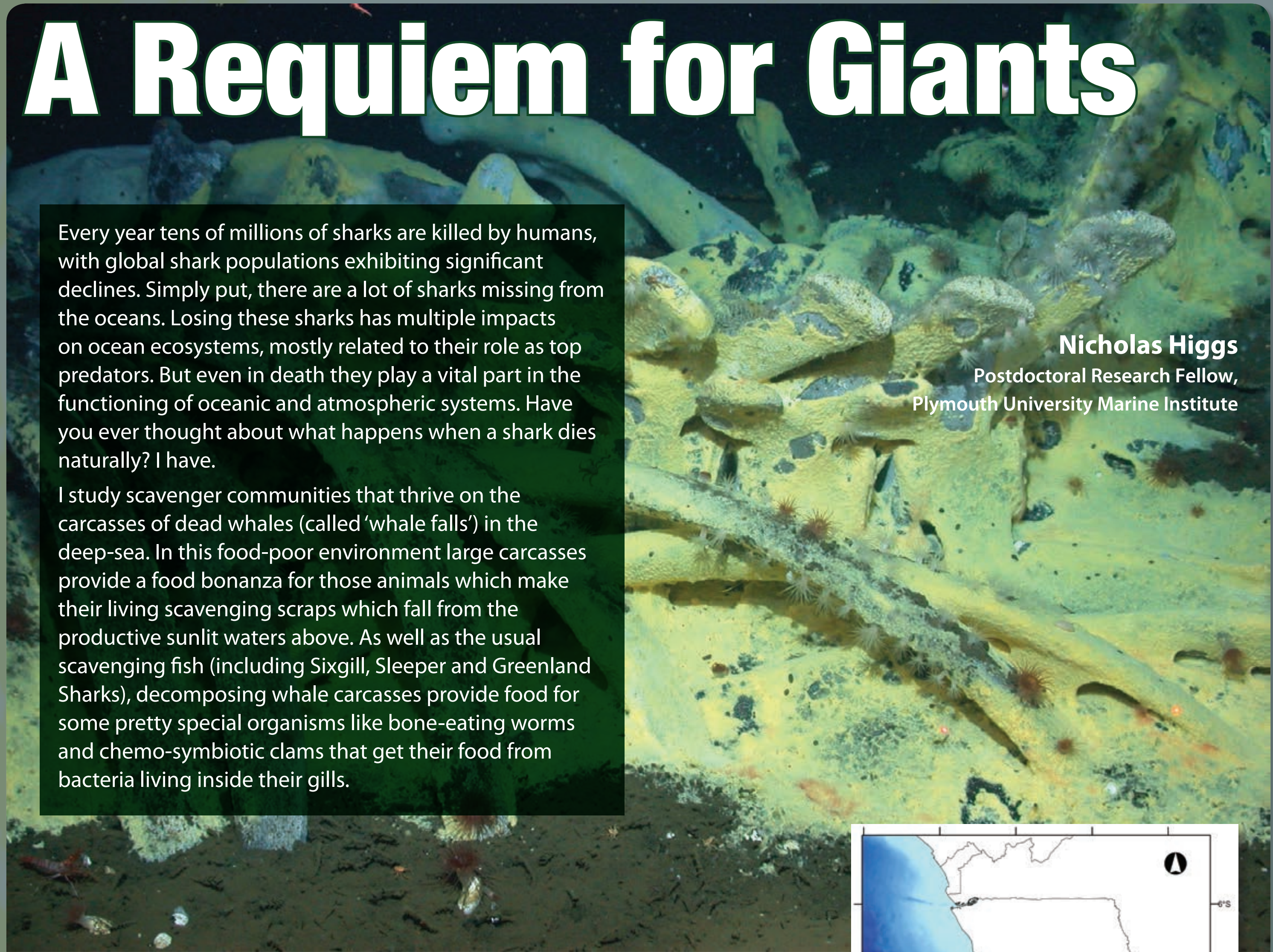
A Requiem for Giants



Every year tens of millions of sharks are killed by humans, with global shark populations exhibiting significant declines. Simply put, there are a lot of sharks missing from the oceans. Losing these sharks has multiple impacts on ocean ecosystems, mostly related to their role as top predators. But even in death they play a vital part in the functioning of oceanic and atmospheric systems. Have you ever thought about what happens when a shark dies naturally? I have.

I study scavenger communities that thrive on the carcasses of dead whales (called 'whale falls') in the deep-sea. In this food-poor environment large carcasses provide a food bonanza for those animals which make their living scavenging scraps which fall from the productive sunlit waters above. As well as the usual scavenging fish (including Sixgill, Sleeper and Greenland Sharks), decomposing whale carcasses provide food for some pretty special organisms like bone-eating worms and chemo-symbiotic clams that get their food from bacteria living inside their gills.

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A shark graveyard at 1200m

After whales, the next largest vertebrates in the oceans are Whale Sharks *Rhincodon typus*. Scientists have long wondered whether their carcasses and those of other large marine animals could also support these weird and wonderful animal communities. But it's not every day that you stumble across a dead whale carcass on the seafloor, much less a dead Whale Shark. In fact, only nine vertebrate carcasses have ever been documented on the seafloor in the entire history of deep-sea research.

That's why I was pretty excited when a deep-sea surveyor contacted me (out of the blue) with video footage of a Whale Shark carcass sitting on the seabed off Angola at a depth of over 1200m. What's more, there were also videos of three mobula ray carcasses discovered during two years of exploration. We think one of the rays could even be a manta ray carcass, another giant of the seas. This was the first time anything like this had ever been seen; it was a kind of shark graveyard!

Interestingly, the carcasses didn't look like the dead whale carcasses that I am used to studying – no carpets of bacterial mat covering the skeletons or dense beds of clams and worms in the mud. The most abundant animals were scavenging eelpouts, sometimes 50 or so, perching on the carcasses. Beyond this there was the odd rat-tail and hagfish, all typical deep-sea scavengers. In short it seems that these large elasmobranch* carcasses are mainly food for mobile scavengers in the deep-sea. So it seems that the shark carcasses are no substitute for whales, but that's not to say they aren't important.

Based on how much of the carcasses were left when discovered and typical rates of scavenging, we estimated that the Whale Shark and rays had only been dead for a matter of weeks to months. Whale skeletons, on the other hand, can last for decades. Nevertheless, we were able to observe a kind of reef-community of scavengers living on and around the elasmobranch skeletons. Previous studies using baited-cameras had only documented these scavenging communities for days at a time whereas we were able to show that they persisted for months.

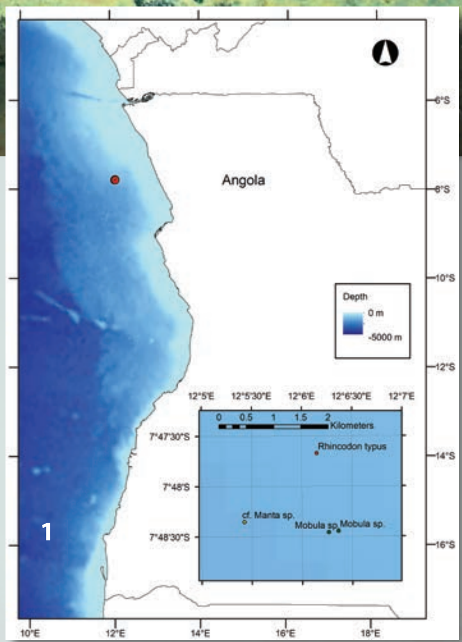
Beggars *can* be choosers...

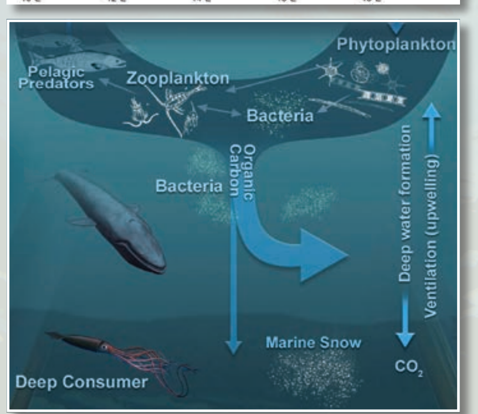
The estimates for how long the carcasses had been dead are based on several assumptions, and each takes us down some interesting avenues. Firstly, it assumes that the shark and ray carcasses are scavenged at a similar rate to other dead animals in the ocean. This might not be the case. Several previous experiments have shown that shark bait doesn't seem to be as popular with deep-sea scavengers as other forms of bait. Indeed, we only observed a couple of the fish actually eating the carcasses. The others just hang around it, probably waiting to eat shrimp-like amphipod scavengers when they show up.

You would have thought that in such a food-poor environment 'beggars can't be choosers', but it seems they are. Maybe the carcass is difficult to get at because of the shark's tough skin or the high ammonia content of the flesh makes it unpalatable. There is one new explanation that I find particularly intriguing. Researchers recently showed that sharks are deterred from feeding when rotting shark meat is present because of some (as yet) uncharacterised chemicals in the rotting flesh. Sharks can, it seems, smell death! And they run away even when it's a different species that is dead. Since the Portuguese Dogfish *Centroscymnus coelolepis* (found down to 3700m) is the dominant scavenger in this area, they may have been deterred from feeding on the carcasses, thereby reducing the overall scavenging rate.

Another assumption is that all of the carcasses died by natural causes and arrived on the seafloor intact. There were no obvious signs of death to cause suspicion, but accidental strikes by vessels and entanglement are plausible. It should also be noted that this footage comes from surveys carried out by the oil and gas industry. I must admit that finding four carcasses in such a small area did set off alarm bells in my head: were industrial operations to blame?

There is no way to tell, but in science we work on a principal that you take the simplest explanation necessary when choosing between competing theories. It turns out that there may be a very good reason to find so many carcasses in a small area. The waters off Angola are a hotspot of ocean productivity and rich in plankton. This in turn probably attracts high numbers of large plankton-feeding animals such as Whale Sharks, manta rays and whales. So it is only natural that there will be a higher concentration of their carcasses in this area too.





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The Biological Pump

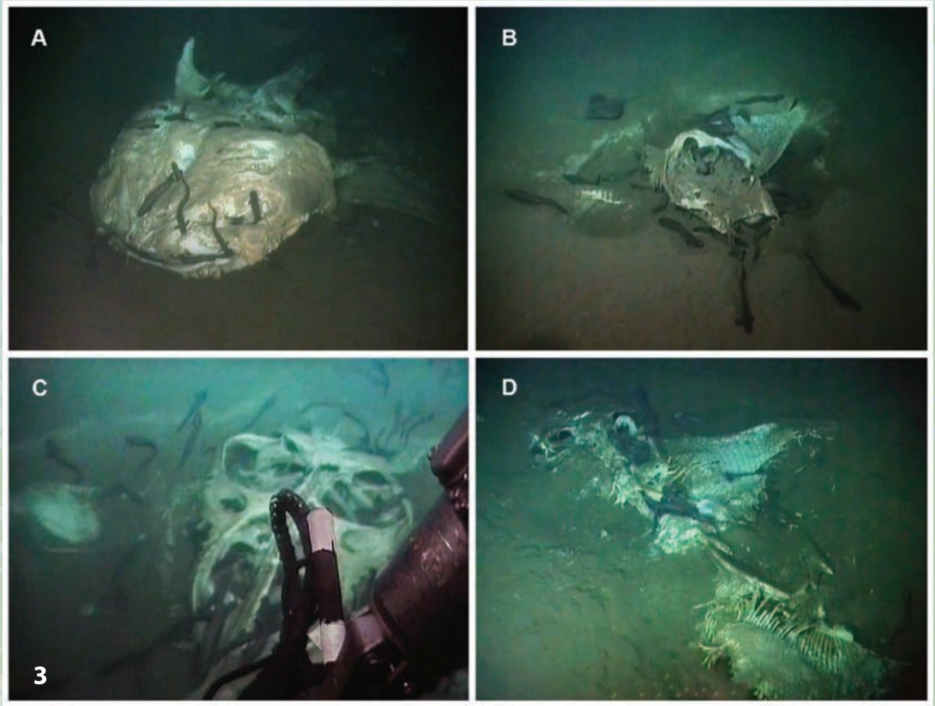
Having lots of big animals concentrated in one part of the ocean has interesting implications. It seems that large carcasses – such as those of sharks – may also be important for the cycling of carbon in the oceans. Here's how: tiny plankton take carbon dioxide out of the air to create food through photosynthesis. A lot of this is consumed by marine animals at the surface of the ocean. Indeed, on average, only a tiny portion (~1%) of this carbon ends up sinking into the deep-sea, either as dead plankton, animal poo or dead animals themselves. This is what the deep-sea animal community have to live off!

This removal of carbon from the upper to lower ocean (carbon sequestration) where it remains for thousands of years is known as the 'biological pump'. Large animals are particularly good at removing carbon from the upper ocean because when they die all of the carbon locked up in their bodies sinks rapidly to the seafloor, unlike small plankton or poo which tends to be recycled on the way down. Big animals with few natural predators are especially good because they are not consumed very often and most of the time their bodies simply sink to the deep-sea floor. So, in places where you have more large animals in the ecosystem, you also have greater carbon sequestration and a stronger link between the surface and deep-sea communities.

This relates to the next surprise that this study revealed. When we calculated the amount of carbon in all of the carcasses, we discovered that they accounted for 4% of the total carbon arriving into the deep-sea from surface waters in that area. This may not sound like much, but it is a comparatively huge number – ten times that previously estimated for whale carcasses. It represents one third of the carbon estimated to arrive in the deep-sea from *all* large animal carcasses. In other words, the biological pump in this region is operating at a high efficiency due to the large populations of Whale Sharks and rays living and dying in the region.

This is good news for the deep-sea scavengers! The more carcasses transported to the deep-sea, the more food there is for the animals down there. Previous studies have shown that changes in populations of deep-sea scavengers clearly track trends in surface fish populations. It is also good news for the wider ecosystem as carbon is being removed from surface layers of the ocean and the atmosphere. Some scientists estimate that we have lost up to 90% of large animals from the oceans. The current decline in global shark populations, and those of other large fish, is having an effect that resonates throughout the ocean ecosystem – from the sunlit surface all the way to the deepest seafloor animal communities.

*Collective term for all sharks, skates and rays – a sub-class of the Chondrichthyes, or cartilaginous fish.



Read the full paper:

Higgs ND, Gates AR, Jones DOB. 2014. Fish Food in the Deep Sea: Revisiting the Role of Large Food-Falls. *PLoS ONE* 9(5): e96016. doi:10.1371/journal.pone.0096016

Graphics

Main image: Whale fall at 1700m depth. © Craig Smith NOAA.

Figure 1: Map showing the locations of elasmobranch carcasses observed on the Angola continental margin © Nicholas Higgs.

Image 2: The Biological Pump © John R. Delaney/ University of Washington.

Image 3: Still images showing each of the observed carcasses: **A:** Whale Shark; **B, C & D:** mobula carcasses © Nicholas Higgs.

Deep-sea scavengers:

Image 4: A rat-tail, in this instance a Ghostly Grenadier *Coryphaenoides leptolepis* at 3158m, 80 miles off California © NOAA/Monterey Bay Aquarium Research Institute.

Image 5: A hagfish – emerging from a sponge © NOAA Okeanos Explorer Program.

Image 6: An eelpout rests on the seafloor between 742–924m on the US Atlantic continental slope © NOAA OKEANOS Explorer Program, 2013 Northeast US Canyons Expedition.