REPORT
ON THE PROGRESS OF THE DISCOVERY COMMITTEE'S INVESTIGATIONS

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REPORT ON THE PROGRESS OF THE DISCOVERY COMMITTEE'S INVESTIGATIONS

SCOPE OF THE INVESTIGATIONS

THE main purpose of the investigations undertaken by the Discovery Committee is to carry out research on the economic resources of the Falkland Islands Dependencies. Since whaling is at present the only industry which is carried on to any large extent in the Antarctic the work is primarily concerned with the biology of whales: and in view of this and of the migratory habits of whales it has spread in time over most of the Antarctic.

Details of the origin and objects of the investigations may be found in the *Report of the Interdepartmental Committee on Research and Development in the Dependencies of the Falkland Islands* (Cmd. 657, 1920), in the Introduction to vol. I of the *Discovery Reports*, and in the Committee's *Second Annual Report*.

Before the effect of whaling on the stock of whales can be assessed, or measures for the regulation of the industry suggested, it is necessary to elicit as much information as possible about the breeding and growth, and the distribution, movements and migrations of the species of whales which are hunted. The elucidation of these points is a deep and complex problem which is not to be solved by direct observations on whales alone. It will be shown in the following pages of this report that the habits of whales are intimately bound up with the whole economy of oceanic life, and that it has consequently been necessary to extend the research to many branches of the science of oceanography. The same necessity for investigating problems of life in the sea on broad and comprehensive lines applies to all fishery research, and the methods used on board the research vessels are essentially the same as those which have been developed for marine research throughout the world.

The breeding and growth of whales, together with the important problem of their specific identity, has been examined by means of direct observations on the carcasses of whales at whaling stations in South

Georgia and South Africa, and to some extent with the help of anatomical specimens collected on factory ships. These observations cover seven seasons at South Georgia and two seasons at South Africa, and have resulted in the establishment of many facts which have gone far to revolutionize previously current ideas and which have a direct bearing on problems connected with whaling.

The more comprehensive problems of the whales' environment in relation to their distribution and movements have been the principal concern of the R.R.S. 'Discovery' during one commission of 2 years and the R.R.S. 'Discovery II' during four commissions. This work at sea has included general oceanographical research in nearly all parts of the Southern Ocean, but mostly in the Falkland Islands sector. Some similar work has been done from time to time by the R.R.S. 'William Scoresby'.

A vitally important part of the work is the marking of whales at sea. This is done with a view to deductions as to the movements of the whales. The marking has been carried out mostly with the 'William Scoresby', but to a considerable extent also with hired "whale catchers" around South Georgia.

Other investigations of economic importance but not concerned with whales have been pursued on a smaller scale. These include experimental trawling on the banks between the Falkland Islands and South America to test the possibility of establishing fisheries in the area, investigations concerning seals, the surveying of imperfectly charted coasts and islands, routine meteorological observations, and a short period devoted to an examination of the Peru coastal current. Of these the trawling and survey work are perhaps the most important.

Though their main objective in the Antarctic has been the elucidation of economic problems, the Committee have always realized that their vessels have unrivalled opportunities for research in pure science, and it has been their policy to encourage such work whenever it can be carried out without interfering with the routine investigations: with modern oceanographic equipment large collections of biological and other material can be secured in a very short time. Specimens which have no close or obvious bearing on economic problems have not been

studied by the Committee's staff, but have been sent for examination to independent specialists, and the results, which have greatly increased our knowledge of the Antarctic fauna, have been published in the *Discovery Reports*. The Committee owes a debt of gratitude to the numerous specialists, many of them of world-wide reputation, who have assisted in this way. This work has been entirely voluntary.

The material and data collected in the course of routine investigations accumulate much more quickly than they can be fully considered and reported upon by the staff at home, and in consequence the results of work at sea during recent years are very far from being completed. However, the new information already gained on the biology of whales represents a very great advance on anything previously known about them: the work carried out for the Discovery Committee has laid the foundations of Antarctic oceanography, and probably will exert a far-reaching influence on the trend of modern oceanographical research.

The laboratory accommodation necessary for the working up of the material collected has been generously provided by the authorities of the British Museum, to whom the Discovery Committee are greatly indebted. The Committee have presented to the Museum many considerable collections of biological specimens.

THE SHIPS AND THE MARINE BIOLOGICAL STATION

The first ship employed by the Committee, the R.R.S. 'Discovery', a vessel of 736 tons gross and 1900 tons displacement when fully laden, was originally built by the Dundee Shipbuilding Company for the National Antarctic Expedition of 1901–3. She was later in the possession of the Hudson's Bay Company, from whom she was purchased for the Discovery Committee. Very extensive repairs to the ship were effected, and in accommodation, haulage and other gear and fittings she was fully equipped for oceanographic research. She is a wooden sailing ship of exceptional strength, barque rigged and with auxiliary steam power. Details of her construction and equipment are given in the *Discovery Reports* (Kemp and Hardy, vol. 1).[1] After the completion in

[1] These and similar references in the text are to the papers listed on p. 48.

1927 of her first commission it was originally intended that she should again sail south to continue investigations in the Antarctic, but it became known that a wooden ship would be needed for the British Australian–New Zealand Antarctic Research Expedition, and the Australian Government offered to charter her for this purpose. The experience gained during her employment by the Discovery Committee had shown that the researches most needed at the next stage of the investigations lay in the open ocean. They could be carried out more expeditiously in a ship of greater speed and range of action, and the unique strength of hull which rendered the 'Discovery' so suitable for the coastal exploration required by the Australian Government was not essential. The Discovery Committee accepted the Australian offer, and sanction was obtained for the construction of a steel steamship, the R.R.S. 'Discovery II' (Ardley and Mackintosh, vol. XIII). She is a vessel of 1036 tons gross and a displacement when fully laden of 2100 tons, an economic speed of 10 knots, and a maximum cruising range of about 10,000 miles. Although it was not intended that she should undertake any extensive work in the ice, she was strengthened forward and along the water-line to withstand ice pressure. In addition to a large winch bearing 5000 fathoms of tapered wire rope she carries three auxiliary winches for small nets and water bottles; she is fitted with a Lucas sounding machine, Admiralty type deep- and shallow-water recording echo sounders, anemometer, and distance thermograph. Her accommodation for research includes a biological and a chemical laboratory besides one for rough work, and a dark room. She was specially designed for oceanographic research, and for this purpose is probably the best equipped vessel in existence.

The smaller ship employed by the Committee, the R.R.S. 'William Scoresby', of 324 tons gross and displacing 715 tons, was built in 1926, and was designed to carry out experiments in marking whales, to assist in general oceanographical work, and to undertake trawling surveys with a commercial otter trawl. She is constructed on the lines of a whale-catcher, but with larger bunker capacity and special strengthening against ice. She has a large winch, which is used for otter trawling in fishery surveys as well as for certain work in deep

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Plate I. THE R.R.S. "DISCOVERY."

water, two auxiliary winches for light gear, and an echo sounder of Admiralty type (Kemp and Hardy, vol. 1).

The Marine Biological Station at South Georgia is situated in the harbour of Grytviken, near the whaling station of the Compania Argentina de Pesca. It is a wooden house, designed to withstand a severe climate, and has accommodation for seven persons. In addition to the living rooms there is a large laboratory equipped for biological and chemical research, a small rough laboratory and a workshop.

COMMISSIONS

The work at sea has been carried out in the 'Discovery', the 'Discovery II' and the 'William Scoresby', and the work ashore mainly at the Marine Biological Station at South Georgia. There have also been detached parties working at South African whaling stations, in factory ships and whale-catchers, at the Falkland Islands, and for surveying at South Georgia.

The actual research under the Discovery Committee began with the opening of the Marine Biological Station early in 1925. Here it was the task of the scientific officers to spend a large part of each day on the flensing platform of the neighbouring whaling station, equipped with knives and hooks, taking measurements of the whales, separating internal organs from the vast mass of viscera, and preserving specimens for subsequent examination in the Marine Station laboratory. This work was continued with periodic changes of staff during each whaling season until 1931. Some months also were spent by certain members of the staff at South African stations in 1926 and 1930.

The general oceanographical work at sea was conducted at first in the 'Discovery', which sailed from England in October 1925, on a two years' commission, during which she made some intensive series of observations on the whaling grounds of South Georgia and the South Shetland Islands, and carried out other work in the Falkland Island Dependencies, between the Dependencies and South Africa and in South African waters.

Similar work, together with initial whale-marking experiments, was carried out by the 'William Scoresby' between 1927 and 1930; and

this ship, owing to her superior mobility, was able to carry out a fuller programme of work in the waters of the Dependencies.

The first commission of the 'Discovery II', from December 1929 to

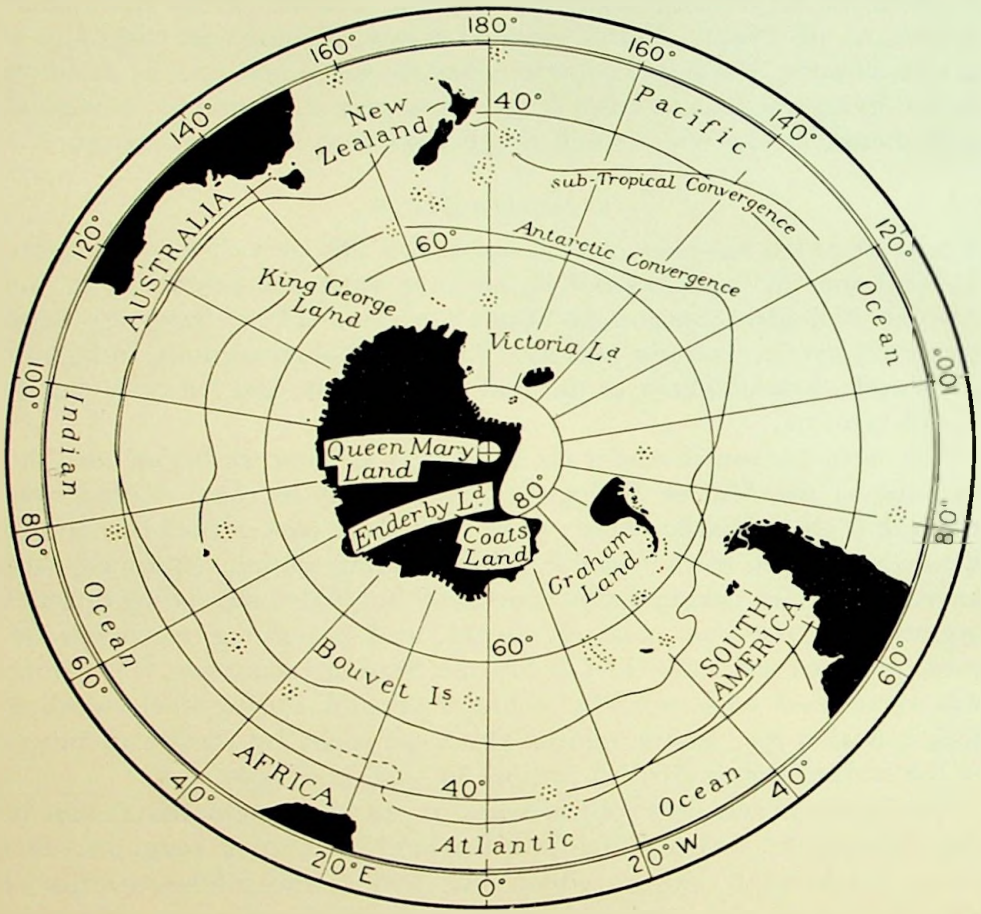

Fig. 1. Chart of Antarctic Regions.

June 1931, was spent largely in the waters of the Dependencies, but observations were also extended to other parts of the South Atlantic sector of the Antarctic, and to the Bellingshausen Sea in the south-east Pacific.

The principal feature of the second commission, from October 1931 to May 1933, was a series of long voyages in the course of which the Antarctic continent was completely circumnavigated. This was the

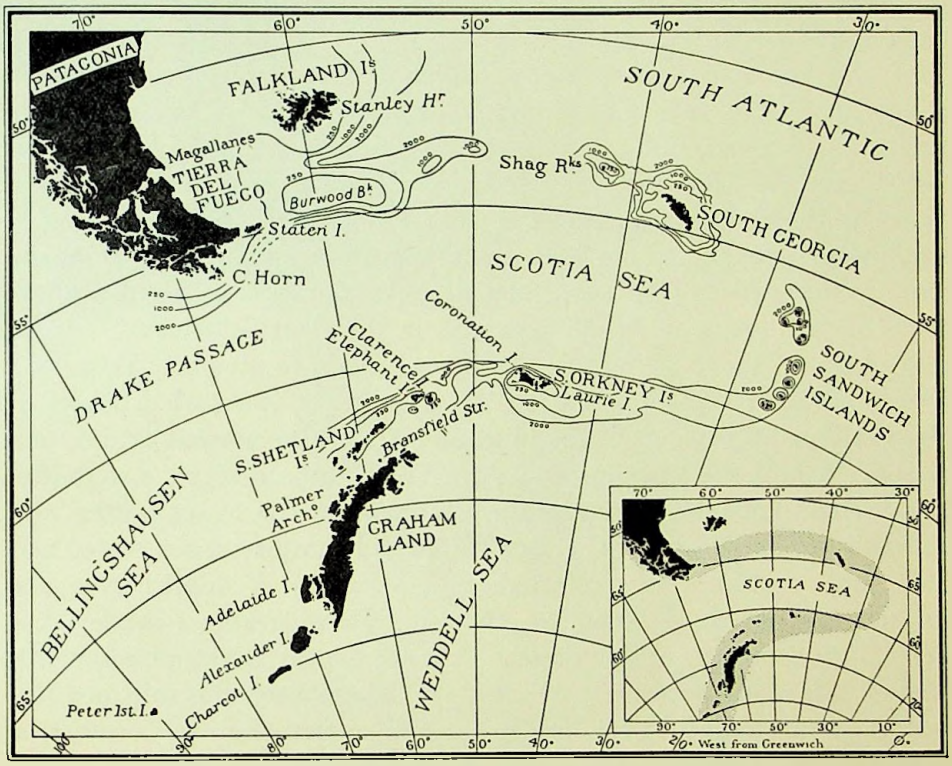

Fig. 2. The Dependencies of the Falkland Islands.
Inset: the Scotia Arc (stippled).

fourth time the Antarctic had ever been circumnavigated, and the first time in winter. The ship's tracks were in the form of V- and W-shaped lines of observations between the pack-ice and ports in the Dependencies, in South Africa, in Australia and in New Zealand. Courses of this character enabled conditions to be studied from the edge of the ice to warmer waters. Many lines of more closely grouped observations were worked again in the waters of the Dependencies.

The third commission's work of the 'Discovery II', from October

1933 to June 1935, included a line of stations (see below) repeated at intervals in the meridian of 80° W for the study of seasonal variations, and several long voyages through the Pacific and Atlantic sectors, in the course of which the whale populations and their environment in these regions were examined.

During the fourth commission, which began in October 1935 and is now at its end, a second circumpolar cruise in the summer months had been planned, but owing to the diversion of the ship for the search for Mr Lincoln Ellsworth and Mr Hollick Kenyon it became necessary to revise the programme, and the work was mostly confined to lines of stations across the Indian and Atlantic sectors and more specialized work in the waters of the Dependencies. Advantage was taken of these relief operations to make observations in the Ross Sea.

A word on the working of a station will help to give an idea of the routine carried out. A "station" is a position at which a series of observations of any sort is made at one time. On normal cruises one or two stations are worked each day. The ship is hove to, a sounding and meteorological observations are taken, and the water bottles and nets are lowered to obtain temperatures and samples of sea water and plankton.[1] Samples are collected from a variety of depths from the surface to sometimes 4000 or 5000 m. Considerable experience is needed for the safe working of gear at great depths, and much depends on the officer of the watch, whose duty it is to keep the ship head to wind and motionless in relation to the sea, so that the wires remain as nearly vertical as possible. The technique of handling the ship on station is now so well understood that a full series of observations can be taken in a wind of 35–40 miles per hour. The work with vertical wires takes 2½–3 hours if there are no delays, and the ship then steams slowly ahead towing horizontal or oblique nets for about 50 min. A station is normally begun every evening at 8 p.m., and a morning station is often added; and this routine is usually maintained the whole time the ship is at sea.

Although very low temperatures are seldom recorded in the open sea, much of the work on deck must be performed with bare hands in

[1] The small animal and vegetable organisms which drift with the water in which they live are known collectively as plankton.

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Plate II. THE R.R.S. "WILLIAM SCORESBY."

freezing wind and spray, and in high latitudes the work "on station" is often protracted through the freezing of sea water which finds its way into the moving parts of the deck machinery. Even so, the inconveniences suffered from the cold are exceeded by the discomfort of the persistent gales which characterize the Southern Ocean. It has been estimated that while the ships were in the latitudes in which a very large proportion of their work was carried out winds of gale force prevailed during about 40 per cent. of the time. The violent and unending motion of the vessel is often excessively trying, and the routine work continued week after week while out of sight of land becomes extremely monotonous. A change of scenery and occupation is provided, however, when the ship visits port for her annual refit and when she is occupied in the surveying work to which a month is usually devoted in each commission.

The work of the 'William Scoresby' has in some ways been more varied and adventurous than that of the 'Discovery II', space is cramped and living conditions are harder than in the larger ship. In addition to the work mentioned above she undertook trawling surveys between the Falkland Islands and the mainland of South America in 1927, 1928 and 1931–2, work on the Peru current in 1931, and miscellaneous whale marking and oceanographical work. The whaling seasons of 1934–5, 1935–6, and 1936–7 have been entirely devoted to whale marking in the south-east Atlantic and southern Indian Ocean. During this work the ship is continuously at sea for 4 or 5 months, supplies of fuel being obtained from whaling factory ships.

DIRECT OBSERVATIONS ON WHALES

An outline of the problems confronting the Committee in respect of whales and whaling was given in their *Second Annual Report*. In the briefest possible terms, their aim was to furnish a basis for the rational regulation of whaling. All the main facts of the life history of the whales hunted must be known before such a basis can be said to have been established. As was pointed out in the *Report* mentioned, one of the first objects was to find whether the Antarctic was visited by one common stock of whales or by smaller stocks, or even separate species

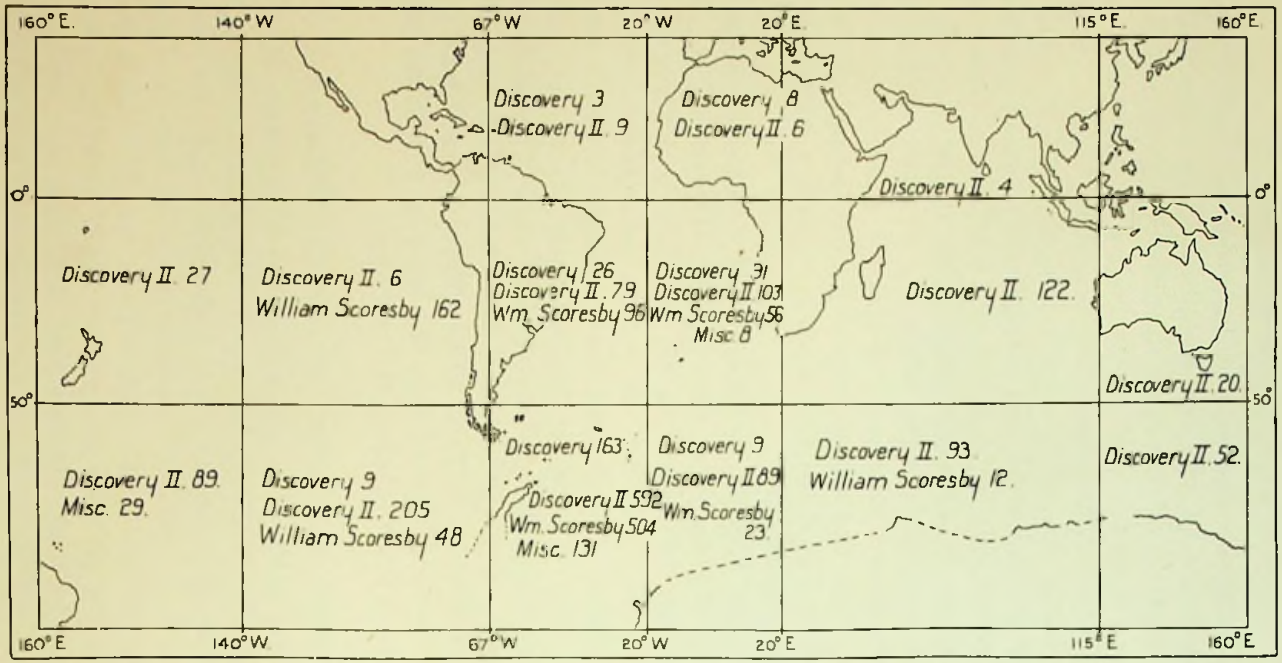


Fig. 3. Chart showing up to June, 1936, the number of 'stations' worked by the ships between arbitrary meridians and parallels of latitude. 'Miscellaneous' stations are those worked ashore or from whaling ships. Totals are: Discovery 309, Discovery II 1496, William Scoresby 201, Miscellaneous 168.

occurring in different areas. Most important was the building up of reliable information as to reproduction and growth, since the amount of destruction which can be carried out without consequences serious to the industry is clearly dependent on the rate of replacement.

It was necessary to study whale migration from every point of view, that is, to ascertain the routes of the migration, the range and speed, and the proportion of the stock which migrates. In particular, it was required to know whether whales returned to the same parts of the Antarctic, or, in other words, whether the depredations of whaling in one area would or would not affect the stock in other areas. The food also had to be ascertained, since as the visit of the whales to the Antarctic is a migration for food, the distribution of the food will affect migration. It is true that on many of these matters a good deal had already been written, particularly on those parts of the subject which could be studied in the laboratory: but to arrive at information sufficiently reliable for administrative and economic purposes, results on an adequate mass of data and on observations in the field were essential. Conclusions must be established as reasonably certain before they can be used.

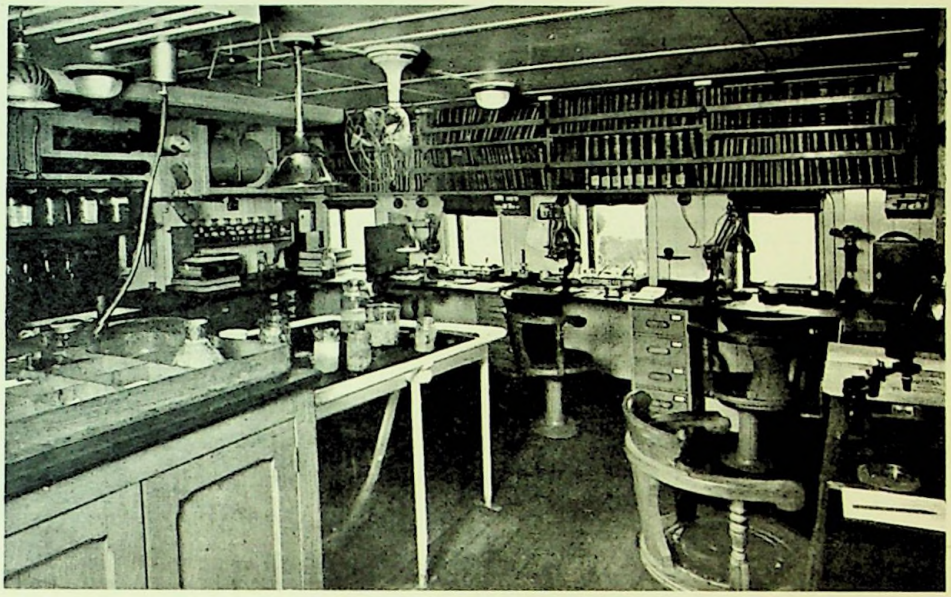
The work was somewhat changed in aspect and greatly increased in scope soon after its inception. When it was planned by far the greatest part of Antarctic whaling took place in the Falkland Islands Dependencies, in which were situated nearly all the shore stations on which it was based. The season in which the investigations started saw also the sailing of the first pelagic factory ship, i.e. factory ship equipped for hauling the whale carcass bodily on board for treatment in the open ocean: and although for a few years shore-station whaling contributed the bulk of the oil output, pelagic whaling quickly grew until it was of major importance. The centre of whaling importance shifted to the open sea: and it became more than ever essential to extend the Committee's investigations to cover the whaling and the conditions of whaling in all parts of the Antarctic.

It should be stated that the species dealt with are almost entirely the Blue whale (*Balaenoptera musculus*) and the Fin whale (*B. physalus*), since it is mainly on these species that the modern industry is based. Most of the work on the whales' anatomy, specific characters, breeding, and

food was carried out at the Marine Laboratory erected for the Committee at South Georgia (described in the Committee's *First Annual Report*). Similar work was done, though on a smaller scale, at the whaling stations at Durban and Saldanha Bay, South Africa, and Deception Island, South Shetlands. Observations were made on board a whale factory in the Ross Sea in 1928. Later, in 1933–4, a large amount of material was examined in the floating factory, 'Southern Princess'.

One of the first studies at Grytviken was that of specific identity. For this purpose records of the length, pigmentation and all obvious external features of the whales brought in, such as the baleen (whalebone) together with the number of ventral grooves and well over a score of body measurements were made as a matter of routine for several seasons. This work failed to reveal any specific or subspecific distinctions between the whales at South Georgia and those of other localities visited. Though there is some reason from other sources to leave open the question whether two slightly differing races of Fin whales exist, it may be taken as established that Blue and Fin whales respectively are materially the same throughout the Southern Ocean, and that no significant difference has been found between the whales known by the same names in the Arctic and Antarctic.

In the same way, by daily dissection and observation, information was accumulated concerning the whales' reproduction and growth. These fundamentally important results will be found in detail in the report on Blue and Fin whales (Mackintosh and Wheeler, vol. 1). The average length at which sexual maturity is reached has been fixed with considerable accuracy. This is of great importance, since it enables the proportion of immature whales to be ascertained in statistics of catches which give only the species, sex and length. It may be added that these figures have been used by Norwegian investigators in their calculations. One point which soon emerged from this work was the fact that at South Georgia a high proportion, varying between 20 and 40 per cent. of the whales killed, were immature, and that at South African stations 80 to 90 per cent. were immature. This heavy destruction of immature whales must have an adverse effect on the stock, since an immature whale has not had the chance of reproducing itself. It



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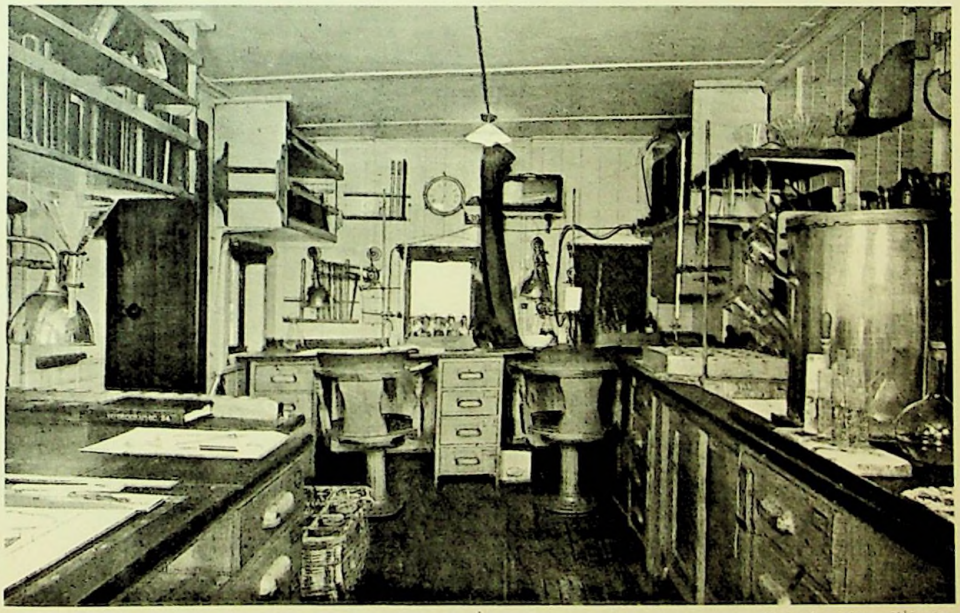

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Plate III. LABORATORIES IN THE "DISCOVERY II."

a.—The biological laboratory. b.—The hydrological laboratory.

was shown that on the average but one Blue or Fin whale was born at a birth, at lengths respectively of about 23 and 21 ft., generally in May or June, after a gestation period of 10 or 11 months. The Blue whale appears to be weaned at about 52 ft. and the Fin whale at about 39 ft., normally in the December following birth so far as can be seen from the data collected at South Georgia. Both species are mature sexually in about 2 years from birth, at which time the Blue male and female are respectively about 74 and 78 ft. in length, and the Fin 64 and 66 ft. From weaning in December to the following June the females are reproductively idle.

Since with the rarest exceptions no nursing female has been found pregnant, it follows that the maximum rate of reproduction for female Blue and Fin whales is one calf in every 2 years: instances of multiple births are too infrequent materially to invalidate this conclusion. It should be emphasized that the maximum rate is not necessarily reached in all cases, and Laurie from observations in the 'Southern Princess' has concluded that in Blue whales the interval between births frequently exceeds 2 years. It will be noted that the early sexual maturity and the rapid growth in size in these two species do something to counteract the slow recuperation of the stock: but the rate of replacement clearly is low. For studies of stock and depletion it is very important that its maximum is known.

While among young whales length is an index of age, when full physical maturity is reached growth ceases owing to the complete ossification of the vertebrae. The study of this change in the vertebrae was the subject of a section in the report on Blue and Fin whales. In Fin whales it was carried farther, with the result that growth was believed to cease at from 6 to 8 years of age (Wheeler, vol. 11).

Any study of decline of stock by observations of the mean lengths of the individuals taken year by year is therefore generally impracticable. A surer method of research, even in the case of fish, where decline in length results from intensive fishing, is consideration of the ages of the animals taken. To apply this method to whales a method of age determination therefore was sought, and in the end was found.

When an ovum is released from the ovary of a mammal, as periodically

occurs, a distinctive and recognizable structure, known as the *corpus luteum*, remains in the ovary for some time. In the baleen whales these structures persist indefinitely. The ovary thus records all the ova which have been shed during the whale's lifetime. It has been found possible

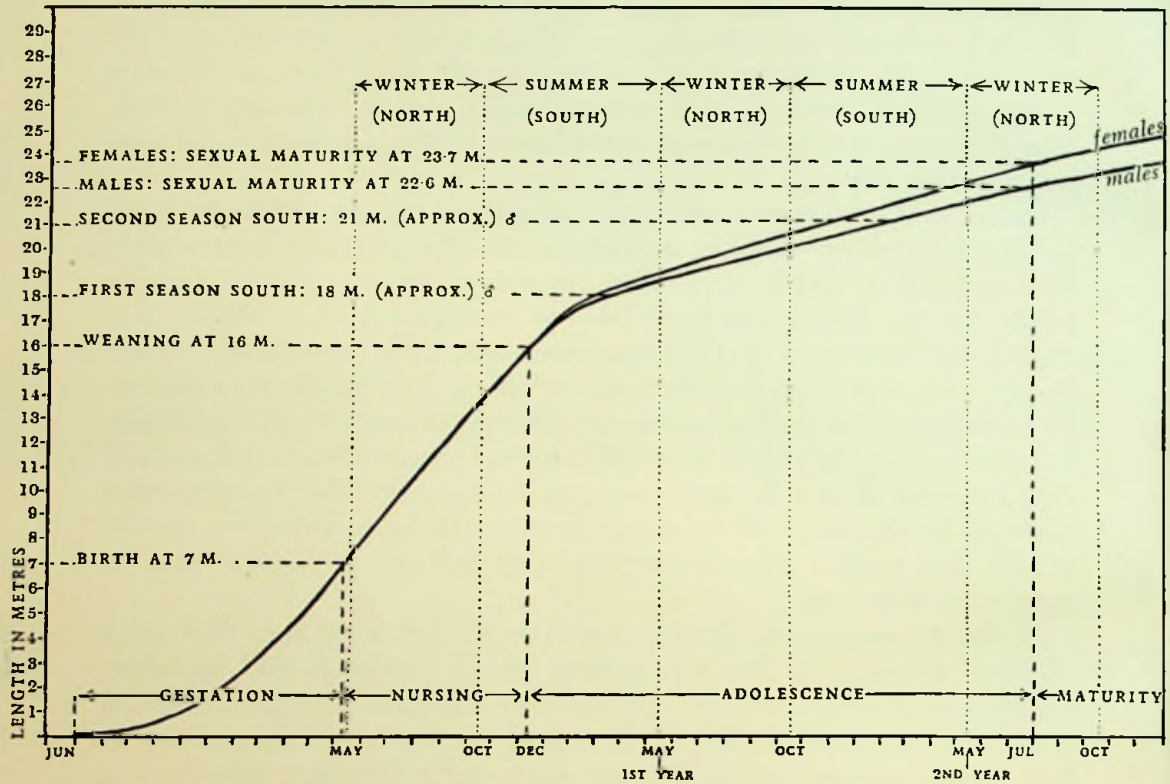

Fig. 4. Blue whales. Estimated mean curve of growth from conception to sexual maturity.

from a study of the numbers of these bodies to estimate the age of the female whale. Much work on these lines was done at the Marine Station. It was continued by Laurie, first in a floating factory and subsequently with the welcome co-operation of the whaling companies on ovaries collected in several floating factories and despatched to London.

Provided we can be sure that we are dealing with the same stock year

by year, this age method enables the enquiry into decline of numbers to be made direct, by the age analysis of the catch. Wheeler made this application (vol. IX). Writing of the years 1924–31 he concluded that the toll apparently taken during each of the first 14 years of the Fin

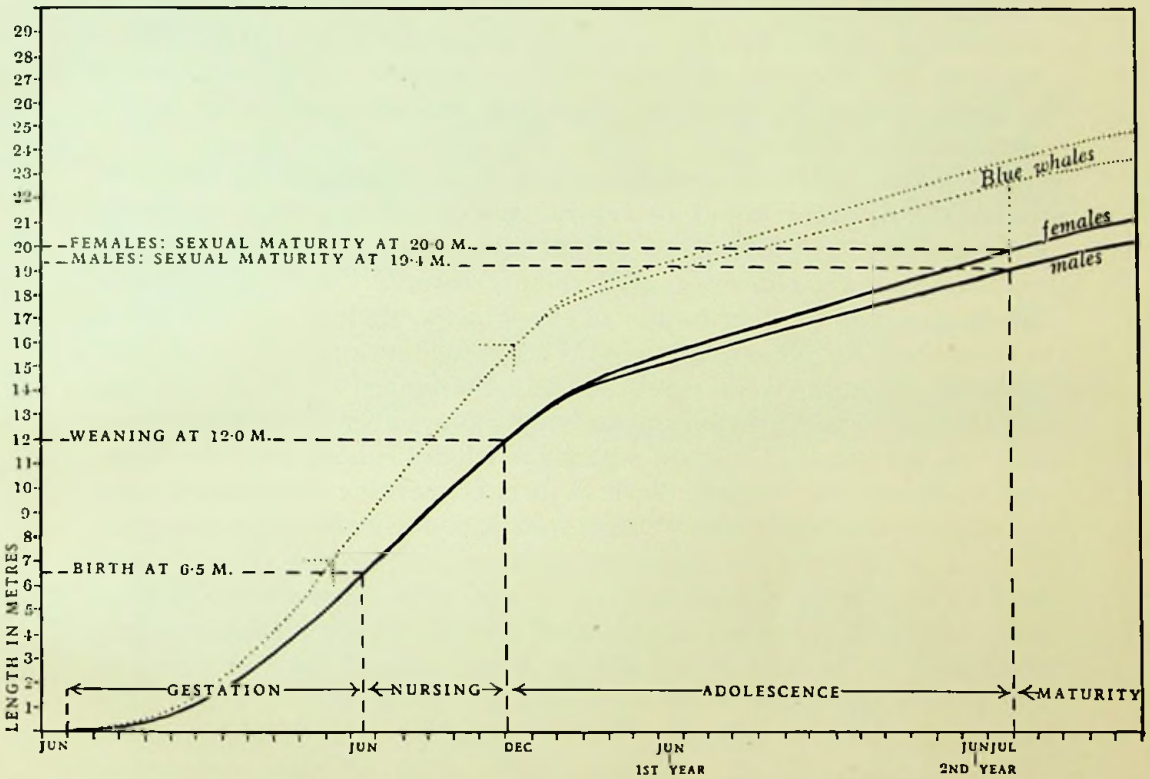

Fig. 5. Fin whales. Estimated mean curve of growth from conception to sexual maturity.

whales' life was 26 per cent: a quarter of each age group present was destroyed during each season. He considered that, bearing in mind the known facts of the reproduction rate, the stock might just meet this elimination, but certainly would fail to meet heavier calls upon it: but that if the older whales, which were poorly represented in the material examined, were in fact subject to attack elsewhere the stock must be declining. Laurie on rather different grounds reached similar con-

clusions concerning Blue whales on the pelagic whaling grounds (82 in list on p. 52).

It will be seen that the security of Wheeler's conclusions depends on whether the South Georgia stock is or is not a self-contained one —whether it is or is not hunted elsewhere. Certain features of the catch which were noticed as soon as the heavy pelagic fishing set in tend to the view that the stock at South Georgia has losses in other localities to meet. Evidently, however, migration is a material factor in the problem.

The influence of food on migration is clear. Blue and Fin whales in the Antarctic were found to subsist entirely on a prawn, *Euphausia superba* (see p. 32), replaced in certain sub-Antarctic waters by another small crustacean, *Grimothea*; and these creatures are found in dense shoals. The patchy distribution of the whales, obvious to the Staff as early as the 'Discovery's' first voyage from the Cape past Bouvet Island to South Georgia, is no doubt greatly influenced by this. For any knowledge of whale distribution and migration, however, direct observation was necessary. Constant watch for whales is kept from the ships, and those seen are logged. Several facts concerning distribution have been discovered in this way. Whales were found to be far more numerous in those portions of the Antarctic south of the Atlantic than in those south of the Pacific: Fin whales were many times more numerous than Blue—probably quite five times—and avoided the very coldest water. Some facts as to migration could be learned also from the season of arrival at South Georgia of immature and adult whales, and of the two sexes: also directions of travel observed by whalers were utilized (Kemp and Bennett, vol. VI). From the inception of the investigations, however, the direct study of migration by the marking of whales was projected.

The difficulties of whale marking proved to be far greater than those encountered in marking fish and birds. The approach to the whale, though far from easy, could be accomplished by hired catchers or by the 'William Scoresby', built mainly for this purpose on whale-catcher lines. The marks first employed proved inefficient, not remaining attached to the whale, and when a mark which remained within the

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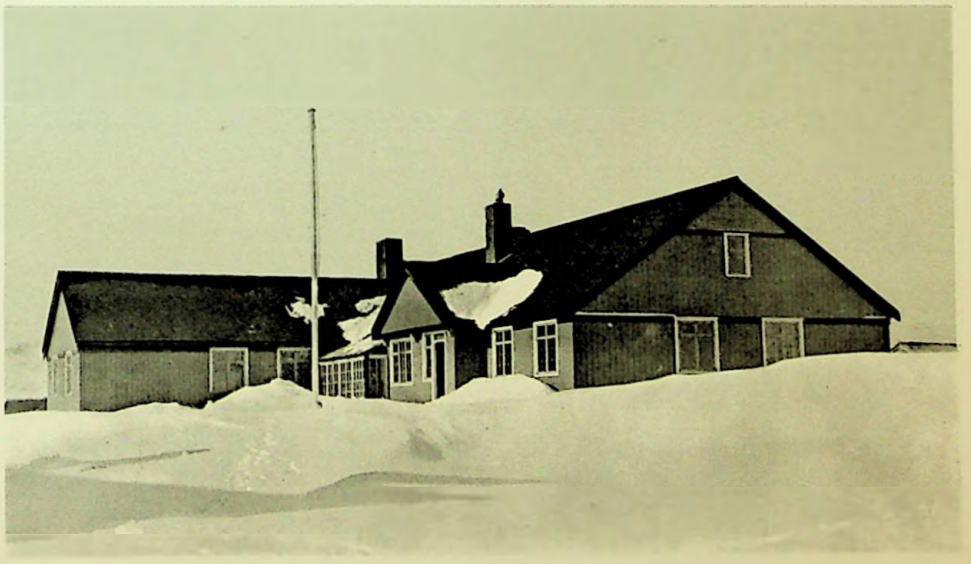

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Plate IV. GRYTVIKEN, SOUTH GEORGIA.

a.—View of the harbour. b.—The Marine Biological Station.

whale was adopted, it was found to suffer serious corrosion. The mark now used, which is proving satisfactory, is a small tube of stainless steel, shot into the blubber of the whale from a 12-bore shoulder gun. Each tube has a serial number, so that when a whale mark, for which a reward is offered, is found during the flensing of the whale and returned to the Committee, it is possible to learn, by comparison of the positions of marking and capture, something of the migration the marked whale has made.

Whale marking has been carried out with success for three successive seasons on pelagic grounds by means of the 'William Scoresby', and from South Georgia in a hired catcher. In the first two seasons a professional gunner was carried, but the 'William Scoresby' this season sailed without one; the ship's officers and the staff are proving quite adequate to the work. This work has been carried out along the ice edge south of South Africa and far to the eastward. She has an endurance of 4500 miles, but naturally is compelled to refuel several times during the season. The Committee is indebted to the whaling companies for permission to fuel from their floating factories; and in this way the 'William Scoresby' is enabled to work through the entire season without touching port.

So far 637 Blue, 3182 Fin, 501 Humpback, 37 Sperm, 18 Sei and 5 Right whales are known to have been marked. This makes a total of over 4000, of which about 670 were marked with the old corrosible darts.

Most of the recoveries naturally have been made in the season of marking, but a fair number of marks have been returned after a year, and a few after 2 years. It would be unwise at this stage to forecast the conclusions to which this work will lead. Many of the recoveries have been comparatively near the point of marking. Some have been at distances up to 2000 miles or more. Marks recovered during the season of marking have thrown much light on the routes taken by the whales as they follow the retreating ice southwards during the summer. From a preliminary inspection of the later recoveries, the most noticeable feature appears to be the return of the whale, season after season, to the same ground. Four recoveries made off the west coast of Australia

may be mentioned as giving definite evidence of a regular migration. All were marked not far from each other, on the ice edge south by west of the locality at which the whales were killed, at a distance of about 2500 miles. One had been marked 18 months previously, the other three 6 months. This suggests that the journey between a definite stretch of the ice edge and the westernmost point of Australia may be undertaken year after year. Marks so far recovered in the South Georgia whaling grounds tend to show that whales do not stay long in that locality, but are constantly moving on and being replaced by others.

It will be seen from this brief outline that considerable contributions have been made towards furnishing that basis of natural fact on which efficient regulation must be based. The main facts of reproduction are now known, and permit of an estimate being formed of the maximum rate of recuperation of the stock of Blue and Fin whales. The age of these whales can be determined, and the rate of total mortality (combining natural mortality and the effects of whaling) can be estimated, at least to some extent, provided that a stock is self-contained, i.e. is the same year by year, and prosecuted only on the ground investigated. Whether or to what extent stocks are so self-contained is a question which with other aspects of migration is under investigation by whale marking. These results and activities constitute an important step towards the solution of the central if recondite problem of the proper regulation of whaling, namely, how many whales of each species exploited can be taken annually without detriment to future supplies?

Fears concerning the depletion of the whale stock were widely entertained when the investigations were planned. They have become far more grave and are now felt by practically all those interested in whaling. Southern whaling grew in intensity until the season 1930–1. That season witnessed an expansion of whaling which proved as unwise as it was remarkable. In addition to six land stations, forty-one factory ships worked in the Antarctic, and in all 232 whale-catchers were employed. Over 3,600,000 barrels of oil were produced. The result was a great fall in price. The following season the whole Norwegian whaling fleet was laid up, and thereafter efforts to avoid unjustified expansion have been made by Great Britain and Norway. In most

recent years production has been limited by voluntary agreement among the whaling companies of Great Britain, Norway and Argentina; the season has been shortened, and some restriction of the number of ships employed has taken place. It is instructive to compare the Antarctic whaling of 1925, when the 'Discovery' sailed to begin the investigations, with the last complete season.

WHALES TAKEN, ANTARCTIC

Species	Season 1925–6	Season 1935–6
Blue	4697	10,382
Fin	8916	4,824
Humpback	364	1,254
Sei	195	—
Sperm	37	110
Others	10	—
Total	14,219	16,570

OIL PRODUCED, ANTARCTIC

	Season 1925–6	Season 1935–6
Whale oil (barrels)*	783,307	1,313,832
Sperm oil (barrels)		6473

* One barrel holds $\frac{1}{6}$ ton.

SHIPS AND STATIONS, ANTARCTIC

Season	Land stations	Factory ships			Catchers		
		No.	Gross tonnage		No.	Gross tonnage	
			Total	Mean		Total	Mean
1925–6	6	15	83,638	5,576	70	—	240*
1935–6	2	23	280,196	12,182	173	43,577†	259†

* Based on twenty-six licensed catchers.
† Exclusive of Japanese catchers.

Notwithstanding the efforts made for restriction, 16 per cent more whales were killed than in the earlier season, and production was higher by 40 per cent.

Between the two seasons improvement of equipment had enabled

whalers to deal in increasing proportion with Blue whales. One Blue whale produces, on the average, twice as much oil as a Fin whale and three times as much as a Humpback. Gunners accordingly prefer to take Blue whales, and, as the table indicates, this species now constitutes the greater part of the catch. The proportion of the carcass utilized has increased, and oil extraction processes have been improved; and owing to these changes fewer whales are needed to produce a given quantity of oil than was formerly the case. The high oil production of 1935–6 is no doubt in great part due to the changed basis of whaling, and aided by increased economy in working up the whale. To produce this yield, however, catchers have been more than doubled in number besides having increased in speed, the total tonnage of factory ships is between three and four times the earlier figure, and their average tonnage more than double. Destruction is at a high and dangerous level, and the difficulties of restriction are now greatly increased by the rapidly growing participation in Antarctic whaling of two countries, Japan and Germany, which commenced work in the South in 1934 and 1936 respectively. The need for a rational basis for the regulation of the industry is greater now than ever before.

It should be added that in the course of the work on age determination an abundant source of supply of a valuable drug, progestin, was found in the ovaries of the whales: and that several anatomical and physiological studies were made which, while not of immediate economic application, are of scientific value. These will be found numbered 25, 26, 42 and 82 in the list of *Discovery Reports* (pp. 49, 50 and 52).

OCEANOGRAPHY

Ever since the Discovery Committee began its work it has been recognized that investigations of the hydrology and plankton of the Southern Ocean must form an integral part of the programme. The importance of this work was stressed by a number of witnesses who gave evidence to the Interdepartmental Committee on Research and Development in the Falkland Islands in 1919 and it is dealt with in some detail by Borley in Appendix XVI to the report of that Committee. Similar work has been found to be essential to an adequate understanding of

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Plate V. THE "DISCOVERY II." IN HEAVY WEATHER.

View from the bridge.

fishery problems, and for many years past, under the co-ordination of the International Council for the Exploration of the Sea, the countries bordering the European coasts have been studying the hydrology and plankton of the waters in which they are commercially interested.

In the Antarctic there were a number of initial difficulties to be overcome. The area to be examined was immense, even if work, as originally contemplated, was restricted to the Falkland Islands sector; and it was very greatly increased when, with the adoption of pelagic whaling, it became necessary to go farther afield and to bring the whole Southern Ocean within the scope of the observations. Previous knowledge, moreover, was extremely scanty: of the hydrology scarcely anything was known, and though the more abundant animals and plants had been described, the little knowledge that existed was by no means readily accessible, while of life histories and in information which would be useful from an economic standpoint our ignorance was complete. Even the food of the commercially important whales was not certainly known.

In one way, however, there were reasons for believing that the work would prove to be less difficult than in some parts of the world. The geography of the Antarctic is built on a grand scale and is, in a large measure, free of the complexities of coast-line to be found in some parts of the world. In regions such as the North Sea studies of the hydrology and plankton are particularly difficult because of the swirls and eddies due to the lie of the land, while irregular incursions of oceanic water bring about vast changes in the organic life of the area. From such complications it was hoped to be largely free and, after ten years' work, it may be said that this hope was well founded. The south-west Atlantic, however, where so much of the work has been done, cannot be regarded as typical of the Antarctic as a whole. There is a ridge of islands and submarine banks which extends from Cape Horn by way of Staten Island, South Georgia and the South Sandwich Islands to the South Orkneys and the South Shetlands; and it encloses an area now known as the Scotia Sea which differs appreciably from other parts of the Southern Ocean. Differences are known too in other areas, and the two deep indentations in the Antarctic Continent—the Weddell Sea and the Ross Sea—differ profoundly both from one another and from

any other place in the Antarctic. But, none the less, it remains true that the work has a comparative simplicity: it is concerned with mass movements of water and with its animal and plant population; over relatively immense areas conditions tend to be uniform, the hydrology of different regions is comparable and the planktonic organisms are almost without exception circumpolar in distribution.

HYDROLOGY

The object of the hydrological work is to make a methodical survey as complete as possible of the waters of the Southern Ocean and, in so far as it may be necessary for the interpretation of Antarctic conditions, of the waters of adjacent regions as well. The Southern Ocean is only a part of a much larger hydrological system: warm water originating in the Tropics reaches almost to the Antarctic Continent, while cold bottom water formed in the Weddell Sea can be traced as far north as the Bay of Biscay.

The relevance of hydrological work to the study of whaling problems can be shown in a number of ways. There is the possibility that whales are directly affected by some of the chemical and physical factors in their environment and, indeed, recent work by Mackintosh tends to show that their distribution in the far south is correlated with temperature. It is, however, indirectly—through a succession of links—that the value of hydrological observations is most readily appreciated. The Euphausians or krill (see p. 32) which form the sole food supply of Blue and Fin whales in the Antarctic are animals which drift passively with the currents, and so too do the diatoms, the vegetation on which the Euphausians feed. The diatoms depend for their existence on sunlight and on dissolved nutrient salts, and the abundance of these constituents and the mass movements of the water are clearly of vital consequence to the whale population. These considerations are to-day something more than theoretical, for, as is shown in more detail below, it has been found (sometimes at least) that Euphausian concentrations correspond with whale concentrations, while Hardy, omitting the intervening links of diatoms and Euphausians, has demonstrated a relation between nutrient salts and the abundance of whales.

There is good reason for the view that whales are relatively abundant in some areas and relatively scarce in others, and it may be that these areas are not always the same in each season. It is by detailed oceanographical work, that is to say by combined study of the hydrology and plankton, that the reasons for these concentrations are to be discovered.

The hydrological observations taken at each station include a sounding and observations at selected depths (of which there are twenty-two in a station of 4000 m.) on temperature, salinity, phosphate, hydrogen-ion concentration and, latterly, silica and nitrite, with readings at less numerous points on oxygen and nitrates.

Of these the temperature and salinity observations have proved to be of primary importance, since from the data so provided it is possible to ascertain the direction of the currents in different horizontal strata. In many parts of the world water movements both at the surface and below it can be calculated mathematically in relation to a lower layer which is assumed to be stationary, from series of observations made at right angles to the line of movement; but this method, which we owe to Bjerknes, is not applicable in the Southern Ocean. It appears that Bjerknes' theorem can only be employed where the water movements are horizontal and that it will not give valid results in regions, such as the Southern Ocean, where sinking and upwelling are conspicuous features. Direct measurements of movements by means of current meters are unsatisfactory in many ways; since it is necessary to anchor the ship in order to take them much time is involved, while in deep water the method is quite impracticable. Movements so far as direction is concerned can be accurately deduced from sectional diagrams showing the course of the isotherms and isohalines,[1] and this is the method which Deacon has adopted in his two important hydrological reports (vols. VII, XV in press). The speed of the movement, which as shown below is of very great importance in plankton problems, is less easily ascertained; but Deacon (vol. VII, p. 224), by an ingenious method based on seasonal changes in salinity and oxygen content, has been able to calculate the speed in a northerly direction of the Antarctic inter-

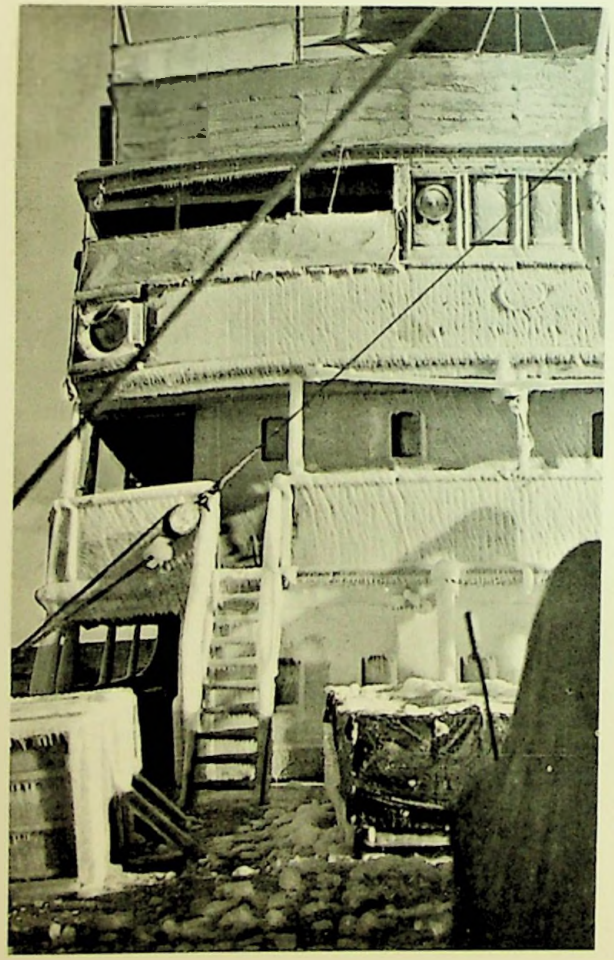
[1] Isotherms are lines joining positions of equal temperature, and isohalines those of equal salinity.

mediate current. This body of water, which is at the surface in the Antarctic, but beneath the surface in more northerly latitudes, takes some five years to reach from 50° S to the Equator. In the south the speed of the surface currents can be determined without difficulty, and by further work along the lines which Deacon has originated we may hope that the speed of all the main movements will be ascertained.

A very important feature in the south is the presence of certain lines of abrupt change in hydrological conditions, known as convergences. To many of the organisms composing the plankton these convergences form barriers which are just as effective in limiting their distribution as are mountain ranges to the fauna and flora of the land. At the time the work began only the bare existence of such convergences was known. Since then important information has been obtained in the Atlantic by the 'Meteor' expedition, and as a result of the continuous work carried out by the 'Discovery II' the course of the convergences in the South Atlantic is now known with a close approach to accuracy. In other parts of the world the existence of similar convergences was merely surmised, practically nothing being known; but during the circumpolar cruise of 1932 the southernmost or Antarctic convergence was roughly demarcated throughout its course, while the sub-Antarctic convergence was fixed at a number of points.

The convergences are formed where cold surface water of low salinity, flowing northwards and eastwards from the Antarctic, meets warmer and more saline water from the north. The cold water is the heavier and thus sinks below the surface to continue its course as an intermediate current.

In the south there are three main currents: a cold surface current of low salinity moving north and east; a warm intermediate current of greater salinity flowing south; and a cold saline north-going current at the bottom. At any point in the open Southern Ocean these three can be observed, and at the middle depths the temperature is always higher than that above or below. A valuable result of the circumpolar cruise of the 'Discovery II' was the demonstration that this system of currents exists in all parts of the Antarctic—a fact which had formerly been disputed.



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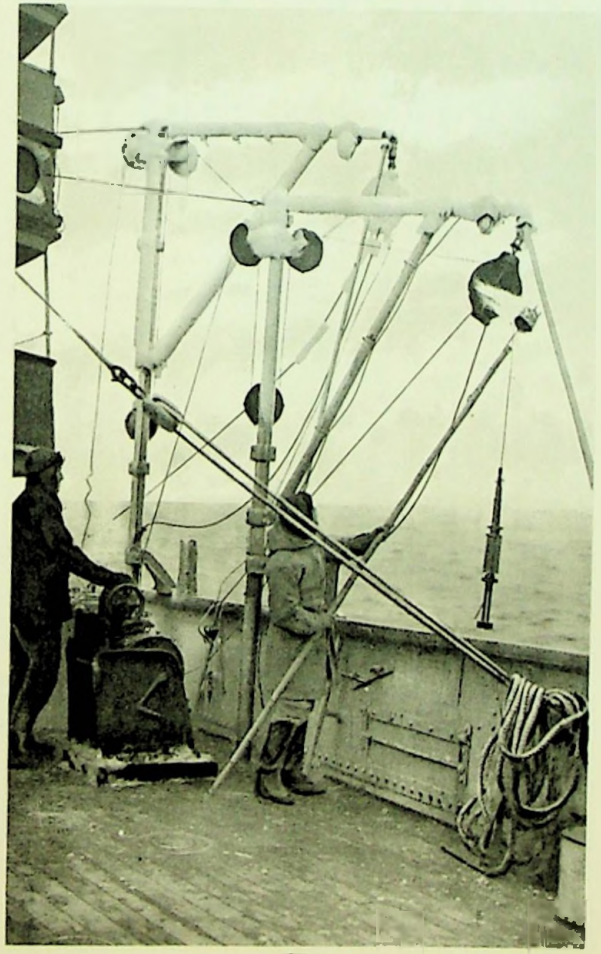

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Plate VI. THE " DISCOVERY II."

a.—Frozen spray on deck and bridge. b.—Davits used for lowering water-sampling bottles; thawing frozen sheaves with a paraffin flare.

The contour of the bottom has a very pronounced effect on the hydrology. The bottom water may be completely obstructed by a submarine ridge, or if the latter is insufficiently high the water will climb over it, and in so doing it will cause pronounced changes in the overlying strata. Accurate soundings are thus of the greatest importance in hydrological work, and, thanks to the echo-sounding apparatus, a very rapid advance has been made in our knowledge of the topography of the ocean basins in the Antarctic.

The most striking series of submarine ridges in the Southern Ocean is that comprising the Scotia Arc, and in the Scotia Sea, which this arc borders, the hydrological conditions differ considerably from those in other parts of the Antarctic. Less conspicuous shoals exerting similar influences occur in other areas, and with the progress made in hydrological knowledge it has on occasions been possible to forecast the presence of a ridge or shoal before its existence has been actually demonstrated by soundings.

In seas completely enclosed by shallow banks the hydrology is fundamentally altered: the three layers referred to above do not exist and the temperature often falls regularly from the surface to the bottom. Clowes (vol. IX) has shown that such conditions exist in the Bransfield Strait. Deacon has recently found that the Ross Sea is an enclosed basin: the shoal at its northern end reaches so near the surface that the warm deep water cannot enter, while at the bottom, owing to the removal of large quantities of fresh water in the form of pack-ice, the water is of much greater salinity than any previously found in the Southern Ocean.

Other recent additions to our hydrological knowledge may be mentioned. Both are of fundamental theoretical importance and, as such, both will no doubt contribute to an understanding of practical problems.

Deacon (vol. XV, in press) finds that the latitude of the Antarctic convergence is not determined by surface movements and by wind as was formerly thought. Although the conspicuous features of the convergence—the abrupt change in temperature and the sinking of the Antarctic water to a lower level—are phenomena limited to a depth of a few hundred metres from the surface, the latitude in which the

convergence lies is determined by the layers beneath, and principally by the volume and progress of the northward-moving bottom water.

Deacon, by a study of the bottom temperatures in their relation to pressure and depth (potential temperatures) in the deep basins of the Antarctic, has shown that the bottom water (water which has been chilled but not diluted by contact with the ice) is not formed, as was hitherto supposed, all round the Antarctic Continent but only in the western and south-western parts of the Weddell Sea. From this sea the bottom water spreads northwards into the Atlantic and eastwards to the Indian Ocean and Pacific sectors: it becomes warmer as it travels from its source, and in the Antarctic the greatest difference in potential temperature is thus to be found on the two sides of Grahamland and the Trinity Peninsula.

The Weddell Sea is thus peculiar, differing from all other parts of the Southern Ocean; and so far as the formation of the bottom water is concerned, the reason is that it is the only deep basin situated in high latitudes. It has other peculiarities also: certain planktonic animals do not breed there, and recently, in the bottom deposits, there have been found crystals of gypsum, calcium oxalate and calcium citrate (the two latter of wholly unknown origin) which have not been met with in marine deposits in any other part of the world (Bannister and Hey, vol. XIII).

The study of the phosphate, nitrate and silica distribution is an important part of the hydrological work. Its chief, though not its only importance, is, however, in relation to the vegetable plankton and it is dealt with below in the section dealing with plankton.

In the foregoing notes on hydrology attention has been drawn to some of the more striking results obtained since the work originated. It must be remembered, however, that these results, though of undoubted importance, have been obtained in the course of a much wider investigation, which aims at a complete hydrological survey of the whole Southern Ocean, with information, where it is possible to obtain it, on the seasonal and annual fluctuations. In conjunction with plankton results, it is the comprehensive data yielded by this methodical survey which should in due course explain the segregation of whales in particular areas and give answers to other questions of immediate economic importance.

PLANKTON

From the days of the earliest explorers everyone who has visited the Antarctic has been struck by the great wealth of animal life, and it appears that these very cold southern waters are in fact the richest in the world. In the sea, as on the land, animal life is dependent on vegetation, the main difference being that the important marine plants, which are collectively known as phytoplankton, are microscopic and not readily observed without special methods. These plants, which may be termed the crops of the ocean, can develop and multiply only in the presence of sunlight and of certain nutrient salts, including nitrates and phosphates, dissolved in the water.

The work of the research ships has thrown a great deal of light on these general questions of the abundance of life in the Antarctic. In spring and summer vast quantities of phytoplankton, far greater than in any other region, are to be found, while the quantities of phosphate and nitrate are much in excess of those observed elsewhere. It is, thus, by the abundance of these nutrient salts that the fertility of an area can be judged. The tropics are the deserts of the ocean, and here, most frequently, the upper layers of water (in which alone the phytoplankton can flourish owing to its need for light) are completely devoid of nitrate and phosphate. In north temperate waters moderate values for these nutrient salts are to be found, but they are rapidly reduced by the phytoplankton growth in spring, and as soon as all has been utilized the plant life dies away, to be succeeded by a second crop in the autumn. The nutrient salts in these regions are thus a limiting factor in phytoplankton production, and it is an interesting fact, one now firmly established by the work of the 'Discovery II', that phosphate and nitrates in the Antarctic are always in excess of requirements, and are at no time so reduced as to check plant growth.

Conclusions reached on such general topics as these are obviously relevant to all life in the Antarctic, but they are none the less important as establishing a reliable foundation for more specialized studies on problems which have a direct relation to the whales taken commercially in the Antarctic.

Since the prawn *Euphausia superba* is the sole Antarctic food of the Blue

and Fin whales, its distribution and life history are among the most important factors which control the numerical strength, the distribution and the movements of the whales. The shoals *E. superba*, collectively known as the "krill", are in turn dependent on the phytoplankton which constitutes the basic food supply of all forms of pelagic or surface-living animals. The specialized side of the plankton research is thus directed to the krill and the phytoplankton, and to the chain of cause and effect which leads through them from the sunlight and nutrient salts on the one hand, to the whales on the other.

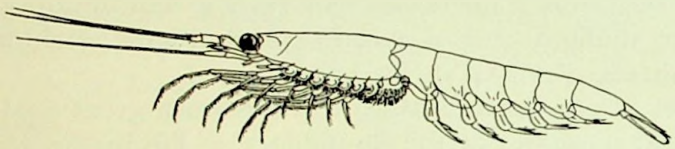
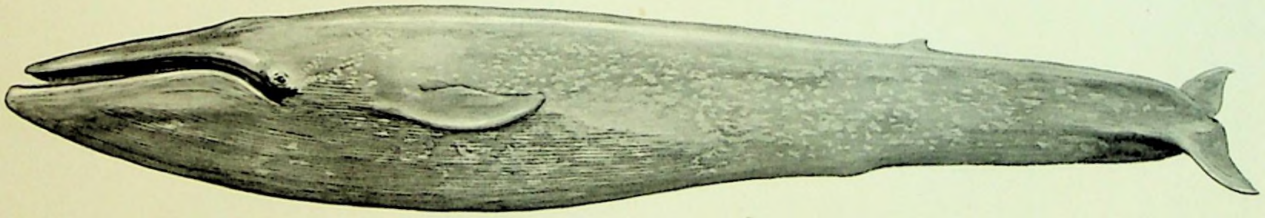


Fig. 6. *Euphausia superba*, shoals of which are collectively known as 'krill' and form the food of Blue and Fin whales in the Antarctic (actual size).

There is also the need for a much more generalized study of the plankton, and this requires a word of explanation. It might be said that the object of all the research at sea is to discover general rules governing the distribution of whales. In the earlier stages of oceanographical science little had been done to formulate such rules for any kind of animal life in the open ocean, and it was only known that currents, the physical and chemical condition of the water, food and reproduction must all have something to do with distribution. Experience gained during the work has shown also that all forms of pelagic life, at any rate in high latitudes, are subject to a seasonal periodicity or rhythm which is reflected in the annual migrations and seasonal movements of whales, in the seasonal multiplication and reduction of the plankton, and in corresponding changes in the distribution of birds and fish. Direct observations at sea on whales are limited and difficult, but unlimited observations can be made on the plankton and can form the basis of more elaborate quantitative investigations. The distribution of both plankton and whales is dependent ultimately on the physical and chemical conditions of the water, and if some important periodic change in the distribution of the plankton is observed this may draw



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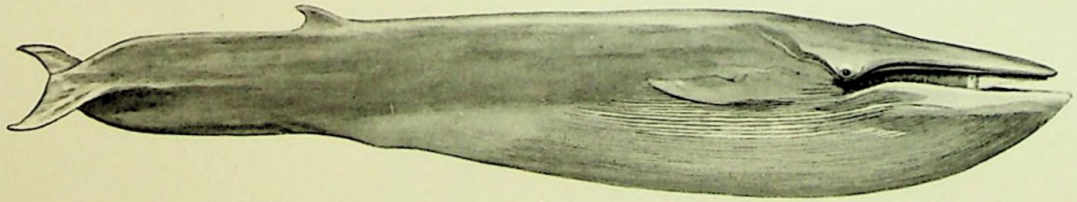

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Plate VII. SOUTHERN WHALES.

a.—Blue whale. b.—Fin whale.

attention to the likelihood of some corresponding change in the distribution of whales. It will be shown below, for example, that certain plankton species have been found in colder water in autumn than in spring, and it was this observation which led to the discovery of evidence that certain whales also penetrate into colder water towards the end of the summer. Again, the mapping out of the distribution of plankton communities at a given time of year draws attention to different regions in the Antarctic, the delineation of which can, to some extent, be correlated with the distribution of whales. Other examples might be quoted, but those mentioned above will serve to indicate how generalized research on the phytoplankton helps to elucidate the social economy of life in the Southern Ocean. It is a line of investigation which might not have been necessary if the science of oceanography had reached a more advanced stage before the Committee's work was begun.

The following are some of the more important facts which have been demonstrated in the work on plankton. It has been found that *E. superba* has a circumpolar distribution, but is normally confined at least in summer to the zone south of the 3° C. isotherm. This is also the zone which is inhabited by the vast majority of the whales in summer. The krill is not distributed evenly in this zone, and its concentration in some longitudes and comparative scarcity in others is dependent on the local hydrological conditions. The "life history" of this species, a knowledge of which is essential to an understanding of the details of its distribution, is the subject of a recent paper by Fraser (vol. XIV), who has shown that growth from the egg to maturity occupies 2 years, that the adults live in the Antarctic surface water, drifting continuously towards the north, and that the eggs and young stages live in the deeper water which carries them southwards, thus restoring the stock to the higher latitudes in the region of the pack-ice. Papers by Bargmann, now in preparation, describe certain points in the anatomy of *E. superba* (a knowledge of which is necessary to a full understanding of the life history of this species) and will give a general account of the distribution of the adults and "subadults". In certain more temperate regions, such as the coasts of the Falkland Islands and Patagonia and of New Zealand, the place of *E. superba* is taken by another crustacean, the "lobster-krill" (*Grimothea*),

and papers have been published describing its life history, distribution and swarming habits, and its relation to the whales, fish and birds which feed on it (Matthews, vol. v; Rayner, vol. x).

The Antarctic phytoplankton presents an immense field for investigation. Work previous to that of the Discovery Committee had been almost entirely confined to the identification and systematic description of species, and little was known of their distribution except that the Antarctic Zone as a whole is extremely rich in phytoplankton. After the first commission of the 'Discovery II', however, an exhaustive paper was issued in which the general distribution of the phytoplankton is described in those parts of the Antarctic which had so far been visited, and certain associations of species, or "floras" are distinguished, which were found to inhabit certain water-masses of differing origin (Hart, vol. VIII). Research at present is directed among other things to the seasonal changes in the phytoplankton, especially in connexion with the great spring development, the time of this development in different latitudes, and its association with the growth of the krill.

Several papers on the more generalized side of the plankton work have been published. A large monograph deals with the material collected in the earlier part of the Discovery investigations. In this the general make-up of the Antarctic plankton population and its horizontal and vertical distribution on the South Georgia whaling grounds are described in great detail. A theory of the interrelations of the distribution of whales, plankton and nutrient salts in the water is formulated, and by making use of the chain of cause and effect referred to above, a method is demonstrated of deducing the distribution of whales in a given area direct from a knowledge of the local phosphate values. The monograph also enters into the mechanism of plankton distribution and the process by which concentration or scattering may take place (Hardy and Gunther, vol. XI). The horizontal distribution of communities of the larger plankton species in the Atlantic sector of the Antarctic has been described, and it is shown that certain of the most important species, which in summer live in the Antarctic surface water, descend in winter into the warmer intermediate water. Since the surface water drifts northwards and the intermediate water southwards

this vertical migration sets up a large-scale circulation which brings about the replenishment of the stocks of plankton in the far south, and enables each species to keep within the normal limits of its habitat. The discovery of this great seasonal circulation in the southern plankton is of primary economic importance, for without information on the extensive movements which are involved our knowledge of the life histories of many abundant Antarctic organisms could never have been completed. The circulation is also of the highest scientific interest, since seasonal movements on so large a scale had not hitherto been demonstrated in any part of the world (Mackintosh, in press).

A study of the larger plankton organisms has also shown that although the Antarctic surface water moves northwards, a given species may occur only in low latitudes in early summer and spread later in the season to higher latitudes—not of course by its own individual activities but by later hatching from eggs or by later rising from deep water in the high latitudes. The species typical of the coldest water tend to disappear in the far south and to be replaced by those which belong to warmer zones. This southward progression is partly correlated with the increasing warmth of the summer, but it continues beyond the time when the temperature begins to fall again, and the organisms thus show an increasing toleration of cold water in the later part of the summer. The point is of importance because it appears to reflect a similar tendency among whales (Mackintosh, vol. IX).

Another paper on the plankton describes in detail the distribution and life history of a single species which occurs in great abundance in the Southern Ocean (Ommanney, vol. XIII). The value of such a paper lies in the fact that a complete description of the habits of one species is likely to apply in a large measure to other species which inhabit the same water, and it thus helps one to understand the distribution of the whole plankton population. A further paper includes an account of the life histories of five, and the distribution of some twelve, species of the genus *Euphausia* other than *E. superba*; the habits of the various species are compared (John, vol. XIV).

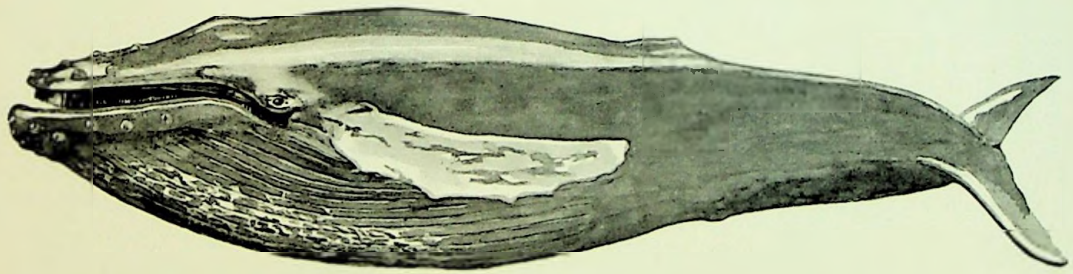
The importance to marine life of seasonal changes is becoming increasingly apparent through the study of the plankton. Individual

organisms are always moving, and the movements are not haphazard. They are directed by the seasonal rise and fall of the temperature, the acceleration and slowing down of the currents, the advance and retreat of the pack-ice, the changes in the chemical condition of the water, and the seasonal reactions of the different organisms upon each other, such as the consumption of the plant plankton by the animal plankton. Distribution is therefore to be regarded not merely as a static pattern but rather as a process, and the problem is best treated from two points of view. In the first place we need to map out the distribution of species and communities at a given time of year by means of surveys carried out in a limited space of time, and in the second place we need to make observations at intervals over the same ground in order to follow the changes which take place and the processes which direct them. The material so far collected is sufficient for mapping out in some detail the distribution of plankton in the Falkland Islands sector both in summer and winter and for tracing the intermediate changes in at least a part of this region. The rest of the South Atlantic region has been covered in the higher latitudes in summer, and by the end of the present commission some information on the winter conditions in 1936–7 will be available. Two cruises have been made across the Pacific sector in summer, but these are inadequate for mapping out the plankton in that region, and an immense part of the Antarctic south of the Indian Ocean and Australia has been untouched in summer, and only visited in winter during the circumpolar cruise of 1932.

ICE DISTRIBUTION

During the voyages of the 'Discovery II' and the 'William Scoresby', many observations have been made on the distribution of icebergs and pack-ice. The distribution of icebergs is of some interest to the Committee's work as an indication of ocean currents, but the pack-ice is considerably more important, for it has a direct influence on the distribution of whales and a profound effect on the hydrology and meteorology of the whole Southern Ocean.

The most detailed information on the distribution of pack-ice in summer in certain parts of the Antarctic is to be obtained from the



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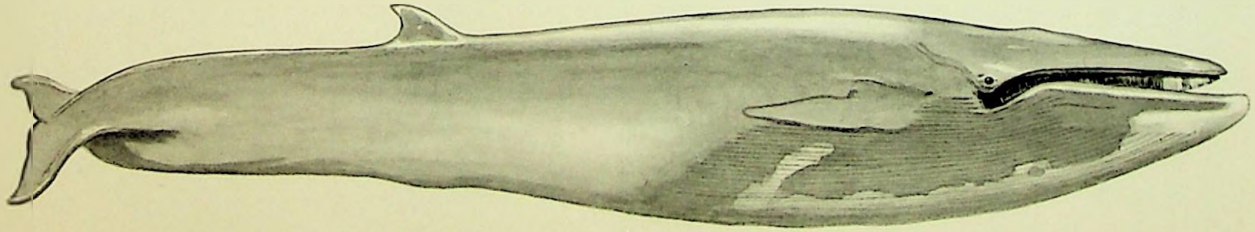

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Plate VIII. SOUTHERN WHALES.

a.—Humpback whale. b.—Sei whale.

movements of the whaling fleet, but hardly any data are to be had from such outside sources on the movements of the ice in winter. In this respect the observations of the 'Discovery II' are almost unique, and when sufficient data have accumulated it will be possible to prepare a report on the seasonal advance and retreat of the ice edge. From the Committee's point of view this is the most important aspect of ice distribution. In general it may be said that the ice extends farthest north in spring (September to November) while the high latitudes are most accessible in late summer (February and March). There is, however, a great difference in the range of movement of the ice in different longitudes. South of the Atlantic, for instance, the ice edge may advance and retreat as much as 900 miles, whereas in the Bellingshausen Sea the movement may not cover more than about 200 miles. This is a subject which requires more observations repeated throughout the year in one or more chosen localities.

It may be mentioned that numerous short papers and reports on pack-ice and icebergs have been contributed by the ships' officers to the *Marine Observer*, and a paper on icebergs by Kemp and Wordie was published in the *Geographical Journal* (see p. 46).

FISHERIES

Accumulations of fish adequate in amount to form the basis of important fisheries are found usually in the relatively shallow waters bordering extensive coasts, particularly in those receiving the discharge of great rivers: they are met with also where two great currents meet. Important fisheries therefore are located in areas possessing these characters: those of the North Sea and of the Newfoundland Banks may be cited as examples. For these reasons extensive grounds in the Falkland Islands region seemed to promise possibilities of fishery importance. An area of some 150,000 square miles stretching west and north-west from the Falklands to the South American coast is all of depth suitable for trawling (50–100 fathoms) and mainly has a sandy bottom. The Burdwood Bank, south of the Falklands, nearly 300 square miles in extent, is of similar depth. Lastly, the Falkland Islands themselves have a long indented coast-line and therefore much coastal water.

All these areas accordingly have been visited. Trawling surveys were carried out in 1927, 1928 and 1931–2. The time so spent was in all about a year. The 'William Scoresby' being built on the lines of a whale-catcher, has in design much in common with a trawler. She is fitted with a trawling winch and an otter trawl of commercial size. Her fishery surveys were mainly carried out with this net, but in addition smaller nets were employed, soundings made, adequate samples of the ground itself taken, the invertebrates collected and studied, and the physical and chemical characteristics of the water ascertained. The object of the work was in brief both to find what fish were present and to understand their presence by studying the conditions in which they live.

The most comprehensive survey was that between the Falkland Islands and the South American coast. The periods in which it was carried out were so chosen as to represent all phases of the life of the fish. The stations were spaced at intervals of from 40 to 60 miles. The fish taken were identified, numbered, measured, their sex and stage of maturity determined, during much of the work the catch of each of the chief species weighed, and frequently stomach contents ascertained.

Many fishes, like trees, indicate their years of growth by concentric markings. These rings are found in the scales and bones, and are particularly clear in calcareous structures (otoliths) found in the ear. Scales and otoliths accordingly were collected for the study of age. The bottom-living invertebrates (benthos) and those drifting (plankton) were both studied, particular attention being given to any species that might be of commercial value.

Considerable amounts of sponge, coral and other rooted forms of life were met with, and in some localities these present many hindrances to trawling: they would, however, tend to decrease were constant trawling to occur. A variety of fish, many of them edible, were found, but two are of outstanding importance. A species of hake occurs in quantity adequate to justify commercial exploitation, though not in remarkable abundance, and another fish, *Macruronus*, is of superior table value but is less common. Hake was found over practically the whole of the area investigated. In some localities the 'William Scoresby' took about

2 cwt. of this fish per hour's fishing. It has been the main basis of the small trawling industry centred in Buenos Ayres. The 'William Scoresby's' catch of hake was irregular. It is probable that the fish congregates for spawning; both this fish and *Macruronus* give indications of very marked shoaling. Among the numerous other species taken should be mentioned a fish (*Stromateus*) resembling the John Dory, and, very widely distributed, several species of *Notothenia*, a somewhat cod-like fish. These latter, however, were usually small. A trawl fishery based on Port Stanley should not experience difficulty as to the supply of fish: and since the South American States import considerable supplies of dry salted, wet salted and tinned fish, it seems likely that markets could be found.

The grounds about the Falkland Islands and on the Burdwood Bank are for the most part rough, and rich in coralline growths which make them unsuitable for trawling. They have a rich invertebrate fauna, but few fish other than *Notothenia*. An edible crab, *Lithodes antarcticus*, which is present on the plateau between the Islands and South America, is, however, here more abundant. The region in which the Falklands lie may thus be divided broadly into a north-westerly part, including most of the plateau towards the continental coast, where marketable fish are moderately plentiful, and a south-easterly part, including Falkland coastal waters, the Burdwood Bank and the southern end of the continental plateau, where invertebrates are plentiful and fishes few.

The observations and material collected have not yet been fully worked out, but the general results obtained are plain. It is clear that while the Falkland Islands area is not remarkably rich, much of it is moderately productive from a fishery standpoint. This source of wealth is almost entirely unexploited.

It may be added that a large species of *Notothenia* occurs about South Georgia, and is taken by the crews of the whaling stations for their own use. The fish is found in extensive shoals; it is very palatable, and clearly more could be made of it.

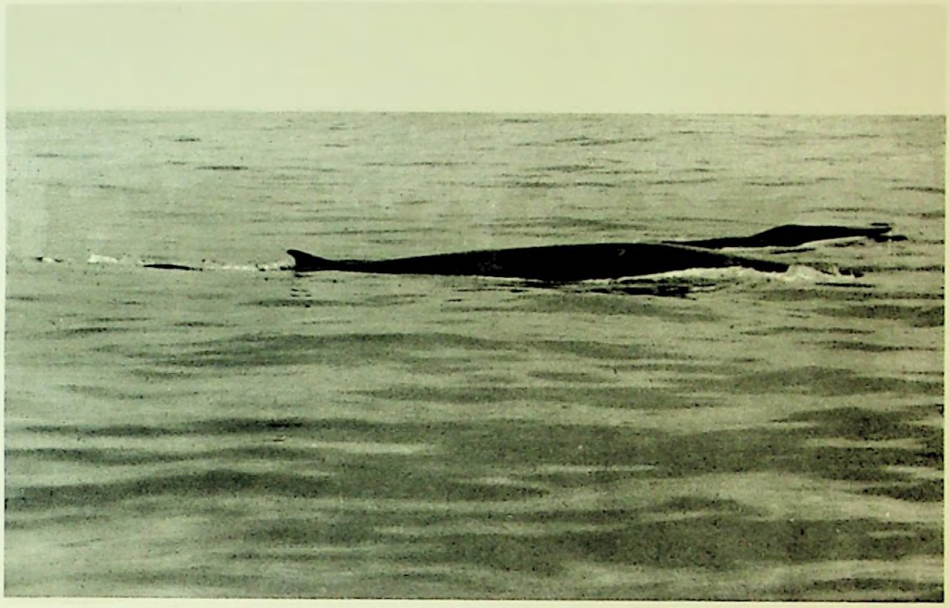
SEALS AND BIRDS

Seals exist in immense numbers in the Antarctic and sub-Antarctic, and in places where they congregate in rookeries they are of some economic importance. Thus at South Georgia the beaches are thronged with Elephant Seals in the summer, and a whaling company has a licence to take a limited number for their oil. The continuance of the stock is guarded by the division of the coast into four tracts, which in rotation are closed to sealing. Oil is produced also from Sea Lions in the Falkland Islands. Under suitable regulations seal can be farmed almost as if they were domestic animals, for they are polygamous, and the slaughter of superfluous bulls for commercial purposes is a benefit to the stock; the Elephant Seal of South Georgia have increased in numbers while yielding a substantial annual return to the sealers.

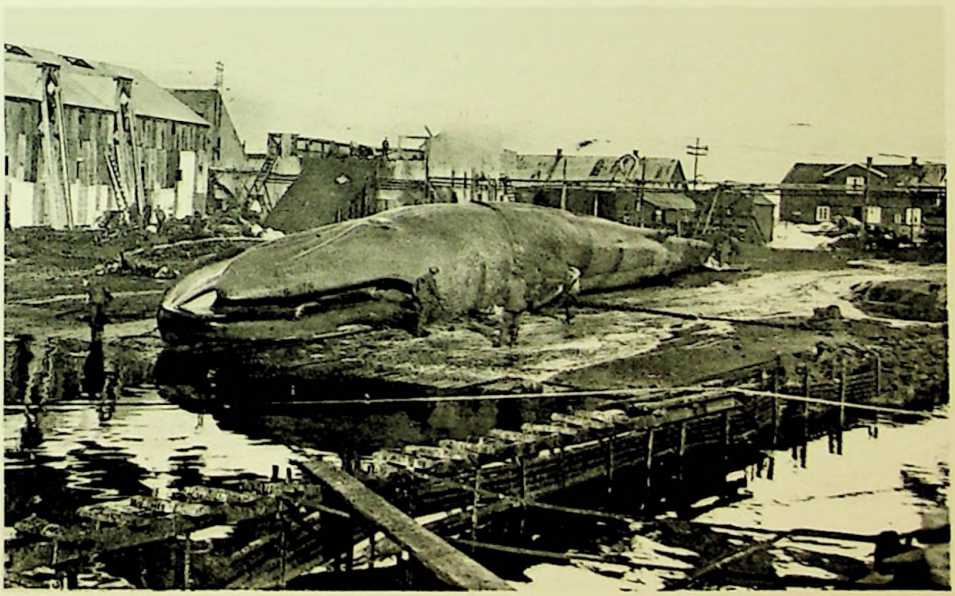
The ships under the direction of the Discovery Committee have made numerous observations on seals of many kinds and papers have been published on the natural history of the Elephant Seal and the Sea Lion (Matthews, vol. I; Hamilton, vol. VIII). It is hardly possible to summarize these papers in a few words, but one or two points may be mentioned. It is estimated that at least 100,000 Elephant Seals frequent South Georgia, and their food appears to consist of cuttlefish. The latter point is interesting since no cuttlefish have been detected at sea, and it suggests that there may be much life in the water which is untouched by the varieties of nets so far devised by naturalists. Investigations on Sea Lions at the Falkland Islands have been pursued for several years, and a careful census has been taken at a large number of rookeries. It is estimated that the population is of the order of 200,000. Much information on their breeding habits has been gathered.

Attention has also been paid to the Fur Seals which frequent some rookeries in the Falkland Islands. At South Georgia where they were virtually exterminated by sealers about 100 years ago there is some hope of their re-establishment.

The birds of the Southern Ocean have as yet no economic importance, but they have a bearing on the general economy of life in the Antarctic, and many observations have been made on them. Papers have been



a



b

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Plate IX. SOUTHERN WHALES.

a.—Fin whales breaking surface. b.—Blue whale on the flensing platform at Grytviken.

published on the birds of South Georgia and the South Orkney Islands (Matthews, vol. I; Ardley, vol. XII), but the most important observations are on birds seen at sea. It has been found that many of the oceanic species are distributed in well defined latitudinal zones. Some species in fact, such as the Snow Petrel which never ventures far from the pack-ice, are of no little assistance to navigation. A report on the distribution of the oceanic birds is in preparation.

SURVEYING AND SOUNDING

The surveying of the groups of islands fringing the Antarctic and parts of the Antarctic itself was undertaken largely in the interests of the whaling industry.

The 'Discovery', 'William Scoresby' and 'Discovery II' have spent certain periods in hydrographic surveying in South Georgia, the South Sandwich Islands, the South Orkney Islands, the South Shetland Islands and Bouvet Island, and observations have been made on a small part of the coast of the continent in the South Indian Ocean.

The main features of the work done up to the end of 1935 are shown in Fig. 7, which is self-explanatory. Much surveying and exploration still remain to be done, and that which is completed has been accomplished more often than not in boisterous weather and in conditions of considerable cold.

In March 1926 a specialist officer, Lt.-Commander J. M. Chaplin, R.N., lent from the Royal Navy, was able to begin survey work in South Georgia, but he was handicapped by lack of a power boat. However, certain points were fixed, plans of three harbours were made, and continuous tidal observations were taken over a period of two months. On the return of the 'Discovery' to England the same officer was provided with a 25 ft. motor launch and returned with a small staff to South Georgia. Most of the work was carried out with this launch, but occasional assistance was given by the 'William Scoresby'. The party worked hard under trying conditions for 470 days. They surveyed some fifteen harbours and fixed the positions of various outlying islands and rocks. The most important of the latter were the Nansen Bank and the Clerke Rocks.

No special officer for survey work was lent to the 'Discovery II', but members of the navigating staff were given a course in hydrographical survey methods by the Admiralty. This enabled them to carry out

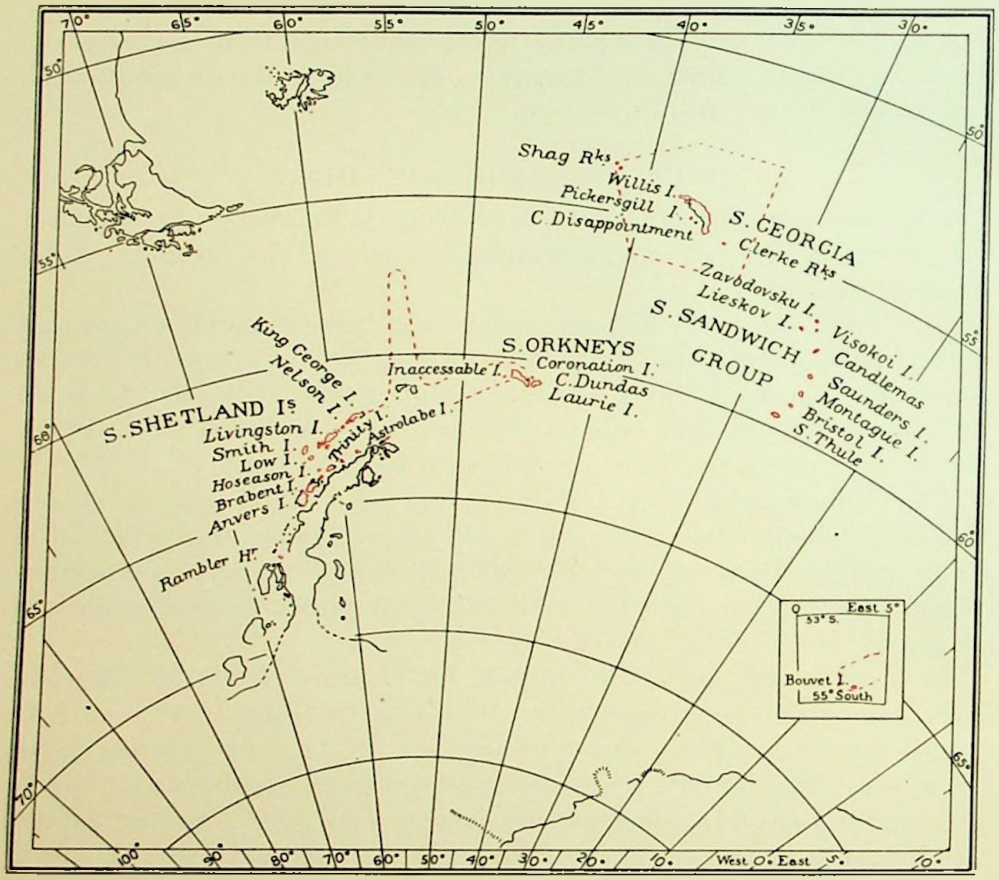

Fig. 7. Surveying in the Dependencies of the Falkland Islands.

Islands and coasts which have been surveyed are shown in red. Areas in which particularly large numbers of soundings have been taken are bordered in red.

successfully running surveys of the South Sandwich group, the South Orkneys and the South Shetlands together with a large amount of miscellaneous work in other regions. For instance, an intensive search

was made by soundings for any indication of Thompson Island, reported to lie 45 miles north-east of Bouvet Island, but no trace of this or of The Chimneys was found, and they have been expunged from the Admiralty charts.

Although in each of the commissions of the 'Discovery II' a time has been devoted to survey, this time is inadequate for the execution of detailed and complete surveys. It is only possible to fix a minimum of points ashore and to carry out the remainder of the work by a running survey. In the hands of a capable man such work can be made to produce exceedingly valuable results. All the Committee's surveying results are communicated to the Hydrographic Department of the Admiralty, and after scrutiny incorporated in the charts of the areas concerned.

The value of the running surveys has been greatly enhanced by the use of echo-sounding. The 'Discovery II' has always been fitted with the latest pattern machines of Admiralty type, and even before a continuous profile of the bottom was available from the recording pattern machine fitted in 1933, three to four soundings a minute could be obtained and logged from the "listening" pattern machines. This frequency of soundings not only allows of the ship being taken closer inshore with a consequent increase in the accuracy of bearings, etc., but permits of a greater speed, thus resulting in a large increase in the area covered in a given time. Also, with the always uncertain weather conditions of these regions, the time saved in taking soundings by echo is extremely valuable.

Echo-sounding is carried on daily at regular intervals in oceanic waters and may be considered to be within the scope of survey work. Much valuable information has been obtained, resulting in extensive additions and alterations to knowledge of the configuration of the bed of the Southern Ocean in the Atlantic and Indian sectors. One of the most important is, perhaps, the delineation of the submarine arc connecting Tierra del Fuego with Graham Land through the various islands of the Dependencies (vol. III, pp. 205–36).

THE PERU COASTAL OR HUMBOLDT'S CURRENT

Between May and August 1931, when Antarctic whaling was not in progress, the R.R.S. 'William Scoresby' carried out a detailed examination of the greater part of the area covered by the Peru coastal current. This current is of great interest, not only on account of both its normal and its abnormal behaviour, but in its connexions with the coast-lands of Chile and Peru and in its effects on the economic life of the inhabitants. Hydrological observations were made from surface to bottom at some 150 stations and the temperature, salinity and oxygen and phosphate contents of the water recorded. Collections were also made of the plant and animal plankton in the upper layers.

The Peru coastal current, with which is bound up the economic life of some 2200 miles of the west coast of South America, flows in a northerly direction from 40–41° S to the point where the cool upwelled water of moderate salinity (which comprises the current) converges with the warm poorly saline water of the equatorial counter current. The position of this convergence was inadequately charted by the 'William Scoresby' in 1931, but it lay between 4 and 6° S. The extreme westerly limit was not determined, as the investigation was restricted by the difficulties of refuelling and obtaining fresh water, but the influence of the current was shown to extend seawards for at least 130 miles off the Chilean coast and 250 miles from Peru. The flow appears to vary greatly in strength, being so weak in some places as to pass unnoticed by ships, and in others moving at 10–12 miles a day.

The most important feature of the current is its exceptional richness in nutrient salts carried in the upwelling of cold bottom water. This results in a very high plankton content, and this wealth of marine life gives rise in the south to a whaling industry and in the north to the richest bird population in the world with its valuable deposits of guano.

In an abnormal year the current may be reversed as a consequence of persistent northerly wind, and in place of the cool Peru current diverging from the shore the warm poorly saline water of the equatorial counter-current flows as a surface current far to the southward and there converges with it. The rise in temperature kills fish and plankton,

a

b

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Plate X. SEALS AT SOUTH GEORGIA.

a.—Bull elephant seal. b.—Southern fur seal.

sulphuretted hydrogen is evolved and the guano birds lose their food. Tremendous mortality results among them and the loss to the guano industry is immense. This counter-current is known as *El Nino* and the conditions resulting from it as *Aguaje*. Somewhat similar conditions can occur through smaller irregularities of the currents, which may cause a wedge of warm water to converge with the coast.

The value of the observations made by the 'William Scoresby' lies mainly in the accurate delineation of the current and in the measurement of its physical features, particularly in those of deeper layers below the surface which had not previously been investigated in detail (Gunther, vol. XIII).

METEOROLOGY

For observations which have a direct bearing on the meteorology of the Southern Ocean, permanently fixed stations are needed. The ships directed by the Committee, however, keep detailed meteorological log-books, and the observations are of value in recording the incidence of air temperature and pressure, precipitation, gales, visibility, etc. All meteorological observations made in the research ships are sent to the Meteorological Office. It must be remembered that the hydrological investigations of the ships must ultimately have a most important bearing on the elucidation of the weather conditions of the southern hemisphere.

REPORTS AND COLLECTIONS

The scientific results of the work accomplished since 1925 are being published by the Committee in a quarto series of memoirs entitled the *Discovery Reports*. Fourteen volumes of these have so far been issued. The principal object of the series is the publication of papers, written mainly by members of the scientific staff, on data and material which have a bearing on economic problems. As has been stated in an earlier part of this memorandum, when the Committee began its work 12 years ago practically none of the information essential to economic research in the Antarctic was available. Apart from mere names and descriptions of species practically nothing was known of the teeming animal and plant life, while our ignorance of the physio-chemical factors which

form a vitally important part of their environment was almost complete. A very large amount of this fundamental knowledge has now been acquired.

A classified list of the more important memoirs which have a bearing on economic problems is as follows: the reference numbers are those in the list of *Discovery Reports* given on pp. 48–52.

Whales: 4, 11, 30, 40, 54, 82.
Seals: 3, 44.
Plankton:
General: 43, 48, 57, 60, 62, 73, 79, 80, 81.
Krill: 27, 56, 72, 74.
Surveys: 14, 19, 32, 58.
Hydrology: 38, 39, 47, 70, 75, 76.
Fish: 78.

The above memoirs are for the most part technical, but the more senior members of the staff, with the approval of the Committee, have from time to time contributed semipopular accounts of the work to the Royal Geographical Society. The references to these papers are:

HARDY, A. C. 1928. *The Work of the Royal Research Ship* 'Discovery' *in the Dependencies of the Falkland Islands*, vol. LXXII.

MARSHALL, E. H. 1930. *Report on a Visit to the Ross Dependency*, vol. LXXV.

KEMP, S. 1932. *The Voyage of the R.R.S.* 'Discovery II': *surveys and soundings*, vol. LXXIX.

WORDIE, J. M. and KEMP, S. 1933. *Observations on certain Antarctic Icebergs*, vol. LXXXI.

JOHN, D. D. 1934. *The Second Antarctic Commission of the R.R.S.* 'Discovery II', vol. LXXXIII.

MACKINTOSH, N. A. 1936. *The Third Commission of the R.R.S.* 'Discovery II', vol. LXXXVIII.

While the Committee's work has been directed primarily to investigation connected with the whales and the conditions under which they live, as has been said in the first section of this report, the investigations afforded unusual opportunities of adding to the existing knowledge of the sea, and of marine life. Most of the material so acquired consists of large and representative collections of biological specimens. Opportunities have been taken at various times to work dredges and trawls, and to tow large nets, often at great depths. The resulting collections

contain representatives of many groups of the animal kingdom, and those which have already been examined and reported on include some hundreds of species which are new to science. The material taken from the nets is sorted out roughly on board and more thoroughly in England, and the various groups are distributed to specialists, the results of whose labours appear in the *Discovery Reports*. The collections are then presented to the British Museum (Natural History).

The reports not listed on p. 46 may be grouped as follows:

Plankton: 12, 15, 23, 24, 35, 36, 37, 41, 46, 51, 55, 67, 68, 71.
Fish, etc.: 9, 10, 63.
Bottom-living animals: 7, 8, 16, 18, 28, 31, 33, 52, 64, 65.
Birds: 6, 29, 49, 66.
Rocks and marine deposits: 50, 53, 59.
Ships, gear and general methods: 2, 61, 69.
Station lists: 1, 13, 20.
Miscellaneous: 5, 17, 21, 22, 34, 45.

The variety of the subject-matter of these reports is evidence that such opportunities as were given by the presence of a research ship in almost virgin waters have been well utilized.

While, however, some of these reports are at present purely of scientific interest, of many of them it would probably be more true to say that their bearing on economic problems is remote or not yet known. Several of those listed under plankton, for instance, are devoted to classification: and clearly no marine biological problem can be attacked until the specific identity of the animals with which it is concerned is known. The distribution of bottom-living forms again, such as sponges, affects very materially that of marketable fish as well as the practicability of their capture by the methods used in commercial fishing. Lastly, the accounts of oceanographic equipment and methods cannot fail to be of much utility to marine research in the future.

LIST OF DISCOVERY REPORTS

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Title-page, List of Contents, List of Personnel, and Preface.

1. *Station List*, 1925–1927. Pp. 1–140, Plates I–VI.
2. *Discovery Investigations: Objects, Equipment and Methods.* By S. Kemp, Sc.D., A. C. Hardy, M.A., and N. A. Mackintosh, A.R.C.S., M.Sc. Pp. 141–232, Plates VII–XVIII.
3. *The Natural History of the Elephant Seal.* By L. Harrison Matthews, M.A. Pp. 233–256, Plates XIX–XXIV.
4. *Southern Blue and Fin Whales.* By N. A. Mackintosh, A.R.C.S., M.Sc., and J. F. G. Wheeler, M.Sc. Pp. 257–540, Plates XXV–XLIV.
5. *Parasitic Nematoda and Acanthocephala. Collected in* 1925–1927. By H. A. Baylis, M.A., D.Sc. Pp. 541–560.
6. *The Birds of South Georgia.* By L. Harrison Matthews, M.A. Pp. 561–592, Plates XLV–LVI.

VOLUME II

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7. *Polychaete Worms.* By C. C. A. Monro, M.A. Pp. 1–222.
8. *Thoracic Cirripedes. Collected in* 1925–1927. By C. A. Nilsson-Cantell, Sweden. Pp. 223–260, Plate I.
9. *Oceanic Fishes and Flatfishes. Collected in* 1925–1927. By J. R. Norman. Pp. 261–370, Plate II.
10. *Cephalopoda. I. Octopoda.* By G. C. Robson, M.A. Pp. 371–402, Plates III and IV.
11. *The Age of Fin Whales at Physical Maturity with a Note on Multiple Ovulations.* By J. F. G. Wheeler, M.Sc. Pp. 403–434, Plate V.
12. *On the Anatomy of a Marine Ostracod*, Cypridina (Doloria) levis *Skogsberg.* By H. Graham Cannon, Sc.D. Pp. 435–482, Plates VI and VII.

VOLUME III

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13. *Station List*, 1927–1929. Pp. 1–132, Plates I–X.
14. *The South Sandwich Islands.* By S. Kemp, Sc.D., F.R.S. and A. L. Nelson, R.N.R., with a *Report on Rock Specimens* by G. W. Tyrell, A.R.C.Sc., D.Sc., F.G.S., F.R.S.E. Pp. 133–198, Plates XI–XXXI.
15. *Nebaliacea.* By H. Graham Cannon, Sc.D. Pp. 199–222, Plate XXXII.
16. *Cephalodiscus.* By C. C. John, M.A. Pp. 223–260, Plates XXXIII–XXXVIII.
17. *Spiders Collected by the Discovery Expedition, with a Description of a New Species from South Georgia.* By W. S. Bristowe, B.A., F.Z.S. Pp. 261–266.
18. *Mollusca: Gastropoda Thecosomata and Gymnosomata.* By Anne L. Massy. Pp. 267–296, Plate XXXIX.

19. *Narrative of Hydrographic Survey Operations in South Georgia and the South Shetland Islands*, 1926–1930. By Lieut.-Commander J. M. Chaplin, R.N. Pp. 297–344, Plates XL–XLIV.

VOLUME IV

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22. *Oligochaeta. Part II. Earthworms*. By Grace E. Pickford, Ph.D. Pp. 265–290.
23. *Foraminifera. Part I. The Ice-free Area of the Falkland Islands and Adjacent Seas*. By E. Heron-Allen, F.R.S. and A. Earland, F.R.M.S. Pp. 291–460, Plates VI–XVII.

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26. *The Urino-Genital System of the Fin Whale* (Balaenoptera physalus). By F. D. Ommanney, A.R.C.S., B.Sc. Pp. 363–466, Plates II and III.
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29. *Report on Penguin Embryos collected during the Discovery Investigations*. By C. W. Parsons, B.A. Pp. 139–164, Plates I–VI.
30. *On the Distribution and Movements of Whales on the South Georgia and South Shetland Whaling Grounds*. By Stanley Kemp, Sc.D., F.R.S. and A. G. Bennett. Pp. 165–190, Plates VII–XLII.
31. *On the Development of* Cephalodiscus. By C. C. John, M.A., D.Sc., D.I.C. Pp. 191–204, Plates XLIII and XLIV.
32. *Report on Soundings taken during the Discovery Investigations*, 1926–1932. By H. F. P. Herdman, M.Sc. Pp. 205–236, Plates XLV–XLVII, 7 Charts.
33. *Sponges*. By M. Burton, M.Sc. Pp. 237–392, Plates XLVIII–LVII.
34. *List of Worms Parasitic in Cetacea*. By H. A. Baylis, M.A., D.Sc. Pp. 393–418.

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35. *Fossil Foraminifera from the Burdwood Bank and their Geological Significance*. By W. A. Macfadyen, M.C., M.A., Ph.D., F.G.S. Pp. 1–16.

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38. *On Vertical Circulation in the Ocean due to the Action of the Wind with Application to Conditions within the Antarctic Circumpolar Current.* By H. U. Sverdrup. Pp. 139–170.
39. *A General Account of the Hydrology of the South Atlantic Ocean.* By G. E. R. Deacon, B.Sc. Pp. 171–238, Plates VIII–X.
40. *Whaling in the Dominion of New Zealand.* By F. D. Ommanney, A.R.C.S., B.Sc. Pp. 239–252, Plates XI–XIII.
41. *Isopod Crustacea. Part I. The Family Serolidae.* By Edith M. Sheppard, M.Sc. Pp. 253–362, Plate XIV.
42. *Some Aspects of Respiration in Blue and Fin Whales.* By Alec H. Laurie, M.A. Pp. 363–406, Plate XV.

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51. *The Development of* Rhincalanus. By Robert Gurney. Pp. 207–214.
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