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Chief editor: **Prof. Shaul Chorev**

Edited and produced by: **Ehud Gonen**

The Effect of the Jellyfish Proliferation – Ramifications on the National Level

Tamar Lotan

Background

Jellyfish developed more than 500 million years ago and the earliest evidence of their existence consists of fossils that have been dated to the Cambrian period. The term jellyfish includes three main groups: the true jellyfish which have a large bell that can be up to 3 meters in diameter in some species; the box jellyfish whose bell is square-shaped and which include the most poisonous species in the world; and the hydra jellyfish which includes thousands of species that live as individuals or in colonies. The jellyfish have a complex life cycle which varies from one species to the next and in general includes a sessile stage attached to the seabed, when it is called a polyp, and a flagellate stage when it swims and is essentially a medusa (Figure 1).

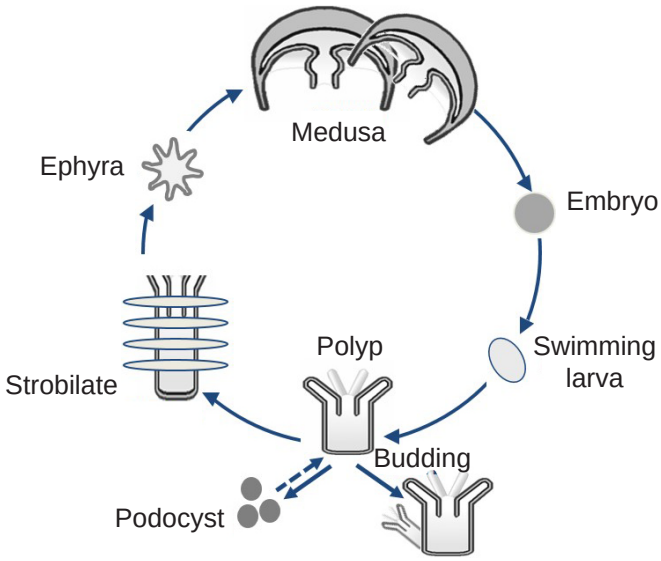

Figure 1: The lifecycle of the medusa. The embryo is created in sexual reproduction by the medusas and develops into a larva that undergoes a metamorphosis to create the polyp. In asexual reproduction additional polyps are created or a strobilate releases ephyra to create medusas

The signal for the creation of the medusas is seasonal and as a result the polyp changes its form and starts to manufacture ephyra, the initial stage in the development of the medusas. The ephyra released from the polyp are a few millimeters in size

and within a short time they develop into medusas, which are what we usually observe in the sea. Depending on the species of jellyfish, the polyp can produce between one and dozens of medusas in a season. The jellyfish carry sex cells and after external fertilization, a larva develops which undergoes metamorphosis into a polyp. The polyp is the permanent stage throughout the year and after the release of the ephyra, the polyp continues to grow and multiply by budding or a lateral process in order to create dozens of additional polyps. In addition, the polyp produces dormant podocysts that can develop back into the polyp stage under the right environmental conditions. Essentially, the lifecycle of the jellyfish is resistant to difficult environmental conditions, such as pollution, saltiness, lack of oxygen or lack of food. These factors are likely to produce years in which there are large blooms and years with small or non-existent blooms. The factors that influence the blooms of the jellyfish are complex and there is currently no general model for predicting blooms. In addition, in recent decades, there have been changes in the global jellyfish map and species that were previously unique to certain areas have now spread to new ones.

The population explosion of the jellyfish is a global phenomenon that is not only causing damage to ecological niches but also economic damage by blocking intake pipes of electricity plants and desalination plants and damage to marine agriculture, fishing and the resort industry, as well as being a threat to the health of vacationers and bathers. Although this kind of damage also occurs in Israel, there is no planning on the national level to prevent possible damage to electricity plants and desalination plants, which draw water from the sea for their operational needs, or the possibility of the arrival of deadly jellyfish to Israel's coast. In this review, I will survey the most vulnerable sectors in Israel and the means that currently exist to deal with the various types of damage.

Jellyfish in the Mediterranean with emphasis on the coast of Israel

There are about 20 species of the Scyphozoa jellyfish in the Mediterranean (Mariottini & Pane 2010), less than half of which can be found off the coast of Israel. Up until the 1980s, the barrel jellyfish (*Rhizostoma pulmo*) was the most commonly observed species found off the coast of Israel. In 1976, the nomad jellyfish (*Rhopilema nomadica*) was first observed (Galil et al. 1990) and about ten years later there began reoccurring seasonal blooms of the nomadic jellyfish along Israel's coast (Figure 2). These blooms were measured to be about $2.1x10^5$ individuals per square kilometer in a total area of about 15 square kilometers (Lotan et al. 1994; Spanier & Galil 1991). Over the years, the jellyfish have spread to the entire Mediterranean,

from Turkey to Tunisia and Malta (Avian et al. 1995; Öztürk & İsinibilir 2010; Deidun et al. 2011; Gülşahin & Tarken 2011; Yahia et al. 2013), an area with a population of about 200 million people. Additional jellyfish that are appearing in large blooms in the Mediterranean (Fuentes et al. 2011) are the pelagia (*Pelagia noctiluca*), the cotylorhiza (*Cotylorhiza tuberculate*) and the aurelia (*Aurelai aurita*). These jellyfish usually first arrive on the coast of Israel as individuals, although in March 2014 a large swarm of pelagia arrived on the southern coast and bathers were stung. A globally invasive species of jellyfish named phyllorihiza arrived from the Western Pacific Ocean to the coast of Israel and at the end of the 2000s adult individuals with reproductive ability were observed. Currently, there are still relatively low numbers of phyllorihiza off the coast of Israel, as opposed to other locations in the world where this type of jellyfish creates huge blooms that damage fishing and a variety of marine species (Boero et al. 2009; Verity et al. 2011; Galil et. al. 2009).

Figure 2: A bloom of nomad jellyfish – a beach in Haifa is covered with jellyfish that have been washed up from the sea

The deaths from jellyfish stings mainly occur in the Indian Ocean on the coasts of Thailand, the Philippines and Australia. The deaths are mainly caused by the box jellyfish found near the equator. One representative (*Carybdes marsupialis*) of the box jellyfish is found in the northwestern Mediterranean, in the region of Spain, but its sting is not lethal. Among the hydra medusa, I would mention here only the

jellyfish known as the Portuguese man o' war (*Physalia physalis*), which constitutes a threat to public health. This jellyfish's locomotion is by wind by means of a gas bladder about 20 centimeters long, which is similar to the sail of the 15th century Portuguese Caravella warship after which it is named. This jellyfish is common along the eastern and western coasts of Spain and from time to time is observed in the Strait of Gibraltar. In 2010, the hydra jellyfish was observed on the coast of Corsica and Italy and there was a report of one death, apparently from a jellyfish sting. Research that has examined the advance of the hydra jellyfish in the Mediterranean in 2010 suggested that its arrival in the Strait of Sicily was the result of unique meteorological and oceanographic conditions and not as the result of a natural expansion of range due to climate change (Peliz & Ruiz 2015).

Power plants and desalination plants

Steam-driven and nuclear power plants and also desalination plants intake seawater in large quantities for their operations and in the process jellyfish are also drawn in. Power plants pump in large quantities of water for cooling and desalination plants pump in large quantities of seawater to create freshwater. The continual pumping from the sea requires constant filtering of the water in order to prevent the intake of animals, plants and waste. The jellyfish blooms and the arrival of swarms on the coast of Japan already in the 1960s have caused the blockage of filtering systems and the closing of a power plant (Purcell et al. 2007).In recent years, dozens of power plants have reported slowdowns in the production of electricity and damage to the their operating systems as the result of pumping in swarms of jellyfish. Furthermore, in various places around the world, such as India, the Philippines, Japan, the US, Sweden and Scotland, the jellyfish proliferation has caused outages of plant operations for various lengths of time (Purcell et al. 2007; Graham et al. 2014; Uye 2014).For example, in 2008 the PG&E company reported the closing for two days of one of two reactors at the Diablo Canyon nuclear power plant, which supplies electricity to about three million people in California (U.S. Nuclear Regulatory Commission Operations Center). In 2011, it was reported that the St. Lucie power plant in Florida was closed for two days and in that same year the Tomess nuclear power plant in Scotland was closed for about a week. In 2013, the Oskarshamn power plant in Sweden, which supplies about 10 percent of the country's electricity consumption, was closed for two days. Israel is defined as an "electricity island" and must produce all of its own electricity without any backup from its neighbors. About 32 percent of Israel's electricity is still produced by coal-fired power plants, which are located along the coast of Israel (Electricity Authority 2017). Each year the power

plants have to evacuate dozens of tons of jellyfish that are caught in their filtering systems (Figure 3), which causes a slowdown in the production of electricity. In 2011, as a result of the arrival of a large swarm of jellyfish, the Orot Rabin power station was forced to close due to the blockage of its pumping system. In addition, the large blooms of nomadic jellyfish arrive in the summer when the temperature of the ocean is relatively high and the cooling pumps must be operated more intensively than in the winter months. Together with the increased demand for electricity in the summer, a slowdown in the coastal power plants' operations is liable to adversely affect the production of electricity.

Figure 3: Jellyfish discharged from the filter of the Orot Rabin power station

Desalinization plants all over the world that pump in water from the sea are forced to deal with jellyfish blooms (Purcell et al. 2007; Peliz & Ruiz 2015). The intake pipe is usually protected by one of a number of systems against the intake of animals or other objects, but these systems do not provide protection against a massive bloom of jellyfish. As a result, the systems become clogged and the desalinization process comes to a halt (Azis et al. 2000; Miller et al. 2015; Ghermandi et al. 2015). In Israel, more than 80 percent of the fresh water for household and industrial consumption is provided by five desalinization plants located along the coast. This trend will only grow in view of global climate change, the drying up of natural sources and population growth. In addition, the use of desalinization plants requires energy which is currently supplied by power plants located along the coast. Thus, the damage from a jellyfish bloom is liable to damage both the production of electricity and that of drinking water.

Fishing and marine agriculture

In recent decades, a connection has been found between overfishing and jellyfish proliferation (Richardson et al. 2009; Uye 2011). In Israel most of the fishing is done from trawlers and although there is damage to certain species of fish, no connection to the proliferation of the nomadic jellyfish has been found (Angel et al. 2016). Essentially, local fishing is on a limited scale and contributes less than 5 percent of the locally consumed fish. Jellyfish proliferation causes large losses to the global fish industry and attempts to limit the damage have primarily involved early warning of a bloom. In Japan, a model was developed based on accumulated knowledge which can produce a warning of blooms. In a joint effort by Japan and China, facilities have been removed from the sea that constitute a platform for the early stages in the lifecycle of jellyfish that arrive in Japan (Uye 2014). Currently, we do not possess the data needed to produce a similar model in Israel and investment is needed in research to understand the proliferation and the oceanographic conditions that facilitate the spread of the nomadic jellyfish. In addition to fishing, jellyfish proliferation causes damage to the fish cages of marine agriculture. A swarm of jellyfish that encounters fish cages on its journey will cause a massive die-off of the fish as result of stings and the blockage of gills (Graham et al. 2014; Purcell et al. 2007; Uye 2014). In Israel, marine agriculture is still in its early stages of development and it is recommended that the location of the cages be carefully planned in order to reduce the damage from jellyfish swarms.

Public health and tourism

Jellyfish constitute a nuisance on beaches all over the world. On the beaches of Florida, hundreds of thousands of bathers are stung, while in Maryland and Virginia, more than half a million bathers are stung every year in Chesapeake Bay. In a survey of lifeguards carried out at 760 beach stations in Spain, it was found that 60 percent of the injuries (a total of 116,000 instances) are caused by jellyfish stings. The survey indicates that the jellyfish in Spain are the main nuisance for bathers (Bordehore et al. 2016). In Thailand, the Philippines, Malaysia and Australia, tourists and natives are killed by deadly jellyfish and dozens of people are hospitalized every year. The prevention and care for jellyfish stings is a global public health problem. Jellyfish have stinging cells that contain a sophisticated microscopic needle structure for the injection of poison into prey and for protection. These needles work under 150 atmospheres of pressure and penetrate the body of their target within microseconds (Beckmann & Özbek 2012; Park et al. 2017). The severity of a jellyfish sting varies

according to the type of jellyfish since the stinging cells of different species contain poisons from different groups (Rachamim et al. 2015). As a result, the means of protection against jellyfish stings varies according to the geographic area and the species of jellyfish found in the sea (Kingsford et al. 2018). In Australia, long stretches of beach are closed to bathers in certain seasons in order to prevent stinging deaths. In addition, thin Lycra suits that cover a bather from head to toe are used on Australian beaches to protect against stings. The level of awareness of the jellyfish danger among residents of Australia Is high as a result of education and public information programs over the years. As a result, the number of deaths from stings is low relative to the Philippines, where many children die every year from jellyfish stings. In the early 2000s, a number of sites were created for the public all over the world with the goal of informing and warning of the presence of jellyfish. A site has also been created in Israel (http:///www.meduzot.co.il) which is based on reports from bathers. In Spain, France and other countries, there is now an app that updates the user on the presence of jellyfish on the beaches (such as http://medjelly.com). In addition, lifeguards in Spain take active part in reporting the presence of jellyfish and also cases of stinging. A purple flag flying on a beach today is an international signal of the presence of jellyfish or other dangerous animals in the water. Recently, this flag has also come into use in Israel on beaches where there is a danger of stinging, but lifeguards are still not part of the reporting and public awareness system. On some of the beaches in Europe, there is use of nets to prevent the penetration of jellyfish, although their effectiveness is not clear. In Spain, on beaches where there is a danger from the Portuguese man o' war jellyfish, the sea is combed and poisonous jellyfish are removed. For personal protection, lycra suits that are used in Australia are now available and there is protective cream against the sun and jellyfish, whose effectiveness in preventing stings has been proven in clinical trials carried out in Israel, the US, Japan and Europe (Kimball et al. 2004; Boulware 2006). The nomadic jellyfish are not deadly, but their sting is very painful and can cause a serious wound and even a systemic reaction in sensitive individuals (Mariottini & Pane 2010; Uri et al. 2005; Friedel et al. 2016; Silfen 2003). Nonetheless, the scope of the problem and the number of people being stung every year is unknown and there is no monitoring of the situation. In addition, and despite the low probability that individual Portuguese man o' war jellyfish will arrive in Israel, lifeguards and the lifeguard organizations should be informed.

The reality of jellyfish on the beaches does not necessarily damage tourism in the long term (Tomlinson et al. 2018). A few studies have been done on the economic damage done by jellyfish to tourism. In Australia, the reality of deadly jellyfish does

not discourage tourism, but a temporary dip in tourism results from a severe sting or death among bathers (Graham et al. 2014). In Israel, the effect of jellyfish on tourism was examined in a survey of about 160 people and its results showed that a reduction of 3-10.5 percent is expected in the number of bathers as a result of a jellyfish bloom (Ghermandi et al. 2015). There is need for further research in order to determine whether the proliferation of jellyfish is a major factor when a tourists decides on his destination.

Conclusion and recommendations

The proliferation of jellyfish in Israel is an annually recurring phenomenon, although its intensity varies. Currently, we do not possess the knowledge to understand, analyze and predict the pattern of a bloom or its intensity. It is recommended that early warning systems for the fishing and recreational sectors according to the European model be created and upgraded. Lifeguards, as well as the maritime police, should report observations of jellyfish on beaches each morning to a center that will report the data to bathers by means of an app. In 2018, the Ministry of Health changed its recommendation for treating a jellyfish sting and it is important to instruct lifeguards in Israel on how to provide first aid for stings and to update the public on the new procedures. There is currently a lack of information on the number of sting cases, the severity of the stings and the side effects, if they exist, of a return sting. It is recommended that an integrated system be created for the gathering of this data, which will include the lifeguards and first aid providers on the beaches. Monitoring the reaction to a sting and understanding the scope of the threat to children and adults will make it possible to provide the most optimal care.

The Ministry of Agriculture and the Planning Authority within the Ministry of Finance are currently in the planning stage for thousands of dunam in the Mediterranean Sea to be used for fish cages and it is recommended that the locations should be chosen so as to avoid the path of jellyfish swarms.

The large swarms of nomadic jellyfish lead each year to the slowdown of operations in the power plants and disrupt the desalinization process. Based on the little data there is, it appears that these disruptions do not at the moment cause serious economic damage. Nonetheless, since Israel is dependent on full production of electricity in its coastal power plants and on desalinization for the production of drinking water, it is recommended that consideration be given on a national level to finding an engineering-biological solution to preventing the intake of jellyfish. The protection of power plants and desalinization plants has strategic importance. The

solution must assume that an increase in magnitude (x10) in the density of jellyfish in the Mediterranean is not impossible. Such a situation is liable to cause major disruptions in the electricity and water sectors of Israel, the Palestinian Authority and Jordan. Israel is known for its ability to find innovative solutions and progress in this area can produce a solution that protects basic systems which are essential to the economy and the welfare of the State. In addition, since the problem of the blockage of intakes systems by jellyfish is global, a solution will also have high commercial value.

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