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IMPACTS OF JELLYFISH: GELATINOUS PROBLEMS OR OPPORTUNITIES?

Impactos de águas-vivas: problemas ou oportunidades gelatinosas?

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ABSTRACT

Some points related to the impacts (either negative or positive) caused by jellyfish (scyphomedusae) are briefly presented. Although medusae cause several negative impacts, they also have a positive side. It is argued that jellyfish blooms are becoming more frequent in areas where anthropogenic impacts are higher. Human perceptions of jellyfish need more study to better understand the role of these animals in the environment. Only then we will be able to decide if they are "good" or "bad".

Keywords: medusa, gelatinous zooplankton, Scyphozoa, marine zoology, marine impacts, climate change.

RESUMO

Neste ensaio são apresentados brevemente os impactos (positivos ou negativos) causados por águas-vivas (cifomedusas). Embora as medusas causem diversos impactos negativos, elas também possuem um lado positivo. Argumenta-se que as explosões populacionais de águas-vivas (em inglês blooms) estão se tornando cada vez mais frequentes em áreas onde os impactos antropogênicos são maiores. A percepção humana sobre as medusas ainda precisa de mais estudos para se entender melhor o papel desses animais no ambiente. Apenas após isso é que poderemos decidir se elas são boas ou ruins.

Palavras-chave: *água-viva, plâncton gelatinoso, Scyphozoa, zoologia marinha, impacto marinho, mudanças climáticas.*

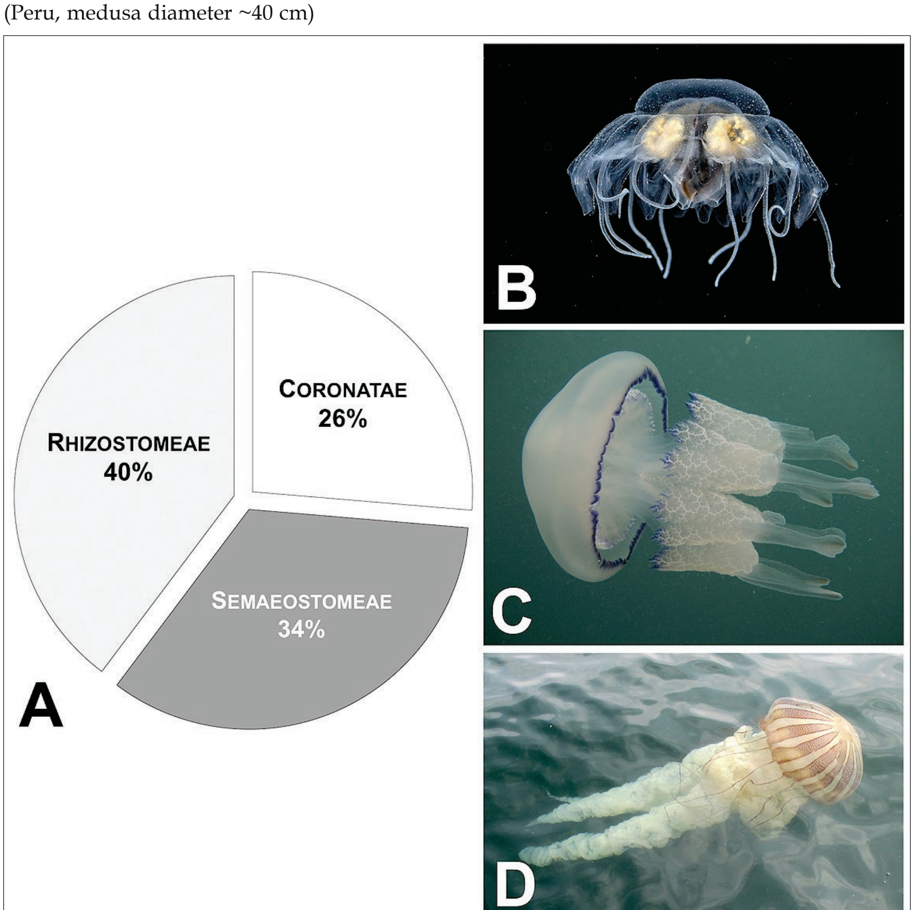
What are jellyfish?

"Jellyfish" is a general term, mostly applied to pelagic cnidarians; there are additional, somewhat similar terms such as "gelatinous zooplankton" or "Gelata" (Braconnot & Carré, 1989; Haddock, 2004). The jellyfishes (the form of the plural for the taxa) are composed of several groups: Nemertea, Radiolaria, Urochordata, Nudibranchia, Chaetognatha, Polychaeta, Ctenophora, and the cnidarians Hydrozoa, Siphonophora, and Scyphozoa (Haddock, 2004).

The main thoughts discussed in this essay refer to the group called scyphomedusae (class Scyphozoa, phylum Cnidaria), commonly known as true jellyfish or macromedusae (generally animals larger than 5 cm in diameter). The views presented here represent the author's personal opinion.

The diversity of scyphozoans is stated as 224 valid species (according to Jarms & Morandini, 2019a; Collins *et al.*, 2021), although more species may not yet have been described (Gómez-Daglio & Dawson, 2017). Among the 224 species, 40% are rhizostomes, 34% semaeostomes, and 26% coronates (Figure 1), which are the main traditional groups of Scyphozoa.

Figure 1 – Diversity of groups of Scyphozoa. **A** – proportion of species number (Coronatae = 59 spp.; Rhizostomeae = 89 spp.; Semaeostomeae = 76 spp.). **B** – *Paraphyllina intermedia* Maas, 1903 a member of the order Coronatae (photo by S.G. Tuason, Philippines, medusa diameter ~13 mm). **C** – *Rhizostoma pulmo* (Macri, 1778) a member of the order Rhizostomeae (Slovenia, medusa diameter ~15 cm). **D** – *Chrysaora plocamia* (Lesson, 1830) a member of the order Semaeostomeae (Peru, medusa diameter ~40 cm)



For most people, the word "jellyfish" brings to mind the cartoon character SpongeBob SquarePants[1] and his eagerness to capture jellyfish. Other people remember the mythological figure of the Medusa, a monstrous gorgon that turns people into stone (Deacy *et al.*, 2016). The artistic aspects of these animals may also come to mind (Connor & Deans, 2002; Goy, 2002). However, many people have strong childhood memories of the gelatinous blobs stranded along beach lines (Figure 2).

Jellyfish are members of the phylum Cnidaria, which comprise animals known as corals, anemones, box jellyfish, and so on (*e.g.*, Morandini; Custódio & Marques, 2016). All representatives of cnidarians share a unique feature among metazoans, stinging cells that contain cnidae (Figure 3) (Watson & Wood, 1988; Morandini; Custódio & Marques, 2016). Cnidae are intracellular structures, most of which have a harpoon-like tubule that can inject venom and ultimately cause stings.

Figure 2 – Scyphozoan jellyfish stranded on beaches. **A** – *Lychnorhiza lucerna* Haeckel, 1880, stranded in Guarujá, São Paulo state, SE Brazil. **B** – *Chrysaora lactea* Eschscholtz, 1829, stranded on La Paloma beach, Uruguay (photo by S.N. Stampar)

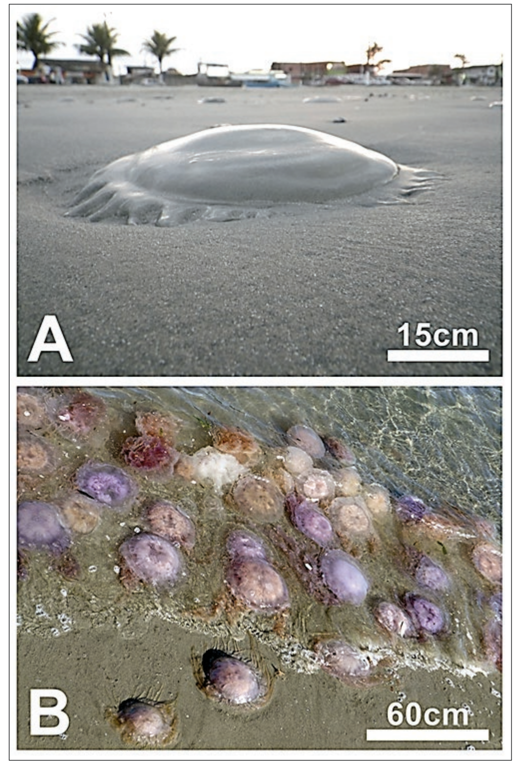
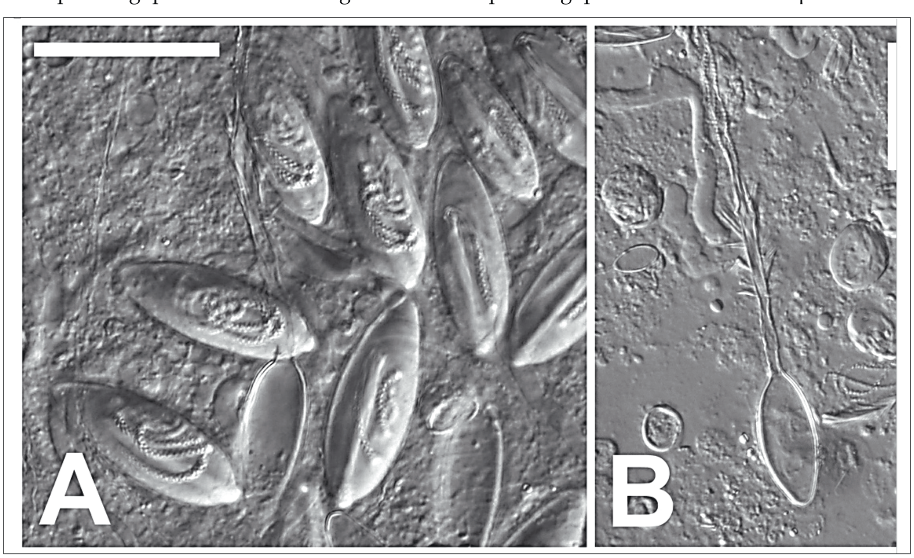


Figure 3 – Tentacle nematocysts (a type of cnida) from the box jellyfish *Tamoya haplonema* Müller, 1859, from a specimen collected in Cananéia, São Paulo state, SE Brazil. **A** – Undischarged microbasic p-mastigophores. **B** – Discharged microbasic p-mastigophore. Scale bars = 40 μm



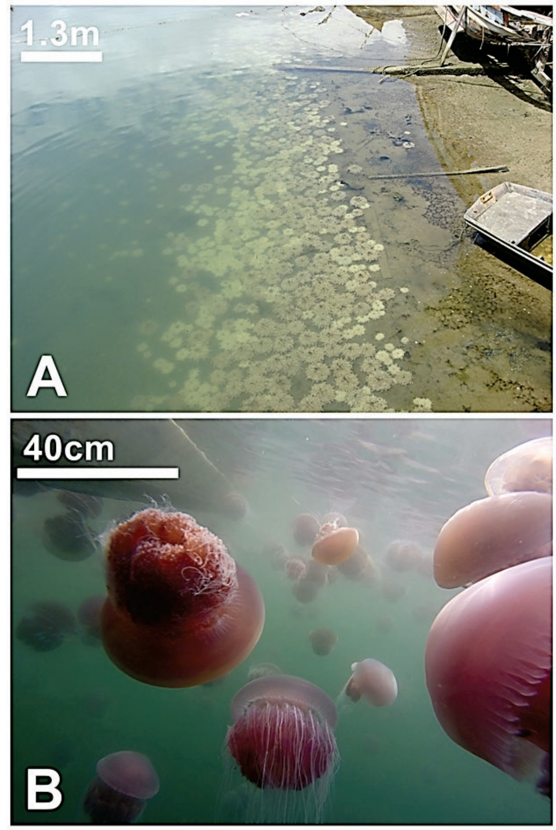
[1] SpongeBob SquarePants is a trademark of Nickelodeon, created by Stephen Hillenburg.

Impacts of jellyfish

Now that we know a little bit about jellyfish, we can focus on the impacts of these animals.

One important fact to keep in mind is that jellyfish form large aggregations, commonly called jellyfish blooms or jellyfish outbreaks (CIESM, 2001) (Figure 4).

Figure 4 – Blooms/outbreaks of scyphozoan jellyfish. **A** – *Cassiopea andromeda* (Forskal, 1775) in Cabo Frio, Rio de Janeiro state, SE Brazil (photo by E.C. Morandini). **B** – *Crambione mastigophora* Maas, 1903 in the Philippines (photo by G. Petines)



These phenomena have been widely discussed in the scientific literature, by defining their coverage (Miranda; Morandini & Marques, 2012), the physical factors that favor them (Graham; Pagès & Hamner, 2001), the causes and consequences (Richardson *et al*., 2009), impacts on humans (Purcell; Uye & Lo, 2007), and management approaches and ways to deal with the issue (Gibbons & Richardson, 2013; Prieto, 2018). In essence, jellyfish blooms are episodic and seasonal, but mostly unexpected (Graham; Pagès & Hamner, 2001). Although jellyfish blooms have recently received widespread attention in the general media (*e.g.*, Mianzan *et al*., 2005; Gershwin, 2013), they have occurred since Cambrian times (Hagadorn; Dott & Damrow, 2002).

A key point when considering the impacts of jellyfish is to determine if the numbers are really increasing, or not (Mills, 2001; Condon *et al*., 2012, 2013). A thoughtful and provoking study suggested that the blooms are a human perception, in some cases unsubstantiated, and with inconsistent data that lead us to perceive a tendency to increase (Condon *et al*., 2012). A further study stressed that our perception that jellyfish blooms are caused by anthropogenic stressors is not supported by strong and robust data (Pitt *et al*., 2018). Here, the possible causes of jellyfish outbreaks will not be discussed, because they were explored recently by several authors (Purcell; Uye & Lo, 2007; Richardson *et al*., 2009; Purcell, 2012). The general thinking about these animals is summarized as: "*… they're causing major problems around the world, clogging fishing nets and power plants, stinging people and ruining tourism*" (Helm, 2013). This view considers the jellyfish as a nuisance or pest (vaguely, with poor impressions of these marine animals), placing them on the "dark side of the force".

The most important aspect when discussing blooms is to have a good series of historical data. In some places the information available is quite extensive and dates back several decades. However, in other areas around the world, not enough data are available. I tend to favor the argument that in general, jellyfish blooms are becoming more and more frequent, especially in areas where anthropogenic impacts are higher due to overexploitation of resources. But it is clear, based on different studies, that the impacts on the oceans due to climate change (temperature, salinity, acidification) cause environmental imbalance and that jellyfish take advantage of this and increase their reproductive rates. Furthermore, nowadays with cameras and internet connection widespread, more people are paying attention to changes in coastal environments and disseminating what they see, especially large animals such as jellyfish.

Indirect impacts

The impacts of jellyfish can be divided into two lines: indirect and direct impacts. The indirect (non-visual impacts) are usually negative or detrimental. We do not see the animals, but they do influence human activities.

Jellyfish (more specifically scyphomedusae) are large marine predators (Purcell, 1997; Ruzicka *et al*., 2019). There are several studies describing the predation effects of jellyfish on zooplankton (*e.g.*, Purcell, 2003; Hansson *et al*., 2005; Pitt *et al*., 2008; Kanagaraj *et al*., 2011; Nagata & Morandini, 2018; Kuplik & Angel, 2020). Others have examined their impacts on fish populations, either as predators of eggs and larvae (*e.g.*, Purcell, 1985; Fancett & Jenkins, 1988; Shoji, 2008; Gordoa *et al*., 2013; Miyajima-Taga *et al*., 2016; Griffin *et al*., 2019) or as direct competitors (*e.g.*, Suchman *et al*., 2008; Robinson *et al*., 2014; Nagata *et al*., 2015; Schnedler-Meyer; Mariani & Kiørboe, 2016).

Jellyfish aquaculture and processing facilities can also be problematic because of the excess of nutrients emptied into coastal waters and the chemicals used in drying (Brotz, 2016; Gibbons; Boero & Brotz, 2016). In fact, any kind of changes that humans cause in the marine environment (through many different activities) cause eutrophication and imbalances, and in most cases will favor jellyfish because of several reasons. A good example is what happened in Mar Menor (Spain) (see Prieto, 2018, and references therein).

Direct impacts (negative)

The direct impacts (visually apparent) can also be negative or detrimental – causing economic losses – but we clearly see that these animals cause problems for humans. Nevertheless, there are also some positive impacts, which will be discussed below.

We are all aware that an encounter with a jellyfish can cause some unpleasant sensations, aka stings. It is not the size of a jellyfish that results in a severe, mild, or moderate sting, but a multitude of different factors. The severity of a sting depends on diverse factors such as the jellyfish species, the types of nematocysts it possesses (= cnidome) and its venom components, the body area affected, the victim's general health, and also allergic reactions. There are many ways to describe the stings, but in general they cause burning sensations, edema, local pain, and occasionally systemic reactions (Burnett, 1991, 2001; Williamson *et al*., 1996; Haddad Jr., 2016). Some small species, such as the coronate *Linuche unguiculata* (Swartz, 1788) (in Spanish "dedalito", or thimble jellyfish in English), are known to cause sea bather's eruption (*e.g.*, Penner, 1962; Segura-Puertas; Burnett & Heimer de la Cotera, 1999; Rossetto *et al*., 2015). Medium-sized species, such as the pelagiid *Pelagia noctiluca* (Forskal, 1775) (mauve stinger), are feared along Mediterranean beaches because of their nasty stings (*e.g.*, Mariottini; Giacco & Pane, 2008; Canepa *et al*., 2014). Indeed, large-sized species, such as the lion's mane *Cyanea capillata* (Linnaeus, 1758), can inflict severe and painful stings (*e.g.*, Heeger; Möller & Mrowietz, 1992). Additionally, even without a close encounter with a jellyfish, you can be stung, for instance, by the "stinging water" associated with *Cassiopea xamachana* Bigelow, 1892 (upside-down jellyfish) in calm, warmer waters (Ames *et al*., 2020).

The presence of many jellyfish in an area will reduce tourist visits because of the potential for stings, and in some extreme cases the beaches may be closed. One of the few studies regarding the impact of jellyfish on tourism activities (Ghermandi *et al*., 2015) estimated the reduction in beach visits due to jellyfish as 3-10%, with financial losses ranging from1.8-6.2 million Euros annually.

An additional negative impact of jellyfish blooms is shutdowns of power plants. Depending on the number and size of the jellyfish species, they can clog the cooling-water intake system, and the entire plant must be turned off to safely remove the jellyfish corpses and clean the entire pipe system. In some areas this causes enormous problems for local communities, not only due to energy interruption but also to several consequences that cause financial losses (*e.g*., Masilamoni *et al*., 2000; Rothe, 2020).

The impacts of jellyfish on fisheries activities are widely known (*e.g*., Uye, 2008; Nagata; Haddad & Nogueira Jr., 2009; Nastav *et al*., 2013; Palmieri *et al*., 2014; Bosch-Belmar *et al*., 2021). They can impair the quality of fisheries by hurting and killing fish (Clinton *et al*., 2021) and shrimp. They can also clog and occasionally rupture fishing nets on artisanal (Schiariti *et al*., 2008; Nagata; Haddad & Nogueira Jr., 2009) and industrial scales (Schroeder *et al*., 2014).

A two-year study (Oct/2010-Sep/2012) along the SE Brazilian coast (Guarujá county, SW Atlantic Ocean), using artisanal trawlers (10-15 min trawls, 10-20 m depth, ~3,000 m^3 filtered volume/trawl), showed that the abundance of jellyfish – the scyphomedusae *Chrysaora lactea* and *Lychnorhiza lucerna,* and the hydromedusae *Olindias sambaquiensis* Müller, 1861, and *Rhacostoma atlanticum* Agassiz, 1851 – varies depending on the season. The data for wet weight indicate that the jellyfish can reach up to 40% of the total wet weight of a trawl (Figure 5); the scyphomedusae comprise most of this weight because of their larger size.

Direct impacts (positive)

The bright side of the story of jellyfish – at least from the point of view of a marine zoologist – is that these graceful and gentle animals do have a positive side (see also Malej; Kogovsek & Uye, 2014; D'Amico *et al*., 2017).

Jellyfish attract humans due to their beauty and balletic movements. Several aquariums around the world take advantage of these features and use them in their favor. They are masters of jellyfish exhibitions (Figure 6) with gigantic "kreisel" aquaria (cylindrical tanks especially adapted for plankton, that rotate to maintain a gentle laminar flow; Widmer, 2008) and can maintain minute to huge species, from tropical to temperate waters, and even compete to have the largest number of species on display. The result is an amusement for the public and an increasing passion for jellyfish in general (Lange & Tai, 2016). Most of these aquariums have educational programs, and while people enjoy seeing the animals swimming in the tanks, they also learn about these creatures and general concepts of marine biology. The commercial value of jellyfish is increasing because they are now being considered as pets. In several countries, different companies are profiting by selling aquaria and species for keeping at home. Social media is also helping people;

different groups discuss the methods, species, and best food to use while maintaining them at home. This amusement is also reflected in general books (*e.g.*, Tuason, 2016; Iannielo & Mears, 2018) and guides to species of jellyfishes (*e.g.*, Heeger, 1998; Wrobel & Mills, 1998; Minemizu *et al.*, 2015; Jarms & Morandini, 2019a).

Figure 5 – **A** – Seasonal variation of jellyfish wet weight percentage (scyphomedusae + hydromedusae) in relation to the total weight of the trawl. Results from artisanal shrimp trawlers conducted from October/2010 to September/2012 in Guarujá county, SE Brazilian coast (10–15 min trawls, 10–20 m depth). **B** – One of the shrimp trawl net full of *Lychnorhiza lucerna* specimens and other invertebrates

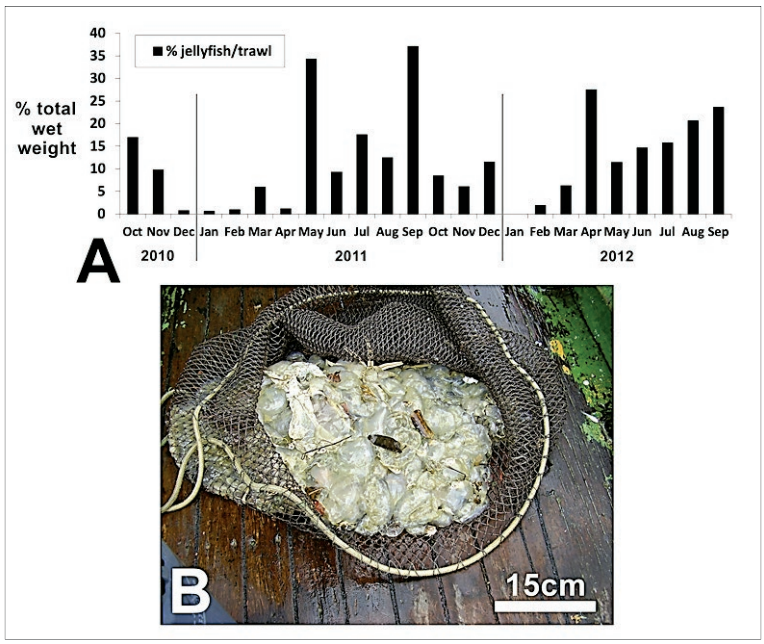
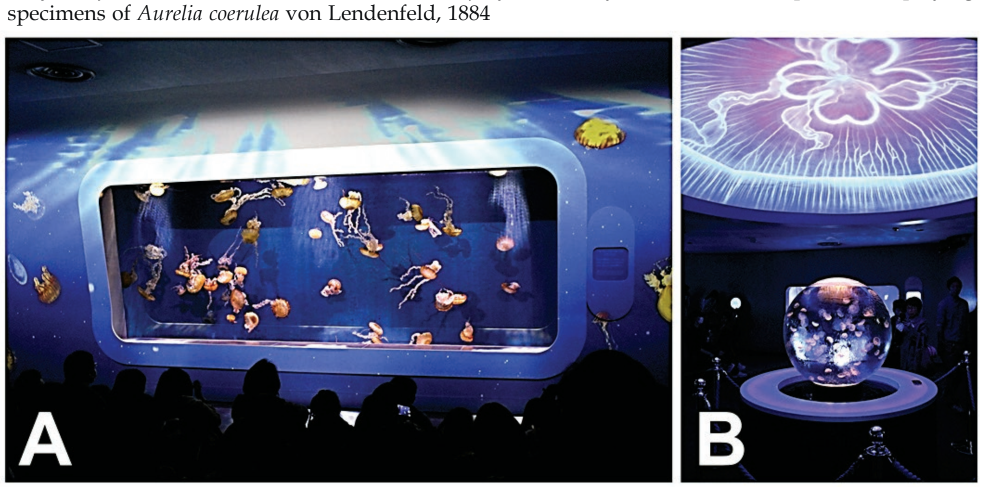


Figure 6 – Aquarium exhibits at Enoshima Japan, 2015. **A** – Large *planktonkreisel* tank with specimens of *Chrysaora fuscescens* Brandt, 1835. **B** – Part of the "jellyfish fantasy hall" with a ball aquarium displaying specimens of *Aurelia coerulea* von Lendenfeld, 1884



Although jellyfish cause some issues for popular tourist areas, they can also be considered an attraction in some places (Dawson; Martin & Penland, 2001). Jellyfish lakes in Palau attract divers and nature enthusiasts to see the daily horizontal migration of the spotted, golden or lagoon jellies *Mastigias papua* (Lesson, 1830) (Hamner & Hauri, 1981).

Likewise, the enormous cosmetic industry is searching for new products more and more. Although jellyfish-derived products have been used traditionally in Chinese medicine (Hsieh & Rudloe, 1994; Hsieh; Leong & Rudloe, 2001; Yang *et al*., 2021), there are no scientific studies proving their efficacy. Jellyfish collagen seems to be quite interesting for both medical/pharmaceutical (*e.g.,* Calejo; Morais & Fernandes, 2009; Mariottini, 2016; Merquiol *et al*., 2019; Prieto *et al*., 2018; Mearns-Spragg *et al*., 2020) and cosmetic purposes (*e.g.,* Leone *et al*., 2015; Kim *et al*., 2016; Trim; Wandrey & Trim, 2021) due to its biocompatibility, non-toxicity, structure and chemical composition, and low antigenicity and immunogenicity. Some hydrating and anti-aging products derived from jellyfish are available in the market.

Besides beauty and medical uses, some jellyfish species are known to produce light (bioluminescence). Most of these are members of Hydrozoa, but some deep-sea scyphomedusae (Herring & Widder, 2004) can also be interesting to study these biochemical properties (Macel *et al*., 2020), which can be used to label genes and specific cell types (*e.g.,* Dhandayuthapani *et al*., 1995).

As is widely known, people in many Asian countries consume jellyfish as food (*e.g.,* Hsieh; Leong & Rudloe, 2001; Kitamura & Omori, 2010) (Figure 7). In some places the medusae are consumed raw, but in general they are eaten following specific techniques to prepare the different parts (Pedersen *et al*., 2017; Jarms & Morandini, 2019b). Interest in eating jellyfish is increasing in Western countries (Hsieh & Rudloe, 1994; Torri *et al*., 2020), either due to the growing Asian populations or from the curiosity of the population in general. In some places, permanent or temporary facilities involve local populations in processing jellyfish tissues for consumption (Brotz, 2016; Behera *et al*., 2020; Asrial *et al*., 2021; Cruz-Colin *et al*., 2021).

If jellyfish are being eaten in many places, someone must provide this “commodity”. Therefore, jellyfish fisheries are directly associated with their use as food. Some studies have reported on the status of jellyfish fisheries on local (Nishikawa *et al*., 2008; Gul; Jahangir & Schiariti, 2015) and wider scales (Omori & Kitamura, 2001; Brotz, 2016; Brotz *et al*., 2017). However, there is a lack of standardized methodology to assess and better understand the jellyfish stocks (Brotz & Pauly, 2017). Jellyfish are an important economic resource in some countries. Estimates of world catches reach almost 1 million

Figure 7 – A diverse array of packaged jellyfish for human consumption. All images taken in a single Japanese market in the Liberdade neighborhood, São Paulo, SE Brazil

tons annually (Brotz, 2016), but these data are hard to compile with certainty. In terms of commodity (= jellyfish), Japan alone imported jellyfish products valued at about 25 million USD yearly from Southeast Asian countries (data from between 1988-1999; Omori & Nakano, 2001), and the global production of edible jellyfish (from 2011-2015) was valued at 20-100 million USD (Duarte *et al*., 2021).

Jellyfish populations meet all the criteria for uncertain fisheries (Kingsford; Pitt & Gillanders, 2000), with wide oscillations in abundance and stocks, both temporally and spatially. In order to maintain reasonable levels, the stock of certain species has been supplemented (Dong *et al*., 2009) by releasing juveniles reared in controlled conditions into the wild. A recent paper nicely summarized an array of methods and aquarium types used for jellyfish husbandry (Duarte *et al*., 2021). The growing market for edible jellyfish products was cleverly exploited by China, which established pond-culture facilities (Dong *et al*., 2009) and also invested in co-cultures with other species (*e.g.*, Li *et al*., 2014).

Jellyfish products can serve additional purposes, such as bait for fish and supplements for other animals (see Duarte *et al*., 2021). They have also been used as fertilizer (see Emadodin *et al*., 2020).

Finally, researchers studying the mucus of these animals have suggested a highly applied use of jellyfish, to remove microplastics from the sea (Patwa *et al*., 2015) – a promising use in view of the uncertain future of the oceans.

"Take-home" message

This essay has presented some brief points related to the impacts (either negative or positive) caused by jellyfish (scyphomedusae). Although medusae cause several negative impacts, they also have a bright positive side. It is important for us humans to change our perception of these gelatinous marine creatures.

The detrimental side for human activities is mostly seen in fisheries, as jellyfish compete with and predate commercially exploited fish species. They also can cause damage to fish and fishing gear. In some areas, large blooms/outbreaks can be problems for power plants. The showiest impact is related to public health (stings) and the consequent effect on tourist activities. Solutions to these problems lie far beyond our comprehension at the moment. A key point highlighted by Gibbons, Boero and Brotz (2016) is that going out to the sea and fishing out all the jellyfish around may not be the best solution.

There is always another side to the story, and jellyfish can be seen as a source of benefits (in a human sense). Jellyfish clearly promote tourism in some places, either by encouraging diving activities or by attracting people to aquarium exhibitions; they can be a source of inspiration for artists and artistic approaches, mostly in the visual arts; there are many benefits from products derived from jellyfish and their number is increasing year by year, for nutraceutical, biomedical, and cosmetic uses; and jellyfish fisheries are enormously profitable, as the consumption of edible species is increasing and spreading in some countries.

We should also consider that jellyfish do have positive ecological roles in the environment (Schiariti *et al*., 2018). They are an ancient lineage of animals and have survived through many changes in our planet, either natural or recently caused by the human species. Therefore, as with several other animal groups, we must support general and detailed biodiversity studies in order to better understand the role of jellyfish in our planetary environment and then, decide if they are good or bad – but my intuition is that we will never find the answer.

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