Climate Change, Geoengineering, and the Great Whales

Photo courtesy of Dr. David MacLaren at Merrimack College

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The Impacts of Climate Change on the Oceans

Unprecedented warming of the climate system has been observed since the 1950s. This warming has been driven by anthropogenic release of greenhouse gases since the beginning of the industrial revolution. Under the highest carbon emission scenario, global average temperatures are projected to increase between four to six degrees Celsius. The ocean warmed by .11 degrees Celsius per decade between 1971 and 2010. Ocean warming accounts for more than 90% of the energy accumulated by the climate system between 1971 and 2010[1].

The ocean has been responsible for sequestering large volumes of carbon dioxide from the atmosphere. Increased carbon dioxide has led to the acidification of the ocean. Ocean acidification threatens marine life; particularly those that rely on the development of hard shells as part of their life cycle. Ocean pH has dropped by 0.1 since the beginning of the industrial era[1]. The ocean has absorbed 30% of the emitted anthropogenic carbon dioxide[1]. The surface waters of the ocean could warm as much as 2.0 degrees Celsius by the end of the century.

The Contemporary Great Whale

Large whale species worldwide have been in recovery since the international ban on whaling in 1986. Only four nations hunt whales. It’s been estimated that at the peak of industrial whaling, between 1920 and 1980, 2 million great whales were harvested from the ocean[2]. Some estimates place whale biomass at less than 25% of pre-whaling levels[3]. Many whale species are protected by endangered species programs in the United States and the international whaling ban.

Six large species of whale are endangered in the United States. Populations of each of these species are in the hundreds, with the exception of sperm whales (*Physeter macrocephalus*), whose Atlantic population remains in the thousands[4]. The minke whale (*Balaenoptera acutorostrata*) population, which largely escaped serious whaling efforts, contains an estimated minimum population of 6900 individuals.

The Whale as an Ecosystem Engineer

Whales play the role of ecosystem engineer at a large scale for many ocean habitats through physically changing their environment, acting as nutrient conveyer belts, and fostering ocean mixing[5]. When whales die, and their corpses sink (known as whale falls), carrying nutrients and sequestering carbon to the ocean floor[2]. They are the single largest form of detritus to fall from the ocean surface.

Whales act as nutrient conveyer belts by effectively pumping Fe and N into ecosystems by way of defecation. They carry nutrients from enriched colder waters to warmer regions during their mass migrations[5]. This fertilizes ecosystems that support fisheries in warm waters.

When diving to feed at or beneath the thermocline, they foster ocean mixing. Plowing of the ocean floor by gray whales can change benthic ecosystems for potentially hundreds of years[5]. Humpback whales have been known to utilize bubble nets, which alters the water column [5]. Their role as predators may increase carbon sequestration of ecosystems, as this impact by predators on ecosystems has been demonstrated in freshwater systems[6].

Anthropogenic Threats to Whales

While incidental whaling does occur, purposeful whaling is only pursued by Native Americans in the United States, Iceland, Norway, and Japan. The capture by the United States is small, and tightly regulated. Japan, Norway, and Iceland have claimed to pursue whaling for scientific purposes, but these claims are highly disputed. Japan has been banned from whaling in the Antarctic by the International Court of Justice since March 2014. A total of 33,561 animals between 1986 and 2010 were killed by whaling according to the World Wildlife Fund[7].

Incidental whaling comes in the form of ship strikes, fishing gear entanglements, and sonar induced stranding. It has been estimated that between 1970 and 2009 a total of 176 whales have been killed from ship strikes in American waters. Fishing entanglement has claimed the lives of 328 whales. Overall approximately 1762 known whale deaths can be linked to humans in the United States and Canada[4].

The impacts of sonar on whales has been highly politically contentious in the United States, and thus difficult to both study and regulate. Sonar has been implicated as a causal factor in a multi species mass stranding event in the Bahamas[8]. The Canary Islands, which had previously been a hot bed for mass whale stranding, has not seen an event since the Spanish government imposed a moratorium on naval exercises in the area[9].

Climate Change Impacts on Great Whales

It is predicted that the ranges of 88% of whales could be impacted by changes in water temperature from climate change [10]. As highly mobile marine species, large whales do not suffer from the same barrier problem that blocks migration for terrestrial organisms. That is not to say that these ranges shifts are not potentially detrimental, as their prey species may shift ranges as well. Changing temperature patterns could impact seasonal migration timings[10].

Ocean acidification will impact marine food webs by disrupting the formation of a calcium carbonate[11]. Phytoplankton, highly calcified mollusks, and crustaceans, are particularly vulnerable. Fish may be vulnerable as well. These species play an important role in the food web that supports large whales. Open-ocean net productivity is expected to fall[11]. Krill play a major role in the diets of baleen species. Thus reductions in krill populations would be detrimental to recovering baleen whale populations.

Species of whales that live in Arctic water are threatened by habitat destruction. Narwhals (*Monodon monoceros*) rely on densely packed ice for foraging, which is projected to be dramatically altered by climate change[1]. Other arctic species such as beluga whale (*Delphinapterus leucas*) are expected to suffer similar stresses from habitat loss.

Using Whales for Geoengineering

A 40 ton a gray whale contains 2 metric tons of carbon, equivalent to 2000 years of background carbon sequestration. Whales are estimated to sequester 190,000 metric tons of carbon per year[3]. The economic value of this carbon sequestration is between 2,090,000 and 20,710,000 depending on the discount rate used to determine the social cost of carbon[12]. While not healthy for the animals, whales have the capability to sequester chemical pollutants. Multiple species have been demonstrated to contain chemical pollutants in their fat[13,14]. When evaluating whales as an ecosystem service, the economic value of pollution abatement they provide increases their value.

The rebuilding of whale populations to pre whaling levels is comparable to existing carbon sequestration projects[3]. Rebuilding the southern blue whale population could sequester as much carbon as preserving a temperate forest the size of Los Angeles. Restoring whale biomass to pre whaling levels would be the equivalent of a forest the size of the Rocky Mountain National Park. This would be equivalent to the geoengineering proposal of ocean iron fertilization. Restoring all whale populations would export an additional 160,000 tons of carbon per year out of the carbon cycle[3]. Equivalent to between 1,760,000 and 17,440,000 depending on the discount rate used in determining the social cost of carbon.

Population restoration at such levels would be complicated. Whales live long lives, and many do not reach sexual maturity until after more than a decade. Captive breeding programs for blue whales would be logistically difficult due to their sheer size. Disruptions to food webs from over fishing worldwide, and ocean acidification may make the maintenance of such a large biomass of top predators extremely difficult. When considering geoengineering alternatives, a benefit cost analysis could be useful.

Considerations for Managers

In the United States whale protection has grown into a large program supported by government grants and nonprofits. Whale protection has long held strong public support. Due to their large biomass, whales are analogous to trees in their ability to sequester carbon[5]. Their role as a nutrient conveyer belt fertilizes ecosystem, increasing productivity and in turn carbon sequestration by ocean biota.

While managing climate change impacts may be more difficult, there are anthropogenic causes of death that can be handled directly. Ship strikes while accidental, can be avoided. The number of fishing gear entanglements can be reduced with the use of “whale friendly” gear meant to be broken by whales. Limiting the use of naval sonar during battle exercises could reduce mass stranding events. Ending whaling as a practice could save more whales than work on any other issue.

Solutions to these problems are not without political management implications. Fisherman may be reluctant to use new fishing gear if it could negatively impact their catch. The shipping industry is unlikely to embrace anything that will increase its costs. The navy has historically shown little interest in reducing its sonar usage, and even fought limitations all the way to the Supreme Court [15]. Regardless, whales provide valuable ecosystem services and have the potential to be used to combat climate change. As the population are now, they are already doing so.

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