**How Great Shark Declines are Changing the Oceanic Food Web**

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**Abstract**

A food web is the transfer of energy between trophic levels in an ecosystem. This energy is continually being passed from one level to another with 10% of it being lost as heat each time until the energy is expended. In an ecosystem there are many webs occurring at a single moment and the functions of these webs depend upon who controls the flow of energy. Many environmental experts believe that the organisms at the bottom of the food web control the flow of energy; however, a recent study involving sharks found that the decline in large shark species populations has led to an unequal distribution in the trophic levels within the oceanic food web. This data suggests that oceanic ecosystems maybe controlled by organisms located at the top of the food web and that the decline of these apex predators could possible affect the whole oceanic food web. These two opposing findings may imply that the control of a food web depends on the composition of the ecosystem and that control of a food web maybe more complex than just a top-down or bottom-up control, but maybe a control from both extremes.

**Introduction**

The oceanic ecosystem contains more than half of the Earth’s biomass. The communities of plants and animals that make up these environments produce a large portion of the Earth’s energy, food, and oxygen sources (Hurd and Polis 1996). Within this ecosystem, the flow of energy between different trophic levels connects to create a multitude of big, elaborate webs. It is known that within these webs the energy flows from the primary producers located at the bottom of the web to the apex predators located at the top. Nevertheless, there is still debate about whether the flow of this energy is controlled by the producers at the bottom or by the predators at the top (Huber et al. 2006).

Over the past century there has been a large increase in oceanic fishing. A main target for these fishermen are large shark species, also referred to as great sharks (Baum et al. 2007). This increase in fishing has led to the overharvesting of these sharks (Cartes et al. 2011).

Great shark species and their niches in the food web are what drive the oceanic ecosystem (Heithaus et al. 2011). Recent data that has been collected for several large shark species will help to understand shark species role in the food web and explain how shark declines have affected the structure of the food web along with resource output.

**Apex Predators and the Flow of a Food Web**

Within each ecosystem, there are multiple, recurrent cycles of flowing energy. This energy starts at the bottom with a primary producer, then is constantly being transferred from one individual to another through consumption. This energy is passed on from each individual until it reaches the top of the web, where the apex predator is located (Figure 1, Pimm 1982).

In each ecosystem, there are copious amounts of webs forming at any given moment, each with a different composition and although the way in which this energy flows is known, there is still dispute as to who controls the flow of this energy. This debate is known as the top-down, bottom-up debate and many scientists have supported the idea of a bottom-up control on a broad spectrum (Bayliss-Brown et al. 2014). Most studies have found data that suggests the primary producers at the bottom control the function of the ecosystem on a board scale (Bayliss-Brown et al. 2014), but with the rise in climate change and population decline of biodiversity, this debate has become a very popular research topic. In a study conducted by Baum and Worm in 2009, data was found to suggest a top-down control of the food web in the oceanic ecosystem.



 **Fig 1. An example of an oceanic food web**. The picture above shows

 a possible example for an oceanic food web. There are several cycles

 of energy happening at one time. All flows of energy start at the bottom

 with the primary producers and are transferred from animal to animal.

 The energy is passed along until it reaches the top, where large sharks

 are located. (Encyclopedia Britannica 2011)

**Main Causes for Great Shark Declines**

 Great sharks, which are sharks whose diets consist of mainly rays, skates and other small sharks, have drastically declined in number in the recent years (Baum et al. 2007). This decline is due to three major problems: food industry, human population growth, and trophy fisherman (Davidson et al. 2015, Strong and Polis 1996, Cooke et al. 2014).

***Rise in Industry***

In many countries sharks are considered a delicacy and are used in many culinary dishes. One dish that is very popular in these cultures is shark fin soup (Alava et al. 2008). The main ingredient for this dish are the fins of the shark, which are obtained through commercial fishing where the shark’s fins are cut off (Figure 2, Alava et al. 2008) and then the shark is pushed over board back into the ocean. When this happens, the shark is unable to guide itself in the water and is unable to produce enough movement for their gills to fully function. This can cause the shark to be vulnerable to other apex predators or can cause them to drown due to lack of oxygen, which both result in fatality.



 **Fig 2. Shark Finning**. The image above shows the fins

 cut during finning. Not all fins are obtained each time.

 The numbers rank the fins by demand. (Alava et al 2008)

***Human Population Growth***

 The rise in human population growth has led to a climate change problem due to extra carbon emissions that is affecting shark populations (Calderia and Wickett 2005). This extra carbon running off into the oceans, is changed in to carbonic acid which lowers the pH of the water causing it to become acidic. Many plants and animals, great sharks included, cannot tolerate these acidic pH levels which leads to declines in these oceanic species populations (Caldeira and Wickett 2005).

***Trophy Fisherman***

Oceanic fishing has risen in popularity over the years, whether it be for sport or for hobby. These fisherman, try to catch big trophy fish, such as sharks, some of their main targets being mako sharks, hammerhead sharks, thresher sharks, and blue sharks. All these sharks are species whose populations have declined by over half their population size (Table 1, Britten el al 2010, Cooke et al 2014, Jennings and Kaiser 1998).

**Great Shark Declines and the Oceanic Food Web**

 Great shark populations have had large declines since the mid-1950s (Baum et al. 2007). Recent studies tracked several great shark populations to quantify the percentage of population loss. Population sizes for hammerhead sharks, white sharks, tiger Sharks, thresher sharks, blue sharks, and whitetip sharks were collected each year starting around 1968 and 1974, depending on species (Baum et al. 2003, Baum et al. 2005). These studies compiled data from previous studies and added new data to track shark populations back to the mid-1900s. These studies found that all sharks experienced large declines in population sizes (Baum et al. 2003, Table 1). Mako sharks experienced a loss of less than half their population size, while all other species experienced losses of over half their population sizes. They found that hammerhead sharks had almost 90% population loss and white sharks and threshers had loss of around 80%. Further analysis of these findings displayed an alteration in trophic levels in the oceanic food web (Baum and Worm 2009), which implies the decrease in great shark species has led to an increase in prey species (Baum et al. 2007) because great shark dietary niches play a big role in trophic level population balance (Heithaus et al. 2011). This has led to an indirect depletion of other ocean species throughout the food web (Baum et al. 2007) and has caused an unequal balance in the trophic levels. This effect is predicted to eventually reach species located at the bottom of the food web (Baum et al. 2007). The change in distribution has affected the function of the food web and displays top-down control in the oceanic food web (Baum and Worm 2009).

**Table 1.** The percent decline of six shark species (Baum et al. 2003, Baum et al. 2005)

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| --- | --- | --- |
| **Shark Species** | **Percent Decline** | **Percent Error Range** |
| Hammerhead Sharks | 89% | 86%-91% |
| White Sharks | 79% | 59%-89% |
| Tiger Sharks | 65% | 58%-72% |
| Common and Bigeye Thresher Sharks | 80% | 76%-86% |
| Blue Sharks | 60% | 58%-63% |
| Whitetip Sharks | 70% | 62%-75% |

**Conclusions and Future Directions**

Little changes in energy transfer create huge impacts on the function of the ecosystem. Some studies have observed a bottom-up control in food webs, while others have observed a top-down control in the food web (Huber et al. 2006, Baum and Worm 2009). Drastic decline in great shark species populations is important to functionality of the oceanic food web because the decline in apex predators in the oceanic food web has led to an alteration of prey populations throughout the whole marine food web (Baum et al. 2007).

Opposing findings about which extreme controls the food web may mean that the flow of energy is not just controlled by the top or the bottom of the food web, but that they may be controlled by both extremes of the food web. Since there are numerous ecosystems with numerous food webs occurring at a given moment, there could be many possible answers. More research in not only great shark species populations, but all oceanic species populations will help to broaden our knowledge on the extent of the problem and may help us determine how these changes will affect the food, energy, and oxygen sources we get from the ocean. More studies will lead to better species population management and may help to reverse the imbalance in our oceans food web.

Bibliography

Alava, J. J., S. Henderson, J. Jacquet, G. Pramod, and D. Zeller. 2008. In Hot Soup: Sharks Captured in Ecuador’s Waters. *Environmental Sciences* 5:269-283

Baum, J. K., P. A. Doherty, S. J. Harley, D. G. Kehler, R. A. Myers, and B. Worm. 2003. Collapse and Conservation of Shark Populations in the Northwest Atlantic. *Science* 299:389–392.

Baum, J. K., R. A. Myers, C. H. Peterson, S. P. Powers, and T. D. Sheperd. 2007. Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean. *Science* 315:1846-J.

Baum, J. K., D. Kehler, and R. A. Myers. 2005. Robust estimates of decline for pelagic

shark populations in the northwest Atlantic and Gulf of Mexico. *Fisheries*  27-29

Baum, J. K. and B. Worm. 2009. Cascading Top-Down Effects of Changing Oceanic Predator Abundances. *Journal of Animal Ecology* 78:699-714.

Bayliss-Brown, G. A., P. Helaouet, M. Llope, C. P. Lynam, C. Mollman, and N. C. Stenseth. 2016. Interaction Between Top-Down and Bottom-Up Control in Marine Food Webs. *PNAS* 114:1952-1957

Britten, G. L., F. Ferretti, M. R. Heithaus, H. K. Lotze, and B. Worm. 2010. Patterns and Ecosystem Consequences of Shark Declines in the Ocean. *Ecology Letters*.

Caldeira, K. and M. E. Wickett. 2005. Ocean Model Predictions of Chemistry Changes from Carbon Dioxide Emissions to the Atmosphere and Ocean. *Journal Of Geophysical Research* 110:

Cartes, J. E., D. Damalas, S. Kavadas, C. Maravelias, F. Maynou, G. Osio, M. Sbrana, and P. Sartor. 2011. Estimating Trends of Population Decline in Long-Lived Marine Species in the Mediterranean Sea Based on Fishers Perceptions. *PLoS ONE* 6.

Cook, S. J., A. J. Gallagher, N. Hammerschlag, C. C. Macdonald, D. S. Shiffman, A. D. Thaler, and J. Wester. 2014. Trophy Fishing for Species Threatened with Extinction: A Way Forward Building on a History of Conservation. *Elsevier* 50:318-322

Davidson, L. N. K., N. K. Dulvy, and M. A. Krawchuk. 2015. Why have Global Shark and Ray Landings Declined: improved management or overfishing? *Fish and Fisheries* 17:438–458.

Heithaus, M. R., C. A. Layman, and P. Matich. 2011. Contrasting patterns of individual specialization and trophic coupling in two marine apex predators. *Journal of Animal Ecology* 80: 294-305

Hurd, S. D., and G. A. Polis. 1996. Linking Marine and Terrestrial Food Webs: Allochthonous Input from the Ocean Supports High Secondary Productivity on Small Islands and Coastal Land Communities. *The American Naturalist* 147

Huber, V., M. Loreau, and E. Thebault. 2007. Cascading Extinctions and Ecosystem Functioning: Contrasting Effect of Diversity Depending on Food Web Structure. *Oikos* 116:163-173

Jennings, S. and M. J. Kaiser. 1998. The Effects of Fishing on Marine Ecosystem. Elsevier 34:201-212

Myers, R. A. and B. Worm. 2003. Rapid Worldwide Depletion of Predatory Fish Communities. *Nature* 423:280-283

Pimm, S. L.1982. Food Webs. *BookMetrix*. 1:1-11

Strong, D. R. and G. A. Polis. 1996. Food Web Complexity and Community Dynamics, *The American Naturalist* 147

Thomson, K. S. and D. E. Simanek. 2015. Body Form and Locomotion in Sharks, *Integrative and Comparative Biology* 17:343-354