NOTES

OCEANOGRAPHIC OBSERVATIONS IN THE CANADIAN ARCTIC AND THE ADJACENT ARCTIC OCEAN*

The history of oceanographic exploration in the Canadian Arctic does not coincide chronologically with that of geographic exploration. In the early stages of arctic sailing the urgency of the discovery of the Northwest Passage took full priority over any other interest and later, during the period of the Franklin Search, little time could be spent in scientific observations. Several of the early arctic captains recorded observations on the natural history of the country and on more than one occasion instruments and methods were developed to sample the bottom and measure the more obvious currents. All the early expeditions made frequent references to local ice and weather conditions and in areas where shoaling water was suspected the soundings were listed in the journals.

One of the first arctic expeditions for which there are records of oceanographic observations is that of Sir John Ross in 1818. On this cruise sub-surface temperatures were taken with a Six's thermometer at 80 and 250 fathoms in the eastern end of Lancaster Sound. For his oceanographic observations Ross designed a type of water bottle that closed at a predetermined depth and a device for bringing up a sample of the bottom sediments.

In 1819 Parry took sub-surface temperatures and recorded depths and ice conditions in Lancaster Sound and Barrow Strait and in 1845 the Franklin Expedition was equipped with a number of bottles and copper cylinders in which messages were to be sealed. These containers were to be dropped into the sea at specific locations north of 65° N.

The second Norwegian Arctic Expedition in the *Fram* was in the Canadian Arctic from 1898 to 1902. During this time plankton collections, surface temperatures and bottom samples were taken at various positions in the region of Jones Sound; however, no sub-surface temperatures were recorded since the ship was not equipped for this type of work.

The voyages of the C. G. S. *Arctic* from 1906 to 1911 under Captain Bernier contributed much significant information concerning the surface temperature, salinity, and bottom topography in Parry Channel as far west as Winter Harbour and in 1916 the Canadian Arctic Expedition made a number of tidal observations at Cape Kellett and at three locations on the north coast of Alaska. During the late twenties various spot oceanographic observations were made by observers carrying out investigations in marine biology for the Fisheries Research Board.

The Danish *Godthaab* Expedition and the work of the United States Coast Guard Cutter *Marion* inaugurated the recent phase of oceanographic research in the North American Arctic in 1928 [1,2]. These ships carried out extensive oceanographic observations in Baffin Bay, Davis Strait and the approaches to the channels leading into the Canadian Arctic Archipelago. The work was continued by the Hudson Bay Fisheries Expedition sponsored by the Department of Fisheries in 1930, and the United States Coast Guard Cutter *General Greene* carried out further investigations in Baffin Bay and Davis Strait between 1931 and 1935. Additional surface observations of temperature and density

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were taken by the Royal Canadian Mounted Police Schooner *St. Roch* during the period 1935 to 1937 in the channels forming the southern route of the Northwest Passage [3].

After the war arctic oceanographic investigations became more specific in character. The growing national interest in the North and the demand for information on the circulation, ice cover, ice movement, navigability, and the productivity of the waters led to the organization of a number of oceanographic cruises the result of which has been a vast accumulation of oceanographic observations within a very short time.

The Fisheries Research Board of Canada has been instrumental in conducting a large proportion of this work beginning with the cruise of H.M.C.S. *Magnificent* and *Haida* to Hudson Bay in 1949. The same year the fisheries research vessel *Calanus* began investigations in Ungava Bay, and in 1951 and 1952 the motor vessel *Cancolim* of the Defence Research Board carried out oceanographic observations in the western Arctic. The surveys conducted from the icebreaker *Labrador* since 1954 have covered a large area of the eastern Arctic and have resulted in the first sequence of oceanographic observations to extend from Baffin Bay in the east to the Pacific Ocean in the west [4].

Ships of the United States have also been active in collecting arctic oceanographic information. During the last 10 years seven American icebreakers have carried out oceanographic surveys in the channels of the Canadian Arctic Archipelago. Many of these surveys have been conducted in close co-operation with the Canadian investigations and all data

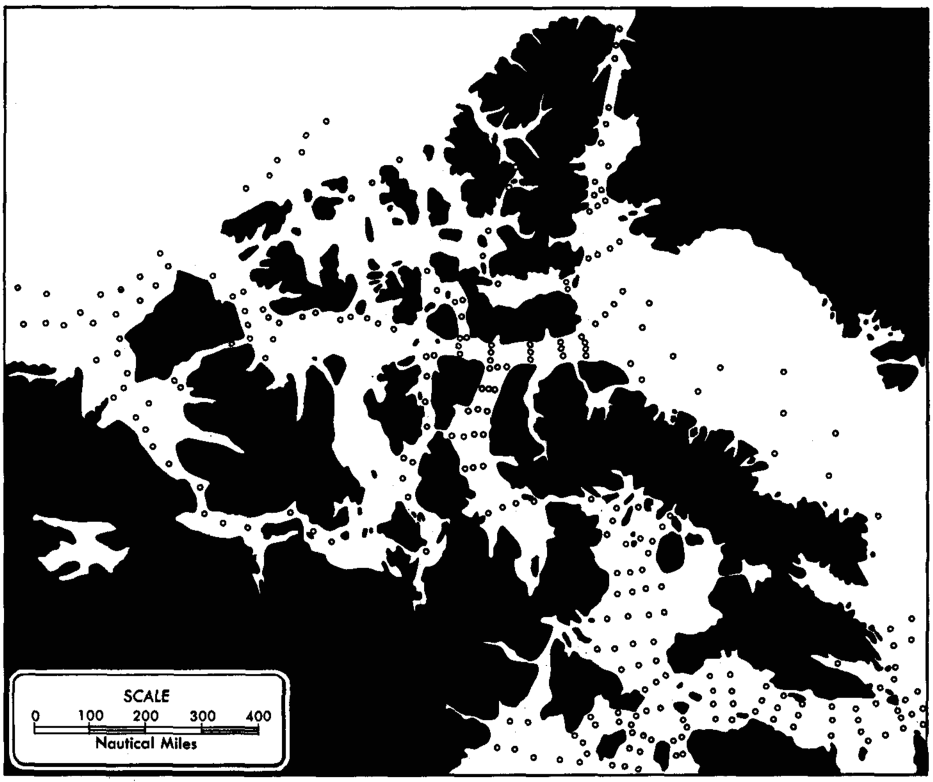

Fig. 1. Location of oceanographic stations.

have been freely exchanged between the two countries.

The most recent oceanographic programmes in the Canadian Arctic have been more confined in geographical coverage than the earlier reconnaissance surveys. Intensive investigations have been completed in Hudson Strait and Lancaster Sound by the Fisheries Research Board and the Hydrographic Service and in 1958 observations were taken from the I.G.Y. drift station T-3, which at that time was close to the western margin of the Canadian Arctic Archipelago.

Fig. 1 shows the distribution of oceanographic stations that have been taken in the North American Arctic within the last 30 years. The majority of the observations in the eastern region were taken from the Canadian icebreaker *Labrador* and the Fisheries research vessel *Calanus*. The stations in Kane Basin and Smith Sound were taken by the United States ships *Eastwind* and *Edisto*. In the western Arctic the United States ships *Burton Island* and *Requisite* and the Canadian motor vessel *Cancolim* have recorded most of the oceanographic observations.

A detailed bathymetric map of the region is unreliable since in many areas there is little or no information on the depth of water. Fig. 2, which is compiled from available sources, shows the general configuration of the bottom in the Canadian Arctic. Unfortunately, in the Queen Elizabeth Islands and the western region of Parry Channel the contours are based on only occasional soundings.

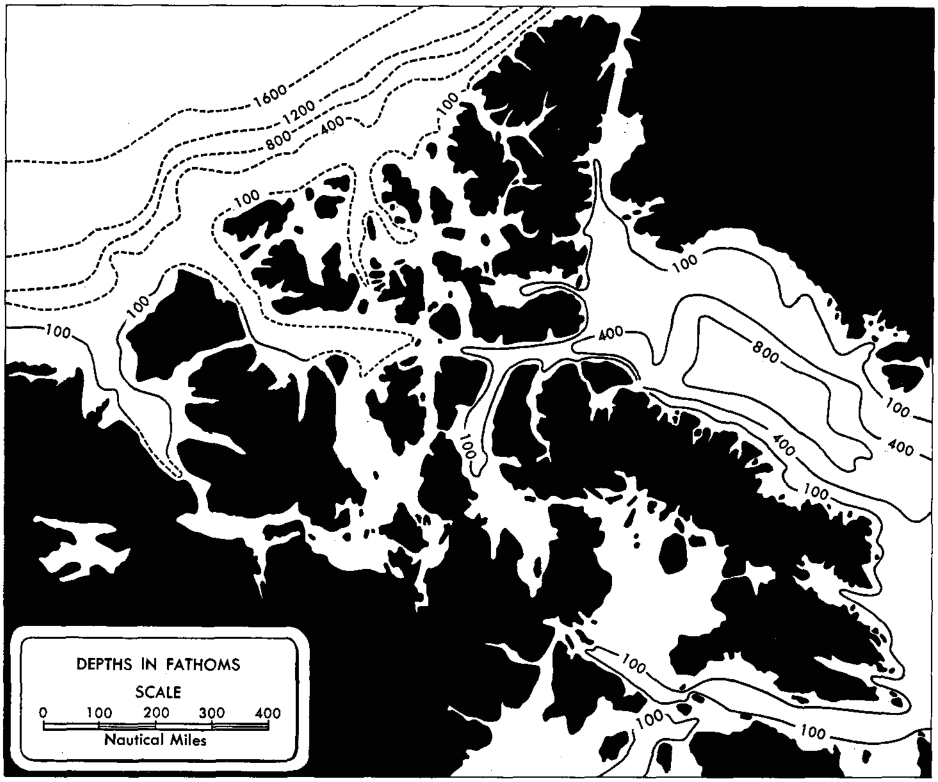

Fig. 2. Bathymetric map.

The deepest water in the Canadian Arctic Archipelago occurs in the eastern

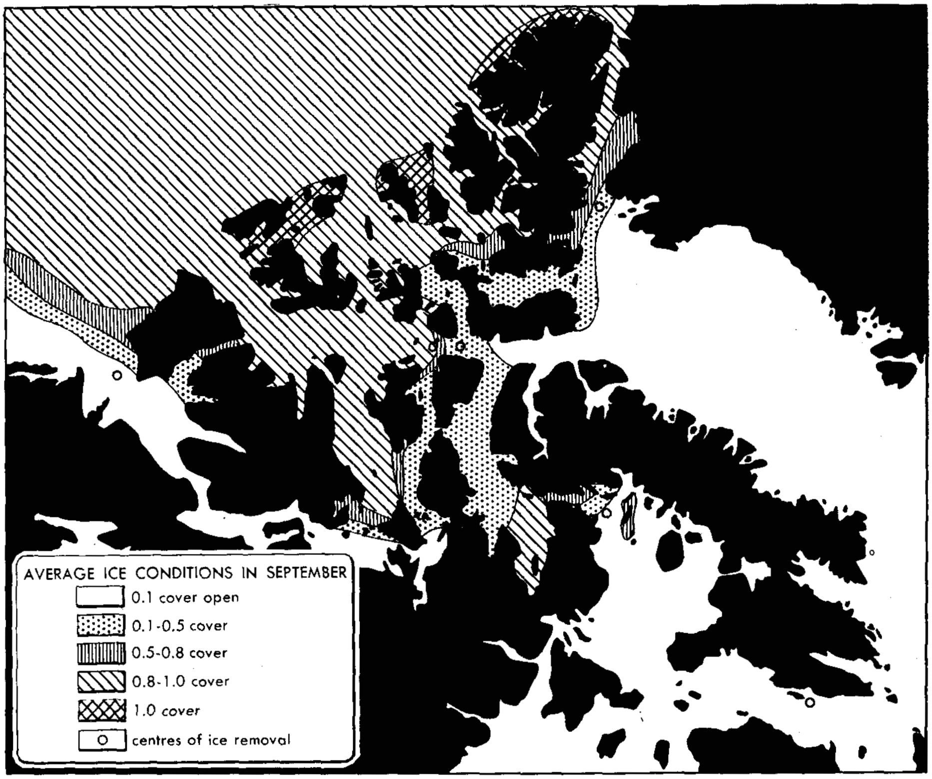

Fig. 3. September ice conditions.

end of Lancaster Sound where depths of 400 to 500 fathoms are common. In Lancaster Sound and Prince Regent Inlet the water depth varies between 100 and 300 fathoms, but to the westward the soundings decrease to about 200 fathoms in M'Clure Strait and Viscount Melville Sound. The sill depth through Barrow Strait is about 80 fathoms.

Few soundings have been taken in the channels in the northwestern part of the Archipelago or on the arctic continental shelf. The reconnaissance soundings indicate that the width of the shelf is approximately 50 miles off the coast of Banks Island and farther north increases to 100 miles. In the last year soundings of 150 to 200 fathoms have been recorded in the northern end of the Prince Gustaf Adolf Sea.

The distribution of sea-ice in the Canadian Arctic Archipelago is now fairly well documented and recently a sea-ice navigability atlas has been completed that will make available ice information in a form similar to that contained in ice atlases of the northern sea route [5].

Fig. 3 has been compiled from several sources including the Oceanographic Atlas of the Polar Seas, Part II [6] and the Ice Atlas of the Northern Hemisphere [7]. In several regions the distribution has been altered according to reports of observers who have been active in the Canadian Arctic, Grainger[8] and Learmonth (personal communication). The chart, which represents optimum ice conditions, shows that Lancaster Sound, Foxe Basin, and the passages south of Victoria Island are normally open, whereas in Prince Regent Inlet, Peel Sound, and Wellington Channel light ice concentrations are to be expected.

Recent analysis of ice records by Schule and Wittmann[9] has shown that there are several areas where perennially unstable ice conditions can be expected. These areas form centres of ice removal and are indicated in Fig. 3 by circles.

Average conditions of temperature and salinity for the eastern and western Arctic are shown in Fig. 4. These curves have been constructed from observations taken in Lancaster Sound in 1957 and from the I.G.Y. drift station T-3, which in September 1958 was in the vicinity of the western end of M'Clure Strait.

Both curves show surface variations of temperatures and salinity caused by local sea ice. As would be expected surface temperatures and salinities are lower, 0°C and 29.90‰, in the Western Arctic since at the time the observations were taken the sea was totally covered with ice. In contrast, observations taken in the Beaufort Sea in September in areas of less than 5/10 ice cover show that under more comparable conditions very low salinities, and temperatures between zero and 6.0°C are characteristic of the surface waters to a depth of 30 metres [10].

The depth of the warm surface layer in Lancaster Sound indicates a prolonged period of surface heating and exchange with the warmer waters of the upper layers in Baffin Bay.

Similar temperature and salinity characteristics appear in both curves at about 180 metres but below this depth there is a uniform difference in both temperature and salinity that persists to the bottom. Bottom temperatures and salinity in the Western Arctic are almost constant at 0.4°C and 34.93‰; in the Eastern Arctic temperature and salinity at the bottom are typically 0.5°C and 34.50‰.

It is interesting to note that the slightly warmer interlayer at 75 metres that has been identified from the oceanographic observations taken from the Russian drifting station of 1950-51 is defined by temperatures of -0.7°C to -1.2°C. This feature does not appear in the 1958 T-3 records that show temperatures below -1.0°C from 10 to 180 metres; however, in 1952 Worthington[11] recognized a similar feature at positions in the same region as the Russian stations. At that time the negative thermal gradient between 50 and 150 metres was regarded as the last remnants of a seasonal thermocline. More recently Gudkovich[12] has interpreted this reversal of the thermal gradient as indicating the penetration of waters from the northern part of the Bering Sea into the arctic basin.

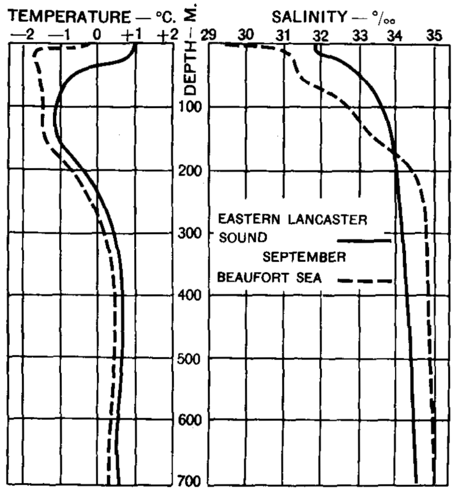

Fig. 4. Temperature and salinity curves.

The longitudinal profile through Parry Channel shown in Fig. 5 gives an idea of the east-west distribution of summer temperature and salinity in the Canadian Arctic Archipelago. In this diagram the bottom contour west of Barrow Strait is based upon very limited soundings and does not present an accurate picture of the bottom topography.

The typical sharp gradient of temperature and salinity in the surface layers is obvious and appears more pronounced in the west where heavy ice exists. Maximum surface temperatures of 2.5°C have been recorded in the eastern end of the section and the minimum surface temperatures of -1.6°C to -1.7°C normally appear in the region of Barrow Strait. The effect of the Barrow Strait sill is obvious in the discontinuity of the isopleths below a depth of 150 metres.

Temperature-salinity curves have been plotted in Fig. 6 for four representative stations in the Parry Channel system to show the variations in water characteristics from east to west. This graph shows the large variations in the surface layers and the pronounced differences in temperature and salinity that persist to a depth of 100 metres. Below 100 metres the curves assume a characteristic shape and can be considered representative for each specific region. temperatures of 0.4°C occur at about 500 metres and the salinity at depth is 34.93‰. These curves also show the similarity of the temperature-salinity characteristics of the deep water of Baffin Bay and the temperature and salinity features at depths of 250 metres in the arctic basin, an observation already discussed by Bailey[4].

Determinations of the concentration of dissolved oxygen in the water have been carried out on most of the recent

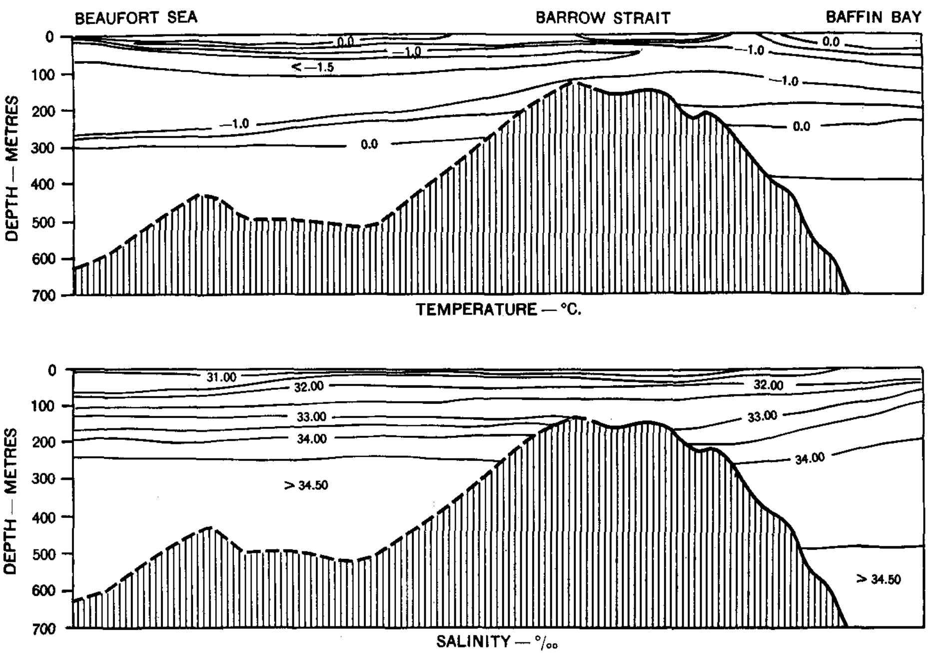

Fig. 5. Longitudinal profile of Parry Channel.

The variation of water characteristics above a depth of approximately 200 metres is apparent in the large spread of values in this depth interval and the east-west differences in the physical features below this depth are obvious in the displacement of the characteristic regional curves.

The graphs for the Eastern Arctic show an increase in temperature to a maximum of 0.8°C at 500 metres and a maximum salinity of 34.45‰ at the bottom. In the Western Arctic maximum oceanographic cruises in the North American Arctic. The observations that are confined to the summer months with few exceptions show that under similar conditions of ice cover there is little difference in the concentration of dissolved oxygen from east to west.

In eastern arctic waters where there are extensive ice-free areas and a constant exchange with adjoining basins the summer oxygen concentration varies from a maximum near the surface of 10.0 ml./l. to a minimum of 7.0 ml./l.

at 300 metres. In the Western Arctic under conditions of permanent ice cover a surface maximum of 10.0 ml./l. occurs after the period of peak surface run-off with a lag of about 1 or 2 weeks and the minimum of 6.0 ml./l. normally appears between 150 and 300 metres. Maximum surface values of dissolved oxygen of over 10 ml./l. usually occur during August and the minimum content, as little as 5.0 ml./l., is found in September.

Calculations of the volume exchange through the channels of the Canadian Arctic Archipelago have been computed by several investigators including Kiilerich[1], Smith, Soule, and Mosby[2], and Bailey[10]. Recent surveys in Hudson Strait and Lancaster Sound by the Fisheries Research Board have determined the volume transport through these two major passages[13, 14].

A summary of recent information indicates that the total eastward transport of water from the Arctic Ocean through the Canadian Arctic Archipelago is of the order of 40,000 km.³ per year. Of this total approximately 16,000 km.³ per year pass eastward through Lancaster Sound and 13,000 km.³ per year enter Baffin Bay through Smith Sound. The remainder leaves the Arctic Ocean by way of Jones Sound and Hudson Strait.

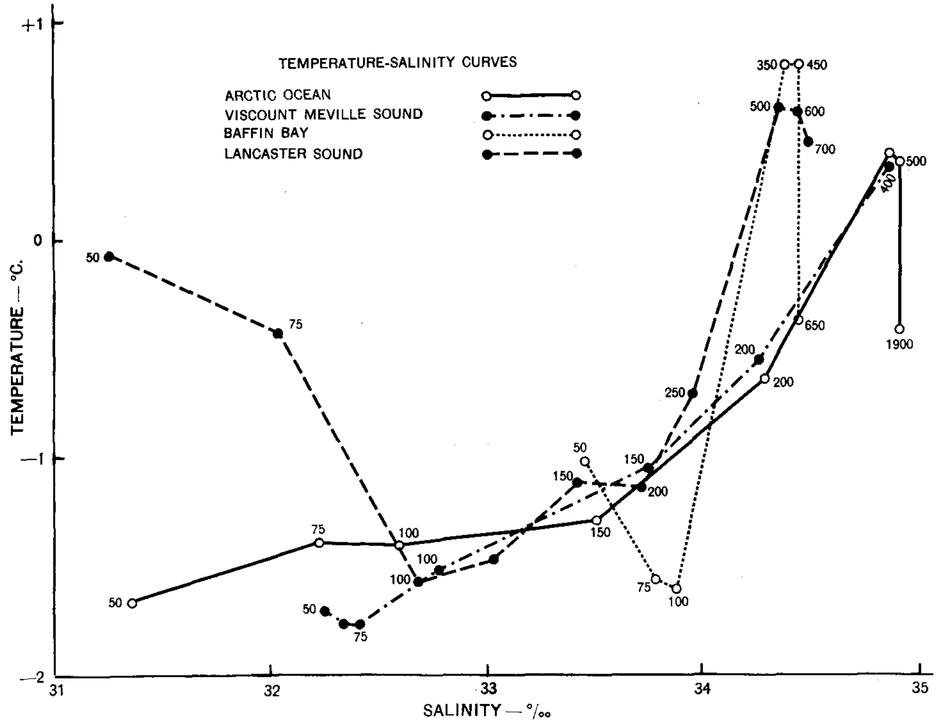

Fig. 6. Temperature and salinity in Parry Channel.

Russian researchers have calculated the flow through the Canadian Arctic Archipelago based on the volume balance of the Arctic Ocean. Their results show a variation of values from 31,000 km.³ per year to the more recent figure of 8,000 km.³ per year [15, 16].

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FIELD STUDIES ON THE BEHAVIOUR OF SEA-DUCKLINGS

During the summer of 1959 the writer was engaged in studies on the behaviour of sea-ducklings in the Belcher Islands, Hudson Bay. This work is centred on an ethological study of eider ducklings *(Somateria mollissima)* with comparative observations on ducklings of old-squaw *(Clangula hyemalis)* and red-breasted merganser *(Mergus serratus)*; it had been begun in the False River area, Ungava in the summer of 1958 [1, 2, 3]. Once again Mr. C. W. Nicol gave able assistance.

The objective of this work is to build up as complete an account as possible of the behaviour of the normal eider duckling in its natural environment, beginning shortly before hatching and ending with fledging. It is hoped that an account of the basic behaviour of this species will provide a sound foundation on which to plan analytical studies. The approach to this work is largely that of the present European vertebrate ethologists[4], but it is planned to develop the more "psychological" aspects of the work in future studies.

The most obvious single comment to be made about the behaviour of the eider duckling is that it is extremely complex, more so than has previously been recognized. This complexity is partly due to the mixture of innate and learned processes, which together enable the duckling to survive the difficulties of the pre-adult stages. One of the present aims therefore is to describe the part played by innate mechanisms and to correlate learning processes with them. A brief summary of the results to date follows.

Two or three days before hatching the duckling pushes its bill through the inner shell membrane into the air space