Subantarctic Marine Food Cycles and Their Relation to Discontinuous Plankton Concentrations

W. H. Dawbin

In the New Zealand subantarctic zone, the area of land in proportion to ocean is extremely small, and as the Southern Ocean is highly productive in plankton and capable of supporting enormous numbers of animals directly or indirectly, the number of vertebrates competing for breeding territories on the small amount of land available is exceptionally high. At the Auckland Islands, four species of seal and many species of seabird make up a vast vertebrate population of marine feeders dependent ultimately on plankton. The dense local concentrations of vertebrates and of plankton make the New Zealand subantarctic islands a particularly favourable site for noting at least some of the seasonal variations in the links of the marine food chain.

Plankton hauls through a twelve month period at the Auckland Islands gave the following picture of seasonal changes. During late summer and autumn, plankton tows were relatively uniform and poor both in species and in quantity with little phytoplankton. Minimum quantities of all species were found in winter. At the beginning of October there was a spectacularly sudden appearance of great numbers of diatoms which lasted until November, by late December diatoms were again relatively insignificant in the catch. After the peak of the diatom blooming, nauplius larvae of copepods appeared, becoming particularly abundant in the middle of November. In late November nauplii were replaced by adult Copepoda and zoaea larvae of decapod crustacea became prominent.

At the time of plankton minimum in late autumn and winter most of the sea birds as well as seals have completed that part of their seasonal cycle which compels their return to land at frequent intervals. The sea birds are then free to forage for long periods over large areas far from land. At the Auckland Islands the reduction in total numbers of marine vertebrates inshore is extremely striking. However, in spring and summer the breeding populations of sea birds and seals feeding their young must obtain a reasonably adequate food supply locally.

There was evidence that this food came largely from very localised plankton concentrations frequently not indicated at all by the routine tows. A number of the concentrations were observed visually, including amphipods, jellyfish, isopods, euphausids and mysids. Many of these groups were not significantly represented in the routine hauls at the time.

The only vertebrates feeding largely on smaller plankton were the prions and diving petrels whose movements in dense flocks over particular kelp beds were a very accurate guide as to the location of local plankton concentrations. Many bodies of these birds killed by wild cats and skuas were seen especially during the summer, and the stomach contents were usually homogeneous at any one time but over a period the diet was found to include most of the small crustacea which had been observed in local concentrations. However, it also included other species which had not been gathered or seen by the human collectors. At the time of the plankton minimum, i.e. late autumn and the winter months, prions were not seen at the Auckland Islands and presumably they feed over a wider area at sea once the chicks have been reared and there is no necessity to return to land. Even during this winter season a number of locally dense plankton concentrations were recorded, including *Aurelia* in April and May, gammarid amphipods in May, the amphipod *Phronima* in June to August, *Mysis* in July.

There was much evidence that the marine vertebrates were locating and feeding on larger plankton in quantity, particularly *Munida* and squid. The first appearance of *Munida* as indicated in the excrement from shags and regurgitated food left by sea lions was in November and December. A single pile counted out at the edge of Carnley Harbour contained the remains of more than 200 *Munida* integuments, while the droppings at shag roosts at Figure Eight Island and other localities in Carnley Harbour were coloured a very characteristic red. From January to April large flocks, including thousands of muttonbirds, were a common sight feeding intensively for a time in one patch and then moving off to another. This was at a period when *Munida* remains were present in their burrows, excrement and stomach contents.

Squid remains occurred in regurgitated piles of food during all months when sea lions were sufficiently numerous near our camps to leave such evidence, but *Munida* was not recorded after the beginning of April. After July very little sign of seals was seen at Carnley Harbour until October; the regurgitated piles then consisted of a macruran prawn and in November *Munida* appeared in them. Squid were still evident in at least some food piles whenever sea-lions were ashore in numbers and the piles of squid beaks around the nests of wandering albatrosses in October were clear evidence that they had been feeding on squid for a considerable period.

At the Auckland Islands it is clear that the two main food organisms are squid and *Munida* and the quantities of these consumed by the countless numbers of albatrosses, muttonbirds and numerous other petrels as well as by penguins and seals must be prodigious.

At one island in the Chinchas group off Peru, Schott (1932) estimated that the 5 or 6 million seabirds there would daily remove at least 1000 tons of fish from the surrounding water. The amount of squid and *Munida* required by the vertebrates in New Zealand subantarctic islands would no doubt be of a similar order for each comparable unit of animals, but the number of vertebrates in this area is many times that discussed by Schott.

In spite of the huge quantities of squid and *Munida* which must be present in the local waters we did not even see, let alone collect, either of these organisms from surface waters. This fact, considered in conjunction with the undoubted presence of other swarms of plankton animals which were not sampled by routine tow-netting, suggests that the routine tows in one locality were giving a very incomplete picture of zooplankton density in the area as a whole. There is evidence that this situation is not restricted to the New Zealand subantarctic waters alone but occurs in many other regions. For instance, many dense local concentrations of plankton have been noted on the New Zealand coast by the author and others.

It might have been argued that localised plankton concentrations were largely neritic and likely to be caused by such special coastal conditions as upwellings or run off of extra nutrients from nearby land. However, Hardy (1936), using a continuous plankton recorder, indicated conclusively that patchiness of plankton distribution occurred in a wide variety of species in oceanic waters.

At the Auckland Islands the many hours of watching dense flocks of seabirds feeding intensively in one patch and then moving off some distance to do the same in another area and the observations on the food of the vertebrates have led me to the conclusion that it is the special localised concentrations that are of the greatest importance in the marine food cycle at this locality, especially as food for seabirds, seals and also migrating whales.

If, as seems probable, a high proportion of marine vertebrates (and quite possibly some invertebrates such as squid) depend more on seeking out localised discontinuous concentrations of plankton organisms for their food than they do on the results of a more diffuse foraging at random, then the whole emphasis in oceanic food cycles is shifted from determining "average" conditions in an area as a whole to determining the extent and frequency of localised concentrations. Instead of regarding the latter as "abnormal" it may well be necessary to pay special attention to a study of the extent and frequency of these shoals.

In addition to this standing crop any estimate of total organic production must include the quantities ingested daily by petrels, penguins, seals, whales and fish. This total mass of macroplankton and squid in its turn would have drawn off many times this quantity of other plankton organisms.

The available data suggest that it would be most useful to gather more information on the following points:

1. The factors which stimulate or permit local blooming of organisms.
2. The frequency and extent of such occurrences.
3. The relative importance of such plankton shoals as food for mobile animals which can search for concentrations.
4. The extent to which the organic material drawn off in this cycle affects the total quantities of plankton organisms remaining.
5. Whether it is necessary to modify plankton sampling methods and quantitative interpretations of the data on organic productivity to make allowance for such draw offs.

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