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History of Norwegian Marine Science

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Abstract
Exact marine science in Norway was initiated in 1760 by pioneers in zoological taxonomy. Fisheries ecology that started in 1863, lead to large oceanic and Arctic expeditions, and a "golden age" of interdisciplinary Norwegian marine science ending with the 1st World War. Governmental poverty between the two World Wars made scientists work on low-budget research in coastal areas or join Arctic and Antarctic expeditions funded by private capital. After the 2nd World War a New Deal appeared when the Government invited the marine science community to organise interdisciplinary research coordination. It ended in 1986 when a new political regime won control over science and established an administrative level of research leadership that managed short-term programs in response to political agendas for economical development during the rest of the 20th century.

Histoire des sciences marines en Norvège

Mots clés : religieux scientifiques, pionniers interdisciplinaires, époques, tournant, organismes scientifiques, contrôle administratif

Résumé
Les sciences marines exactes furent développées, en Norvège, par des pionniers de la taxonomie animale, dès 1760. L´écologie des pêches, qui débuta en 1863, contribua à de vastes expéditions d´exploration océanique, notamment dans les régions arctiques. L'« âge d'or » de la

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science marine interdisciplinaire norvégienne s'acheva avec la Première Guerre mondiale. Le manque de ressources gouvernementales entre les deux guerres mondiales força les scientifiques à travailler sur des budgets restreints. Ils limitèrent leurs activités à la zone côtières ou se joignirent à des expéditions arctiques ou antarctiques, financées sur des capitaux privés. Après la Seconde Guerre mondiale, l'État norvégien invita la communauté scientifique à coordonner une recherche interdisciplinaire en biologie marine. En 1986, le système politique norvégien changea et pris le contrôle de la recherche en science. Les priorités de recherches sont à présent décidées à un niveau administratif et suivent des programmes à court terme qui répondent aux agendas politiques de développement économique.

1. Introduction

The scope of the present paper is to present information that may explain how Norwegian marine science emerged and developed as a result of human potential, resource exploitation, national policies and international relations.

The sea and its forms of life have forged the national identity of Norwegians from ancient times, because it provides seaways and resources for survival and trade. However, the absence of written records prevented contemporary documentation of early relationships except for reports written by foreigners. This changed when Christianity was introduced about 1 000 years ago. Numerous warlords surrendered their powers and became the nobility of Norway, a feudal nation governed by a sovereign king who needed scholars to manage his nation.

The literacy of the ruling classes resulted in a manuscript possibly written between 1250 and 1260 titled *Konungs skuggsjá* ("King's Mirror"). It may have been written by one Einar Gunnarson who became the bishop of Trondheim in 1255. The text appears to be a dialog between a tutor and a student of high social standing, maybe a prince being prepared for duties that required encyclopedian knowledge (Hanner, 2007). Paragraphs on sea mammals in the Greenland and Iceland Seas are obviously based on second-hand information, but may be regarded as the very first Norwegian attempt to record a marine natural history of Arctic waters (Broch, 1955). The marvellous document served as a source of reference for scholars for more than 350 years.

Between 1397 and 1523 Norway, Denmark and Sweden existed as a single Nordic union under a common monarch residing in Denmark. The union included Finland, the Faeroes, Iceland and Greenland, which provided important biological resources for the common economy. Towards the end of the era the Catholic Church assigned a young Swedish cleric, Olaus Magnus, to sell indul-

gences in the northern parts of the union. He travelled there in 1518-19, and accumulated first-hand as well as second-hand information on natural history and culture. His work came to a halt when he had to leave his Stockholm residency in 1523 after the Swedes broke with the union, elected their own king and adopted the protestant teachings of Martin Luther. Olaus Magnus spent the rest of his life in Rome where in 1555 he published a richly illustrated account of the Nordic peoples and their environment. His works are a primary source of written evidence that describes the rich Lofoten cod fisheries and the Moskenes Current, a World famous tidal maelstrom later described by Sir Arthur Conan Doyle in one of his books. However, he also included second-hand information on sea monsters, being evident in his big *Carta Marina* (plate 1).

After the Nordic Union ceased in 1523, Norway came under direct Danish rule in 1536, but kept a few legal rights that maintained a national identity. However, in 1814, as a result of the Napoleonic wars, Denmark had to give up Norway. The Norwegians wrote a new parliamentary constitution but had to accept rule by a Swedish monarch residing in Stockholm. The united kingdom split in 1905 when the Norwegians achieved total liberation and elected their own sovereign monarch.

After Norway had become a Danish province in 1536, scientific affairs were governed by a central administration in Copenhagen. The early marine scientists in Norway were educated in theology at European universities and granted commission as priests from the Danish king. The first Norwegian university was established in 1811 at the end of Danish rule, which allowed Norwegian students to develop their science rather independently after Swedish rule was established in 1814.

2. Sources of historical information

The most comprehensive source for the early history of marine science in Norway was written by Broch (1954). It is devoted mainly to general zoology, but serves also as a reference work for fisheries biology. Marine resources were important to Norway and naturally interested many zoologists. Sakshaug & Mosby (1976) included excerpts from Broch, and added information on other marine disciplines. Both works terminate their accounts at the start of the 2nd World War. However, books edited by Rollefsen (1962) and Sakshaug *et al*. (1976), serve as contemporary sources in their time, describing the state of the art in all fields of Norwegian oceanography. Several authors have added new historical information on the scientific progress after the 2nd World War in a book dealing with the ecology of the Norwegian Sea (Skjoldal, 2004). A history paper published by the Association of Norwegian Oceanographers

for its 50th Anniversary (Hognestad, 1999) reflects many of the scientific problems addressed by Norwegian marine science towards the end of the 20th century. Reports from the Annual Meetings of the Association of Norwegian Ocanographers treat the development of oceanographic science during recent years (NHF 1999-2005). Some data have been found in Anonymous (1980) and the Internet (Google).

3. The birth of marine science

Marine science in Norway was brought into being by the activity of several poly-historians working as clerics within the Protestant Church. The first was Peder Claussøn Friis (1545-1614), a priest who attempted to write a natural history of Norway. He wrote a work on "Animals, Fishes, Birds and Trees in Norway". The text from about 1599 no longer exists, but a shortened copy

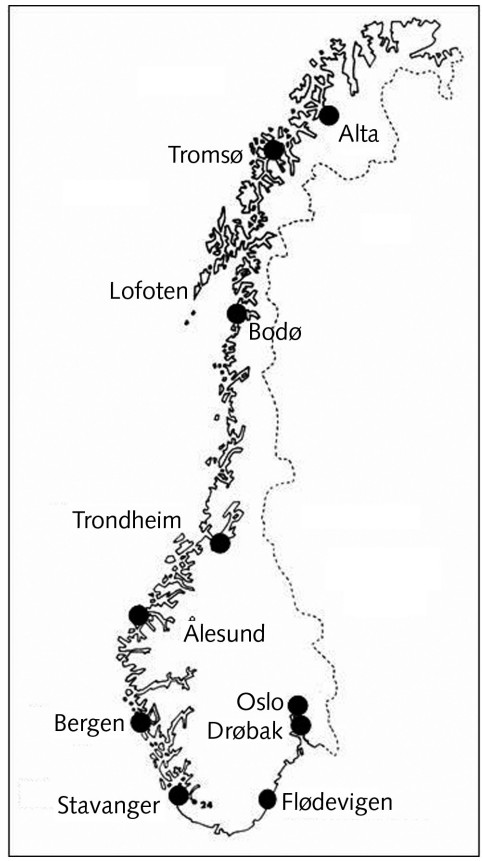

Figure 1 – Map of Norway with places mentioned in the text.

Plate 1 – Detail from *Carta Marina* published by Olaus Magnus in 1539, showing sea monsters in the Norwegian Sea, and the Moskenes tidal current in Lofoten, northern Norway.

Plate 2 – R/V *Hansteen* in Trondheim harbour, the first vessel built for bathymetric and fisheries research, a veteran ship that is still sailing. DS "Harsteen" Foundation (www.harsteen.no)

was later found and printed in 1881. His information on seals and whales is obviously taken from the works of Einar Gunnarson and Olaus Magnus, but a rather comprehensive section on commercial fish and shellfish probably originated from personal experience and contemporary common knowledge. His work served as a reference for scholars during the following centuries.

Plate 3 – Artwork by G.O. Sars: Blue whale (*Balaenoptera musculus*).

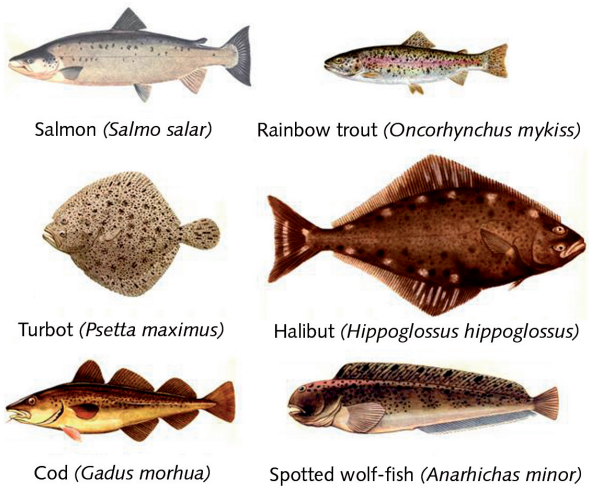

Plate 4 – Fish that have been target species in Norwegian mariculture research during the last decades.

Petter Dass (1647-1707) who served as a priest in northern Norway, wrote a masterpiece of popular marine science, printed after his death. He described marine resources and wildlife, and the living conditions in fishing communities, as beautiful poems transferred verbally by the public down through the generations into modern times. *Nordlands Trompet* are still printed and sold in different editions, and are read, not only by lovers of good literature but also by scholars seeking references for their science and teaching. Ironically, its standing as a scientific reference work has been underestimated throught the years due to the beauty of its language and its quality as a piece of art.

The first true natural history of Norway was written by Erich Pontoppidan (1698-1764) while serving as a bishop in Bergen from (figure 1) 1747 to 1755. He devoted his work to all natural sciences. One of the volumes deals with zool-

ogy and contains several chapters describing marine life. They contain graphic pictures of species that are easily identifiable, and document that Pontoppidan had in person performed pioneering zoological studies as a source for his scientific work. However, his book is also a compilation of contemporary information. Substantial parts were delivered by subordinate priests and other second-hand informers. Although he was inspired to write a chapter that described sea-monsters, his work stimulated the birth of true natural science in Norway.

One of Pontoppidan's informants was Hans STRØM (1726-1799) who served as a cleric in one of his parishes. Strøm's interest for Nature developed the sort of qualities that characterise modern science by presentation of personal, first-hand observations and critical analyses. His description of natural and economical conditions in his parish, published in 1762, contains a major treatise on fisheries which is still an important reference paper in Norwegian fisheries science. The publication won him a membership in the newly established the Royal Norwegian Society of Sciences and Letters (DKNVS) in Trondheim, a research academy that stimulated him to pursue his interests in zoology. He published very good descriptions of species based on morphological characters and developed skills that resulted in an outstanding anatomical study of a marine gastropod.

DKNVS was founded in 1760, partly due to the vigour of Johan Ernst GUNNERUS (1718-1773). He was Norwegian by birth but was a professor in theology at the University of Copenhagen when he became the bishop of Trondheim in 1758. One year later, a visit to northern Norway that was part of his diocese, woke his interest for natural science and especially for zoology and botany. In the following years, he developed close collaboration with the famous Swedish biologist Carl VON LINNÉ who had then established his binary nomenclature for classification of organisms. Linné devoted himself mostly to terrestrial and freshwater forms of life, which allowed Gunnerus to specialise in marine species. Most of his publications deal with invertebrates, like a well known paper printed in Copenhagen, where he described for the first time in science a copepod, named *Monoculus finmarchicus*. It was later renamed as *Calanus finmarchicus*, an ecological key species in North Atlantic zooplankton. Most of Gunnerus' other excellent scientific works were published in *Skrifter*, a journal issued by DKNVS. He also inspired many of his priests to study natural science and publish their papers in *Skrifter*. However, the journal had limited distribution, which is why Gunnerus and his colleagues did not gain more international recognition for their work.

In 1771, Gunnerus was invited by the Danish government to reform the University in Copenhagen and used the opportunity to suggest plans for a Norwegian university. Unfortunately, the head of administration fell into the

King's disgrace in 1772, which depressed Gunnerus and probably caused him to fall ill and die in 1773. However, Strøm raised the proposal again in 1793, and suggested that it should be established in Bergen. He may have made an impact, but did not live to see it when it became established in Oslo eighteen years later, in 1811.

It was Jens Rathke (1769-1855) who brought marine science into the new university. He graduated in theology at the University of Copenhagen, but devoted himself to natural history leading to a thesis in 1794. He was then commissioned to perform studies of the natural resources and economy of Norwegian fisheries communities, which resulted in a report that still serves as a reference work for Norwegian fisheries science. He was rewarded by getting governmental support to pay scientific visits to many European countries, from Russia to Spain. His achievements won him the position as professor of zoology at the University of Copenhagen in 1810, before he became the first professor of zoology at the new university of Oslo when it was opened in 1813. That was only one year before the Napoleonic wars ended, and the national ties between Denmark and Norway broke.

4. Marine biology in early Norwegian academia

When Norway separated from Denmark and became a monarchy with a Swedish king, the new university in Oslo was rather dispersed among various existing buildings. Professor Rathke soon became engulfed in administration at the university, and was forced to teach mineralogy and botany as well as zoology, which left little time for research until he resigned in 1845. He was succeeded by one of his assistants who interestingly did not start his academic career as a student of theology, but had devoted himself to biology from the very beginning. Halvor Heyerdahl Rasch (1805-1883) pioneered artificial fertilisation of salmonid eggs, which had large impact on the cultivation of salmon rivers in Norway and Sweden. Taking into account that the Atlantic salmon is anadromous, stocking of juvenile salmon in rivers and catching of adults on their return from the sea, is in fact a case of sea ranching. Taking also into account that this activity continued unbroken in Norway, the successful industrial farming of Atlantic salmon owes much to Rasch. In addition, he published reports on applied oyster cultivation and must be regarded as the true initiator of Norwegian aquaculture research.

Rasch became professor in 1852, when the university in Oslo finally moved into new buildings. He devoted much of his time as a professor to teaching and application of zoological knowledge in exploitation of terrestrial and aquatic resources. This may explain why he is not ranked as one of the greatest scien-

tists in Norway. The other explanation may be that he promoted a person with larger potential for scientific leadership. In 1854, he managed to get Michael Sars (1805-1869) into an extraordinary professorship in zoology at his university. Sars was then already an international figure who required space, and certainly came to overshadow his colleague in research.

Michael Sars, from his youth onward, showed a deep interest in natural science, and zoology in particular. Though he studied theology and graduated as a priest in 1828, one year later he managed to publish a small paper on cnidarians that raised international interest. However, to support his family, he took a position as priest in 1831 and served for 23 years in different parishes on the western coast of Norway. During all these years in the service of God, he continuously studied marine animals and published works that won him international acclaim. His publication of 1835 on coelenterates, polychaetes and molluscs became internationally recognised, and a series of publications from 1839 to 1845 on developmental biology and metamorphosis in different phyla caused him to be created honorary doctor at the University of Zürich in 1846. His list of merits caused the Norwegian government to grant several scholarships that allowed him to visit European institutions and to perform field work in Norway and Italy, devoting himself to zoogeography including bathymetric studies of the fauna. Finally, his friends and colleagues convinced the university to establish a particular professorship that allowed Sars to resign from the priesthood and become a full-time scientist and scholar in zoology.

The 15 years that Michael Sars served as a professor in Oslo was a period of major achievements in marine zoology. He became the leading force in a scientific community counting many contemporary colleagues who caused Norwegian zoology to leap forward in the fields of taxonomy, anatomy and life history. He became an international pioneer in the study of deep sea biology which started with investigations in the Oslofjord and coastal areas in western and northern parts of Norway. Thus, he added a new dimension to zoogeography and stimulated the equipment of large oceanographic expeditions, including the British HMS *Challenger* expedition (1873-1876) and the Norwegian S/S *Vøringen* expeditions (1876-1878) that were initiated by his son Georg Ossian Sars (1837-1927). The very successful career of Michael Sars made him the most influential Norwegian zoologist ever.

5. The infancy of Norwegian fisheries biology

Fisheries science was initiated by Jens Rathke while Norway was still in union with Denmark, but he did not continue the task when he became professor of zoology in 1813. However, his suggestions for improvements in Norwegian fisheries came into effect some years after his death in 1855. The Norwegian government then made some far-reaching decisions resulting in the foundation of modern Norwegian oceanography. This started in 1862 when Jonas Axel Boeck (1833-1873) was commissioned by the government to perform research on the Norwegian herring *(Clupea harengus)* fisheries. Two years later, G.O. Sars was commissioned to serve as a fisheries scientist on the biology of North-East Arctic cod *(Gadus morhua)*. In the same period, the Norwegian government commissioned the very first Norwegian oceanographic ship, that was launched as R/V *Hansteen* in 1866 (plate 2). The rationale for building it was mainly the need for mapping of the coastal sea bottom topography and charting the currents that affect navigation, but it would also serve fisheries biology, and function as a royal yacht for the Swedish crown prince Oscar.

Boeck was devoted to zoology and published some papers while at the same time he was studying medicine and graduated as a medical doctor in 1863. He continued to publish papers on marine zoological systematics while he served as a fisheries scientist. He became a pioneer in fisheries oceanography thanks to his understanding of how the physical environment influenced migration in the spawning stock of Norwegian spring-spawning herring and the spreading of their juveniles from the demersal spawning habitats. He never succeeded in discovering where the spawning stock stayed between each spawning, as he died shortly after the results from his six years of investigations were reported and published as a book on herring population ecology and herring fisheries.

The year before Boeck died, G.O. Sars assisted the herring research programme by going to sea on R/V *Hansteen* to study the spawning process along the Norwegian North Sea coast. He had by then already made the remarkable discovery that the cod spawns pelagic eggs. He performed laboratory studies of their ontogeny, which established the basis for artificial fertilisation and hatching of cod eggs. This stimulated a sea captain, Gunder M. Dannevig (1841-1911) to establish an enterprise that produced larvae for a stock enhancement programme on coastal cod in southern Norway. The Flødevigen hatchery was established in 1882 and is today a department of the Norwegian Institute of Marine Research (IMR).

Besides his research on NE Arctic cod, and taking over herring research after Boeck, G.O. Sars also investigated the food selection of blue whales in the southern Barents Sea (plate 3), and studied the biology of mackerel *(Scombrus*

scombrus), lobster *(Homarus gammarus)* and cod in the North Sea. On top of that, he became professor of zoology at the University of Oslo in 1873, and was able to combine these interests for several years. From 1871 he had established scientific collaboration with Henrik Mohn (1835-1916) who in 1866 had become the first professor in meteorology at the University of Oslo and initiated the establishment of the Norwegian Meteorlogical Institute in the same year. His interest in air-sea interactions lead him to measure sea temperatures between Norway and Iceland, which is why he and G.O. Sars organised summer expeditions with the steam ship S/S *Vøringen* to the Nordic Seas in 1876-78 (Christiansen, 2007). They brought with them a chemist and two zoologists working at the Bergen Museum that had gradually won prestige as a centre for marine taxonomy since its establishment in 1825. The expedition moved northwards from the Faeroe Islands in 1876, reached Jan Mayen Island in 1877, and ended up in Spitsbergen in 1878.

The S/S *Vøringen* expeditions had a great impact on the initiation of physical oceanography in Norway. Mohn published his results in 1887, which was a breakthrough for Norwegian physical oceanography. He owed some credit to Carl Anton Bjerknes (1825-1903), a professor of mathematics at the University of Oslo who had started to develop hydrodynamic theories. Vilhelm Bjerknes (1862-1951) later extended the works of Mohn and his father to the forefront of international geophysics and practical weather forecasting, which resulted in today's Bjerknes Centre for Climate Research in Bergen, which is a European Centre of Excellence.

The accounts from the S/S *Vøringen* expeditions count 28 papers published in seven volumes during 1890-1901, regarding water masses, the deep sea sediments and their fauna. G.O. Sars failed to observe adult Norwegian spring-spawning herring in their oceanic feeding habitats in the central Norwegian Sea, but observed adult NE Arctic cod *(skrei)* in the northern Barents Sea. Thereby he closed the life cycle of a fish population of immense importance for Norwegian economy and established the scientific premises for fisheries management. G.O. Sars kept the leadership for Norwegian fisheries investigations until 1893 when he resigned. For the rest of his life, he devoted himself to his work as a professor of zoology. He became part of a nationwide team of taxonomists who was devoted to the description of new marine species. By then natural history was established in museums in Tromsø, Trondheim, Bergen and Oslo, and new marine biological stations became established outside Oslo, Bergen and Trondheim in 1892-1900. The facilities allowed the scientists to do field work at any time and work with live animals and fresh biological material. Moving on from fish, G.O. Sars won international acclaim for his monumental works on Crustacean taxonomy (Sars, 1895, 1928).

6. The beginning of modern oceanography

G.O. Sars initiated Norwegian marine research in polar regions by taking S/S *Vøringen* into the high Arctic waters of Jan Mayen Island and Spitsbergen. However, it was one of his students, Fridtjof Nansen (1861-1930) who managed to lift Norway into the international premier league of polar research. He became a student of zoology in 1880 and was in 1882 inspired to follow a vessel hunting seal in the East Greenland Current near Jan Mayen Island, to study the life of seals and collect zoological material for the Zoological Museum in Oslo. He accepted the job as a curator at the Bergen Museum when he came back, and continued his zoological studies there. He defended a doctoral thesis on the nerve system of the Atlantic hagfish *(Myxine glutinosa)* and was from 1889 employed as curator studying whales at the Zootomical institute established by G.O. Sars in Oslo. By then he had traversed the Greenland icecap on skis and was inspired to organise new Arctic expeditions. When he started the 1st R/V *Fram* expedition in 1893, he actually initiated a career that made him leave marine zoology.

The crossing of the Polar Sea from Siberia to Spitsbergen, onboard a ship locked up in drifting polar ice for three years was not only an epic and heroic achievement. Nansen was devoted to science and had R/V *Fram* built as a polar research ship. He brought with him equipment for physical oceanographic studies, and had included magnetic and meterological observations, and biological sampling in his program. The successful return of the expedition in 1896 brought Nansen and Norwegian marine science full international acknowledgement. He was appointed professor of zoology at the University of Oslo in 1897 but soon became involved in physical oceanography that would become his main scientific interest for the rest of his life. He was concerned to improve the accuracy of temperature and salinity observations from his expedition and sought support from other Scandinavian oceanographers. They urged him to stand in front during the initiation of the International Council for Exploration of the Sea (ICES) that was established in Stockholm in 1902. From the start they established the ICES Central Laboratory in Oslo with Nansen as its director. His deputy was Vagn Walfrid Ekman (1874-1954), a Swede who solved the enigma of effects of wind on water transport at the sea surface as observed by Nansen in the Polar Sea, which gave name to Ekman currents and the Ekman spiral. In 1908, the Central Laboratory was moved from Oslo to the ICES head-quarters in Copenhagen.

Johan Hjort (1869-1947) and Nansen were the leading Norwegian scientists within ICES, from its beginning. Hjort had finished his studies in Munich by defending his doctoral thesis on the life histories of colonial ascidians. In

1893 he took over Nansen's position as a curator at the Zootomical Institute in Oslo, as well as becoming the leader of applied fisheries investigations when G.O. Sars retired from that position. He also became director of the marine biological station in Drøbak in 1897, where he combined his interest for general marine zoology with basic fisheries research. However, the Norwegian government decided to establish the Norwegian Fisheries Directorate in Bergen which made Hjort leave the University of Oslo in 1900 to become its first director for fisheries research. He brought with him several young and gifted marine scientists who were specialists in different disciplines and was given R/V *Michael Sars*, a new ship specially designed for fisheries research.

Although the main emphasis of Hjort's group was to investigate fisheries resources and develop new fisheries technology, ecological relationships were highlighted to improve the understanding of the forces that caused fluctuations in annual landings of fish. Thus, one position was given to Haaken Hasberg Gran (1879-1955) who became a pioneer in plankton ecology and a grand old man in Norwegian phytoplankton research. Another was Bjørn Helland-Hansen (1877-1957) who together with Nansen in 1909 published *The Norwegian Sea*, a classical, voluminous and pioneering work on fisheries oceanography. In 1910 Hjort himself organised an expedition on R/V *Michael Sars* across the Atlantic Ocean, financed by Sir John Murray who took part in the former HMS *Challenger* expedition. Murray and Hjort edited the reports that were published in 1912 as *The Depths of the Oceans*, a book that for decades was recognised as an oceanographer's "bible".

The multi-disciplinarity in Hjorts leadership and scientific approach eventually caused him and his colleagues to write a large report on the *Fluctuations in the Great Fisheries of Northern Europe*. This publication from 1914 contains Hjort's famous critical period concept, a hypothesis suggesting that environmental factors control larval food abundance, juvenile survival and recruitment to fish stocks. These are still the prime unsolved problems for fisheries research recommended by ICES scientific and assessment working groups.

In 1902, the establishment of ICES inspired Hjort to organise international courses for marine scientists taught by his group and zoologists at Bergen Museum, until the 1st World War started in 1914. Then, the government confiscated R/V *Michael Sars* and turned it into a coast-guard vessel that defended Norway as a neutral nation. Hjort lost his ship, his international arena for science, and several of his colleagues who found other careers. In 1916, he resigned in bitterness, which ended a "golden age" of Norwegian marine science.

Nansen was probably a pillar of support for Hjort's career as a fisheries research director, and also stimulated polar research. After having returned from the 1st R/V *Fram* expedition, Nansen commissioned his captain Otto Sverdrup

to lead the 2nd R/V *Fram* expedition that explored islands and waters to the north-west of Greenland in 1898-1902. However, Nansen's national and international fame brought him to play influential political roles when Norway claimed full sovereignty, tore loose from Sweden and appointed its own monarch in 1905. He then served as Norwegian minister in London for two years and had to postpone personal ambitions about going to Antarctica with R/V *Fram*, to ski towards the South Pole.

Nansen's plans for Antarctica were clearly disrupted by his involvement in politics and were finally ruined by Roald Amundsen (1872-1928). Amundsen was an explorer, navigator and magnetographer who had successfully opened the North-West Passage to Alaska, by navigating a small sailing ship, the S/S *Gjøa* from the Atlantic to the Pacific in 1903-06. He won fame and credentials that enabled him to raise money for establishing another expedition that was meant to reach the North Pole, which Nansen had not managed. Amundsen had provided Nansen with valuable measurements from the S/S *Gjøa* expedition, and was entrusted to have R/V *Fram* for the purpose. He left Norway to sail around South America to the Pacific in order to use the Bering Sea as an entrance for his attempt to drift across the Polar Sea. However, he changed his plans when Robert Peary was reported to have reached the North Pole by trekking over the ice. Amundsen instead went to Antarctica and in 1911 achieved what Nansen attempted, to reach the South Pole.

Fridtjof Nansen never lost touch with science, but was detained by other duties laid on him, by others or himself. He saw the 1st World War coming and argued for military armament to defend Norway's neutrality and negotiated trade with foreign nations during the war.

7. Between the two wars

After the 1st World War ended in 1918, Nansen became deeply involved in humanitarian work for refugees and in 1922 was awarded the Nobel Peace Price for his achievements. It brought him into the centre of international politics as High Commissioner for Refugees, a position he held until his death. However, he kept on with his science, did field work, supported other scientists, and wrote papers and books that stimulated the imagination of recruits to marine research, until his death in 1930.

Amundsen had used the war years to prepare for a new expedition to the Polar Sea. He managed to finance a new polar research ship, the R/V *Maud* that he navigated through the North-East Passage and operated north of Siberia and Alaska from 1918 to 1925. He failed to reach the North Pole, but succeeded in directing an operation of immense importance to international

physical oceanography, thanks to his chief scientist, Harald Ulrik Sverdrup (1888-1957). Sverdrup had worked with professor Vilhelm Bjerknes in Leipzig. He was well prepared for all kinds of geophysical field work and stayed with the expedition for all its seven years. On his return, he was offered a position in Bergen where he succeeded Bjerknes as head of the meteorology department of the Geophysical Institute that was established by Bergen Museum in 1917 with Hellend-Hansen as its director. This position allowed Sverdrup to complete the monumental scientific report from the R/V *Maud* expedition.

Sverdrup's scientific achievements brought him to the USA where he served as director of Scripps Institution of Oceanography in La Jolla for twelve years from 1933 and a professor at the University of California throughout the 2nd World War. In 1942 he published *The Oceans* together with two American scientists, Martin W. Johnson and Richard H. Fleming. The book that still inspires students and scientists in all disciplines of oceanography.

During the World-wide economical depression, marine biology in Norway survived at the museums and marine biological stations that could afford inexpensive vessels suited for inshore work. However, the research department of the Fisheries Directorate in Bergen suffered. Some of Hjort's younger colleagues remained in their jobs, but were given little support. The Norwegian government continued to use R/V *Michaels Sars* for coast guard service and built R/V *Johan Hjort* as compensation. The vessel, only 70' (21 m) long, seems hardly worthy of the great man after whom she had been named, and who had then (1921) become Professor of Zoology at the University of Oslo.

Hjort allied himself with Professor Gran who had served under his leadership as a specialist in plankton ecology at the beginning of the century, but now managed the Botanical Laboratory at the university. Hjort also managed to merge his new marine biological laboratory with a governmental institute for whale research and establish an institute that taught Marine Zoology at the M.Sc. level. In 1924, he led an expedition on R/V *Michael Sars* to the Davis Strait, resulting in a publication on whaling and fishing in the north Atlantic. Whaling in Norwegian waters had become a controversial issue, and the whaling industry was looking for opportunities in Antarctica. Private interests funded the M/S *Norvegia* expeditions in 1927-1931 to investigate resources of marine mammals in Antarctic waters. Several Norwegian scientists were engaged to make scientific observations that could support whaling operations. In 1929-30, Hjort joined the M/S *Vikingen* whaling expedition, which enabled him to establish population dynamics as a basis for management of the Antarctic whale populations.

Despite the depression, Norway managed to develop strong academic research at the University of Oslo and at the museums in Bergen, Trondheim and

Tromsø. Scientists who had been in junior positions before the 1st World War under the leadership of world famous superiors, could concentrate on working up an immense amount of material and data from pre-war and post-war expeditions. Some came into leading positions and learned to exploit meagre governmental resources, in conjunction with their international science networks to succeed in their disciplines. Alliances were made with different branches of the fishing industry. When the Government decided not to grant money for running of the small R/V *Johan Hjort* in the mid-thirties, the fishing industry granted support from their research foundation. Thus, the young scientists from the "golden age" that ended with the 1st World War, managed to survive and even gain international acknowledgements before the 2nd World War started. Mentors like G.O. Sars, Nansen, Hjort, Helland-Hansen, and Gran were then dead or had retired. The new generation of mentors shouldered the war and waited for a new deal.

8. The New Deal

The 2nd World War ended with Norwegian marine science deprived of resources and even some of the potential leaders lost in warfare, but the peace lit the way for an enthusiastic drive forward to challenge and reshape the future. The University of Oslo resumed its marine science that organised research and master's studies in physical, chemical, botanical and zoological oceanography. The University of Bergen became established in 1946, founded on the solid biological traditions of Bergen Museum and its legitimate child, the geophysical sciences of the "Bjerknes School". It also established marine geology as a new discipline, but for two decades it remained small, concentrating on the quaternary science of underwater glacial sediments.

The Government made large efforts to rebuild Norwegian fisheries. The Ministry of Fisheries reorganised the Fisheries Directorate and established "Fiskeridirektoratets Havforskningsinstitutt" (the Fishery Directorate's Institute for Marine Research) which is now simply the Institute of Marine Research (IMR) in Bergen. The institute commissioned an ocean-going research vessel that was launched in 1950 as the first R/V G.O. *Sars*. It was equipped with modern hydraulic deck machinery for trawling and deployment of oceanographic underwater samplers and instruments. It also carried acoustic instruments that were constructed for submarine warfare but proved indispensable for finding, tracking and observing fish.

In 1947, in order to succeed in its ambitions for national marine research, the Ministry of Fisheries tried to establish a scientific fisheries advisory council. The attempt failed, but next year the ministry invited 30 oceanographers to

discuss options, which in 1949 led to the establishment of "Norske havforskeres forening (NHF)", *i.e.* the Association of Norwegian Oceanographers. The 31 founding members elected Sverdrup as the first chairman of the NHF Board. He had then returned from USA to become the director of the Norwegian Polar Institute in Oslo.

During the war, the legal Norwegian Government that was exiled in London had learned how natural science could serve technological development. Thus, the Norwegian Research Council for Technical and Applied Natural Science (NTNF) was founded in 1946, and established an Institute for Seaweed Research in Trondheim in 1949. The Government, moreover, had also understood the importance of basic and free research, and established the Norwegian Research Council for Natural Science and the Humanities (NAVF) in 1949. It played a very important role for basic oceanographic science, including fisheries oceanography, from the very beginning.

9. Interdisciplinary oceanography managed by the marine science community

At the founding of NHF in 1949, the members decided to establish a Marine Biological Planning Committee that was invited to give advice to NAVF, and did so until 1970. In 1950, NHF also established a Fjord Committee that planned and implemented a multi-disciplinary research project in the Hardanger Fjord, with financial support from NAVF. It was an exercise that pointed the way forward for marine ecology as a coordinated way of organising Norwegian oceanographic research. However, NHF was based on personal memberships and single scientists could not commit their institutions. The members saw the need for an organisation based on institutional memberships and forwarded the suggestion in 1969. NAVF adopted the idea and established the Norwegian Oceanographic Committee (NOK) as its advisory board from 1971.

Norway had started to exploit hydroelectric power as an energy source since the beginning of the century. Based on results from the Hardanger Fjord, concern was expressed that construction of large reservoirs for storage of meltwater in spring and discharge to the sea over the remaining year, would affect geophysical and biological processes in the receiving sea areas. Tromsø Museum and the universities in Bergen and Oslo received funding from the Norwegian Water and Electricity Board to perform multi-annual investigations in fjords near Narvik and Stavanger, which started in 1969.

In 1972 NHF was made aware that the many changes due to regulation of river flow for hydroelectric production to a region's coastal waters might influence marine biological productivity in the Norwegian Coastal Current

(NCC) and thereby, recruitment to fish stocks. NHF decided to organise its first international symposium in 1974, on the Influence of Fresh-Water Outflow on Biological Processes in Fjords and Coastal Waters, and published the proceedings in 1976 under the title of *Fresh Water on the Sea*.

During the 1974 symposium, the NHF participants met informally and agreed to suggest a multidisciplinary NCC Project. The suggestion was adopted and forwarded by NOK which caused NAVF to finance a five-year project, starting in 1975, to gain better understanding of abiotic and biotic processes in the NCC system. The project formally terminated by a symposium in 1980 and the proceedings were published in 1981 in two volumes by the University of Bergen, titled *The Norwegian Coastal Current*.

The NCC Project was followed by Pro Mare, a large national project recommended by NOK. It was established by a consortium of institutes to study marine ecological processes in the Barents Sea. It was implemented in 1984-89, financed by NAVF, NFFR and the Ministry of the Environment. The project proved very successful, in 1992 resulting in about 300 scientific and popular articles, and *Økosystem Barentshavet*, a popular book serving as a summary report to sponsors, scientific institutions, organisations and the public.

In 1973, NOK had decided to perform an analysis of the perspectives of Norwegian oceanography, which was published as a book (Sakshaug *et al*, 1976). It was a very timely presentation of the state of the art in Norwegian marine science, serving as a source of information, and not only for managers, civil servants and politicians. It served also as a reference for the marine science community that consisted of specialists trained within different particular oceanographic disciplines. The perspective was not very far-reaching and did not at all reflect later experience regarding the dominance of Norwegian petrochemical and salmon industries on the national economy and research development. It mostly reflected scientific problems that were already identified and expressed overdue requests for infrastructure, manpower and equipment for marine science. The report caused NOK to take immediate action and establish a committee that analysed the need for technological development and replacements in the fleet of Norwegian research vessels. At that time Norway had two ocean-going research vessels, two for operations in open coastal waters, and five in the range of 50-100 tons for inshore operations, not counting a weather-ship (M), and a ship for naval research. The report was delivered to NOK in 1978 and suggested modernisations over the next 10 years, which was actually implemented.

Naval warfare in the Norwegian and Barents Seas during the 2nd World War made them sanctuaries for commercial fish stocks that had grown into large resources by the end of the war. The introduction of purse seines and hydraulic

power blocks in the herring fishery, and numerous industrial plants for production of fish meal and oil made the Norwegian spring-spawning herring stock a bonanza. The total landings increased to a maximum in 1966, before it dived to practically nothing in 1970, unleashing an economic catastrophe for many coastal societies. It sent a shock wave through the marine science community, seeing that Nature's bounty had limits. It caused a regime shift in Norwegian fisheries oceanography from fish-finding and forecasting of immigration time and region, to a complete moratorium, stock assessment, quota regulations and sustainable management that finally brought back a strong herring stock by 1990.

The scientific community that was represented in NHF and NOK in the early seventies still saw its future lying in research that was a continuation of traditional fields of oceanography. The new understanding in Norway, as well as within ICES, that fish populations had limited capacity for exploitation, and that Hjort's critical period concept was still an untested hypothesis, made fisheries biology turn towards studies of the early life history of fish and multi-species population modelling of food chains. However, several events that happened before 1970 gained so much momentum that the entire Norwegian marine research and technology took turns and became reshaped more than anybody expected.

10. Implementation of Governmental strategies for academic development

In 1968, the Norwegian Parliament established new universities in Trondheim and Tromsø, based on the scientific institutions that were already there. Marine science at the University of Trondheim grew from the biological research traditions at the DKNVS Museum and its Marine Biological Station, and the seaweed science at the Norwegian College of Technology. Marine scientists who worked at the Tromsø Museum took on pioneering responsibilities that eventually resulted in the present Norwegian College of Fishery Science of the University of Tromsø. However, teaching in fisheries science started as a dispersed national college with its departments hosted by the universities in Bergen, Trondheim and Tromsø, funded through a special chapter in the budget of the Ministry of Education. In the same time, the Ministry of Fisheries established the Norwegian Institute of Fisheries Technology, with departments in the same cities. After a brief period, both organisations ceded their departments in Bergen and Trondheim to the respective universities. In Tromsø, the Ministry of Fisheries reorganised its department of applied biotechnological research into an institute that caused commercial breakthroughs in new proc-

ess technologies, bio-prospecting of cuts from fish, and vaccines for farmed fish. Tromsø became a growth centre for marine science and technology, and attracted new activities. The Norwegian Polar Institute that in 1998 was moved from Oslo to Tromsø now includes a department of marine science, and IMR runs a department there. Moreover, SINTEF, established in Trondheim as a national technological research foundation to support industry, now also supports marine science in the fisheries and aquaculture sector.

From 1969, the Parliament also established regional colleges for professional studies at the undergraduate university level, to educate industrial managers and public servants. Marine science and technology courses are now provided at teaching institutions or associated institutes established in Alta, Bodø, Ålesund, and Stavanger.

11. Stochastic forcing that reshaped Norwegian marine science

In 1968, an oil exploration company struck oil in Norway's sector of the North Sea. The event immediately mobilised investors, politicians and the geosciences. The group of quarternary marine geologists in Bergen and Oslo drew some advantages, but the main development in marine geology came in Trondheim where NTNF in 1969 established IKU (the Continental Shelf Institute), an institute for continental shelf investigations based on seismological investigations. Trondheim now hosts the Norwegian geological surveys ("Norges geologiske undersøkelse", or Norwegian Geological Research, NGU) that maps off-shore bedrocks. A long, but very thin line of geological sea-bottom surveys from the times of R/V *Hansteen* and S/S *Vøringen* preceeded the revolution when oil reserves caused Norway to establish geological oceanography as a substantial field of science.

University institutes in Bergen and Oslo soon became involved in work intended to solve problems related to effects of ocean currents on off-shore constructions, and pollution from drilling and production platforms. The Norwegian Institute for Water Research (NIVA) that was originally established 1958 in Oslo to investigate and monitor industrial and municipal waste in rivers and marine municipal waters soon became involved in the effects of drilling operations on the continental shelf. The fishing industry expressed concerns that brought IMR and the University of Oslo on to the scene to assess the effects of petrochemical exploration and exploitation on marine organisms.

Another event was also sensational. In 1969, an industrial company locked up thousands of salmon smolts in a western Norwegian bay and succeeded to make a profit on feeding them to commercial size in a few years. Some experienced herring fishermen who were trained to close herring in fish pens to im-

prove the quality of their catch, thought that their technical skills would allow them to succeed as well. They did and the Norwegian coast seemed open for anyone to try making a fortune investing little else than their savings, existing infrastructure, available technology and hard work. Banks turned up, willing to provide financial support and politicians were eager to develop a new industry that could blow life into local societies dying from the lack of fisheries resources. However, public managers feared that free development could destroy valuable future options, and regulated access to the business. They also mobilised research institutions that could solve emerging problems regarding failing growth, diseases and problems in downstream areas. IMR was among the first to initiate relevant marine research on general salmon biology, parasitism and environmental issues. The Norwegian College of Agriculture near Oslo represented a very long tradition in general animal husbandry and started salmon studies on juvenile stages, selective breeding, and feeding. Within a few years the two institutions became rivals in aquaculture research.

The large expansion in all fields of marine science after 1970 was allowed by the Parliament that borrowed money abroad on the expectancy of large tax returns from oil production. Much of the big governmental funding of marine science and technology in the oil sector was channelled through NTNF that also claimed control over funding of technological R&D in mariculture. The Norwegian Research Council for Agriculture (NLVF) that was established in 1949 soon became a major source for financing biological and technological research on juvenile salmon rearing which requires freshwater. NAVF was not organised for managing applied marine research, which caused the Government to establish the Norwegian Research Council for Fisheries (NFFR) in 1972. It covered all fields of research, from natural science and technology to economy and sociology, within aquaculture as well as the fisheries sector.

12. The decline of free, basic research

NAVF kept supremacy over general marine research for nearly a decade after 1971, with NOK as a generator of premises. The other research councils sent observers to the annual meetings of NOK and were invited to share the responsibility for coordinated marine science in collaboration with the scientists themselves. They refrained from doing that, however, probably because NAVF kept the NOK secretariat. Concurrently, the Government shifted priority from basic marine and fisheries research to applied petrochemical and aquaculture research, which forced NAVF to reduce the NOK Secretariat to one part-time position. The institutes lost faith in NOK and finally saw little possibility of regaining a position in marine science politics, and the member

institutions voted to terminate the activity in 1986. The majority of NHF members disagreed and several chairmen were given the mandate to work for the re-establishment of an organisation that could represent their institutions in concerted strategic planning of marine science. In 2001, NHF initiated the Norwegian Cooperative Council for Marine Sciences (NOSAM) that is based on institutional memberships, but the organisation did not win approval by the government bodies that manage national research. It has therefore not succeeded in gaining substantial influence on the progress of Norwegian marine science and technology.

NHF still exists, but no longer as an organisation with political ambitions or influence on the domestic scene, like it did in the first decades of existence. It has, however, maintained its role as a forum for free exchange of scientific results and ideas, and supports basic science in an informal role. NHF became member of the European Federation for Marine Science and Technology Societies (EFMS) in 2001 to join the reciprocal exchange of information between scientists, and support free basic marine science in Europe.

In Norway, only small sums have been available for basic and free applied marine research during the last decades. However, universities and colleges with marine scientists on their teaching staffs, and technicians, laboratories and ships represent a resource base with considerable research potentials. Some have succeeded in exploiting their own budgets for equipment and consumables in ways that have allowed basic research matching the standards in international publication in peer review journals. However, there can be no doubt that pooling of resources would release synergies that would increase the volume as well as the quality. This is what NOK managed, and was also NHF's rationale for the establishment of NOSAM.

13. The success of modern marine science in Norway

The infighting between the many research councils in Norway was counterproductive and caused the Parliament to merge all into one Norwegian Research Council in 1993. The reorganisation took resources as well as time, and it is too early to assess the result in a historical perspective. However, taking into consideration the state of the art in 1970, there is no doubt that centralised political control over scientific resources has resulted in impressive national progress, economically as well as scientifically.

From the aquaculture industry that came into being around 1970, the production of salmon and a small fraction of rainbow trout increased exponentially to about 150 000 tons in 20 years, and exceeded 500 000 tons in 2000. The success is thanks to research that identified the environmental carrying

capacities of aquaculture habitats, nutrition and other factors for growth, immunology and treatment of diseases. White-fish research on sexual maturation, reproduction biology, and the environmental requirements of embryos and juveniles over many decades has resulted in today's marketing of farmed turbot, halibut, Atlantic cod and spotted wolf-fish (plate 4).

Petrochemical resources have made Norway a wealthy nation, apparently not at the expense of the environment. By documenting lethal levels of hydrocarbons on marine organisms, Norwegian research institutions have helped environmental authorities setting technical standards for release of toxic substances into the sea. The scientists have developed methods for detecting toxic substances in cost-effective ways, and test procedures and protocols for the monitoring of organisms and their environment.

Norway has succeeded in developing two new and very profitable fields of business, possibly within precautionary conditions. It could probably not have happened without strict priorities in national research budgets and restrictions on scientists expressing a professional curiosity that tends to drive them into seemingly unproductive fields of basic science. However, it is ironic that a nation that fostered some of the greatest marine zoologists in the World, has neglected a field of science that is needed for marine bio-prospecting and monitoring of marine biodiversity. It will require marine biologists qualified in classical taxonomy and systematic biology but unfortunately, the nation has failed to educate enough students in this direction.

14. Contemporary state of a historical process

Present-day Norwegian marine science is the result of forging over centuries by combined forces. The technology and skills of seafaring hunters and fishermen allowed curious and adventurous Norwegians to experience the sea and its forms of life. It was facilitated by the political powers and administrators who needed to know the nature of resources that could support their national economy. The grinding between personal and collective ambitions still generates the energy that drives Norwegian marine science forward. However, during the last decades political and administrative control has kept the majority of scientists within mainstream research that pays off in terms of economic growth. Little room has been given to the testing of new hypotheses that challenge existing paradigms. The contemporary success of Norwegian marine science probably rests on the momentum of post-war initiatives taken by the collective mind of individual scientists and institutions cooperating within NHF and NOK.

The administrative control of Norwegian marine science has prevented an undergrowth of new ideas, hypotheses and theory building by neglecting the

value of empirical knowledge and data acquisition. Most time series of abiotic and biotic variables established by provident scientists lasted for their life-time but were seldom continued. Even national fisheries statistics recorded in wonderful detail before and after the 2nd World War were rationalised into a simplicity that deprived them of scientific precision. Today, scientists and managers often seek in vain for abiotic and biotic time-series to analyse trends that may separate anthropogenic effects on climate change from those caused by natural fluctuations. The national response to the UN Convention on Biological Diversity has created a demand for base-line information, which is inadequate. What exists is thanks to stubborn and painstaking work performed by single scientists at the universities of Bergen, Trondheim and Trømsø. On several occasions NFH and NOK have advocated the need for time-series and base-line studies for the purpose of scientific analyses as well as monitoring and management. However, scientific strategies for long-term observations and deep understanding of marine ecosystem dynamics were never established as a main goal for Norwegian marine research. Rather, the research was carried out as short-term sub-goals in strategies established by national politicians to stimulate economic growth, usually running for periods less than an election term in the Parliament.

Norwegian scientists have taken part in international science organisations that hammer out strategic plans for basic marine science. Thus, Norwegian marine scientists contribute to CLIVAR, the World Climate Research Programme on Climate Variability and Predictability, and GLOBEC, the worldwide program on Global Ocean Ecosystem Dynamics, among others. On the other hand, Norway has not contributed to LOICZ, the large international program, Land-Ocean Interaction in the Coastal Zone, even though Norwegian marine scientists saw strong reasons to participate. Decision-making for implementation of Norwegian marine science is no longer an open process that allows the scientific community to understand the underlying premises for the directions chosen.

There are signs that the political nearsightedness is about to change. Ecosystem-based management is adopted as a principle in Norway. The Pro Mare program in the Barents Sea, and the Mare Cognitum program carried out by IMR in the Norwegian Sea in 1993-2001 (Skjoldal, 2004) have provided basic knowledge about marine food webs and abiotic forcing processes. Norwegian modellers are at the forefront of large-scale numerical simulation of marine ecological processes. More empirical information, however, is needed to establish conceptual models as guidelines for the numerical modellers, and serve as reference for simulated results. Norwegian universities have gained important roles as providers of empirical data to models developed for applied

purposes, and are now calling for better national organisation of basin-scale marine ecology.

Norway is about to implement a program for monitoring marine biodiversity along the mainland coast, as well as in the open sea, including Arctic islands like Jan Mayen and the Svalbard archipelago. The planning process has promoted coordinated collaboration among marine scientists in Norway, which may continue if the monitoring management requires concerted action from several institutes.

In 2006, institutions that own research vessels decided to pool their ships and oceanographic field equipment, and organise the exchange of such resources. The activity may lead to more concerted strategic marine research financed by pooling available man-power and existing consumables, if politicians and managers entrust the universities and institutes to do so.

15. A short retrospect on 250 years of marine science

During five centuries from about 1250, several servants of God wrote accounts of the natural history of Norwegian waters, before pioneers formally established systematic marine zoology as an exact science in 1760. From then on, marine science developed in epochs, gradually changing from individuals taking leadership over their science, to modern times when scientists act collectively in response to political and administrative directives.

Pioneering fisheries biology started in 1862 and led to large oceanic and Arctic expeditions organised by leading scientists who performed inter-disciplinary research to understand the marine ecosystem. A "golden age" of interdisciplinary Norwegian marine science ended with the beginning of the 1st World War. The government poverty that existed between the two World Wars suppressed marine science depending on ocean-going ships. It made the scientists work within their respective disciplines with older data and material, or turn to low-budget research in coastal areas. However, some joined Arctic and Antarctic expeditions funded by private capital and firmly established Norway in polar research.

A New Deal appeared after the 2nd World War when the Government invited the community of marine scientists to cooperate within interdisciplinary organisations. These organisations established long-term strategies for marine science, organised research and provided council to politicians and managers, until 1986 when a new political regime won control over Norwegian science. It established an administrative level of research leadership that managed short-term programs in response to political agendas for economical development for the rest of the 20th century.

During the last decades some Norwegian scientists have taken part in strategic planning of basic marine research initiated by international organisations that organise world-wide science networks, and some times managed to generate Norwegian sub-programs. However, initiatives from free marine research organisations to re-establish strategic planning organised by the Norwegian marine science community, has so far not won administrative acceptance.

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