The Seas are Full of Krill

Daniel Manson
Centre for Mathematics and Physics in the Life Sciences and Experimental Biology, University College London

Krill, Latin name *Euphausiacea*, is an order within the subphylum Crustacea.

For the first few weeks of development, krill larvae are small enough to be considered zooplankton, but as they mature they grow to be a few centimeters long and become capable of short bursts of movement.

The global biomass of krill is thought to be around half a billion tonnes, roughly double that of humans. This biomass is distributed across all the oceans, but is more concentrated around the two poles.

Krill are an important part of the marine food chain as they consume phytoplankton and zooplankton, making the products of photosynthesis available to many larger animals, including whales.

Many fish farms use krill as a food source, and in some cultures krill is eaten in a similar manner to shrimp. This has led to overfishing and subsequently to the establishment of fishing quotas to enable sustainable fishing.

In addition to their role in the food chain, krill may be an important mechanism by which carbon is transferred from the ocean surface to the ocean depths, where it no longer contributes to the greenhouse effect or to the acidification of the oceans.

The krill life cycle is thought to start near the surface of the ocean where adult females lay several thousand eggs. The eggs descend and begin to develop. At some point, which depends on the species, the egg hatches and the larva starts to ascend. However, until the larva reaches the surface waters it remains dependent on the yolk for energy. The ascending larva progresses through several stages with distinct anatomy. And every few days throughout the development process it molts - i.e. sheds its exoskeleton. The discarded exoskeletons are carbon rich, so act to sequester carbon as they fall to the ocean depths.

Once mature, the krill is able to cycle vertically through the upper layers of the ocean several times a day. This allows it to alternately feed near the surface and metabolize its catch away from predators.

In the polar regions the long summer days result in huge volumes of phytoplankton, which support vast swarms of krill. During the dark winter months, krill consumes plankton on the underside of sea ice.

Female krill are known to be capable of spawning multiple times over one or two year life span. Each spawning event causes them to regress through one developmental sub stage until they are no longer fertile.

To facilitate the development of more complete models of marine nutrient cycles, samples of Antarctic krill were caught, frozen for transportation, and then subjected to various tests in the lab. These tests identified wet and dry weight, as well as the carbon, nitrogen, protein, lipid, and caloric content of the krill. The data were grouped according to gender and developmental stage. Similar measurements were made for the particulate matter (skeleton) on which the krill feed.

The results obtained indicate that mature females have a significantly higher lipid concentration than mature males. Fertile females also have significantly higher carbon concentration than spawned females, with the reverse being true for nitrogen concentration.

The data were then aggregated and a series of regressions performed. \( R^2 \) values were as follows:

These regressions demonstrate a linear relationship between all pairs of variables. Thus it is possible to calculate nutrient densities from weight data.

Applying this to a data set from the 1980s produces the following spatial plots:

Together, these figures suggest that krill grazes exhaustively in one area before moving on to another. And in the area examined, food appeared to be plentiful, i.e. it was not a limiting factor.