Altering the Behaviour of the *Catostylus mosaicus* Jellyfish using Electromagnetic Fields

Alberto Ivars[1], Francisco Javier Diaz[1], Lorena Parra[1], Eva S. Fonfría[2], Cesar Bordehore[2,3], Sandra Sendra[1], Jaime Lloret[1*]
[1]Instituto de Investigación para la Gestión Integrada de Zonas Costeras, Universitat Politècnica de València, 46730 Grau de Gandia, Spain
[2] Instituto Multidisciplinar para el Estudio del Medio Ramon Margalef, Universidad de Alicante, 03690 Sant Vicent del Raspeig, Spain
[3] Departamento de Ecología, Universidad de Alicante, 03690 Sant Vicent del Raspeig, Spain

Email: aivapal@epsg.upv.es, fjdiabla@upv.edu.es, loparbo@doctor.upv.es, eva.fonfria@ua.es, cesar.bordehore@ua.es, sansenco@upv.es, jlloret@dcom.upv.es

***Abstract*— Jellyfish bloom implies an economic issue directly affecting tourism, fishing, aquaculture, and oil plants. Although many methods have been used to repel jellyfish arrivals to our coasts, such as nets or water currents, none seems to be a permanent solution. In this paper, we test the effect of applying a medium-frequency Electromagnetic (EM) field on jellyfish behaviour, specifically, their movement. A coil inside a jellyfish aquarium is used to generate the EM field. A current generator powers the coil. As an indicator of jellyfish movement, jellyfish pulsations are counted in the presence or absence of the EM field. Selected jellyfish species (*Catostylus mosaicus*) present two types of colouration, blue and brown. According to the results, blue jellyfish showed different behaviour than brown jellyfish. Blue jellyfish have about 50 pulses without an EM field, decreasing slightly in the presence of an EM field. On the other hand, brown jellyfish pulses about 40 times without an EM field, dropping to values below 20 when the EM field is applied. As suggested by the obtained data, we can propose different systems to prevent jellyfish from getting close to the shore, based on the use of coils to generate EM fields and bottom water current.**

Keywords- Medusozoa; Medium-frequency, Marine animals; Motion, Anti-jellyfish barrier

I. INTRODUCTION

The growing bloom of jellyfish in some areas and other gelatinous organisms can provoke multiple economic problems [1]. Moreover, some jellyfish stings can be cause injuries and even deaths [2]. Regarding the economic impact, we must highlight that the impact of jellyfish blooms in tourist destinations, which could reduce the number of visitors due to the fear of jellyfish stings.Jellyfish also generate problems in other sectors such as fishing, where they clog the nets; aquaculture, in which jellyfish can kill fry; and desalination and refrigeration of different industries (power and oil plants), where they obstruct the pipes [3]. Overfishing, water eutrophication, modification of coastal areas and habitats, and climate change are some factors to which these increasing blooms of jellyfish are attributed [4].

Different systems are currently being developed and used to avoid the interaction between humans and jellyfish. These systems consist of meshes, nets or water currents that prevent the passage of jellyfish to the shore. Nevertheless, these methods are costly, and data obtained in different tests do not confirm their effectiveness [5]. It has been shown that with a 25 mm mesh, the presence of jellyfish is significantly reduced. The number of jellyfish would be further reduced with a smaller mesh. Nonetheless, it would increase the number of detachments of the seabed vegetation, the entanglement of the fauna in the area, and the accumulation of rafts of marine debris.

The effectiveness of these methods might depend on the area in which they are deployed. They were proven as a successful system for preventing jellyfish in areas where the energy of the waves, wind, and tides was low. In areas with higher hydrodynamic conditions, modifications should be made to increase the success rate, which leads to a higher cost [6]. Considering the normal hydrodynamic conditions on our shores, the shallow water current pushes the jellyfish to the shores. If the motion of jellyfish can be altered, the bottom water currents will return the jellyfish offshore.

Electromagnetic (EM) fields have been used for behaviour change experimentation in animals and plants. In the case of animals, low-frequency EM fields have come to modify the behaviour. On the one hand, EM fields were used to see if they affected the orientation of birds, concluding that individuals exposed to EM waves tended to become disoriented [7]. On the other hand, the EM fields were used with seeds of two plant species. The selected species were *Rhododendron smirnowii* and *Morus nigra* . In the case of the first species, seed germination increased by up to 70%. However, in the case of the second species, the germination percentage decreased by 24%. Therefore, according to these two examples, it can be seen that EM fields can affect the behaviour of living beings.

The aim of the paper is to verify if medium-frequency EM fields can alter the behaviour of jellyfish, particularly their motion (pulsation rate), to explore possible solutions to the problems they generate on the shore. These EM fields are expected to modify the motion of *Catostylus mosaicus*, a common jellyfish in Australia. The EM waves are expected to reduce their pulse rate and remain motionless on the bottom, avoiding advection by currents. The conducted tests consist of exposing the jellyfish to an EM field generated with a coil. The exposure time to the EM field was set at five minutes. The pulse rate is used as an indicator of the jellyfish's motion. Twelve individuals of *C. mosaicus* were selected. Half of the jellyfish were bluish, while the other half was brown. It should be added that the size of the selected individuals was between 2.78 and 4.63 cm.

The rest of the paper is structured as follows; Section 2 outlines the related work. Section 3 details the test bench. The results are discussed in Section 4. Finally, Section 5 summarises the conclusion and future work.

II. RELATED WORK

In this section, we will summarise the current proposals for jellyfish barriers and the existing studies about the use of EM fields on animals.

A. *Jellyfish barriers*

In [6] Vasslides et al. test the efficiency of anti-jellyfish barriers. Their results indicate that the captured bay nettles in the area where the any-jellyfish barrier net was installed decreased by 28 to 67 %. In addition, the jellyfish captured in the area protected by the net was significantly smaller than in the adjacent areas. Nevertheless, this type of barrier's impact on fauna and flora and its relatively low effectiveness precludes its general use. The successfulness of air bubbles curtains in preventing the passing of jellyfish into aquacultural facilities was tested in 2021 by Haberlin et al. [9]. Their results were not entirely satisfactory. While high airflow reduces the number of jellyfish, low airflow does not affect the amount of jellyfish that passes the curtain. Moreover, the hydrodynamics link to waves increases the number of jellyfish that passes through the curtain.

In a recent survey, N. Killi et al. [10] concluded that early warning systems and barriers are being used in some regions of Spain and France. These barriers are designed for *Pelagia noctiluca* blooms. Another survey by T. A. Morsy et al. [11] indicates that both stinger nets and stinger suits have a limited impact on jellyfish avoidance. While barriers do not affect tiny jellyfish, the suits' performance has not been demonstrated in trials.

B. *EM field effects on animals*

In this subsection, we detail the existing reported effects of EM fields on animals. Several papers have been published in which the effect of EM fields on different animals is evaluated. There is an increasing tendency for this sort of study in marine animals due to the high number of high-power cables placed in the oceans. Although much literature can be found on this topic, few papers presented a proper comparison of animals' mobility of performance when exposed to the EM fields.

In 2020 Z. L. Hutchison et al. evaluated the behaviour of *Leucoraja erinacea* and *Homarus americanus* (little skate and American lobster) when exposed to anthropogenic EM fields [12]. The selected EM field was the emissions of subsea high voltage cables for domestic electricity supply with a high voltage direct current. They analyse the impact of the EM field on animal mobility. The indicators used were the total distance travelled, the mean speed, and the proportion of significant turns, among others. All factors were affected by the EM field being considered a difference statistically significant for little skate. The EM field did not affect the lobster's total travelled distance and speed of movement. Similar tests were conducted with european lobster (Homarmus Gammarus) by R. Taormina et al. in the same year [13]. In these tests, the authors exposed juvenile individuals to magnetic fields generated by AC/DC submarine power cables. The mobility indicators used were the activity ratio, the mean velocity, and the distance travelled. Their results indicate that no differences in European lobster mobility were detected.

The impact of EM fields on fish was studied by D. P. Fey et al. in 2019 [14]. The authors exposed the eggs of rainbow trout to an EM field for 36 days. Their objective was to detect if the EM field might affect fish development in the early stage. The measured parameters included time to hatching, mortality, and growth rate, among others. Their results indicated no variation between the control and exposed fish. Even there are few differences. Those differences were not statistically significant. The effect of the EM field in simple animals, such as on placozoa, a basal form of a marine multicellular organism, was evaluated in 2020 by A. V. Kuznetsov1 et al. [15]. They used a square pulse with shallow frequency. As a mobility indicator, the fraction of immobilised individuals of *Trichoplax sp*. was considered. Results indicate that the higher the voltage, the greater the number of immobilised individuals. The exposition time also impacts the number of immobilised individuals greater after 1000 ms than after 1 ms.

Numerous surveys have been published in recent years with mixed results. The main conclusion is that no apparent EM field effect has been demonstrated on marine animals. The main problem of existing research is the differences among studied EM fields and animals. In [12] and [13], scientists used anthropogenic EM fields generated by high-voltage cables with frequencies that range from 1 Hz to 2.5 kHz [12]. There is no information about the frequency in [13]. Meanwhile, in [15], a specific EM field was generated for the experiment with an Arduino Uno microprocessor that generates rectangular pulses with a frequency below 2 kHz.As far as we know, no publication has been found in which the effect of EM fields on jellyfish is studied.

III. TEST BENCH

In this section, the complete test bench is detailed. Firstly, the type of coil used and the current generator have been described to quantify each jellyfish pulsation. Next, the jellyfish used in the tests are described. Later, the followed methodology in the conduct tests is explained. Finally, the used indicator, the pulse rate, is defined.

A. *EM field characterisation*

To generate the EM field, a coil is used. According to Ampere Law, Eq. (1), it is possible to estimate the generated EM field. The magnetic flux density (B) inside a coil is proportional to the magnetic permeability of the water (μ_0), and the characteristics of the coil, including the number of

Copyright (c) IARIA, 2023. ISBN: 978-1-68558-058-2

spires (N) and the length of the coil (l), and current (I_C). In our scenario, de magnetic flux density in the centre of the coil is 10.3 mT.

$$B = \mu_0 I_C N/l \qquad (1)$$

B. Equipment

In order to keep the specimen during the tests, we used a cubic tank. The aquarium was filled with 18 L of seawater, with an average temperature of 21.6 ± 1.1 ºC and 31.8 ± 0.42 ppm of salinity, from the aquarium where the jellyfish were maintained; see Figure 1.

As explained before, the coil will be powered with a current generator AFG1022 from Tektronix [16]. The electronic circuit to power the coil includes a resistance of 100 KΩ with a 5% tolerance on the positive side of the copper coil. The generated signal to power the coil was a sinus signal of 3.3 Vpp.

C. Jellyfish description

In order to perform our tests, we selected a total of 12 specimens of jellyfish provided by Oceanogràfic de Valencia. All the individuals belong to *C. mosaicus* and have a similar age. In this case, even though they were all the same species, they presented two types of colouration (blue or brown). We balanced the number of brown and blue specimens among the selected individuals. Their size, measured using a calliper, varies between 2 cm and 5 cm, the smallest 2,66 cm and the largest 4,87 cm, as shown in Table 1.

D. Conducted test

The methodology followed for this experiment can be separated into two stages. In all the tests, the coil is placed in the aquarium. The first one, where the EM field was not activated, also known as the blank test, serves to have information about the regular motion of jellyfish. In the second test, also known as the exposition test, the EM field was activated by powering the coil with the generator. This simulates the exposition of the proposed system. Each stage consisted of a 5 minutes lapse in which the behaviour was recorded every minute.

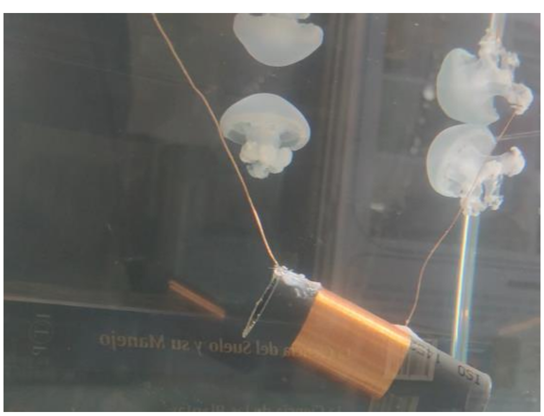

Figure 1. Assembled test with jellyfish and the coil.

TABLE I. SUMMARY OF CHARACTERISTICS OF THE SELECTED JELLYFISH

ID	Characteristics	
	Size (cm)	***Colour***
1	2,78	Blue
2	3,26	Brown
3	4,06	Blue
4	4,52	Brown
5	3,85	Blue
6	3,71	Brown
7	3,39	Brown
8	4,63	Brown
9	3,73	Blue
10	4,87	Blue
11	3,61	Blue
12	3,24	Brown

E. Behaviour's indicator

The pulse rate corresponds to the number of complete pulses performed by the jellyfish every 30 seconds. The pulses were counted during blank and exposition tests. The pulse rate has been selected as an indicator to characterise the jellyfish's behaviour.

Measurements were taken in slots of time of 30 seconds along the 5 minutes of trials. The first data collection started 30 seconds after the beginning of the experiment, and the last one was at 4 minutes and 30 seconds.

IV. RESULTS

In this section, we describe the obtained results from the conducted tests. First, the results of the descriptive statistics are shown. The comparison of jellyfish behaviour when they are exposed or not to the EM fields is detailed later. Finally, the evaluation of the suitability of this system to prevent jellyfish on our shores is discussed.

A. Descriptive statistics of obtained results

Next, we describe the variability of data gathered during the different experiments. First of all, five histograms are included in Figure 2, in which we can see the distribution of pulses. During the data collection in the tests, we noted that the blue jellyfish behave differently than the brown ones. Thus, besides the histograms for the EM field and no EM field, the data is also divided according to the colour of the jellyfish. In addition, the descriptive analyses of this data are summarised in Table 2.

In Figure 2 a), we can see the histogram for all collected data; it is possible to identify that the variable does not follow a normal distribution (kurtosis and skewness in Table 2). In most cases, jellyfish pulse rate are close to 50 pulses every 30 seconds. Nonetheless, we can see differences when differentiating between colours, especially when jellyfish are exposed to the EM field. The blue jellyfish have, in most cases, values close to 50 pulses every 30 seconds, see Figure 2 b). When they are exposed, the histogram shows a decrease in the number of pulses, see Figure 2 c). Concerning the brown individuals (Figure 2 d)), even when they are not exposed to the EM field, they have a lower pulse rate, with the maximum of the histogram in 40. Finally, when brown individuals are exposed to the EM field, they decrease the number of pulses even more. It is possible to find pulse rate values below 20, see Figure 2 e).

When data is analysed independently according to the jellyfish colour and EM field exposition, in some cases, the pulse rate follows a normal distribution. This happens with data on brown jellyfish.

The main conclusion of the descriptive analyses is that if all data is going to be analysed, non-parametric methods must be used. In addition, de descriptive analyses have already shown that there are differences between individuals when they are exposed to the EM field. These differences are more evident for brown jellyfish than for blue ones.

B. *Comparison of jellyfish behaviour when they are exposed to EM field*

Now, the comparison of results among tested individuals when they are exposed to EM fields is presented. Figure 3 and Figure 4 depict the registered motion of jellyfish under the blank and exposition test. The X-axis includes the number of individuals and the type of exposition (Yes or Not). It is possible to see that the pulsation rate along the test is similar for the blue individuals, with very few differences between individuals and in exposition. For the brown individuals, higher variability in data is seen. It is possible to see in Figure 5 that when individuals are under EM, the pulses decrease considerably.

In order to evaluate if differences are statistically significant, we used a Kruskall-Wallis non-parametric test since parameter did not follow a normal distribution. Table 2 summarises the results of the different tests. First, we compared the data of all individuals using the presence of the EM field as a factor. The results indicate that differences were not statistically significant (p-value of 0.098). The case in which differences in motion due to the presence of EM field were statistically significant was for the brown individuals, with a p-value of 0.02.

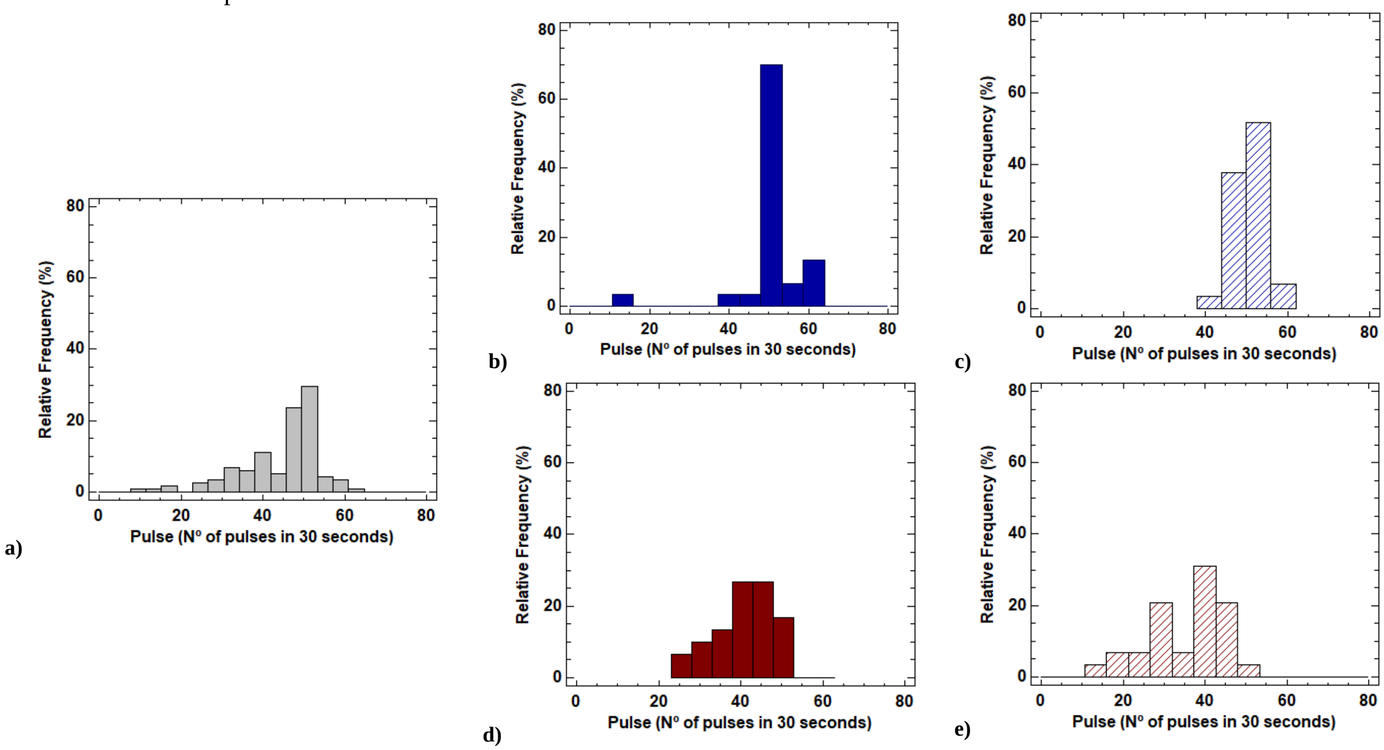

Figure 2. Histograms of pulses recorded in the different experiments including a) all data, b) blue jellyfish with no EM field, c) blue jellyfish with EM field, d) brown jellyfish with no EM field, and e) brown jellyfish with EM field.

TABLE II. SUMMARY OF CHARACTERISTICS OF THE SELECTED JELLYFISH

ID	Used data				
	All	***Blue with no EM***	***Blue with EM***	***Brown with no EM***	***Brown with EM***
N	118	30	29	30	29
Mean (Pulses/30s)	44.66	50.96	50.55	41.27	35.75
σ	9.89	8.63	3.77	7.12	9.57
Kurtosis	-5.14	-8.10	-1.47	-1.35	-1.47
Skewness	2.78	18.58	2.38	-0.45	-0.26

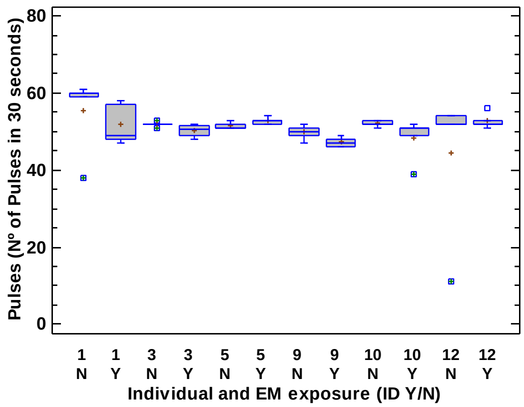

Figure 3. Boxplot for blue individuals during exposition tests (Y) and in blank tests (N).

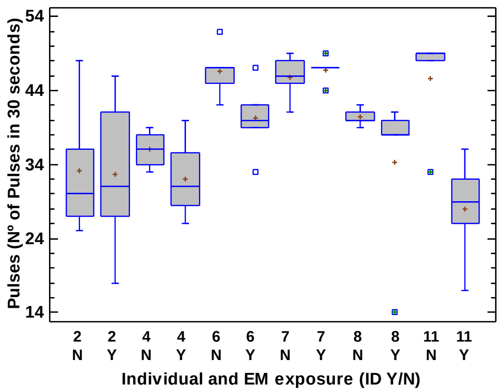

Figure 4. Boxplot for brown individuals during exposition tests (Y) and in blank tests (N).

TABLE III. SUMMAY OF KRUSKAL-WALLIS TESTS

ID	Factor	Characteristics	
		Statistic	*p-value*
Brown individuals	EM field	5.32949	0.0209648
Blue individuals	EM field	2.64529	0.103853
All individuals	EM field	2.72585	0.0987317

C. *Impact and limitations*

Our results indicate that using an EM field only for 5 minutes can alter the mobility of brown jellyfish. During the test, the jellyfishes that stopped pulsing were in the bottom of the aquarium. Regarding the blue individuals, even though the pulse rate was not altered, they experienced moments when they stopped pulsing and went to the bottom, as can be seen in Figure 5. After each period in which the jellyfish stopped pulsing when the jellyfish start pulsing the pulse was faster than before. This explains why in some individuals, even if they remain for some seconds without pulsing, the pulse rate does not vary. Nevertheless, in those situations, the velocity of the jellyfish was almost null. Although an exhaustive study of the jellyfish's behaviour has not been carried out after its exposure to the EM field, it is possible to see a partial recovery in their ability to pulsate.

Figure 5. Picture of jellyfish in the bottom of the aquarium due to the EM.

Before applying this solution to real environments, some adjustments must be made. The system can be extended by adding a method to detect the jellyfish for activating the EM field. It is not expected any problem between affected and non-affected jellyfish since, as far as we know, no communication has been described among jellyfish. Moreover, during the performed test, it was not detected that the jellyfish avoided contact with the coil that generated the EM field.

The most challenging issues of this system are the powering and the structural aspects. In addition, it will be necessary to study the potential effect of generated EM fields on other organisms. The full system is expected to be developed and tested in the next year thanks to the collaboration of partners of the SALVADOR project.

V. CONCLUSIONS AND FUTURE WORK

The arrival of jellyfish blooms to the coast significantly affects areas in which the economy relies on tourism. Existing any-jellyfish barriers, mainly based on nets or air bubbles, are not fulfilling the expectations. Some public agencies are demanding adequate jellyfish management strategies [19].

In this paper, we presented a new any-jellyfish system based on the generation of EM fields that modify jellyfish's motion. The impact of EM on mobility was tested with 12 individuals of *Catostylus mosaicus*. A copper coil and an alternating current generator generated the EM field. The results show that EM fields alter the mobility of half of the tested individuals according to the registered pulse rate. Initial results pointed out that using the EM field has clear potential as an alternative option for an anti-jellyfish barrier.

The impact of these EM fields in other species of jellyfish as well as in other local fauna, must be tested in future work. Additional tests will include changing the signal used to power the copper coil to evaluate the effect of different generated EM fields. It would be interesting to study the behaviour in adult specimens by using the same parameters in this study in order to compare behaviours with younger individuals. Furthermore, since it is intended to modify the used signal, it can be tested in adult jellyfish. Another possible work for the future would be to change the size and type of coil, using a larger one or changing the number of spires to generate an EM field with higher magnetic flux density.

ACKNOWLEDGMENT

This research was funded by ThinkInAzul programme and was supported by MCIN with funding from European Union NextGenerationEU (PRTR-C17.I1) and by Generalitat Valenciana (THINKINAZUL/2021/002), by “Proyectos de innovación de interés general por grupos operativos de la Asociación Europea para la Innovación en materia de productividad y sostenibilidad agrícolas (AEI-Agri)” in the framework “Programa Nacional de Desarrollo Rural 2014–2020” project GO TECNOGAR, and by the "Generalitat Valenciana" through the project INVEST/2022/467. It had also support from the Ajuntament de Dénia, Conselleria d’Agricultura, Desenvolupament Rura, Emergència Climàtica i Transició Ecològica de la Generalitat Valenciana and the University of Alicante through the Montgó-UA-Dénia Research Station agreement. We want to thank the Oceanografic staff for providing the jellyfish.

REFERENCES

[1] B. Mghili, M. Analla, and M. Aksissou, “Estimating the economic damage caused by jellyfish to fisheries in Morocco,” African Journal of Marine Science, 44(3), pp. 271-277, 2022, doi:10.2989/1814232X.2022.2105949.

[2] R. E. Welton, D. J. Williams, and D. Liew, “Injury trends from envenoming in Australia, 2000-2013,” Internal medicine journal, 47(2), pp. 170-176, 2017, doi:10.1111/imj.13297.

[3] M. Bosch-Belmar et al., “Jellyfish impacts on marine aquaculture and fisheries,” Reviews in Fisheries Science and Aquaculture, 29(2), pp. 242-259, 2021, doi:10.1080/23308249.2020.1806201.

[4] J.E. Cloern et al., “Human activities and climate variability drive fast-paced change across the world's estuarine–coastal ecosystems,” Glob Change Biol, 22(2), pp. 513-529; doi:10.1111/gcb.13059.

[5] C. Lucas, S. Gelcich, and Shin-ichi Uye, “Living with Jellyfish: Management and Adaptation Strategies,” Jellyfish Blooms, pp. 129–150, 2013. doi:10.1007/978-94-007-7015-7_6.

[6] J.M. Vasslides, N. L. Sassano, and S. Hales, “Assessing the effects of a barrier net on jellyfish and other local fauna at estuarine bathing beaches,” Ocean and Coastal Management, 163(), pp. 364-371, 2018, doi:10.1016/j.ocecoaman.2018.07.012.

[7] H. G. Hiscock, H. Mouritsen, D. E. Manolopoulos, and P. J. Hore, “Disruption of magnetic compass orientation in migratory birds by radiofrequency electromagnetic fields,” Biophysical Journal. 113(7), pp. 1475-1484, 2017, doi:10.1016/j.bpj.2017.07.031.

[8] V. Mildaziene et al., “Response of perennial woody plants to seed treatment by electromagnetic field and low‐temperature plasma,” Bioelectromagnetics, 37(8), pp. 536–548, 2016, doi:10.1002/bem.22003.

[9] D. Haberlin, R. McAllen, and T. K. Doyle, “Field and flume tank experiments investigating the efficacy of a bubble curtain to keep harmful jellyfish out of finfish pens,” Aquaculture, 531, 735915, 2021, doi:10.1016/j.aquaculture.2020.735915

[10] N. Killi at al., “Risk screening of the potential invasiveness of non-native jellyfishes in the Mediterranean Sea,” Marine Pollution Bulletin, 150, 110728, 2019, doi:10.1016/j.marpolbul.2019.110728.

[11] T. A. Morsy, N. M. Shoukry, and M. A. Fouad, “Jellyfish Stings: Complications And Management,” Journal of the Egyptian Society of Parasitology, 50(2), pp. 270-280, 2020, doi:10.21608/jesp.2020.113048.

[12] Z. L. Hutchison, A. B. Gill, P. Sigray, H. He, and J. W. King, “Anthropogenic electromagnetic fields (EMF) influence the behaviour of bottom-dwelling marine species,” Scientific reports, 10(1), 4219, 2020, doi:10.1038/s41598-020-60793-x.

[13] B. Taormina, et al., “Impact of magnetic fields generated by AC/DC submarine power cables on the behavior of juvenile European lobster (Homarus gammarus),” Aquatic Toxicology (Amsterdam, Netherlands), 220, 105401, 2020, doi:10.1016/j.aquatox.2019.105401.

[14] D. P. Fey et al., “Are magnetic and electromagnetic fields of anthropogenic origin potential threats to early life stages of fish,” Aquatic toxicology (Amsterdam, Netherlands), 209, pp. 150–158, 2019, doi:10.1016/j.aquatox.2019.01.023.

[15] A. V. Kuznetsov, O. N. Kuleshova, A. Y. Pronozin, O. V. Krivenko, and O. S. Zavyalova, “Effects of low frequency rectangular electric pulses on Trichoplax (Placozoa),” Marine Biological Journal. 5(2), pp. 50-66, 2020, doi:10.21072/mbj.2020.05.2.05.

[16] Web page of the current generator used. Available at: https://www.mouser.com/datasheet/2/403/AFG1022-Arbitrary-Function-Generator-Datasheet-1-540840.pdf [Last access on 16/02/2022].

[17] S. Sendra, J. M. Jimenez, L. Garcia, and J. Lloret, “LoRa-based network for water quality monitoring in coastal areas,” Mobile Networks and Applications, 1-17, 2022, doi:10.1007/s11036-022-01994-8.

[18] L. Parra, S. Viciano-Tudela, D. Carrasco, S. Sendra, and J. Lloret, “Low-Cost Microcontroller-Based Multiparametric Probe for Coastal Area Monitoring,” Sensors, vol. 23, no. 4, p. 1871, 2023, doi:10.3390/s23041871.

[19] I. Shepherd. European efforts to make marine data more accessible. Ethics in Science and Environmental Politics, vol. 18, p. 75-81, 2018.

 ISBN: 978-1-68558-058-2