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OCEANOLOGY IN DENMARK

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20. Abstract (continued)

of Education (programs in University of Copenhagen and the Technical University of Denmark) and the Ministry of Public Works. Although the total budget is small they maintain an excellent reputation for work in shallow water environments, particularly the low salinity and strong mixing circumstances encountered on their European coasts and Arctic problems near Greenland. Priority is generally given to problems of importance in the areas of economic potential (gravel, petroleum), safety at sea and pollution.

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## OCEANOLOGY IN DENMARK

### Introduction

Denmark is an island nation in the fullest sense, with water surrounding its three geographic areas. Denmark "proper," a group of almost 500 islands and a large peninsula between the Baltic and North Seas, with a population of slightly more than five million and a total land area of 17,000 miles<sup>2</sup>; Greenland, the world's largest island, of which only 132,000 of its 840,000 miles<sup>2</sup> is ice free and with a population of about 50,000; and the 19 small islands in the North Atlantic which make up the Faeroe Islands and which have a total of 570 miles<sup>2</sup> inhabited by about 39,000 people. No Dane lives more than 40 miles from the sea, and 80% of the population lives less than six miles from the sea. The total coastline of Denmark proper is 4500 miles, of which 16% is usable for recreation.

Therefore, the ocean and hydrography/oceanography are very important to this nation. Illustrative of this fact is that between 15-20% of the population is involved directly in maritime activities, including merchant marine, commercial fisheries, shipyards and the navy. However, of the approximately 5500 scientists in Denmark, fewer than 100 -- or, about 2% -- are involved in marine sciences and less than 5% of the national budget is earmarked for marine research! Thus, the Danes must be critically selective as to where they spend their limited funds. Close examination of the "Danish way of doing things" may be a look into the future for the US where money for marine research is becoming more difficult to procure.

The strategic position of all the Danish islands has made it a particularly important NATO maritime ally. This implies the need for accurate ocean environment information for defense purposes. In addition, Denmark has non-military international interests in marine science programs and organizations. It is a member of the Baltic Oceanographic Committee and the Baltic-North Sea Prediction Group which are composed of nations bordering on the Baltic and North Seas, and support intensive investigative programs of temporal changes in these waters. Most recently, Denmark has joined with a number of other European governments to establish a permanent network of telemetering meteorologic/oceanographic stations in European waters. This is called Project COST 43 and is intended to form part of the Integrated Global Ocean Station System (IGOSS). Denmark is also an active member of the International Commission for the Northwest

Atlantic Fisheries (ICNAF) which investigates all aspects of the fisheries industry from ecological parameters to marketing. Other international memberships are held in the International Union of Geodesy and Geophysics, International Association for the Physical Sciences of the Ocean, Intergovernmental Oceanographic Commission, the International Council for the Exploration of the Sea, the World Meteorological Organization and the International Hydrographic Organization.

Most important to the Danes, nationally, is the safety and efficiency of the maritime activities which are the lifeblood of the nation. Accordingly, hydrography and oceanography directed toward safe navigation, better fishing and pollution control receive the most attention and money. However, other activities such as obtaining gravel from the seabed, offshore oil exploration, and research for defense (primarily in the area of mine and antisubmarine warfare) also receive some emphasis.

This report will address principally those oceanographic and hydrographic activities conducted by various government agencies toward the achievement of the above-mentioned national maritime goals. More than 90% of all marine-related research in Denmark is conducted by the government agencies. Figure 1 is an organization diagram which outlines the structure of Danish government-sponsored institutions involved in oceanology.

### Ministry of Defense

Mine warfare will undoubtedly play a dominant role in any naval conflict in the Baltic area; thus, one-third of the Danish Navy is directly involved in the execution of mine-warfare related tasks. (See United States Naval Institute Proceedings, January 1968, "Maritime Denmark,") Several thousand mines have been laid in both world wars in local Danish waters and have caused hundreds of ship losses. In the intervening period, the Danish Navy has swept or rendered harmless more than 13,000 mines, but even today some are still found by fishermen. Since these waters are so critically located, it is essential that accurate ocean environment information be available to NATO forces. Collection of this information is the primary task of the "Oceanographer" of the Navy. His small but efficient staff conducts surveys in selected areas consisting mostly of near-bottom current measurements and submarine topography studies. His office is making a concerted effort to update existing mine warfare information by gathering and processing new data as well as verifying old information about wrecks and other anomalies which make the job of the mine warfare forces more difficult. Most of the

officers on the Oceanographer's staff have received oceanographic and hydrographic training at the US Naval Oceanographic Office.

The second organization involved directly with military-related marine research is the Danish Defense Research Establishment (DDRE). It consists of civilian and military scientists who receive their direction and funds from the Danish Defense Command. The DDRE's function is to upgrade the equipment and instrumentation of all their defense forces. In relation to the Navy it works on operations research and development of both acoustic and non-acoustic undersea warfare detection devices. It should be pointed out that Danish waters, particularly "local" waters, are physically extremely complex. The Danish straits are the "mixing bowl" for the fresh Baltic waters and the salty North Sea waters. Furthermore, the basin is quite shallow (the navigable depth is only 17 m) and thus very responsive to meteorological changes, tidal, seasonal and even diurnal variations. The problem of finding a submarine in such waters is complex and unique, requiring special instrumentation. The specialists at DDRE approach these problems with ingenuity and intelligence. One particular approach they are using is to develop an expendable sound velocity meter which is more responsive to the local, rapidly changing, physical properties of the water than the standard derivative technique of gathering sound velocity information. However, as with all marine research in Denmark, they are hampered by limited equipment and funds, so projects take longer to complete than in the US. That is not to say, though, that the end result is any less effective. In the past this laboratory has had research contracts with the US Office of Naval Research.

The third organization under the Defense Ministry is the one least involved in direct military-related marine research; however, it is the largest in terms of the scope of oceanographic and hydrographic activities. The Administration of Navigation and Hydrography -- called the Waters Directorate, for short -- was established in March 1973, and is an amalgam of several former institutions including the Light House Service, Pilot Service, Life Boat Service and the Hydrographic Office. The first three "services" are just that, i.e., they perform services directly related to the safety of navigation in Danish waters. They conduct virtually no oceanographic or hydrographic research or survey work; however, they do provide certain support services and facilities to other government agencies which do perform such work. Accordingly, the Light House Service provides use of lighthouses and lightships as platforms for collecting oceanographic and meteorologic data. This Service also assists the Hydrographer and the Navy in locating and "clearing" wrecks, mostly those found in the shipping channels.

The old "Hydrographic Office," now known as the Nautical and Hydrographic Division, thus is the major agency under the Ministry of Defense involved in hydrography and oceanography. The organization chart of this Division may be seen in Figure 2. It is headed by "the Hydrographer," Knud Kaergaard, and deals with nautical matters and navigational safety in Danish, Faeroe and Greenland waters. It provides aids to navigation, pilotage and lifeboat service, nautical publications, hydrographic and oceanographic surveys, and prepares technical reports and charts. In addition, it is involved in the planning of measures to improve navigational safety.

The hydrographic surveys conducted by this Division are done by Danish Naval officers who have received their hydrographic training at the US Naval Oceanographic Office. Since 1965, seven officers have received training in hydrography and oceanography for periods ranging from eight to 18 months. This procedure ended in early 1974 due to the relatively high costs involved and the desire to have a course more tailored to Danish needs. A new course is being prepared now by the Admiralty Hydrographic Office in England for training future officers. The surveying efforts of this Division are varied. In local waters, ship channel resurveys are conducted in the continuing search for safer, deeper and shorter channels. Also, coastal and beach surveys are necessitated by the constantly changing sandy coastline. For this purpose, a converted US minesweeper is used. However, most of the hydrographic charting effort since WWII has gone into surveying the intricate and hazardous western coast of Greenland. This work can be conducted only in the summer months under relatively severe conditions using 45-ft motor launches called SKA-boats, assisted by the Danish Fishery Inspection ships equipped with Decca 12F, Raydist and Hydrodist surveying gear. The extreme Arctic conditions and remoteness of the surveying areas taxes the ingenuity of these hardy officers who, in almost all cases, manage to make the most of the situation to enable a few hundred miles more of detailed surveys to be conducted each summer. These same officers spend the winter months working up the raw data for publication in charts. The Hydrographic Surveying Section is run by naval officers with ships manned by naval crews (mostly short-term conscripts), so the naval regimen is obvious. A primary difference between the US and Danish Navies is the training of the ships' crews. It must be remembered that almost every Dane knows the sea either as a working fisher or as a seafarer. Thus the "conscripts," or, draftees, are quite familiar with ship routine before they come into the Navy. One entire crew, with the exception of a senior enlisted sergeant or petty officer, can leave a ship on Friday, and on Monday be replaced by a new crew that is ready to sail. This, of course, applies to the smaller ships and basic ship handling functions -- not to the more sophisticated electronic gear. Nevertheless, the efficiency of new crews is truly remarkable. Generally, the

surveying section utilizes either one of two fishery inspection ships which are 240-ft stabilized vessels with a helicopter deck, excellent navigation equipment and small boat handling capabilities; or a converted US minesweeper. On special occasions during the summer months, icebreakers are used. The inspection ships are utilized mainly for North Sea, Greenland and Faeroe Islands charting work, while the minesweeper and the icebreakers are used in the Kattegat, Belts and to support coastline surveys. For several years, this Section has been working on increasing the surveying capability of the converted minesweeper by adding a system of Paravanes, which are dragged behind the ship and allow several sounding tracks to be made simultaneously. Partial success was achieved in the summer of '73, but mechanical problems continue to plague the system. Full utilization would be a big boost to the Danes because their surveying season is so short.

All of the surveying effort is eventually turned into charts by the Cartographic Section which publishes charts of all the Danish coastlines. There is a basic inventory of 147 charts of Danish waters including normal bathymetric, fishery and Decca charts, plus 19 new "miniaturized" sailing or yachting charts. For Greenland, there are 143 coastal, normal and Loran charts.

The Oceanographic Section was established several years ago when Dr. Milan Thamsborg -- the first graduate from the University of Copenhagen Institute of Physical Oceanography -- joined the Waters Directorate. This section has a modest current research program in conjunction with the proposed series of oceanographic monitoring stations to be established on lighthouses and buoys in local Danish waters. This program includes the collection, processing and writing of technical reports on currents and other water properties in the Kattegat and Belts. Two reports have been published on this work, the latest entitled, Oceanographic Measurements in Kattegat and Great Belt, 1973. The purpose of this work is to aid in the safety of increased deep-draft shipping to and from the Baltic, as well as to serve in the establishment of long- and short-term pollution monitoring stations. Since Thamsborg is also a geodesist, he is called upon to provide technical assistance to the Danish Foreign Office which is in the process of preparing at-sea boundary treaties with Denmark's many neighbors. It should be remembered that Denmark has sea boundaries with Poland, East and West Germany, Sweden, Norway, Canada, Iceland and the United Kingdom. During 1973, a treaty was signed with Canada dividing the boundary along the Greenland west coast. A unique problem here is a small uninkhabited island -- Hans Island -- in

the Nares Strait. The exact ownership of the island has not been agreed upon yet, so the boundary stops about 1 nm on either side of the island with the area around it being a "no-man's land." The staff also has been working on an extremely complex computer program which will mathematically compare the various techniques for obtaining boundaries depending on the map projection and the various definitions of control points. This program will provide a more exact tool for fair arbitration of sea boundaries by all coastal countries regardless of the definition system utilized.

The last group under the Ministry of Defense is the Meteorological Institute. Its obvious primary function is weather forecasting and research. However, since sea conditions in the shallow local Danish waters are so greatly influenced by meteorological conditions, this Institute inevitably becomes involved in air-sea interaction studies. Many of these studies are conducted in conjunction with the two universities and with neighboring countries in Northern Europe and Scandinavia. For a number of years, this Institute was responsible for all the oceanographic data collection from the lightships in local Danish waters. This function has recently been turned over to the Waters Directorate.

#### Ministry of Fisheries/Ministry of Greenland

The Institute for Fisheries and Marine Research and the Greenland Institute for Fisheries Research, both headquartered in Charlottenlund (a suburb of Copenhagen), are concerned with the condition of the commercial fish harvest. This includes the environmental factors that affect stock abundance.

The Institute for Fisheries and Marine Research is concerned mainly with fishery problems in the waters around Denmark proper and the sea around the Faeroe Islands. It maintains a laboratory and freshwater fish farm in Jutland and a laboratory in the Faeroes. Denmark's Aquarium is also maintained by this Institute. For field work, it operates four research vessels, the largest being the 250-ton DANA. The headquarters, which has a staff of about 40, has been reorganized recently into two main sections, the Theoretical and the Assessment Sections, plus several smaller support groups. The Theoretical Section consists mostly of mathematicians who are developing a computer model for the fisheries in the North Sea. They will attempt to predict the productivity and availability of a particular fish species. The Assessment Section examines the biological factors and adds historical perspective through literature search. The two sections, of course, must work

closely together. Their results are furnished as recommendations to the Ministry of Fisheries in its efforts to control the catch of fish and to assure future catches at near maximum levels. Fish quotas are set in conjunction with the International Council for the Exploration of the Seas. The species most examined at present by the Institute are flatfishes, herring, cod and eels. Physiological research with eels has been going on for years in the experimental research section of this Institute. The question of where do the eels go after they leave the northern European rivers is still unsolved; however, a dramatic breakthrough of raising in captivity a fertilized female eel has just been made. This means that eels could be "farmed" locally and could therefore increase the availability of this important food delicacy of northern Europe. Much work also is going on to find other species of fish which can be exploited commercially. Research results are published in many international journals, as well as in their own.

The Greenland Fisheries Institute, on the other hand, deals with the problems of the cod, salmon, shrimp and shellfish fisheries along the Greenland coasts, mainly the west coast. A full-time research ship, ADOLF JENSEN, is operated in these waters. In general, this Institute has less difficulty than the Ministry of Fisheries in obtaining funds for research because of the tremendous dependence of Greenlanders on the fishing industry. The Arctic Institute also comes under the Ministry of Greenland. It publishes a report called Danish Arctic Research which deals mostly with accounts of Greenland mapping and ice research.

The Geological Survey of Greenland is increasing its marine research efforts on the continental shelf around Greenland, directed mainly toward exploration for gas and oil deposits.

#### Ministry of Environmental Protection

In the last two years, there has been an extraordinary impetus in Denmark to reorganize various national research efforts into the field of environmental protection. An environmental protection bill was introduced and a ministry formed to centralize the many diverse agencies dealing with air, food and water pollution; this move was similar to the formation of the US Environmental Protection Agency.

Marine pollution and control is a significant part of this effort when seen from the point of view that the Baltic Sea, with all the pollution from the industrial countries surrounding it, flushes itself through the Danish straits. Second, the

tremendous amount of shipping which passes through these straits each year -- more than 80,000 ship transits in 1973 -- places great responsibility on the Danish government to prevent or at least control pollution from a marine disaster. The Sound (Øresund) is a sewage outlet for 36 Danish municipalities, and for at least the same number on the Swedish coast. In addition, a new nuclear power plant is being constructed on the Swedish coast which will effluent hot water into the Sound. This, combined with the normal flushing of pollutants from the Baltic, could substantially change the ecology of the area. Treatment plants for sewage outlets are now being installed which, it is claimed, will make the Sound free from pollution by local sources by 1977.

In recent years, there have been scientific investigations into the trend toward reduced oxygen content in the Baltic, but there is no proof that pollution is the sole cause. Thus, a major five-year project -- called the Belt Project -- was inaugurated in 1973 to examine the exchange of water through the Sound, the Great Belt and the Little Belt in order to assess the changes caused by pollution. Also, an emergency system for dealing with cases of oil pollution has been established, including training of personnel from the Navy and procurement of special cleanup boats and equipment. To enable assessment of marine resources, the Belt Project will include investigations of the processes which have potential for moving or altering the concentration of pollutants entering the system. Monitoring systems will be installed to observe water circulation and mixing, suspended and dissolved material flushes, existing load of nutrients, sediment composition, tidal effects, sea-air interaction and wave effects. The staff of the Ministry of Environmental Protection has been expanded, a new 120-ft ship specially designed for handling the monitoring systems has been acquired, and there has been a considerable increase in available funds.

The Fishery Pollution Laboratory, previously under the Ministry of Fisheries, has been brought into the new organization. In addition, all of the laboratories belonging to the two universities will get increased funds to participate in the Project.

Assisting the Environmental Protection Ministry is a semi-governmental agency, the Danish Academy of Technical Sciences, which has an Isotope Laboratory for examining impurities in the food obtained from the sea; similarly, the Danish Water Quality Institute examines both drinking and swimming water for dangerous substances. Danish industrial interests also are

heavily involved in pollution monitoring and control. Numerous companies have instrumentation efforts along these lines. It is interesting to note that the Japanese, who have the most highly polluted island nation in the world, have recently made large investments in these Danish companies to help them in their cleanup efforts.

In total, this Ministry's activities are a substantial boost to marine research in local Danish waters.

#### Ministry of Education

The two major universities in Denmark, the University of Copenhagen and the Technical University of Denmark, come under this Ministry and both have extensive marine-related research programs.

The University of Copenhagen is concerned mainly with physical and biological problems through its six marine-related laboratories/institutes. They perform basic research and also work closely with other government agencies, particularly the Agency of Environmental Protection, to conduct applied research. For example, the University's Institute for Physical Oceanography will receive from the Ministry for Environmental Protection approximately five times the amount of support normally provided by the Ministry of Education to fund applied research for the Belt Project. In addition, these laboratories act as teaching institutions not only for their own students (mostly graduate students), but also for students from other parts of the University who want to take courses related to the particular lab's specialty. This is similar to the research/teaching arrangement recently established at the Woods Hole Oceanographic Institution.

The Institute for Physical Oceanography under the direction of Professor Nils Jerlov, a leading world authority on optical oceanography, conducts most of the physical oceanography research. The basic research emphasis by Jerlov, his staff and graduate students, is on the analysis of the physical and chemical properties of sea water using sophisticated optical techniques. Besides the funding sources mentioned above, several of Jerlov's co-workers have received grants from the Danish "National Research Fund" under the direction of the National Research Council. This is a system very similar to research grants awarded for basic research in the United States by the National Science Foundation or the Office of Naval Research. These grants support basic marine research and development of new instrumentation, particularly optical and an advanced acoustic current meter. It must be remembered that these rather unique waters around Denmark require unique instruments. Results of the research are published

in international oceanographic journals and in their own research reports. The Institute has, at present, about five undergraduate students and another six to eight "graduate" (doctoral candidate) students, including one American. Close ties are maintained with scientists in the US; during 1971-72, Dr. Glen Jung from the US Naval Postgraduate School spent a year's sabbatical at the Institute.

The other laboratories attached to the University of Copenhagen deal primarily with marine biological research. These, along with the Fisheries' laboratories, account for the largest number of marine scientists in Denmark. The Marine Biological Laboratory at Helsingør conducts research and some undergraduate teaching mainly on invertebrate marine biology. The lab has a 45-ft research boat and recently built a modest but interesting aquarium. The lab lost its director several years ago and the search for a new one is continuing.

Closely affiliated are the three other marine biology laboratories. The Isefjord Lab handles special problems associated with the brackish water environment present in Denmark's fjords. The "Limnology Lab" at Hillerød is concerned with both primary production in the sea as well as numerous freshwater problems. Professor Steemann-Nielsen, a noted marine biologist, heads this lab. Finally, the Skallingen Marine Laboratory at Esbjerg on the west coast of Jutland is concerned mostly with the marine biology of the tidal area and the adjoining North Sea.

The Mineralogical-Geological Central Institute maintains the Mineralogy Museum in Copenhagen and teaches courses in geology and related fields. The professional staff and graduate students conduct geological research for economically valuable minerals, mostly on Greenland. Close cooperation is maintained with US marine geologists and several joint expeditions have been undertaken. One of the most recent cruises was aboard the USS LYNCH to the area around the Reykjanes Ridge. Several papers resulting from this and other similar expeditions, which discuss both mineralogy and geology, have been published in international journals. The US participants on the LYNCH cruise were from the US Naval Oceanographic Office, Chesapeake Bay Laboratory.

The Technical University of Denmark and its three institutes, the Institute of Hydrodynamics and Hydraulic Engineering, the Mathematical Statistics and Operations Analysis Institute, and the Coastal Engineering Laboratory, conduct studies related to marine engineering in the coastal zone and in the deep sea. Most of the staff of these Institutes consists of engineers and mathematicians. In

addition to examining the problems related to building structures along the coasts, they conduct fundamental research on waves and littoral drift.

These Institutes provide assistance to the Hydraulic Institute (a semi-private organization) and to the Department of Coastal Engineering of the Ministry of Public Works. In June 1974, they joined together in a Symposium on Coastal Engineering in Copenhagen. The papers presented at this Symposium detailed the work done by these groups over the past few years. Also, much new information was presented by numerous international groups on coastal engineering problems. The proceedings were published by the Coastal Engineering Research Council of the American Society of Civil Engineers.

#### Ministry of Public Works

In addition to the Geological Institute, Denmark maintains a Geological Survey which is charged with the detailed geological mapping of all Danish territory (and in Greenland that is no small task). With the recent high level of interest in the North Sea bed, the Survey's marine section has been very busy investigating the possible oil reserves of the Danish sector. So far, very limited quantities have been found, but private exploration is still in a fairly early stage. Successful exploitation could be a major boon to this fuel-importing nation. A second mineral resource for which the Geological Survey is always searching is offshore gravel deposits. It must be remembered that Denmark is composed almost entirely of sand and that there are few non-glacial stone quarries or land gravel deposits. Although modern concrete techniques have caused a decline in the "stone fishing," dredging for gravel is still a very important economic necessity.

The final organization on the national level is the inter-ministerial Danish Royal Society of Natural Sciences. This Society is composed of leading national scientists who provide guidance and direction to research in the natural sciences. Of particular interest is the National Council on Oceanology which is presently headed by Professor Nils Jerlov.

Mention should be made of one other institute, which is international and receives partial government support. It is the International Council for the Exploration of the Seas (ICES) -- one of the oldest (founded 1902) organizations designed for international cooperation in marine research and free exchange of basic research data, which is essential to the international utilization of the seas and their resources. It is supported mainly by contributions from the member nations and serves primarily as a data repository; however, it does

sponsor some international marine research projects. It is located in Charlottenlund and publishes a report on sponsored surveys, particularly on fish assessment in the northeast Atlantic. The United States only recently formally joined this organization in 1973; however, close liaison has been maintained for many years.

Thus, Denmark, which in the early 1900's was one of the first leaders in worldwide oceanographic research, is still involved -- as it must be -- in all facets of this research. However, because of budget restrictions the government has had to concentrate on the problems closer to home. Economic, safety and pollution considerations take priority. Nevertheless, Denmark still has an impressive commitment to marine research for a country with a population as small as that of Leningrad or the San Francisco Bay area. Like the little Mermaid, Denmark always looks to the sea.

FIGURE 1.

DANISH OCEANOLOGY INSTITUTIONS

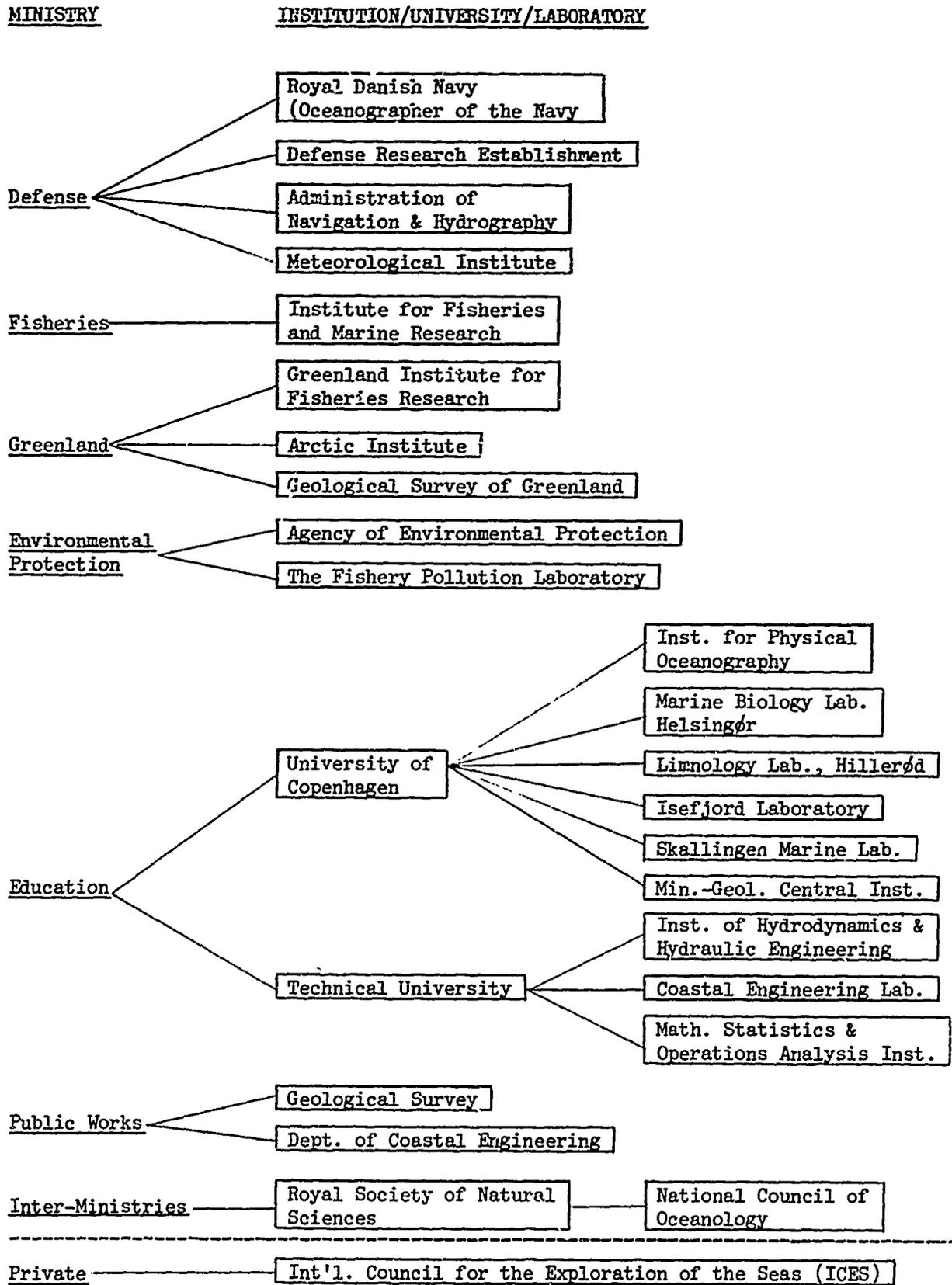


FIGURE 2.

ROYAL DANISH ADMINISTRATION OF NAVIGATION AND HYDROGRAPHY

