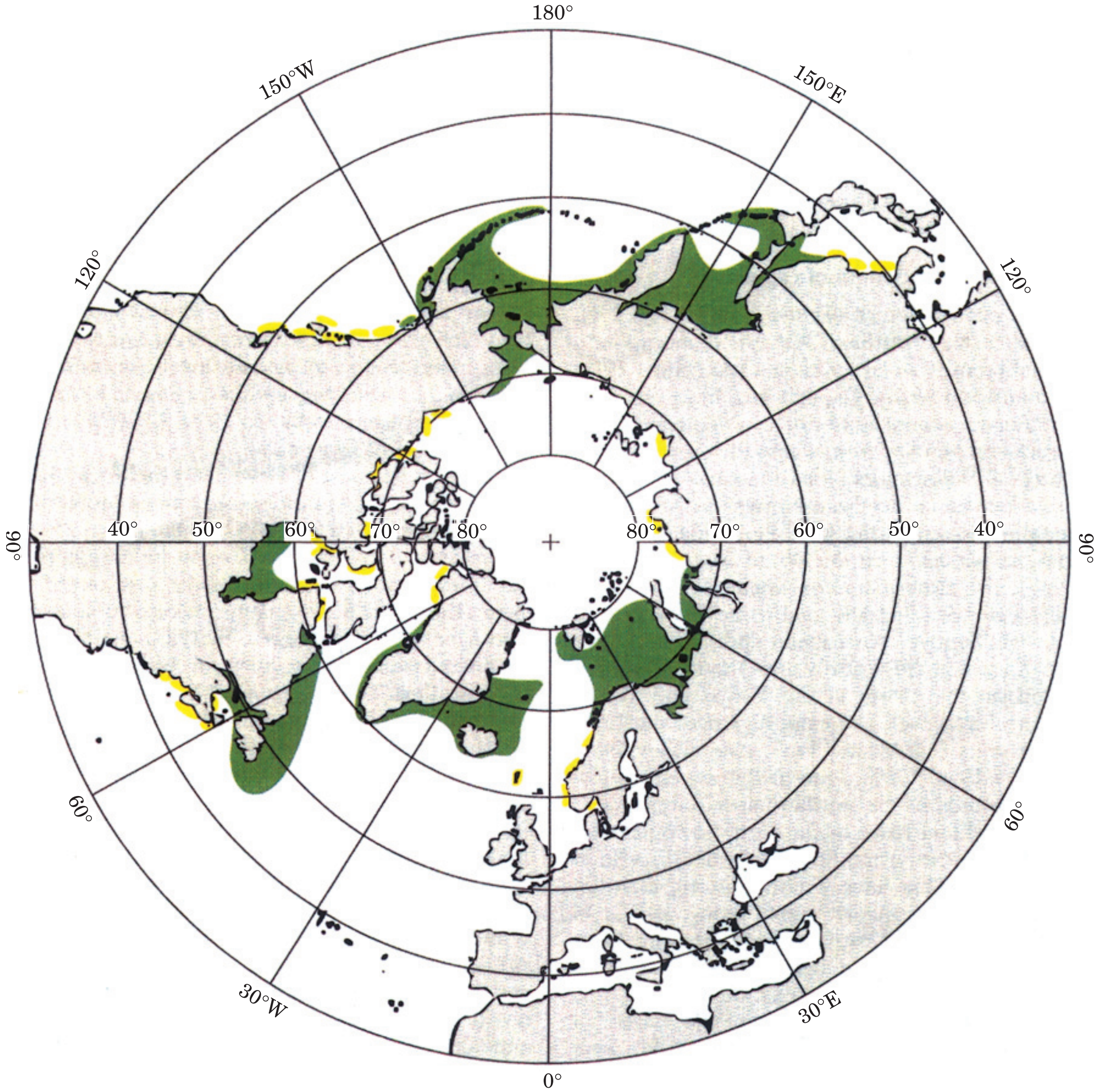

Figure 1. World distribution of capelin. Green denotes common occurrence; yellow, rare or sporadic occurrence.

1963). It is considered a cold-water species that occurs throughout the northern hemisphere (Figure 1). In the Atlantic, capelin are abundant in the Barents Sea, around Iceland and Greenland, and off the Newfoundland and Labrador coasts. In the Pacific, they are believed to be very abundant in the Bering Sea. Capelin are also found elsewhere in the northern hemisphere, but less is known of their abundance in those areas. Vilhjálmsson (1994) gives a detailed description of global capelin distribution.

Capelin are short-lived, few surviving past four years of age. At one time, it was believed that all fish died after spawning, but recent studies (Forberg, 1982; Shackell *et al.*, 1994; Vilhjálmsson, 1994; Burton and Flynn, 1998; Christiansen and Siikavuopio, 1998) have shown that there is likely some survival after spawning, especially by females. Nevertheless, the existence of few older fish in capelin populations indicates that natural mortality is high. During the spawning season, capelin are sexually dimorphic. Males develop enlarged pectoral and anal fins, and the scales along the lateral line become enlarged. Females show fewer changes, but they are easily distinguishable from the males because of the lack of secondary sexual characteristics and the distended, egg-filled abdomen.

Fecundity increases with length and weight; it varies among regions. Fecundity is highest among beach-spawning capelin in the Northwest Atlantic and Pacific, where the number of eggs per female can range between approximately 15 000 and 50 000 (Velikanov, 1986; Nakashima, 1987; Jóhannsdóttir and Vilhjálmsson, 1999). In contrast, bottom spawners in the Northeast Atlantic produce fewer eggs, rarely exceeding some 15 000 eggs per female (Huse and Gjøsæter, 1998; Jóhannsdóttir and Vilhjálmsson, 1999; Tereshchenko, 2002). It is noteworthy that the bottom-spawning Newfoundland capelin stock produces egg quantities per female similar to that of beach spawners in the Northwest Atlantic, an apparent paradox that may be explained by the fact that this stock was probably once a beach-spawning one (Carscadden *et al*., 1989; Jóhannsdóttir and Vilhjálmsson, 1999).

Capelin are demersal spawners, producing eggs that stick to the substratum. Spawning locations range from beaches (intertidal) to bottom substrata in deep water. Capelin in Icelandic waters and the Barents Sea are deep-water bottom spawners. In Norway, some fjordic stocks are beach spawners. Capelin in Alaska, British Columbia, Greenland, and the Sea of Okhotsk spawn on beaches (Dodson *et al*., 1991; Naumenko, 2002). Only in the Northwest Atlantic is there both beach and deep-water spawning (Dodson *et al*., 1991). There, capelin spawn on beaches along both Newfoundland and Labrador coasts as well as on the Southeast Shoal of the Grand Banks, about 350 km from the nearest spawning beach, where they spawn on the bottom in water depths of about 60 m (Carscadden *et al*., 1989). In Newfoundland and Labrador, beach spawning dominates, but spawning in deeper water adjacent to spawning beaches is also common. The hypothesis has been advanced that this behaviour occurs when intertidal water temperatures become too warm (Templeman, 1948). However, recently it has been noted that both modes of spawning can occur simultaneously when water temperature is suitable (Nakashima and Wheeler, 2002). Spawning appears to be substratum-specific, spawning taking place most often on fine gravel of diameter 0.1–15 mm (Vilhjálmsson, 1994). Water temperature has also been cited as a determinant of spawning location (Carscadden *et al*., 1989). Bottom spawning appears to be more common at lower temperatures than beach spawning. Nevertheless, the recorded lowest and highest temperatures for both modes of spawning are 1.5 and 14.0°C (Vilhjálmsson, 1994).

Throughout their range, capelin are key forage species. They undertake extensive feeding migrations and, in doing so, they transfer energy from areas of high seasonal production in the north to more southerly areas. For example, around Iceland, juvenile capelin migrate to summer feeding grounds in the north, where they grow rapidly, increasing their body weight by a factor of up to two, depending on age (Vilhjálmsson and Carscadden, 2002). They then migrate south to their spawning grounds, where they become important energy-rich prey for a suite of finfish, marine mammals, and seabirds. Similar feeding and spawning migrations with the resultant energy transfer also takes place in the Barents Sea (Gjøsaeter, 1998), and around the coasts of Newfoundland and Labrador (Lilly and Davis, 1993).

The results of quantitative research on predation on capelin by predators in the Atlantic indicate that millions of tonnes of capelin are consumed annually. Less research in this field appears to have been conducted on capelin in the Pacific, probably because of the lack of commercial fisheries there. However, because of the importance of cod (*Gadus morhua*) in these northern ecosystems and their apparent dependence on capelin, we highlight some of the studies on that species to illustrate the importance of capelin as a forage species. In the Barents Sea, estimates of annual capelin consumption by cod, derived from model calculations, ranged between 200 000 and 3 000 000 t for the years 1984–2000. Consumption of capelin was lowest when capelin biomass was small and increased when capelin abundance increased (ICES, 2001). Liver condition (considered a proxy for cod well-being) of Northeast Arctic cod decreased rapidly when the capelin stock biomass dropped below a million tonnes (Yaragina and Marshall, 2000). Using simulations, Marshall *et al.* (1999) showed that mean spawner biomass, mean total liver energy, and mean total egg production of Northeast Arctic cod were positively correlated with capelin biomass. At Iceland, the mean weights of cod aged 5–8 were positively correlated with capelin abundance (Vilhjálmsson, 2002). For Newfoundland and Labrador, Carscadden *et al.* (2001) reviewed the consumption estimates of capelin and noted that, with the drastic decline of cod, annual capelin consumption has declined from approximately 2 500 000 t in the 1960s to about 100 000 t in the 1990s. Questions have been asked about the possibility of a cod recovery in the absence of an adequate capelin stock (Anon., 2001), and Rose and O'Driscoll (2002) suggest that cod will not recover unless capelin return to their "traditional" distribution patterns off the coast of Labrador (see Carscadden *et al.*, 2001, for a description of the changes in capelin distribution). Attempts to identify significant relationships between cod population characteristics and capelin in that region have been inconclusive (Akenhead *et al.*, 1982) or unsuccessful (Millar *et al*., 1990).

In addition to their key ecological role as a forage species, capelin are fished commercially. The size of the estimates of capelin consumption indicate that capelin biomasses are large, and this has been confirmed through several years of acoustic surveys in three areas of the Atlantic, the Barents Sea, around Iceland and in the Iceland Sea, and off the coasts of Newfoundland and Labrador. These acoustic estimates reveal that abundance can fluctuate dramatically from year to year, a phenomenon that is not surprising for a species with

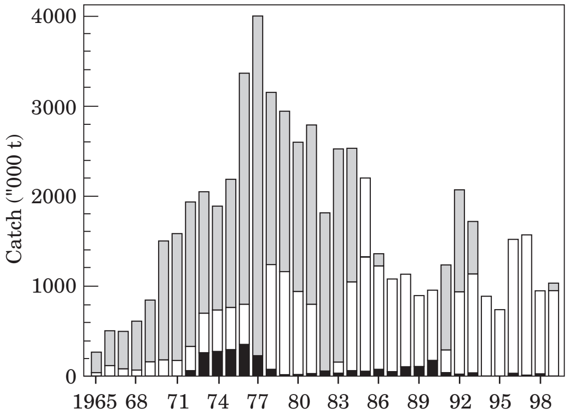

Figure 2. Catches of capelin, 1965–1999, from the Barents Sea (grey bars), Iceland (open bars) and Newfoundland and Labrador (black bars).

such a high mortality rate and short life. In all areas, acoustic estimates have resulted in biomass estimates in excess of a million tonnes when the stocks are healthy. In contrast, biomass estimates as low as a few hundred thousand tonnes, and occasionally lower, have been measured when the stock is depressed. An exception to this is the Newfoundland area, where low estimates were derived even when the stock was not as depressed as the acoustic estimates suggested (see Carscadden *et al.*, 2001, for a description).

The abundance of capelin has initiated the development of large-scale commercial fisheries in the Barents Sea and the Iceland–East Greenland area, and smaller fisheries in the Newfoundland–Labrador area. Around Iceland and in the Barents Sea, the directed commercial fisheries developed just after the collapse of the Norwegian spring-spawning herring stock in the late 1960s, when the pelagic fleets needed raw material to sustain themselves and the fishmeal plants. The fishing industry consequently turned its attention to capelin, and large-volume capelin fisheries developed during the 1970s. At about the same time, commercial capelin fisheries began offshore around Newfoundland and Labrador. There, foreign trawlers, mainly from the USSR and other eastern countries, and seiners from Norway and Iceland, took most of the catch. The foreign fishery declined rapidly in the late 1970s when recruitment of capelin was low. At that time a smaller, inshore Canadian fishery developed on roe-bearing capelin to supply a limited market in Japan. Generally, catches in this inshore Canadian fishery were much lower than in the offshore foreign fishery. In addition, catches in Canadian waters were much lower than in the Barents Sea and Iceland, where annual catches exceeding a million tonnes (Figure 2) are not uncommon when the stock is abundant. Around Greenland, relatively small quantities are taken for domestic use (Jangaard, 1974); between 1960 and 1997, annual catches rarely exceeded 3000 t. In the western Pacific, fish companies and canneries on the western coast of Kamchatka fish for capelin during its spawning season. Catches there are also small relative to commercial catches in the Atlantic, not exceeding 4000 t per year between 1962 and 2000 (Naumenko, 2002).

The symposium

Papers were solicited and received for five theme sessions: biology and ecology, multispecies interactions, abundance estimation, management, and capelin as an experimental animal. In addition, a separate poster session was held.

Biology and ecology

In all, 21 papers were presented in this, the largest session. They were well distributed regionally, two from the western Pacific, three from the eastern Pacific, one from the St Lawrence River estuary in Canada, six from Newfoundland and Labrador, one from Greenland, one from Iceland, one from the Faroe Islands, and six from the Barents Sea. The papers describing the biology of Pacific capelin were particularly well received because they presented information for capelin that had not previously been available or had been written only in Russian. Many papers from other regions presented analyses on specific topics such as vertical migration, condition factor, factors affecting beach spawning, survival of eggs and larvae, environmental variability and its effect on capelin, capelin and krill distribution, early life history, growth, and fecundity. Although no papers attempted to synthesize information among the many stocks, the papers illustrated the range of research being conducted on capelin biology and, in some cases, the similarities and differences among capelin stocks worldwide.

Multispecies interactions

Only six papers were presented in this session, surprisingly few given the importance of capelin as a forage species. One paper presented an overview of capelin as prey for finfish in the Barents Sea, two presented data on the importance of capelin as food for cod around Iceland and Newfoundland, and the remainder described interactions among capelin and seabirds in the Newfoundland/Labrador area.

Abundance estimation

Estimating capelin abundance has become critical for both fisheries management and ecosystem modelling. The high rate of mortality and short life of capelin renders the application of traditional stock estimation techniques (e.g. sequential population analyses) problematic. Five papers were presented in this session and, given the importance for this species of abundance estimation using acoustics, it was somewhat surprising that only two dealt with acoustics. One addressed a key issue in acoustic methodology, target-strength estimation, and the other compared estimates of abundance derived acoustically and from trawl catches. The remaining papers presented the results of abundance estimation of capelin using novel techniques, including trawl catches, lidar, and digital imagery from aerial surveys, and the use of a mathematical model to combine disparate indices to produce estimates of relative year-class strength.

Management

All six papers on management concentrated on management problems around Iceland and in the Barents Sea, where the largest commercial fisheries for capelin operate. The Icelandic paper described the historical management scheme, as well as reasons for, and methodologies used in, acoustic assessment surveys. One paper presented the results of DNA analysis and how these results might be used to describe the genetic population structure of capelin. The remaining four papers outlined various aspects of the management of Barents Sea capelin; this stock has been a key element of multispecies modelling for nearly two decades, and this modelling has been intimately linked to management initiatives for capelin.

Capelin as an experimental animal

Most traditional capelin research has been field research, but in recent years, there have been initiatives to maintain capelin in the laboratory. The five papers in this session all originated from the Tromsø laboratory, where J. S. Christiansen has led laboratory experimentation on the species. Although this approach to capelin research is relatively new, it appears to have wide application. Papers on such topics as survival, growth, metabolism, foraging behaviour, and larval development were presented.

Poster session

Of the 17 posters presented, one on mtDNA analysis of capelin worldwide created considerable interest. This analysis indicated that Atlantic and Pacific capelin were different enough genetically to be considered separate species. This paper has been submitted for publication to another journal and, therefore, has yet to be scientifically evaluated. Nevertheless, the results and the DNA results presented in another paper contributed to one of the recommendations cited later.

Special sessions

During one afternoon, discussions focused on research approaches that might be taken in the Gulf of Alaska, using the experiences of capelin researchers in other parts of the world. Videos highlighting the ecology around Newfoundland and Kamchatka were presented.

Recommendations

The Symposium was organized to provide maximum interaction among the participants on an informal basis. These opportunities and the discussion session at the close of the Symposium resulted in a number of recommendations.

- There were several areas of future research that would benefit from international coordination. First, all papers at the Symposium presented results on capelin from particular regions. It is obvious that there are both similarities and differences that would be useful starting points for coordinated worldwide capelin research, and it is recommended that researchers from different countries pursue these aspects of capelin biology. Second, it is recommended that an age-determination workshop be organized to standardize age determination of capelin. Comparative studies among regions have not been undertaken for at least 30 years and, with the increase in research on Alaskan capelin, this would be an opportune time to hold a workshop there. Third, before research on Alaskan capelin is initiated, a workshop should be convened to examine the availability of capelin data from that region. In addition, information on the oceanography of the area should be examined. It is recommended that capelin researchers from other regions participate in this workshop to offer advice on planning surveys, etc., using their own knowledge of capelin biology. These three activities could be convened in workshop settings, possibly under the joint auspices of ICES and PICES.
- Data presented at the Symposium suggest that capelin in the Pacific and Atlantic may be separate species. It is recommended that genetic studies on capelin continue in order to clarify the relationships among stocks. Capelin have been examined from most major stocks, but capelin also occur between major stocks (e.g. Canadian and Russian Arctic), and the genetics of those capelin should be examined.
- Overviews of climate in each region were missing from the Symposium. Closer cooperation between oceanographers and capelin biologists should be encouraged to further understanding of the reaction of capelin to climate change and variability.
- Because capelin are so important in the ecosystem, it might be useful to consider setting up several small study areas, where the role of capelin can be studied

on a comparative basis. Areas such as the Laurentian Channel and around breeding islands of birds might be considered.

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