Ocean and Coastal Management 163 (2018) 364–371

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Assessing the effects of a barrier net on jellyfish and other local fauna at estuarine bathing beaches

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ARTICLE INFO

Keywords:
Bay nettle
Chrysaora chesapeakei
Jellyfish
Barriers
Barnegat Bay

ABSTRACT

On the east coast of the United States increases in the abundance of stinging bay nettle (*Chrysaora chesapeakei*) has negatively impacted recreational use of estuarine waters, particularly for bathing. A net-style barrier was assessed as a means to reduce the potential for adverse human-jellyfish interactions. The presence of a barrier reduced the mean number of bay nettles captured within the exclusion areas by 28%–67% compared to immediately adjacent waters depending on the mesh size of the barrier, with smaller mesh having a greater effect. The mean size of the nettles (bell diameter) captured within the exclusion areas was also significantly smaller than that in the adjacent areas. Fish entanglement in the barrier was limited (< 0.5 fish per set), while crab entanglement varied with site and barrier material. This study shows that a low-cost, durable, temporary barrier can effectively reduce the size and number of jellyfish within a bathing area.

1. Introduction

An apparent recent increase in jellyfish population abundance in coastal waters has received considerable attention worldwide (Condon et al., 2012; Gibbons and Richardson, 2013, Purcell, 2012). While some work has cast doubt on a global increase in gelatinous zooplankton populations (Condon et al., 2012), localized blooms of jellyfish can have adverse ecological and economic impacts (Fenner, 1997; Gershwin et al., 2010, Purcell, 2012). Rapid localized increases in jellyfish populations (or blooms) have had negative impacts on fishing industries (Palmieri et al., 2014; Quiñonesa et al., 2013), desalination and coastal power plants, aquaculture (Bosch-Belmar et al., 2017), and marine biological surveys (Brotz et al., 2012). The impact most likely to affect the public is that of nuisance and lethal jellyfish driving bathers from recreational beaches. The most well documented examples of adverse bather - jellyfish interactions are from the Indo-Pacific region (Fenner et al., 2010; Purcell, 2012) and the Mediterranean Sea (De Donno et al., 2014; Ghermandi et al., 2015), although the presence of nuisance jellyfish at public bathing beaches has been reported globally for more than 50 years (Fenner et al., 1996).

Managers have used a variety of approaches to protect the local communities they serve (Gershwin et al., 2010). Organizations such as the Whitsunday Marine Stinger Management Committee of Australia have been established with the goal of providing practical advice to the public on avoiding encountering harmful jellyfish species and treatment of their stings. Personal protective gear such as "stinger suits" made from Lycra or other materials are worn by bathers along the Australian coast to prevent contact with the tentacles of the potentially lethal Irukandji box jellyfish (Gershwin and Dabinett, 2009). In the last few years (2014–2015) Spain, Italy, Malta, and Tunisia began an exploratory program of placing barrier nets within the Mediterranean Sea to reduce human-jellyfish interactions as part of the MED-JELLYRISK program (http://jellyrisk.eu, Piraino et al., 2016). Australia, Monaco, and coastal communities along the eastern coast of the United States have also used barrier nets surrounding swimming areas as an effective way of reducing the amount of jellyfish found in public bathing areas (Schultz and Cargo, 1969; Fenner et al., 1996). In more recent years, a variety of private companies have brought a number of products to market (anti-jellyfish barrier nets, creams, and clothing) for use by municipalities and the public (BoomSwim, 2018; EcoBarrier, 2018; Mavideniz, 2018; Ribola Retificio, 2018).

Along the east coast of the United States apparent increases in the abundance and range of bay nettle (*Chrysaora chesapeakei)* has been of interest to scientists and the public (Cargo and Schultz, 1966; Decker et al., 2007). Recent publications suggest that local or regional proliferation of jellyfish populations may be an effect of anthropogenic activities, including overfishing, eutrophication, pollution, and an increase in hard substrates on which the planula life stage can settle

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https://doi.org/10.1016/j.ocecoaman.2018.07.012
Received 3 October 2017; Received in revised form 8 June 2018; Accepted 12 July 2018
0964-5691/

(Parsons and Lalli, 2003; Purcell, 2012). These drivers also likely influence bay nettle populations, which reside predominately in estuarine systems, where human influences are exacerbated due to increasing population pressures (Baird and Ulanowicz, 1989, Condon et al., 2001, Purcell et al., 1999). While bay nettles have been evident before the 1960s in the Chesapeake Bay (Cargo and Schultz, 1966), their abundance has only become a concern within the past two decades in the Barnegat Bay, an estuarine system in New Jersey.

Like many other estuaries worldwide, the Barnegat Bay has been subject to increased human population over the past few decades, leading to changes in land use throughout the watershed, decreased freshwater input, and increased nutrient loads (Barnegat Bay Partnership, 2011), contributing to the bay's classification as highly eutrophic (Kennish et al., 2007). These factors contribute to an ideal long-term habitat for the bay nettle, which can outcompete many other taxa, including competitors and predators, in highly eutrophic systems (Breitburg et al., 1994; Gibbons and Richardson, 2013). Coincident with human induced changes to the ecosystem, reports of bay nettles "invading" the Barnegat Bay have been rising throughout the past decade (Intrabartola, 2013). Barnegat Bay related activities contribute an estimated $4 billion to the local economy each year (Kauffman and Cruz-Ortiz, 2012), so negative public reaction to an increase in jellyfish, perceived or real, has the potential to adversely affect the regional economic well-being (Baumann and Schernewski, 2012). Thus it is crucial for coastal managers to focus on understanding the implications of blooms and how to manage them (Gibbons and Richardson, 2013).

Using jellyfish net barriers historically deployed in the Chesapeake Bay (Schultz and Cargo, 1969) as a model, the Barnegat Bay Partnership (BBP) undertook an assessment of the efficacy of net barriers to restrict the movement of bay nettles (*C. chesapeakei*) into bathing areas. Cegolon et al. (2013) have shown that an increase in jellyfishes' bell diameters typically leads to increasing tentacle lengths, which increases the potential number of nematocysts that can be discharged, and therefore a higher proportion of envenomation (but see Kitatani et al. (2015) for a discussion of the differences in pain perception between the sting of different jellyfish species). The project was thusly designed to limit larger jellyfish from bathing areas. We anticipated that the barriers would also reduce the total number of bay nettles within the exclusion area as compared to the immediately adjacent waters, and that a reduction in the mesh size of the barriers would lead to additional decreases in bay nettle size and abundance. The impact of the barrier on other local fauna was also assessed to determine if the barriers would function as *de facto* fishing gear and lead to substantial mortality of fishes and crabs.

2. Materials and methods

2.1. Study area

The Barnegat Bay-Little Egg Harbor system is a shallow lagoonal estuary located along the Atlantic coast of New Jersey, USA. The bay has a surface area of approximately 294 km^2, and can be divided into northern (Barnegat Bay), central (Manahawkin Bay), and southern (Little Egg Harbor) segments based on hydrologic similarities (Kennish, 2001). The bay has limited exchange with the ocean, and as such residence time of the water in the bay varies based on bay segment, with the northern area having the longest residence times (Defne and Ganju, 2014). Salinity increases along a north to south gradient within the estuary, with a mean of approximately 22–25 ppt (Kennish, 2001). The project sites, Windward Beach in Brick Township and Brooklyn Avenue Beach in Lavallette Borough, are both located in the northern portion of Barnegat Bay (Fig. 1). Both sites are located within heavily developed portions of the bay, but differ in respect to their hydrologic siting and substrate. Windward Beach (WB) is on the north shore of the tidal portion of the Metedeconk River, a fifth order river that enters along the bay's western side. The substrate in this area is primarily a mucky fine sandy loam to mucky silt loam with areas of sand (Natural Resource Conservation Service, 2012). Brooklyn Avenue Beach (BAB) is on the eastern side of Barnegat Bay, along the bayside of a barrier island where the substrate is sandy (Natural Resource Conservation Service, 2012) with patches of eelgrass (*Zostera marina*). The bathymetry at both beaches is similar: at 20 m from shore, the water was generally between 0.7 and 1.0 m in depth. The tidal range in the northern portion of the Barnegat Bay is approximately 15 cm (Kennish, 2001).

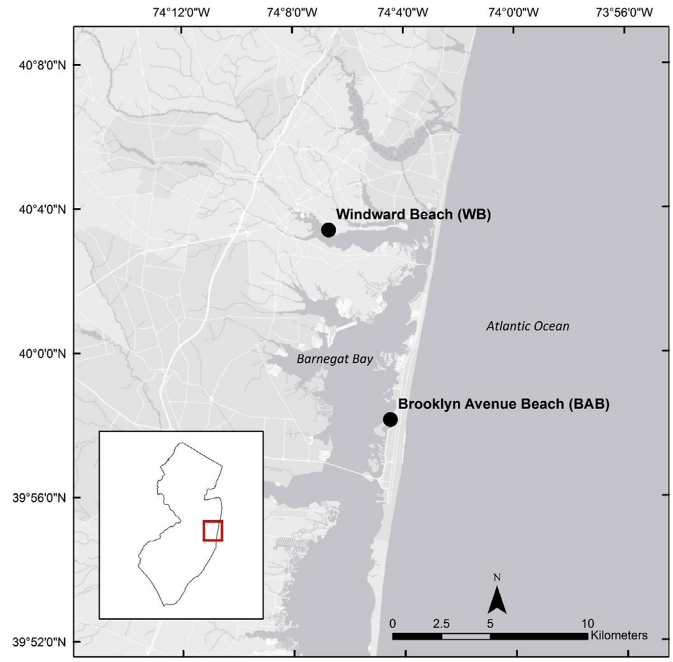

Fig. 1. Location of the jellyfish barriers deployed in Barnegat Bay, New Jersey. Deployment sites are denoted by filled circles. The inset shows the site locations (rectangle) with respect to New Jersey.

2.2. Methodology

Bay nettle barriers were deployed two days per week at each location from June through August of 2011 and 2012 from approximately 0930 to 1430 h each day. Barriers were not deployed when conditions were considered unsafe for bathing by the local lifeguards (thunderstorms occurring or highly likely, bacterial closures). The ends of the barrier were secured on the beach using fluke anchors secured directly to the net ends while two 33-cm diameter buoys secured by polypropylene lines to 7 kg mushroom-style anchors approximately 30 m perpendicular to the shoreline served as in-water attachment points, forming the barrier into a trapezoidal shape (Fig. 2). In 2013, at BAB, the buoys were replaced with PVC poles that were jetted into the sand. A 0.3 m polypropylene line was tied to each buoy/pole and a net snap attached to the free end. The net snap was then clipped to the float line of the barrier net to secure the barrier in place.

The same type of barrier was deployed in both years, although the material of the net itself varied within year (2011) and between years. In June 2011 the initial barriers were constructed of 137 m of 0.52-mm diameter multifilament gillnet with 38-mm square mesh (76-mm stretched) 1.8 m deep. Due to the need to patch the barriers between deployments as a result of damage from blue crab (*Callinectes sapidus*) entanglements the original nets were replaced for two deployments in 2011 by 1.473-mm dipped nylon seine material, also 38-mm square mesh and 1.8 m deep. In 2012 the barrier nets consisted of 115 m of 1.295-mm multifilament nylon with 25-mm square (51-mm stretch) mesh 1.8 m deep. All nets were "rigged for coastal waters", which entailed replacing the polypropylene sinking line with leadcore line (23-