Global Ocean Sprawl:
A Driver of Jellyfish Blooms

Lily Munsill
Life 2.0 Research Paper
Bio401/ Senior Seminar
Wheaton College, Norton, Massachusetts, USA
December 1, 2014

Introduction

The world is on a slimy slope to global jellyfish ecosystem domination. There is no single cause to increasing jellyfish, or Cnidarian, populations, but rather many contributing anthropogenic factors including eutrophication, climate change, ocean acidification, and overfishing. An often-overlooked factor however is global ocean sprawl, or the proliferation of artificial structures in the ocean. Global ocean sprawl is hypothesized to be a driver of jellyfish blooms in coastal systems as it provides valuable habitat for jellyfish polyps, the benthic stage of the jellyfish lifecycle (Duarte et al 2012). The observed increase in jellyfish populations in coastal systems has harmful implications for fisheries and environmental health, causing potentially irreversible ecological phase shifts and trophic cascades (Lyman et al 2006).

Technology: Global Ocean Sprawl

Global ocean sprawl applies to any man-made structure that is in the ocean. Examples of artificial structures in the ocean include docks, pipes, ship bottoms, sunken ships, docks, buoys, offshore wind turbines, harbor infrastructure, seawalls and breakwaters, piers, aquaculture infrastructure, artificial reefs, and oil rigs.

Figure 1: Activities, structures, and industry growth contributing to global ocean sprawl. MT=metric tons, µ=annual growth rate. Other numbers show global occurrence. Areas without numbers show unquantifiable structures (cemented shoreline, breakwaters, recreational boating, buoys and moorings) that account for a large portion of artificial structures in the ocean. Additionally, intentional artificial reefs are listed as being present in at least 34 countries. This figure depicts the largest existing contributors to global ocean sprawl and shows industry growth of marine transport, aquaculture, and offshore wind.
Increasing coastal populations allow for the expansion of coastal industries like shipping and aquaculture, which contributes to the global ocean sprawl of artificial structures. Figure 1 depicts some of the larger contributors to global ocean sprawl. There are more than 14,000 commercial harbors globally and 4100 kilometers of channels and inlets, providing infrastructure for polyp growth, the benthic stage of the jellyfish lifecycle (Duarte et al. 2012). Growing industries like aquaculture, offshore wind energy, and marine transport are also large contributors to polyp growth, growing at rates of 7.5%, 28.3%, and 3.7% per year, respectively (Duarte et al. 2012). Artificial structures have been introduced into the ocean for as long as human civilization, however, global ocean sprawl has not been seen as a problem until recently where the magnitude of artificial structures in the ocean has been observed to impact ecosystems (Duarte et al. 2012).

Biology: Influences on Cnidarian Populations

Cnidarians are some of the world’s oldest and most resilient organisms. Cnidarian populations are influenced by a number of natural and anthropogenic factors including rising sea temperatures, increased ocean acidity, high salinity, eutrophication, overfishing, and natural global oscillations (Condon et al. 2012, Quinones et al. 2013, Purcell 2012, Haroldsson et al. 2012, Uye 2011, Lyman et al. 2010, Richardson et al. 2009).

Without any anthropogenic influence, Cnidarian populations fluctuate cyclically; observed minima and maxima of jellyfish populations supports global jellyfish oscillation cycles with 20 year periods (Condon et al. 2012). Jellyfish abundance also correlates with major physical phenomena, like El Nino and El Nina periods of the El Nino Southern Oscillation cycle; Cnidarian populations increase during the El Nino and El Viejo periods when climate is warmer, but decreases are observed with the cooler La Niña period (Quinones et al. 2013).

Cnidarian populations have been fluctuating as a consequence of anthropogenic influences before the introduction of artificial structures in the ocean became problematic (Brotz et al. 2012). In addition to natural phenomena eutrophication, climate change, and overfishing have been leading contributors to increasing populations (Purcell 2007, Purcell 2012, Haroldsson et al. 2012). Phase shifts in pelagic ecosystems have been related to overfishing and the filling of an absent niche by jellyfish; an alarming figure, 100-120 million tonnes of fish is annually removed from global oceans (Richardson et al. 2009).

The low water clarity, high nutrients, and anoxia in eutrophic regions are all favorable conditions for jellyfish (Purcell 2012). As nonvisual predators, jellyfish can outcompete lower trophic level fish as water clarity decreases with eutrophication (Haroldsson et al. 2012). Jellyfish can survive in very low oxygen environments, up to <1 mg O2 per liter, well below the toxic level for fish, around 2 or 3 mg per liter (Purcell 2012).

Climate change also creates ideal conditions for jellyfish blooms (Purcell 2007). Warming sea temperature has been associated with higher rates of asexual reproduction in some jellyfish like moon jellies, Aurelia labiata, (Purcell 2007) and a scyphozoan species Cotylorhiza tuberculata (Purcell et al. 2012). Some fish species cannot survive the harsher conditions associated with climate change, especially ocean acidification, further enabling jellyfish domination (Purcell et al. 2012). Stronger winds associated with climate change will be beneficial to dispersal of jellyfish populations, aiding in the spread of blooms (Lyman et al. 2010).

Most of these anthropogenic factors influence the pelagic phase of the Cnidarian lifecycle, however, the benthic is often overlooked. Some classes in the phylum Cnidaria, like Scyphozoa, Hydrozoa, and Cubozoa have a benthic stage in their lifecycle where a sessile benthic polyp attaches to a substrate, which produce ephyrae, or juvenile jellyfish medusa (Duarte et al. 2012). Polyps can produce asexually and during each asexual reproductive event, a single polyp can create up to 40 juvenile medusa (Duarte et al. 2012). Benthic polyps can remain attached to a substrate for many years, releasing medusa seasonally or when environmental conditions are optimal for the jellyfish (Duarte et al. 2012). A single polyp can produce hundreds or thousands of medusae, and those medusa can go on to produce thousands or millions of polyps (Duarte et al. 2012). As Cnidarians have characteristics of a fast growing r-selected population, the ability of these polyps to produce many medusa allows for exponential growth of jellyfish populations.

The Hybrid System: Cnidarian Benthic Polyp Growth on Artificial Structures
Artificial structures in the ocean are hypothesized to magnify the intensity of jellyfish blooms (Duarte et al 2012). The proliferation of artificial structures in the ocean has had unintended consequences for jellyfish populations by providing valuable substrate for the benthic Cnidarian polyp to attach and release juvenile medusa, especially in areas with soft benthic sediments that lack natural rock substrates (Duarte et al 2012). The introduction of artificial structures provides a perfect substrate in regions with less then ideal substrates for attachment. The magnitude of space that artificial structures provide polyps is of concern since polyps are only a few millimeters in length for most Cnidarian species, but polyps can be found on artificial structures in densities from 10,000-100,000 individuals per square meter (Duarte et al. 2012). Thus seemingly insignificant artificial substrates, even plastic garbage pollutants like plastic bottles can contribute greatly to blooms since polyps have high-density populations.

Blooming Cnidarian populations have found to be correlated with areas with high occurrences of artificial substrates, and when artificial structures are removed, densities of medusa has declined (Duarte et al. 2012). Artificial structures, especially in harbors, provide shaded surfaces which are preferable to polyp growth, and provide shelter to polyps in areas where high wave energy would otherwise destroy them. The high level of artificial structures in ports in combination with high fishing pressures, eutrophication, increased pollution, and hypoxia creates perfect environments for polyp growth in conjunction with the removal of competing species (Duarte et al. 2012). In this way, artificial structures provide a nursery habitat for blooming Cnidarian populations.

Consequences and Future Predictions

Cnidarian blooms as an unintended consequence of global ocean sprawl have negative impacts on ecosystems, causing ecological phase shifts and shifting towards Cnidarian dominance in the lower trophic level (Lyman et al 2006). Additionally, blooms have economic consequences as they impact tourism, fishing industries, and nuclear power plants (Richardson et al 2009). However, artificial structures also have unintended positive consequences as they provide benthic substrate for many organisms including corals and oysters, providing a productive marine habitat in areas of otherwise poor nutrients and low biodiversity (Duarte et al. 2012).

As a consequence of increasing sea temperature and ocean acidification, in combination with the increasing presence of artificial structures in the ocean, scientists expect to see future increases in occurrence and intensity of Cnidarian blooms (Duarte et al. 2012, Brotz et al. 2012, Richardson et al 2009). Both climate change and the existence of artificial structures in the ocean are likely irreversible, so jellyfish populations may continue to increase globally.

While the expansion of coastal industries can’t be slowed, artificial substrates can be modified with different surfaces that polyps cannot attach to, which would effectively reduce coastal jellyfish blooms (Duarte et al. 2012). In addition, eutrophication induced blooms can be mitigated with better coastal management and run off systems. Furthermore, research can be conducted to reverse existing jellyfish blooms (Gibbons, Richardson 2013).

Global ocean sprawl has unintentionally provided habitat for benthic jellyfish polyps. This new hybrid technology, combined with other favorable factors for jellyfish growth including eutrophication, increasing temperatures, and ocean acidification is causing coastal populations of jellyfish to increase, which consequently causes irreversible ecological phase shifts and trophic cascades.

References


