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capensis), Cape jumping hare (*Pedetes caffer*), Cape long-eared fox (*Otocyon megalotes*), vaal bushcat (*Felis caffra*), slender mongoose (*Herpestes gracilis*). Besides these there are many other varieties.

To sum up, given plenty of water, the Kalahari desert would be an ideal cattle country, and probably if water were bored for, it would be found at no great depth.

THE NORWEGIAN SEA.*

BEFORE 1876 the explorations dealt with in the Report by Dr. Helland-Hansen and Dr. Nansen had been confined almost entirely to the outskirts of the Norwegian sea, viz. the sea between Scotland and the Færoes, near the east coast of Greenland, the sea between Spitsbergen and Norway, and the sea off the Norwegian coast. The Norwegian sea itself was practically a *mare incognitum* before the Norwegian *Vöringen* Expedition (1876-1878). From this date up to 1900 many expeditions have collected observations within the basin of the Norwegian sea.

There is no doubt that it is to Dr. Hjort's researches that we are indebted for the splendid results arrived at by the explorations of MM. Helland-Hansen and Nansen. Dr. Hjort's studies in the waters along the Norwegian coast in 1893, and carried on in the succeeding years under his supervision, had been extended to the Norwegian sea. The results obtained were of so much importance that they led to the building of a ship, the *Michael Sars*, to study the problems of the Norwegian sea and bearing more or less on the Norwegian fisheries.

In Chapter II. we find a short account of the cruises during the years 1900 to 1904. Most of the observations discussed have been collected during the cruises of the Norwegian Fishery Research steamer *Michael Sars* during the years 1900 to 1904, and during May, 1901, and May, 1902, between Norway and Iceland, on board the *Heimdal*, of the Royal Norwegian Navy. Special attention has been paid to the work at each station, in order to get the best possible series of observations to show the vertical distribution of salinity and temperature at certain selected points. The distance between the stations was 20 miles, or even less. Since 1902 Danish and Scottish oceanographers have made investigations between the North sea and Iceland, and the authors have made use of these observations in connection with their own for the discussion of the special problems of the Norwegian sea.

The third chapter on instruments and methods is very important. In the case of the central part of the Norwegian sea the salinities are between 34·85 per mille and 35·20 per mille. With such a slight total range in the salinity of the various waters, the seasonal and annual variations are still smaller, and to be detected the most accurate methods must be employed. The accuracy required by the International Council for the Study of the Sea is 0·05 per mille of the salinity. It is, in some cases, not sufficient for the variations of the Norwegian sea. If we take the deep strata of the Norwegian sea below 300 fathoms, I quite agree with

* 'The Norwegian Sea: its physical oceanography based upon the Norwegian Researches, 1900-1904.' By Björn Helland-Hansen and Fridtjof Nansen. Report on Norwegian Fishery and Marine Investigations. Vol. 2, 1909, No. 2. With 28 Plates. Bogtry K. Reri. Kristiania: Het Mallingske. 1909.

the authors when they write, "The quality of the observations, especially in this deep part of the sea, is of much greater importance than their quantity."

During the first cruises of the *Michael Sars* the deep-sea temperatures were taken with the Negretti and Zambra reversing thermometer, and with the insulated water-bottle. During the latest cruises the observations of the temperature of the deep strata have been made with the new Richter reversing thermometer, that can give an accuracy of ± 0.01 C. On the other hand, Nansen made a great improvement on the Pettersson insulated water-bottle by fixing a thermometer in the lid of the water-bottle; it is the so-called "Great Nansen insulated water-bottle" (made by Andersen in Christiania), with a capacity of 5 or 6 litres. The Nansen stop-cock water-bottles have been constructed on the principle of the Buchanan stop-cock water-bottle of the *Challenger* Expedition. Attached to the sounding-line, they were of great help in getting water-samples at intermediate depths, and worked very well.

The preservation of the water-samples is of great importance, and the authors recommend the discontinuance of the use of bottles with corks, and the use instead of indiarubber stoppers when the samples have to be stored for more than two weeks.

The Basin of the Norwegian Sea and its Bathymetrical Features.—The Norwegian sea is the whole sea-area enclosed between Norway, the Shetlands, the Færoes, Iceland, Greenland, Spitsbergen, and Bear island. It is divided into three parts: (1) The Greenland sea, between Northern Greenland (north of 71° lat. N.), Jan Mayen, and Spitsbergen; (2) the Iceland sea, between Iceland, Jan Mayen, Greenland (south of 71° lat. N.), and the Iceland-Greenland submarine ridge; (3) the Denmark strait, being a portion of the latter sea, lying between Iceland and Greenland. The fact that the Norwegian sea is situated between the deep North Polar basin and the Atlantic ocean, *i.e.* in the way of the waters travelling between the two seas, has a fundamental effect on its circulation.

Now let us glance at the bathymetrical features of the Norwegian sea as shown on the beautiful map compiled from the latest sources. The floor of the Norwegian sea is divided into two deep basins, viz. the Norwegian deep and the Greenland deep. The map shows very few soundings in the middle part of the Norwegian deep, and, as stated by the authors, it might be that this basin is divided into two portions by a continuous ridge crossing the Norwegian deep from Jan Mayen to the Helgeland coast in Norway. The Greenland deep is separated from the Norwegian deep by "Mohn's transverse ridge" trending from Jan Mayen to the great submarine valley of the Barents sea. The *Belgica* found a hollow 1700 fathoms deep to the north of the Greenland deep, and separated from the latter by a submarine ridge trending westwards from Prince Charles foreland. The most important feature of the Norwegian sea is the submarine ridge known as the "Wyville-Thomson ridge," extending from Scotland to Greenland through the Færoes and Iceland. The greatest depth recorded on the ridge between Scotland and the Færoe bank is 290 fathoms. The Færoe-Iceland ridge forms a fairly level plateau at depths of 200 to 250 fathoms, with a maximum depth of 260 fathoms. The Iceland-Greenland ridge has a saddle-depth of about 300 fathoms.

General Description of the Water-masses of the Norwegian Sea.—The water of the Norwegian sea may be divided into two layers, viz. a surface layer 200 to 250 fathoms deep, and a bottom layer. There is a striking contrast between the physical characters of these two bodies of water; the surface one is heterogeneous, while the lower one is of remarkable uniformity. We find the explanation of this difference in the geographical position of the Norwegian sea.

The different water-masses in the surface layer are—Atlantic water with high

salinity, above 35 per mille; coast water from the North sea, the Baltic, and the Barents sea, salinity below 35 per mille; central water-masses, formed by the mixture of Atlantic water and Polar water, salinity below 35 per mille.

The bottom water representing the bottom layer fills all the deeper parts of the Norwegian sea. It is of constant salinity (a little above 34.90 per mille), and temperature (-1°C). Thousands of observations led the authors to this very important conclusion, that can be extended to the ocean in general, that *the density gradually increases from the surface to the bottom*.

Chapter vi. deals with the apparent irregularities in the horizontal distribution of temperature, salinity, and density. The equilines (isothermes, isohalines, as well as isopycnals) form bends or undulations like waves, sometimes great, sometimes small. The study of the exact nature and mode of formation of these "waves" and their movements is of great importance. Helland-Hansen and Nansen cannot solve this problem for the present, but they demonstrate how these "irregularities" may be formed in three different ways—(1) by "waves, of some kind, on the boundary between water-strata of different densities; (2) by sudden variation or direction of the surface currents; (3) by great vortex movements or horizontal movements with vertical axes, as shown by the sections of the Lofoten."

To find the solution of the question, oceanographers will have to follow the advice of the authors, "Take as many stations as possible, with the shortest distances between them, and also—at any rate, at some of the stations—repeat as often as possible the observations from the same depths at different hours of the day and night, in order to find out whether the different strata have changed their level during twelve or twenty-four hours." The determination of the distribution and volume of the different waters in the sea depends mostly on the solution of the "oscillations" problem.

The Norwegian Atlantic Current.—The Norwegian current is formed by the entrance of Atlantic water through two openings, viz. the Færoe-Shetland channel and the opening between the Færoes and Iceland, the deepest part of these submarine ridges being not more than 280 fathoms; if we find "35-water" at greater depths, it must be caused by vertical movements of some kind.

The Atlantic water forms cyclonic or anti-cyclonic vortices that carry the water in directions more or less different to that of the Norwegian current. From the study of the equilines, we can summarize the course and extent of the Norwegian Atlantic current as follows: Where a submarine channel exists in the Færoe-Iceland ridge, we find a "tongue" of water with salinities below 34.90 per mille, moving in a southerly direction. The surface layers are checked by the Atlantic water flowing towards the north-east, while the deeper strata advance further south, and it is possible that they cross the ridge and sink in the deep basin of the Atlantic. The Atlantic water immediately to the east of the cold tongue trends for some time in a northerly direction, then is deflected sharply to the east. It passes to the north of the Færoes, and runs into the Færoe-Shetland channel close along the slope of the Færoe platform. The Atlantic water immediately to the west of the "tongue" moves in an anti-cyclonic direction. Along the southern coast of Iceland we find it with a westerly movement.

The main portion of the Norwegian-Atlantic current enters the southern part of the Færoe Shetland channel having a north-easterly direction. It generally keeps to the Shetland bank. Then in the southern part of the Norwegian sea the Atlantic current is made up of water that has come both from the south and the north of the Færoes.

In the Norwegian sea the main body of the Atlantic current keeps close to the continental slope. The western part of it meets the East Iceland Arctic current,

and forms a cyclone in the southern half of the Norwegian sea at from 65° to 66° N. lat. and from 0° to 4° W. long.

Water from the Atlantic current covers the bottom of the deeper hollows and submarine fjords of the continental shelf off western Norway. This Atlantic water (35 per mille salinity) in the fjords and over the continental shelf is always covered by coastal water.

Let us now consider the outflows from the Norwegian sea-basin. (1) The opening between Norway and Bear island, where the water of the North Cape current, eastern branch of the Atlantic current, runs into the Barents sea, either to come back again to the Norwegian sea south of Spitzbergen, or to enter the North Polar basin to return with the East Greenland Polar current. (2) The opening between Spitsbergen and Greenland, that allows the Spitsbergen Atlantic current, the northern branch of the Atlantic current, to enter the North Polar basin. (3) The opening between Iceland and Greenland, through which the main outflow finds its way across the Iceland-Greenland ridge. (4) The opening between the Faroes and Iceland. Only the first two outflows contain a small quantity of Atlantic water, with salinities above 35.00 per mille, proving that the greater part of the Atlantic water entering the Norwegian sea is changed within this sea-area by admixture with other waters.

The surface velocities of the Atlantic current in the eastern part of the Faroe-Shetland channel are of 30 cm.-sec. in May and about 20 cm.-sec. in August, these figures showing a maximum velocity of the current in spring and a minimum in autumn. At 50 or 100 fathoms the velocity is as great as at the surface. The velocity decreases generally from 150 fathoms, down to 200–350 fathoms where the velocity reaches zero.

The investigations of the annual (or secular) variations of the Norwegian-Atlantic current have led the authors to the following conclusions:—

1. "Observations of the mean temperature of the Atlantic water, in the southern Norwegian sea at the surface, as well as in the deeper layers, afford a method of predicting, several months or more, in advance: the anomaly of the air-temperature in Norway, the prospects of the Lofoten fisheries (whether they come early or late), the growth of the fir-wood, the agricultural prospects, and probably also the growth and spawning of the food-fishes, which again determine the fisheries several years later.

2. "Some prognosis of this kind may be based on meteorological observations, but a much greater number of observations, distributed over a large area, would be required, and the mean of even a huge observation-material of this kind would give no more trustworthy prognosis.

3. "The thermal conditions of the Atlantic water are partly of primary, partly of secondary nature, as compared with the thermal conditions of the air in Norway. The conditions under the surface are chiefly primary; they determine the anomaly of the air temperature of Norway, especially in the winter and spring, because different quantities of heat are given off to the atmosphere by the vertical circulation of the water-strata during the cold season. The thermal conditions of the air (and its moisture amount of clouds, etc.) influence the surface temperature of the sea, which so far is secondary. In this manner we find that a *low temperature*, or rather a comparatively *small quantity* of heat, contained in the layers of the Atlantic water *below* the surface should, as a rule, be followed by a low temperature at the surface the following year, and *vice versâ*. This agrees with our observations of the surface temperatures of the four years 1901–1904; but 1905 forms an exception in this as in other respects.

4. "The mean temperatures and the volume of the Atlantic water below the

surface, in a section across the southern Norwegian sea in May, can be used for the prognosis of the character of the air-temperature of Norway in the following winter, the time of the Lofoten fishery (whether early or late) the following winter, probably also the character of the spawning, and the relative quantity of cod-liver.

"The *surface temperature* of the Atlantic water along the same section in May can be used for a prognosis of the growth of the fir wood during the summer a year later, and the quantities of the products of agriculture in the following autumn, in a similar manner as the air-temperature in the spring may be used for the same purpose."

The authors point out that there seems to be a good agreement between the curve representing the variations in quantity of cod-liver and the curve showing the variations in the number of sun-spots, the maximum of cod-liver having a marked tendency to coincide with the minimum of sun-spots. But the periodicity in the sun-spots, or rather in the energy received from the sun, causes variations in the oceanic currents (either directly or indirectly, through the atmosphere), that have a great influence on the climate of Norway and the fisheries, as shown in the above-mentioned conclusions.

The Norwegian Coast Water.—"Coast water" means waters that are found along the coasts with a salinity below 35.00 per mille. The boundary between the Atlantic water and the coast water is generally sharply defined.

The surface salinity along the west coast of Norway, outside the "Skjaergaard," is generally above 31 per mille, increasing towards the Atlantic current. The coast water is moving along the coast of Norway, being a continuation of the Baltic current, from the Skagerack up to the Barents sea. It is worth noting that the average salinity, on the whole, increases along the route of the coast water, while it is the reverse for the Atlantic current. The temperature of the coast water in the Skagerack follows more closely the air-temperature on the Continent than farther to the west and in the Norwegian sea, where the "climate" of the coast water is much more like "oceanic climate" with comparatively small variations.

The coastal current of Norway originates from the Baltic current passing through the Kattegat into the Skagerack. The velocity near the surface is about 1 metre per second. It receives river-water from the fjords.

The variations of the coastal current depend on different factors, as the rainfall and the melting of ice and snow on land, the air-temperature and the insolation. The authors found a very interesting relation between the variation of the coast water and the fisheries of sprat and small herring. Observations during a period of five years show that a small area of coast water (May) corresponds to small catches (autumn) of sprat in the same year, and of small herring in the following year. As the coastal-water variations correspond to the variations of rainfall during the previous year, there should be a correspondence between the rainfall of a certain year and the sprat fishery a year afterwards, as well as the small herring fishery two years afterwards.

Polar Currents.—In chapter ix. we find a description of the Polar currents, based principally on surface observations collected in the Arctic seas by sealing and whaling captains, on observations from Captain Roald Amundsen, and from the *Belgica Expedition*.

The Polar water is a typical coast water, with salinities from 30 per mille at the surface to 34.7 per mille at 90 or 100 fathoms, and with temperatures varying from -1.8°C. to 0°C. The typical feature of the Arctic seas and currents is the presence of an intermediate warm layer between the top layer of Arctic water and the cold bottom layer filling the deeper parts of all northern seas. The presence of

this warm layer is due to the fact that there is a gap in the density between the lighter Polar waters with low salinities and the much heavier bottom water. Waters of Atlantic origin, with densities corresponding to the gap, come from the adjacent seas and flow between these two layers.

There are three Polar currents running into the Norwegian sea: the Bear island Arctic current; the Spitsbergen Polar current; and the East Greenland Polar current. The Bear island Arctic current comes from the Barents sea, and follows the southern slope of Bear island bank. It is composed of Arctic water with temperatures between 0°C . and -1°C ., and salinities below 34.7 per mille. This narrow and almost insignificant current often carries ice far towards the south-west of Bear island, and may be dangerous for navigation. The Spitsbergen Polar current runs round South cape, Spitsbergen, and northwards along the west coast, inside the Spitsbergen Atlantic current. It affects the navigation, as it carries ice along the coast, round South cape, in the early summer.

The East Greenland Polar current comes from the North Polar basin; it runs along the north-eastern coast of Greenland, and crosses the ridge between this coast and Spitsbergen, and follows the edge of the Greenland continental shelf southwards. It is composed of cold water with temperatures below 0°C ., and with low salinities. If one considers the conditions of motion of this current, it will be found that they are similar to those of the Atlantic current off the Norwegian coast, the greater velocity being limited to the continental slope and the edge of the continental shelf, while the motion is comparatively slow over the shelf. The main body of the current is narrow, and only 100 metres deep. The vertical distribution of temperature and salinity in the cold layer of polar water has the same characters both in the East Greenland Polar current and in the North Polar basin.

The East Iceland Arctic current is formed by admixture of Atlantic water from the Atlantic current, of Polar, Arctic, and Iceland coast water. The authors point out that the designation "Polar" to this current is misleading, as it contains only a small quantity of Polar water. The authors call "Arctic water" the water formed in the Norwegian sea by admixture of Atlantic water with originally Polar water and with water cooled during the winter in the Norwegian sea, and which during the summer may be diluted by the water of the melting ice. The greatest motion of this current is limited to the continental slope on the right side of the current.

The "tongue" of Arctic water over the Færoe-Iceland ridge certainly follows the cyclonic movement of the southern Norwegian sea, and the last traces of its water disappear near the central part of the cyclone, on account of intermixture with the surrounding waters. The "tongue" is formed of Arctic water, evidently coming from the deeper layers of the East Iceland Arctic current.

Ice.—There are two kinds of ice occurring in the region of the East Greenland Polar current, viz. North Polar ice and Arctic ice. The former ice comes from the North Polar basin. It forms extensive floes, 2 to 3 metres thick, with great hummocks 60 to 70 metres thick. The latter ice is formed between Jan Mayen, Greenland, and Spitsbergen, and between Jan Mayen, Greenland, and Iceland. It consists mostly of floes about 1 metre thick, formed during the preceding winter and melting during the following summer. The authors point out the importance of this difference, that has not been taken into account by those who frame theories based upon the variations in the distribution of ice.

The authors are led, by the study of the ice and of vertical temperatures, to the following conclusion: "The cover of ice protects the underlying sea against the cooling by radiation of heat from the surface during the winter, and much heat is moreover disengaged by the formation of new ice."

The Cyclonic Systems of the Southern and Northern Norwegian Sea.—The great primary system of circulation is formed by the Norwegian Atlantic current running along the eastern side-slope of the Norwegian sea, and by the East Greenland Polar current flowing on the western side-slope. It is a cyclonic movement round the whole of the Norwegian sea and basin, along its side-slopes. This primary system is divided into several smaller systems, very likely on account of the topographical features of the sea-bottom. The authors point out how perfectly their chart of the movements in the southern part of the Norwegian sea agrees with Dana's chart of the distribution of *Calanus finmarchicus*, *Calanus hyperboreus*, and *Pseudocalanus*. According to Gran's and Dana's studies, different plankton organisms, like the *Calanidæ*, are characteristic for certain areas in the open sea, where they are stationary. The areas where these organisms have been found correspond exactly to those where the water masses are more or less stationary.

The westerly movement of the Atlantic water in the northern part of the Norwegian sea (about 75° N. lat.) may be compared to the westward movement of the same water west of Lofoten. It coincides in a remarkable manner with the hypothetical low elevation of the sea-bottom off Spitsbergen, trending in a south-western direction.

In the sea west of Spitsbergen the branch of diluted Atlantic water sinks under the Polar current and forms the intermediate warm-water layer. The formation of this branch corresponds to the presence of a submarine ridge trending westwards from the northern end of Prince Charles foreland. The central part of the great cyclonic system of the northern Norwegian sea is the area where the bottom water is formed during the winter.

The Bottom Water.—The formation of ice during winter and spring increases the salinity of the surface water, which then sinks beneath the surface to form at first an intermediate layer. The vertical circulation gradually extends deeper and deeper, until finally what was originally surface water sinks to the bottom, forming a bottom stratum characterized by low temperature (0° C. to -1°·3) and very uniform salinity (about 34·92 per mille).

Nansen pointed out, in 1906, that the bottom water cannot get out of the Norwegian sea. But if this water is warmed up to 0° C. by admixture with the warmer overlying strata, it can be carried out chiefly by the Polar current. On the other hand, very small quantities of bottom water can be formed each winter by the cooling of the sea-surface in such a limited area. The authors conclude that the bottom water of the Norwegian sea, forming the floor of the currents, remains practically unaltered for a very long period of years.

This book throws light into the darkness of the ocean, and will be read with great profit, not only by oceanographers, but also by those who are interested in the problem of the fisheries. Indeed, by the accurate methods employed, Helland-Hansen and Nansen have proved that physical oceanography can and must be an exact science. Their conclusions on the relations that exist between the annual variations of the Norwegian Atlantic current and the Lofoten fisheries, between the variations of the coast current and the sprat and small herring fisheries, are of great value from an economical point of view.

LEON W. COLLET.