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EDITORIAL

Norwegian fjords: From natural history to ecosystem ecology and beyond

The original articles in the first issue of *Marine Biology Research* in 2011 (volume 7) were led by a study of trophic relationships and the food web of Kongsfjorden, Svalbard archipelago (Renaud et al. 2011). In the year before (volume 6), the zooplankton-mediated carbon export in Balsfjorden (northern Norway) was dealt with (Wexels Riser et al. 2010), and in 2009 (volume 5) populations of the lanternfish *Benthosema glaciale* (Reinhardt, 1837) from Herdle-, Mas- and Sognefjorden (Western Norway) and the Norwegian Sea were compared with each other (Kristoffersen & Salvanes 2009). It is no coincidence that papers on the biology and ecology of Norwegian fjords are appearing in our Journal on a regular basis. In fact, this follows a long publishing tradition that began 50 years ago, when *Sarsia* (see Brattstrøm 1961), one of the two predecessors of *Marine Biology Research* (the other being *Ophelia*), was launched.

The very first article published in *Sarsia*, named after the Norwegian pioneer in marine zoology, Professor Michael Sars, was a presentation of an important joint national project or programme at that time, 'The natural history of the Hardangerfjord' (Braarud 1961). Eventually most of the published results from 'The natural history of the Hardangerfjord' programme appeared in *Sarsia*, culminating in a series of 14 articles (Aarthun 1961; Braarud 1961, 1974, 1975, 1976; Sælen 1962; Bennett & Samuel 1963; Cone et al. 1963; Jorde & Klavestad 1963; Brattegard 1966; Lie 1967; Aas 1971; Braarud et al. 1974; Tambs-Lyche 1987).

However, even though the project 'The natural history of the Hardangerfjord' was unique in many ways, it by no means represented the first attempt to study the fjords in Norway. Norwegian fjords are numerous and diverse, and have been localities for scientific studies for centuries. The first fjord investigation in Norway was undertaken by the great Danish naturalist O.F. Müller. He lived at Drøbak in Oslofjorden, and dredged Oslofjorden from Drøbak to Tønsberg each summer of 1773, 1774, 1775 and 1778. Oslofjorden thus was the first Norwegian fjord exposed to the scrutiny of a zoologist. Müller described hundreds of marine benthic organisms from this fjord system. The work of Müller was followed up by the eminent zoology professors M. Sars and his son G.O. Sars. Other scientists employed at the University of Oslo continued their study of Oslofjorden throughout late 1800 and early 1900 (Broch 1954).

Initially, the study of marine life was carried out in the fjords because it was convenient. The larger cities are located on or near major fjords, and as the academic institutions naturally were located in these cities (Trondheim, Oslo and Bergen) the natural history of marine organisms studied in Norway was studied in fjords. Viewed from Bergen, Hardangerfjorden was a natural choice for a large fjord to study by most of the active zoologists in Norway in the middle and late 1800s. At first the studies were concentrated at the inner part of the main fjord outside Utne, for example by P. Chr. Asbjørnsen, D.C. Danielssen, M. Sars, G.O. Sars, the German J. Verkrüzen, and the Swedes P.O. Aurivillius and C. Bovallius (see Grieg 1914). Grieg (1914) extended the geographical range of these studies, and he presented a list of all mammals, fishes and invertebrates known from the middle and inner part of Hardangerfjorden. He also summarized all biological knowledge of the fjord at that time.

The large-scale programme for investigating Hardangerfjorden introduced by Braarud (1961) was the first attempt at a comprehensive study of all aspects of the natural history of a Norwegian fjord, from topography and geology to all aspects of marine life. The programme was started with field work in 1955 and was officially closed by the publication of an article on the fishes of Hardangerfjorden by Tambs-Lyche (1987). Remarkably this programme was started as a cooperation between scientists from many institutions, and covering most of the fields of marine science, without any

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Figure 1. A view of Hardangerfjorden in winter (Photo: Vivian Husa).

immediate 'practical' motivation, i.e. 'pure science'. Most of the later fjord investigations have been motivated by concerns of how large anthropogenic projects, industrial or others, might influence fjords. One large project was a large-scale investigation carried out in the late 1970s of how modified freshwater discharge into fjords caused by hydroelectric power production might disturb the natural fjord ecosystems. Two fjord systems exposed to major modifications due to the building of hydroelectric power plants, Skjomen in northern Norway and Ryfylkefjordene were studied. The main results were summarized in Kaartvedt (1984).

As the 1900s proceeded, it became more and more clear that the increasing anthropogenic eutrophication of Oslofjorden seriously affected the fjord communities. This initiated a number of investigations, of which the Oslofjord project (1962–1965), carried out by the Norwegian Institute for Water Research, was the most comprehensive (Ruud 1968a,b). Comparisons with older studies clearly showed effects on the biota of the fjord as a result of the eutrophication (e.g. Beyer 1968; Ruud 1968b; Bokn & Lein 1978).

In the early 1980s, the newly developed technologies for producing large quantities of cod juveniles led to the idea that enhancement of the cod stock in a fjord (by releasing large quantities of artificially reared cod juveniles) might result in higher yields for the local fishermen. Masfjorden was chosen as a fjord for a pilot release and was intensively studied for a period in the 1980s. Even though the main conclusion was that no benefit to local stocks would result from such a release, the Masfjorden project was very successful by contributing to a greatly increased knowledge of ecosystem processes and food webs in fjords (e.g. Giske et al. 1990; Baliño & Aksnes 1993; Salvanes & Nordeide 1993).

The Masfjorden project illustrates some of the scientific advantages of doing fjord studies. For one thing, biological oceanographic processes are complicated. Fjords as ecosystems have the same basic properties as the much more open ecosystems of the oceans, and biological processes in a fjord can be treated as a model of processes in much larger oceanic systems. Hence, some biological processes of the ocean may, with advantage, be studied in fjords.

Functional studies of the pelagic food chain – a key process in biological oceanography, may be easier to carry out in a closed fjord system than in an open ocean system. Matthews & Bakke (1977) studied the deep-water pelagic community in a small fjord (Korsfjorden) and observed that the composition of macro- and microplankton changed from month to month and year to year during three years. Despite this variation, the biomass estimates showed a consistent group pattern when the species were grouped as herbivores, omnivores and carnivores. Thus, even though the study showed considerable flexibility in the species composition of a plankton community, there were no corresponding marked effects on the trophic structure.

Studies of population dynamics of oceanic species seldom give results of sufficiently high quality due to the difficulties of sampling the *same* population over time. Deep fjords often contain oceanic species whose populations may be isolated from other populations for long periods of time. Such populations are close to the ideal population for studies of growth, mortality, life span, and succession of generations. In Korsfjorden, Matthews et al. (1978) observed a very high instant mortality rate of the copepodites from stage III onwards of *Calanus finmarchicus* (Gunnerus, 1770), and virtually the whole population appeared to fall prey to carnivores. On the other hand, the larger and more translucent

Calanus hyperboreus Kröyer, 1838 had a constantly low early mortality rate, and a large proportion of its biomass seemed to pass to the decomposers.

Behavioural studies are also much easier in fjords than in the open ocean. The large coronate medusa *Periphylla periphylla* (Péron & Lesueur, 1810) is a good example. The medusa is semi-cosmopolitan and occurs in most of the oceans and in many fjords, but nowhere in such densities as in the 440 m deep Lurefjorden, western Norway (Fosså 1992). The population has been studied by several investigators using different methods. Acoustic observations of diel vertical migration were made by hull-mounted echosounders and an echosounder located on the seabed (Dupont et al. 2009).The behaviour of *Periphylla* has been studied *in situ* by SCUBA divers at night when the medusa are close to the surface. During daytime when the medusae are in the dark deeper waters, they have been studied by use of still-cameras and video-cameras mounted on an unmanned submarine or ROV (Remotely Operated Vehicle) (Båmstedt et al. 2003). Many scientists and TV crews have been lured to Lurefjorden to study *Periphylla*.

The number of fjord investigations along the Norwegian coast is too large for a complete list to be made here. The various fjord projects, large and small, have one thing in common – they have extended our understanding of how fjords work as ecosystems, and of the precautions necessary to avoid serious disturbance of these systems. However, we will mention the most recent Norwegian research programme about fjords, 'Ecological Processes and Impacts Governing the Resilience and Alternations in the Porsangerfjord and the Hardangerfjord – EPIGRAPH', covering two Norwegian fjords. The project was initiated in 2008 by the Institute of Marine Research. While a possible anthropogenic impact on the fjord biota or hydrography was not at all considered during the first research programme of Hardangerfjorden, the present investigation of this fjord has to a greater extent included this aspect. Since the time when 'The natural history of the Hardangerfjord' was carried out, salmon aquaculture has started in the fjord. The effects of salmon farming on wild salmon stocks in Hardangerfjorden have been given much attention in the present investigation of the Hardangerfjord. The EPIGRAPH project will close in 2011 and plans towards a Thematic Issue in *Marine Biology Research* are currently underway.

Our future hope for fjord research is that studies on every aspect of our fjords should continue and hopefully increase in quality and quantity. Fjords represent a topographically unique landscape type produced by the Quaternary glaciation periods, and are not present in many parts of the world. However, when present they are an extremely important part of the coastal environment. Many fjords in Norway are now suffering from pollution, and from water column darkening (Aksnes et al. 2009). We need more research to make contributions towards the goal of getting a sound scientific basis for policies of fjord management.

Marine Biology Research is a natural journal outlet for publications on fjord research in Norway, and also for fjord research in other regions (e.g. in Sweden: Thomasson & Tunberg 2005; Tønnesson et al. 2005; Greenland: Jones et al. 2007; New Zealand: Poorbagher et al. 2010a,b). Like all populated estuaries, the fjords are very vulnerable to pollution and anthropogenic impact in general. We hope the focus on fjords in *Marine Biology Research* will continue to raise national and international awareness, communication and collaboration to the levels needed for thorough investigation and sustainable management of these sensitive ecosystems.

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