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# Jellyfish outbreak impacts on recreation in the Mediterranean Sea: welfare estimates from a socioeconomic pilot survey in Israel

Andrea Ghermandi [a,*], Bella Galil [b], John Gowdy [c], Paulo A.L.D. Nunes [d]

[a] University of Haifa, Department of Natural Resources and Environmental Management, Mount Carmel, Haifa 3498838, Israel
[b] National Institute of Oceanography, Israel Oceanographic & Limnological Research, POB 8030, Haifa 31080, Israel
[c] Economics Department, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180, USA
[d] Ecosystem Services Economics Unit Division of Environmental Policy Implementation (DEPI)UNEP – United Nations Environment Programme P.O. Box 30522, 00100 Nairobi, Kenya

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ABSTRACT

Jellyfish outbreaks in the Mediterranean Sea are part of an anthropogenic alteration of the marine ecosystem and have been documented as health hazards and threats to tourism. Their impacts on human welfare have, however, been poorly quantified. A socioeconomic survey, carried out in summer 2013, captures the impacts of an outbreak of *Rhopilema nomadica* on seaside recreation in Israel. Welfare losses are estimated based on per-visit value and expected change in visits patterns. We estimate that an outbreak reduces the number of seaside visits by 3–10.5%, with an annual monetary loss of €1.8–6.2 million. An additional 41% of the respondents state that their recreational activities on the beach are affected by the outbreak. Through a contingent valuation, we find that 56% of the respondents state a willingness to contribute to a national environmental protection program with an estimated annual benefit of €14.8 million. These figures signal an opportunity to invest in public information systems. A pilot study for adaptation was conducted in Barcelona, whose results confirm the importance of the welfare benefits of real-time public information systems. This study provides a benchmark against which the economic impacts of jellyfish outbreaks on coastal recreation and potential adaptation policies can be evaluated.



## 1. Introduction: marine biodiversity in the Anthropocene

Recent human impacts are so pervasive and prevalent that the era since the industrial revolution began has been dubbed Anthropocene – the age of humans (Steffen et al., 2011). Human activity so dominates basic biophysical processes that it is influencing the course of evolution (Barnosky et al., 2012; Steffen et al., 2007; Vitousek et al., 1997). One of the most critical effects of human activity is the loss of biological diversity and the disruption of ecosystems worldwide. Biodiversity loss may arise from a number of causes, from overharvesting species to the unforeseen consequences of human activity on complex biological systems. Biodiversity losses due to invasive alien species, nitrogen pollution, ocean acidification and climate change appear to be increasing (Butchart et al., 2010). It is impossible to determine just how many species have been lost so far, or the extent to which current losses exceed the background extinction rate, but it seems clear that we may be pushing the biosphere toward catastrophic changes seen only a few times in the history of complex life on earth (Barnosky et al., 2011).

Of particular concern is the worldwide human impact on marine ecosystems. There is evidence that many ocean fisheries are reaching a critical point in terms of their ability to continue to support current levels of commercial fishing. The extent of human impact on the world's oceans is difficult to gauge because reliable data has only been collected in recent decades. Jackson et al. (2001), using a variety of anthropological, historical, and anecdotal data on ocean fisheries, conclude that "Historical abundances of large consumer species were fantastically large in comparison with recent observations." Worm et al. (2006) conclude that marine biodiversity loss is negatively impacting the ocean's capacity to provide critical ecosystem services such as food, water quality, and resistance to perturbations. A study published in 2005 estimated that the biomass of the ocean's large predators has declined by about 90% in recent decades (Myers and Worm, 2005). Extracting rents from common property or lightly regulated fishery resources has resulted in the economic "feeding down the food chain" with serious negative consequences for the ocean's ecosystems (Infante, 2013; Pauly et al., 1998).

The key human impact on the oceans is overfishing (Jackson et al., 2001). The effects of removing all or most members of a key species are synergistic. As Pauly et al. (1998) argue, fishing down

* Corresponding author. Tel.: +972 4 828 8542; fax: +972 4 824 9971.
*E-mail address:* aghermand@univ.haifa.ac.il (A. Ghermandi).

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food webs from large high trophic fish to fish at lower trophic levels is not only disruptive to ecosystems, it is commercially unsustainable. It first leads to increasing catches, then to stagnating or declining catches (see also CIESM, 2000). Related to this is the disruptive population growth of species that were present in a particular ecosystem but formerly lived in balance with others. The documented instances of sudden changes in population abundance of native and alien species could be part of a profound anthropogenic alteration of the marine ecosystem through habitat destruction, pollution, overfishing and rising seawater temperature.

In this context, this article proposes a socioeconomic analysis of jellyfish outbreaks with a particular focus on the Mediterranean Sea. The recurrent massive jellyfish outbreaks have been amply documented as health hazards and constitute a significant threat to the economies of the Mediterranean countries, where international tourism brings 215 billion € a year in export earnings (WTO, 2012). The article is organized as follows. Section 2 presents and describes the impact of jellyfish on the Mediterranean Sea. Section 3 examines the economic effects of these impacts. Section 4 looks at the economic impact of jellyfish on beach recreation in Israel and Section 5 presents the economic valuation estimates obtained in a pilot survey in the summer of 2013. Section 6 discusses the potential for adaptation by means of a real-time jellyfish outbreak information system and its application to Barcelona. Section 7 concludes.

## 2. The jellyfish invasion

Studies conducted in the Mediterranean Sea over the past three decades indicate both the increasing frequency and extent of blooms of native jellyfish and the influx of non-indigenous scyphozoans and ctenophorans (Brotz and Pauly, 2012, Boero, 2013, Galil and Goren, 2013). Periodic increases of indigenous jellyfish outbreaks have long been noted in the Mediterranean Sea: a bloom of *Pelagia noctiluca* lasted a decade (1976–1986) (UNEP, 1991; CIESM, 2001). Studies of the phenomenon identified various anthropogenic perturbations – eutrophication, overfishing, global warming, and the increase of man-made marine hard substrates – that may have contributed to the proliferation of jellyfish populations in recent decades (CIESM, 2001; Boero, 2013; Canepa et al., 2014). Jellyfish are both predators and competitors of fish, and outbreaks are often accompanied by a decline in fishery resources. Modeling suggests that the increased competition for zooplankton during a jellyfish outbreak may lead to negative impacts upon small pelagic fish and their predators, and result in disruption of the pelagic trophic pathway and a reduction in pelagic fishery resources (Jiang et al., 2008). Boero et al. (2008) proposed that the removal of top predators and the formation of oligotrophic temperature-stable water masses may cause the suppression of the high energy fish and mammal-dominated food web and the re-emergence of a medusozoan-dominated food web.

Whatever the cause, the recurrent massive jellyfish outbreaks appearing along the shores of the Mediterranean have been amply documented as causing health hazards and costly damages to tourism (Canepa et al., 2014, De Donno et al., 2014). In 2006, 21,000 people were stung by *Pelagia noctiluca* on the beaches of Catalonia, 11,571 of which were attended by health authorities in Valencia; on a single day in August, 400 bathers were treated at a beach in Malaga (The Daily Telegraph, 2006). Some of Spain's most popular holiday destinations have been affected including the Costa del Sol, Costa Blanca and the Balearic Islands. The warm, salty lagoons near the fashionable Murcian resort of La Manga, Mar Menor, became so infested with *Cortylorhiza tuberculata*, that a thousand tonnes had to be carted away. In the summer of 2007, The Associated Press reported that at least 30,000 people had been stung by jellyfish off the coast of Spain. The Sunday Times (2007) reported that from the Costa del Sol to the French Riviera, an infestation of jellyfish forced seaside resorts to set up defenses and repel the invaders to protect the tourism industry. Spain has launched a national "jellyfish plan" to tackle the menace. The numbers of lifeguards and first-aid staff have been increased, and leaflets created to warn tourists of the danger. The Environmental Ministry organized a network of fishermen and pleasure craft operators to inform the coastguard of jellyfish sightings as well as using a spotter plane and satellite images. More than a dozen boats, which are normally used for scooping up rubbish at sea, were deployed to suck jellyfish into their holds. The city of Cannes on the Côte d'Azur, shoveled over 11 million tons of jellyfish off its beaches and invested nearly $50,000 in floaters and netting to create jellyfish-free zones the size of Olympic swimming pools at two of its most popular beaches (Travelmole, 2006, Time 2008, The Sunday Times, 2008). Fearful of the effect on the tourist trade, Monaco too installed booms and nets on several beaches. Marine biologists reject the use of fixed nets or barriers around swimming areas since the waves could amputate the tentacles of an ensnared jellyfish and carry the venom-filled extremities toward swimmers. Stray tentacles and even dead jellyfish can still be dangerous. In Antibes, a 30-feet catamaran, which has been described as a "jellyfish hoover," patrolled the coastline, ready to suck up any jellyfish. Prodded by Spain's tourism industry, environmental authorities now support major anti-jellyfish measures, ranging from year-round monitoring to jellyfish hunting boats. Nevertheless, the Spanish Environmental Minister Cristina Narbona admitted in 2008 that even with preventive measures in place "we cannot guarantee in any way the complete absence of these organisms in bathing areas" (The Independent, 2008c). In July 2012, outbreaks of *Pelagia noctiluca* washed ashore at popular resorts along Spain's Costa del Sol, causing the closure of beaches with the summer tourist season under way. More than a thousand bathers sought treatment along the Malaga coast over a weekend and beaches were red-flagged – prohibiting swimmers from entering the water (The Daily Telegraph, 2012).

Whereas most recurrent jellyfish outbreaks in the western and central Mediterranean are made up of indigenous species, alien species have taken over in the east. The southeast Levant is unique in hosting four alien scyphozoan jellyfish and two combjellies (Galil and Goren, 2013). In Israel, jellyfish made their first recorded appearance in 1935 and, since 1986, their outbreaks have become a regular occurrence during the summer months, when the use of beaches by bathers, surfers and other recreationists is highest (Lotan et al., 1994). Typically, jellyfish appear between the months of May and August, peaking in July when they tend to fill all of Israel's Mediterranean shores. The Erythraean *Rhopilema nomadica*, first recorded in the Mediterranean in the early 1970s, is notorious for the huge outbreaks it has formed each summer since the early 1980s along the southeast Levantine coast (Galil et al., 1990). *Rhopilema* outbreaks adversely affect tourism, fisheries and coastal installations. Each year the outbreaks result in envenomation victims suffering burning sensation, erythema, papulovesicular- and urticaria-like eruptions that may last weeks or even months after the event (Benmeir et al., 1990; Silfen et al., 2003; Yoffe and Baruchin, 2004; Sendovski et al., 2005). Following such outbreaks, local municipalities in Israel reported a decrease in holidaymakers frequenting the beaches because of public concern over the painful stings inflicted by the jellyfish (Galil, 2012, Avian et al., 1995, Kokeli et al., 1995). Although no nationwide database of jellyfish stings is kept, Benmeir et al. (1990) report to have treated, as early as in the summer of 1987, 30 patients who suffered from jellyfish injury at the emergency ward of Soroka Medical Center, in Beer Sheva. Looking at the entire Mediterranean shores, Coastal trawling and purse-seine fishing are disrupted for the duration of the outbreak due to net clogging and the inability to sort yield (S. Azoulay, pers. comm. in IUCN, 2013). Jellyfish-blocked water intake pipes pose a threat to desalination plants, cooling systems of port-bound vessels and coastal power plants. In the summer of 2011, Israel Electric Corporation removed loads of jellyfish from its seawater intake pipes at its largest power