Jellies and Fish: A Bad Sting for Fisheries

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Abstract
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Introduction

Within the last century, human involvement and activity has increased in marine environments. This has led to an increase in negative effects in marine systems, such as overfishing, habitat alteration, climate change and invasive species introductions (Tomlinson et al. 2018). These effects can have cascading impacts on marine food webs, especially in ecosystems where the interactions between different trophic levels helps maintain a biologically diverse and stable ecosystem (Baum and Worm, 2009). In ecosystems where these effects have occurred, diversity and stability can be threatened by certain species that thrive in the absence of others, such as jellyfish. The existence of jellyfish in marine ecosystems is a natural occurrence, with seasonal increases in population number (blooms) observed in many species (Bosch-Belmar et al. 2020). Jellyfish numbers are typically kept in check by a variety of predators including fish, scavengers, and sea turtles (Heaslip et al. 2012; Chiaverano et al. 2018). However, the previously mentioned effects of human activity in the oceans can tip the scales of this natural balance by reducing the abundance of jellyfish predators or creating situations in which they can rapidly proliferate (Richardson et al. 2009).

Frequency and abundance of jellyfish blooms, which can contain hundreds to thousands of individuals, have been observed to be increasing over time in many ecosystems around the world, although there is still uncertainty whether this is a chance occurrence or correlated with human activity (Purcell et al. 2007; Bosch-Belmar et al. 2020). Nevertheless, the implications of increased jellyfish abundance can be striking. Increased concentrations of jellyfish in coastal waters can impact beachgoers and become a real threat to human safety, therefore diminishing the economic gain from beach tourism (Tomlinson et al. 2018). Fisheries can also be affected by jellyfish, either directly or indirectly. Direct effects include being caught in fishing nets, where their tentacles can sting and potentially kill any fishes caught with them, reducing the value of those fish, as well as clogging of fishing gear and increased labor from attempts to remove them

(Baxter et al 2011). Indirect effects include jellyfish preying on fish species targeted by fisheries or jellyfish competing with fishes for the same prey, reducing the number of available fish to catch (Tilves et al. 2018). Interactions between fisheries and tourism mean that these impacts can have devastating effects on marine economic development around the world, and it is imperative that the causes for large jellyfish blooms are understood.

In this paper, I will review the biology and ecology of jellyfish and discuss how the effects of overfishing, habitat alteration, climate change and invasive species introductions can influence their abundance. I will also include recommendations for better management of these activities and jellyfish populations.

Jellyfish Biology and Ecology

Gelatinous predators commonly known as jellyfish belong mainly to the phylum Cnidaria (Purcell, 1997). In the context of this paper, the term jellyfish refers mainly to three classes within Cnidaria, Scyphozoa, Hydrozoa, and Cubozoa, in which members of these classes are free-swimming and use stinging tentacles to catch prey at some point in their life (Katsuki and Greenspan, 2013; Coates, 2003). Combined, there are over a thousand species within these three classes (Purcell et al. 2007). Located along the tentacles of jellyfishes are stinging cells known as cnidocytes that allow them to capture and paralyze prey that contact their tentacles, which they bring up to their oral opening to digest (Katsuki and Greenspan, 2013).

There are two main stages in the life cycle of jellyfish. The polyp stage is a sessile form that attaches to a substrate and reproduces asexually (Katsuki and Greenspan, 2013). The medusa stage is what most jellyfish are identified as and are free-swimming, reproduce sexually, and have tentacles covered in stinging cells (Katsuki and Greenspan, 2013). There are differences between classes, but generally the polyp stage precedes the medusa stage, and in rare cases the medusa can revert back into the polyp in response to harsh environmental conditions (Katsuki and Greenspan, 2013; He et al. 2015).

Almost all jellyfish prey on zooplankton, but some larger species can prey on fish, their eggs, and their larvae (Purcell et al. 2007). Seasonal jellyfish blooms are a result of massively increased abundance of prey such as zooplankton, which themselves are likely a result of increased nutrient availability in the water column (Dong et al. 2010). These life cycle traits combined with a broad diet allow jellyfishes to take advantage of changes in nutrient availability caused by human activities, which lead to blooms of plankton followed by blooms of jellyfish (Oguz, 2005).

Effects of Overfishing

It is estimated that 100 to 120 million tonnes of marine life are removed from the world's oceans every year, and this has caused an increase in size and frequency of jellyfish blooms (Richardson et al. 2009). Zooplankton, as one of the most common food sources for jellyfish, are also preyed upon by a wide variety of fish that act as competition and potential predators to jellyfish (Purcell and Arai, 2001). Thus, removal of these fish reduces competition and predation pressures on jellyfish, allowing them easy access to more food and leading to a rapid increase in numbers. Fishing activities can also have a significant impact on sea turtles, particularly the leatherback sea turtle (Dermochelys coriacea) which includes jellyfish as a major part of its diet (Heaslip et al. 2012). Sea turtles are commonly found trapped and entangled in fishing gear, potentially reducing the survival of these important jellyfish predators (Bugoni et al. 2001). Jellyfish may also be accidentally caught when harvesting large quantities of fish, causing stinging of fishes leading to decreased potential market value (Baxter et al. 2011).

Effects of Habitat Alteration

Human activity resulting in habitat alteration also has implications for increasing jellyfish blooms. Trawling of the ocean floor can not only remove predators of jellyfish, but also provide additional habitat for their polyps to attach to and develop, increasing their number (Richardson et al. 2009). In coastal habitats, disturbance of the ocean floor can displace nutrients from beneath the sand, providing additional food for phytoplankton that ultimately lead to increased jellyfish abundance. Runoff from sewage, factories and farms can also add excess nutrients to coastal waters, further increasing food availability for phytoplankton that are then preyed upon by zooplankton, which are the prey of jellyfish (Purcell et al. 2001). The passive lifestyle displayed by most jellyfish may be more suitable for a disturbed habitat, as they would be less affected by disturbances, and so could provide them an advantage in that aspect over many fishes.

Effects of Climate Change

The most pronounced effects of climate change on marine ecosystems are warming of ocean water and ocean acidification. Warming of ocean water, especially the surface, can lead to stratification within the water column that favours certain types of phytoplankton over others, most notably flagellates (Cushing, 1989). It has been hypothesized that a higher abundance of flagellates would be better for jellyfish to thrive (Richardson et al. 2009). A more direct benefit that jellyfish receive from warmer waters would be enhanced growth and reproduction during their developmental stages, accelerating them towards the problematic medusa stage (Richardson et al. 2009). Ocean acidification as a result of climate change severely affects organisms which are dependent upon calcium carbonate for survival, of which jellyfish have little to none, which could be to

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their benefit (Attrill et al. 2007). However, continued increases in acidity could eventually negatively impact jellyfish, as they do have calcium carbonate structures within their bodies that they use for orientation, but the impacts are unknown (Richardson and Gibbons, 2008).

Effects of Invasive Species Introductions

Invasive species are characterized by their ability to grow and reproduce quickly and outcompete native species for space and resources. This would have less of an impact on jellyfish compared to fishes and other organisms due to the flexibility of their lifestyle. Their stinging tentacles could also deter introduced species from preying on them. More notably, some jellyfish species themselves can act as invasive species as the medusa are easily carried in ballast water of ships while polyps can attach to ship hulls and be transported to new habitats (Graham and Bayha, 2007). The introduction of jellyfish to an ecosystem that has recently lost a dominant species or has no natural jellyfish predators could be devastating and would lead to massive jellyfish blooms. For an important fishery, this could mean millions of dollars lost from reduced catch numbers and costs of managing the jellyfish population.

Controlling Jellyfish Blooms

There is much evidence that suggests human activities have not only been responsible for jellyfish blooms in the past but have actually increased their frequency and quantity within the past few decades. Yet, the solution is much more complicated than it may seem due to the deep interactions between all the existing factors. Overfishing can be managed with a reduction in fishing intensity, but comes at the cost of economic losses, and would only be a temporary fix (Daskalov et al. 2007). Likewise, habitat alteration, climate change and invasive species introductions are not easily solved without drastic overhauls of corporate and governmental management and regulations.

One solution that has been rising in popularity and feasibility is the creation of jellyfish fisheries to harvest and consume jellyfish. It is popular in Asian countries such as Japan, Korea, Thailand and especially China, where it is seen as agourmet food (Omori and Nakano, 2001; Richardson et al. 2009). Harvest of jellyfish for consumption is an incredibly sustainable source of potential food due to their extremely high numbers and relatively quick proliferation time (Omori and Nakano, 2001; Youssef et al. 2019). Jellyfish as a food product is seeing some rise in certain western parts of the world but has still not reached the mainstream yet due to stigma associated with their stings (Youssef et al. 2019). Hopefully, western fisheries can catch on to this idea that would not only provide economic benefits, but also alleviate current issues related to human activity and the global impacts on marine ecosystems.

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