



THE RIVER OF KRILL

JAMIE WATTS

I'm sitting 20 miles offshore, where South Georgia's shelf drops off into deep water. This is right over the small patch of ocean where hunters once came, every summer, in search of the largest animal that has ever lived, in numbers seen nowhere else. A few of the giants remain, and some still come here, occasionally, in summer. They have dwindled, but the reason they like this spot hasn't changed. It's a truly gigantic mass of life, and it writhes, swarms and fizzes directly beneath me. And it's pink.

ONLY a small number of vessels that don't have the capacity to catch, process or store more than a tiny proportion of the quota operate there, Three thousand tons of krill is about six billion individuals, equivalent to earth's human population; enough to feed seven of those giant blue whales for an entire summer season. This sounds like a lot, but to put it in context, it's barely a couple of *hours* food for the vast populations of predators breeding in South Georgia each summer. However, with nearly seven billion hungry human mouths to feed, an unprecedented mass of large mammals for such a small planet, and with global protein sources stretched, this situation is unlikely to remain the case for long as interest in this enormous resource is already picking up.

On an ecological context, there are probably between a third and half a billion tons of *Euphausia superba*, the Antarctic krill, in the Southern Ocean in summer, which gets eaten and replaced each year. That's far more than all the human consumption of meat, chicken and seafood combined; which will make us the earth's biggest single-species animal consumers. In terms of biomass, the only other single species animals that have far exceeded ecological norms are humans and the cattle bred to feed us. Humans probably amount to a little over a third of a billion tons, slightly less than krill, while cattle are almost certainly the single largest biomass of all at a staggering two thirds of a billion tons. It is very odd, in ecological terms, that two of the top three are such large animals.

The normal situation is one where the vast majority of the biomass is at the lower levels of the food web which generally means small animals.

While the krill catch itself is not a concern, finding and assessing the bycatch matters. Inshore fish populations are tens of thousands times lower than krill populations, making even a few kilos of fish per ton of krill a major impact on fish stocks. Like the proverbial search for needle in a haystack, we sift through bucketful after bucketful of krill, looking for semi-transparent fish larvae the size of a child's finger, among literally tens of thousands of semi-transparent krill, the size of a child's finger.

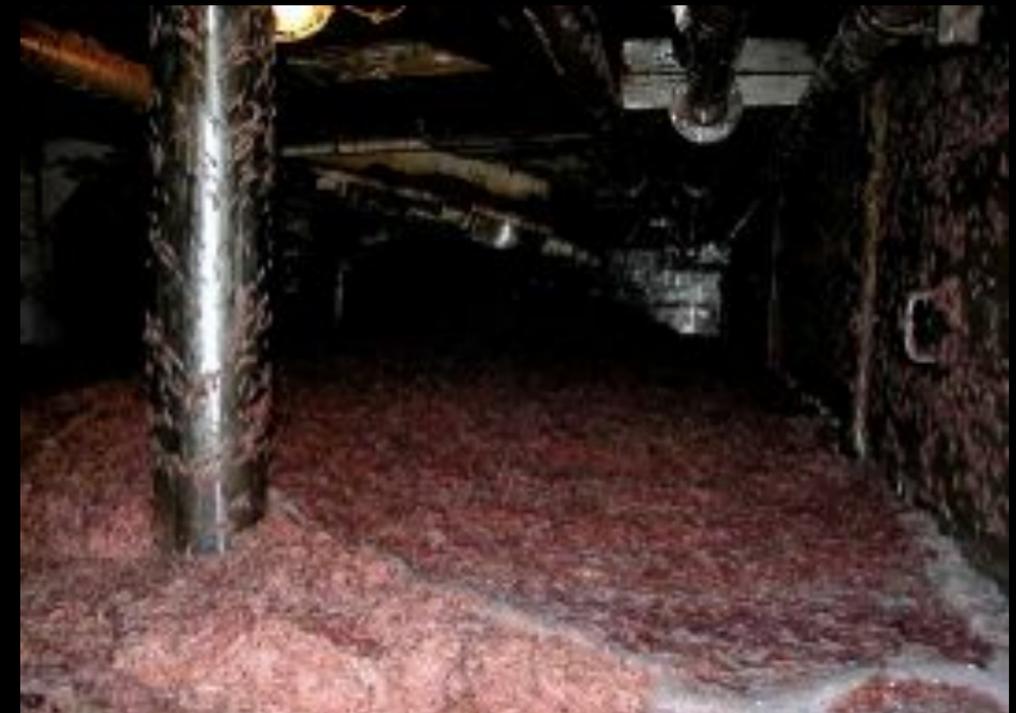
The only way to appreciate the sheer scale of these swarms is with a modern, high frequency sonar array. It's fascinating to watch the sonar screen in high resolution picture of huge areas of sea in real time. No wonder dolphins and whales are so successful with sound; it really is the only way to 'see' effectively underwater. Throughout the day and night we watch this immense mass of life contracting, stretching, breaking up, broadening, swimming upwards and downwards like a single, enormous organism in its daily cycle; dense, red patches representing pure krill. The first swarm we fish is over 100 metres thick, and three miles across at the densest core. Its full extent goes much further, a great swath ten miles in both directions, following the edge of the continental shelf.



SEMI TRANSPARENT FISH LARVAE in the midst of semi transparent krill



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(Top) **OVER 10,000 PAIRS OF CHINSTRAP PENGUINS** congregate to breed on Deception Island; and female take turns to feed, walking up to 3kms over an undulating Pink Highway to reach the sea. A highway of pink poo from a diet of abundant krills.

(Bottom) **KRILL HAUL** In the belly of a Krill Boat

The Antarctic Peninsula and Scotia Sea

A combination of oceanographic, biochemical and ecological features make the Antarctic Peninsula and Scotia Sea the biological epicentre of the Southern Ocean. The Antarctic Circumpolar current is by far the largest on earth and the only one that circles the globe. It is a broad, deep ring of water that flows slowly around Antarctica, taking eight years to make it all the way round. At the Drake Passage, between the Antarctic Peninsula and South America this current is constricted. Here, the water is funneled through the passage, up onto the Scotia Plate and over the relatively shallow banks of the Scotia Ridge, bringing with it deep water nutrients reinforcing the upwelling driven by the melt and freeze cycles of the Antarctic ice over the edge of the shelf; making the Southern Ocean the largest nutrient-rich area of ocean on earth. Additionally, the clockwise-spinning Weddell sea is the largest of only two areas on earth where appreciable amounts of silicate are also brought up to the surface by water movement. All that remains to make good plankton fertilizer is a little iron. This is the limiting nutrient to much of the deep Southern Ocean, but it is found downstream of the southern tip of Patagonia and around the banks of the Scotia Ridge.

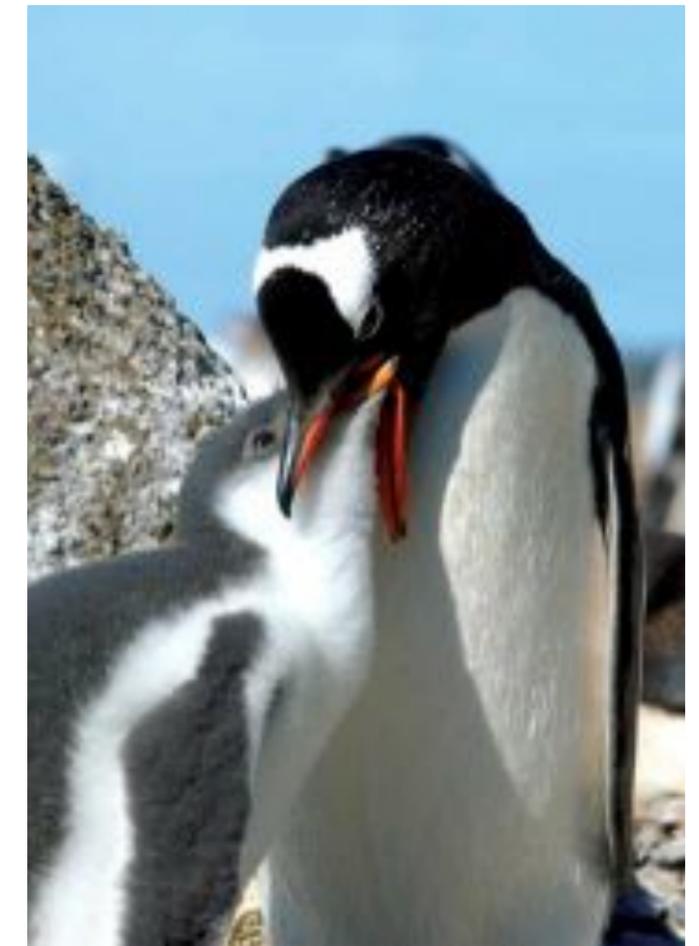
When the Weddell sea and the Scotia water run together, the combination makes for rich, thick 'phytoplankton soup', the best grazing place on earth for krill megaswarms. This maximum-productivity region, also the place where the densest concentrations of krill are to be found, snakes from the edges of the ice on the Antarctic Peninsula around to the South Orkneys then up across to wrap around South Georgia's eastern end and head back westwards before drifting out into the broader mass of the circumpolar current. I call this meandering highway of life the Scotia Sea's 'river of krill'. This area, the Antarctic Peninsula, South Shetlands, South Orkneys and northeast to the South Sandwich islands and South Georgia, supports far more krill than anywhere else on earth, perhaps a quarter or more of the entire biomass of Southern Ocean krill.



(Top) **THE RIVER OF KILL** meandering highway of life the Scotia Sea's.
(Right) **NEARLY 200,000 KING PENGUINS** colonize on South Georgia; the beach has constant of traffic of penguins returning and penguins leaving to feed. Too young to go fishing for themselves, those fluffy brown balls are young penguins waiting on for their parents to return. Sharing the same real estate are thousands of elephant and Wedell seals.



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(Left) **CHINSTRAPS OFF FEEDING**
on the river of Krill.

(Right) **A MUMMY GENTOO PENGUIN**
regurgitating krill to feed her young.

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The krill predators

The krill fishermen's quota, for seven or eight krill fishing boats, is a little over a million tons for the Scotia Sea area, ten to twenty times more than is currently being taken. Even this quota is really conservative when compared with the fifty to two hundred million tons of krill in the Scotia Sea area. We are, to date at least, one of the most minor amongst the krill's many predators. The krill fishery is probably one of the only fisheries on earth that's *underfished*. (that could be one of those things you end up wishing you hadn't said). Following this 'river' are the incredible numbers and variety of predators the krill supports. Together with a large proportion of the world's penguins, it attracts a sizeable fraction of the world's seal and whale populations. Several of the world's most abundant seabirds are also supported by the 'river', and beneath the surface are icefish, rockcods and squid. The best concise description I have heard of this ecosystem is, 'it makes the Serengeti look like a petting zoo'.

The greatest of all krill predators is the crabeater seal, by sheer force of numbers. These medium sized, rather doglike seals have specialised, slightly ornate teeth, designed almost like strainers to catch krill. The crabeater's closest cousin, the somewhat more impressive, bulkier leopard seal, surprisingly, eats far more krill than anything else. The penguins and seals in their diet are probably just a seasonal habit, and many penguin and fur seal colonies only have their attendant leopard seals at the most vulnerable time, when the young are going into the water for the first time.

Seals are warm blooded and energetic and need a lot of food. The smaller fur seals may eat a ton of krill a year, crabeaters may munch through five tons or more and leopard seals maybe seven. It is the sheer numbers of the seals that makes them such a key predator. In the Scotia Sea region, there are five million or more Antarctic

fur seals, about seven million crabeaters and a hundred thousand or so leopard seals.

Due to whaling, the ecological impact of the great whales is considerably lower than that of the seals. Yet, the Southern Ocean probably supports more whales than anywhere else, and their appetite for krill is impressive. During the summer, humpbacks may eat a ton of krill a day, the right whales perhaps twice this much of krill, amphipods and copepods, and a blue whale may eat four tons of krill or more a day.

South Georgia is as far north as Antarctic krill thrive. Indeed, krill is what makes South Georgia different to all the other subantarctic islands and is a major reason its life is so rich. The combination of both krill and copepods in high concentrations is why South

Georgia supports 90% of the world's Antarctic fur seals and half of the global population of the most abundant penguin, the macaroni, along with millions of seabirds.

Historically, ten miles out from the north of South Georgia was home to perhaps the densest regular concentration of blue whales on earth. The vast majority of the large whales seen around the Scotia Sea region these days are the slightly smaller, but still impressive fin whales. Accepted wisdom is that the whale numbers are highest around February in late summer, when the krill have fattened up on the bounty of the season. Two summers ago, a tourist boat reported witnessing a gathering of whales greater than anything seen in nearly a century northwest of South Georgia. Blues, fins, rights, humpbacks and minke were all feeding off a single krill swarm. The whale recovery is slow, but it is happening.



A SUPER MAGNIFICATION
using high intensity light to
illuminate this *Euphausia superba*
Antarctic krill.

DR RUSSEL HOPCROFT

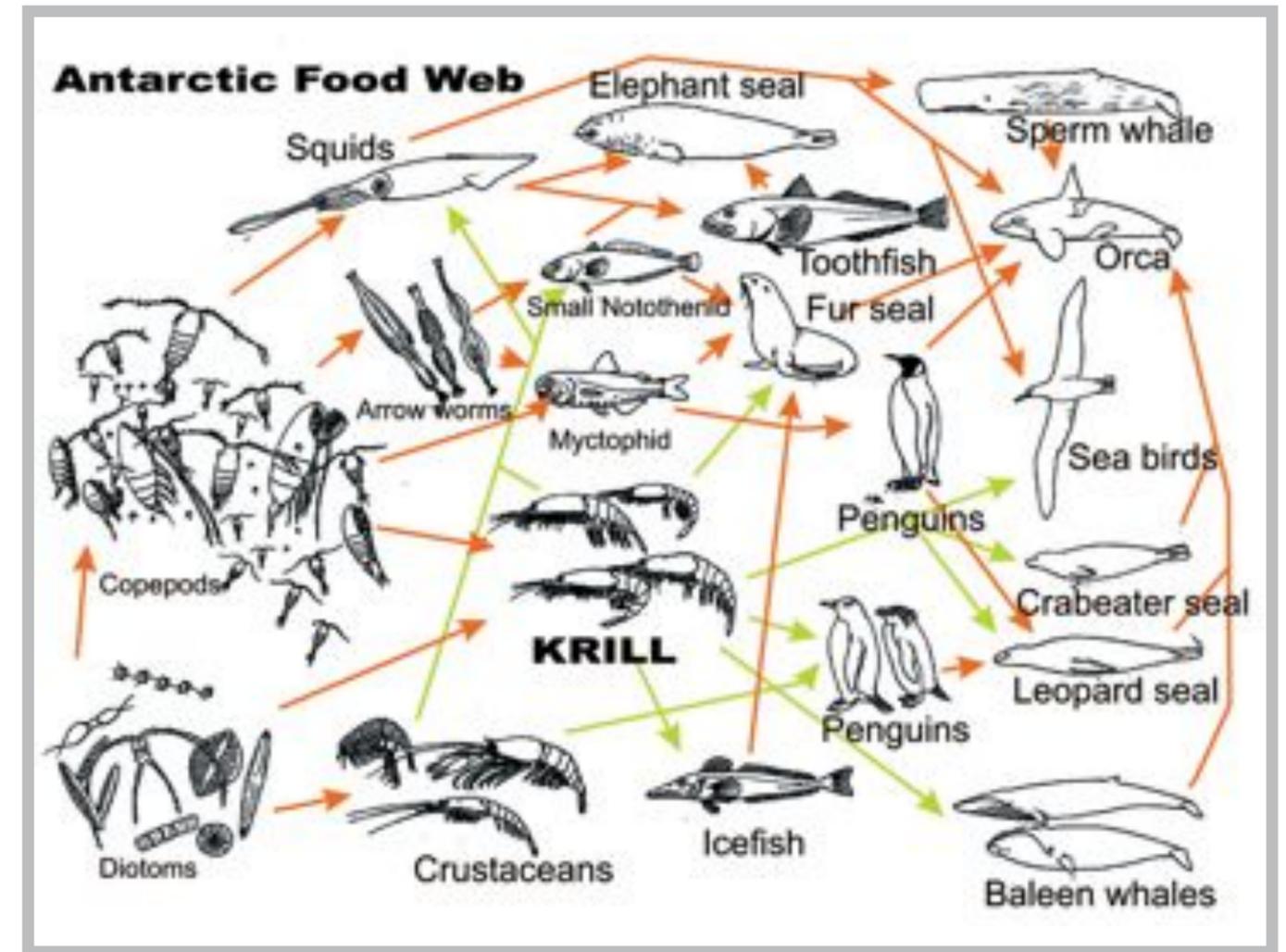
The life of krill

Most krill are hatched around the Antarctic Peninsula and along the northeastern edge of the Weddell Sea. Krill eggs and early larvae stay in deep water, most of them returning to the surface under protection of the sea ice to grow and build their strength before moving into open sea and running the impossible gauntlet of the millions of predators scouring the oceans looking for tasty morsels.

Krill is pretty impressive as an individual animal. Considered to be a slightly 'primitive' cousin of true shrimps, its build is light and spartan. The smooth, thin shell forms a sleek spindle shape in the water, and the large swimming legs and bushy gills hang in a 'tunnel' made by the overhanging edges of the shell. As it swims water funnels through, and the slender, double-pronged, forward-facing feeding legs can stretch out, their hairs forming a net with which to scoop phytoplankton, or tighten up to make the front of the animal into a sharp, streamlined nose cone. The build is for an active lifestyle, and krill are constantly on the move. They are oily, and when fresh are a rather beautiful translucent golden

pink. Only after an hour or so do they lose the golden hue, turn a slightly milkier pink, and take on the 'fresh seafood' smell I associate with prawns.

We have plenty of research data on krill from the summer, when the water is thick with plantlike food. Scientists have had surprisingly few opportunities to watch what these animals do in winter though, especially considering how much research has gone into this one species. For one thing, it appears they may not be quite so herbivorous after all, once the summer plankton bloom has died down. One field of current interest is how in winter, krill around South Georgia seem to switch and feed on protozoans and copepods. Watching the echo sounder, the krill swarm formed a bowl moving upwards into a dense swarm of smaller plankton, almost certainly copepods. This explains how the populations of copepods, which are an even greater producer of animal biomass than krill around the edges of the Southern Ocean, are kept under control.



Other ecosystems

The dominance of krill and copepods have 'ecologically spilled over' into the niche normally occupied by herrings and sardines. These tiny planktonic animals are easily studied, and have been observed from every angle. Fish, on the other hand, are a very much smaller part of this ecosystem. One thing that is apparent, though, is that offshore, in deep water and away from the axis of the krill 'river', lanternfish and squid form ecosystems that are impressive in their own right. These fish and squid live in deep and remote areas and are surprisingly hard to find; although from the known diet of the warm blooded predators there are undoubtedly millions of tons of both down there. The more we look at this system, the more we see that the straightforward picture of an ecosystem resting entirely on krill is ludicrously simplistic.

For example, king and emperor penguins and elephant seals all happen to specialise in eating both lanternfishes and squid, and neither eats krill as a general rule. Yet, these warm blooded animals thrive in enormous numbers alongside the krill eaters. Sizeable populations of sperm whales are supported almost entirely by colossal squid around the Southern Ocean, yet as far as we can tell krill play almost no part in the food webs of any of these animals.



ICEBERG THAT SINKS SHIPS are the average penguins favorite playground.

Cycles and change

Things in nature move in cycles and last year looked to be a 'high krill' year for this particular ecosystem. Every few years there is a poor krill year, like the previous one. It's a bit like La Nina following El Nino and this analogy may have something to it. It seems like the Scotia Sea climate might have relationships to El Nino, but with a three year lag. The warm pool of water that plays havoc with the ecosystem off the coast of Peru may travel across the Pacific, around down to the Antarctic and back through the Drake passage three years later. The effects, however, may be different. Perhaps a slight increase in water temperature here allows a longer growing season and means a good year for krill. However, warmth also means a reduction in sea ice, the sea ice that young krill depend on for shelter. A good years growth in one season may be counterbalanced by a lower survival of young krill for the next year.

The Antarctic Peninsula area, however, also looks to be warming in the long term as well as cyclically. It may be the fastest warming sea on earth and there are definite signs of a serious ecosystem shift. Overfishing may be one thing that is in no danger of taking out the krill just yet. But the two to three degree Celsius of temperature rise since 1950 at the Antarctic Peninsula, where the early stages of krill's life cycle depend heavily on sea ice, just might. Since the early twentieth century, krill stocks have been estimated to have dropped by over a half.

An ecosystem doesn't just stop producing There will not be less life if this trend continues, just a different life, with unknown results for this enormous ecosystem. It looks as if salps, a group of free-swimming planktonic sea squirt, and perhaps lanternfish, could be taking up the slack left by the reducing krill numbers. If this happens, then, the winners may well be king penguins and elephant seals, while the losers might be the other penguins, the crabeaters and the great whales. ○