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Jellyfish blooms perception in Mediterranean finfish aquaculture

Mar Bosch-Belmar[a,b,*], Ernesto Azzurro[c], Kristian Pulis[d], Giacomo Milisenda[e], Verónica Fuentes[f], Ons Kéfi-Daly Yahia[g], Anton Micallef[h], Alan Deidun[i], Stefano Piraino[a,b,*]

[a] Dipartimento di Scienze e Tecnologie Biologiche ed Ambientali, Università del Salento, Lecce, Italy
[b] Consorzio Nazionale Interuniversitario per le Scienze del Mare (CoNISMa), Rome, Italy
[c] Institute for Environmental Protection and Research (ISPRA), Livorno, Italy
[d] Department of Physiology and Biochemistry, University of Malta, Malta
[e] Dipartimento Terra e Ambiente, CNR – IAMC Mazara del Vallo, Italy
[f] Institut de Ciències del Mar, ICM-CSIC, Barcelona, Spain
[g] National Agronomic Institute of Tunis, Research group of Oceanography and Plankton, Tunis, Tunisia
[h] Institute of Earth Systems, University of Malta, Malta
[i] Physical Oceanography Research Group, Department of Geosciences, University of Malta, Malta

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ABSTRACT

In recent years, negative impacts of jellyfish blooms (JB) on marine human activities have been increasingly reported. Aquaculture has been affected by jellyfish outbreaks, mostly documented through repeated episodes of farmed salmon mortalities in Northern Europe; however, the valuation of JB consequences on the aquaculture sector still remains poorly quantified. This study aims to provide the first quantitative evaluation effects of JB on finfish aquaculture in the Mediterranean Sea and to investigate the general awareness of JB impacts among Mediterranean aquaculture professional workers. The aquaculture workers' perception about JB was assessed through a structured interview-based survey administered across 21 aquaculture facilities in central and western Mediterranean. The workers' awareness about JB impacts on aquaculture differed among countries. Italian and Spanish fish farmers were better informed about jellyfish proliferations and, together with Tunisian farmers, they all recognized the wide potential consequences of JB on sea bream and sea bass aquaculture. On the contrary, the majority of Maltese respondents considered JB as a non-significant threat to their activity, mostly based on off-shore tuna farming. This study for the first time shows that JB may negatively affect different Mediterranean aquaculture facilities from Tunisia (Sicily Channel) and Spain (Alboran Sea), by increasing farmed fish gill disorders and mortality, clogging net cages, or inflicting painful stings to field operators, with severe economic consequences. Available knowledge calls for the development of coordinated preventive plans, adaptation policies, and mitigation countermeasures across European countries in order to address the JB phenomenon and its impacts on coastal water activities.

1. Introduction

In spite of the lack of scientific consensus in identifying global trends in jellyfish blooms (hereafter referred to as JB) [1], negative impacts of JB on human activities in coastal waters are remarkably increasing in frequency and severity [2,3]. Assessing the ecological and societal consequences of these events is one of the pressing challenges for marine researchers [4,5]. Separately or in combination, several anthropogenic stressors have been suggested as potential causes of increasing jellyfish: a) ocean warming, boosting higher reproduction rates and wider distribution areas; b) eutrophication, leading to higher availability of nutrients and plankton food sources; c) overfishing, by removing jellyfish predators and competitors; and d) the proliferation of artificial hard substrates, providing suitable habitats for jellyfish-producing polyps [2,6–8]. In turn, massive proliferations of gelatinous organisms may have broad negative consequences on many sea-based human activities [2]: tourism and maritime leisure may be negatively affected because of dangerous jellyfish stingers (medusae and their relatives), forcing temporary beach closures [9]; fishing activities may be impaired by net clogging, fish deterioration, increased fishing time and costs [10]; and overall fishery catches may be reduced by jellyfish outcompeting fish for food or directly preying on fish eggs and larvae [6]; coastal industrial plants (e.g. energy or desalination plants) may be forced to shut down by jellyfish clogging of cooling systems [2]. Open-

* Correspondence to: Università del Salento, Ecotekne (Dipartimento di Scienze e Tecnologie Biologiche ed Ambientali, Di.S.Te.B.A.), Strada Prov. Lecce-Monteroni, 73100 Lecce, Italy

E-mail addresses: maria.boschbelmar@unisalento.it (M. Bosch-Belmar), stefano.piraino@unisalento.it (S. Piraino).

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sea finfish aquaculture may be particularly threatened by the envenomation potential[1] of stinging jellyfish. Jellyfish can enter fish cages pushed by currents and waves washing in through the net cages [11,12] causing physical injuries on caged fish (skin lesions and gill epithelium damage), metabolic distress, and mass mortality [13,14]. In the last decade, Northern European aquaculture has experienced important economic losses due to JB, repeatedly killing several hundred thousands of farmed salmon in Ireland and Scotland [15–17].

In the Mediterranean, recent studies highlighted the negative impacts of JB on tourism [18], on public health [19] and on fisheries [10,20], as well as the increasing occurrence of large populations of invasive native and non-indigenous species [7,21–23]. Aquaculture represents a key source of food production worldwide [24], however the impact of JB on Mediterranean caged finfish aquaculture is still poorly understood. JB events have been reported in Spanish and Tunisian facilities [25,26] whereas recent laboratory based studies showed jellyfish stings may represent a high potential risk for the Mediterranean finfish aquaculture, by triggering gill disorders and mortality or affecting fish metabolic performances [25,27]. Even if fish survive after the jellyfish sting/envenomation, fish growth may be reduced, with relevant economic consequences for the facilities [26]. In addition, the impacts of low-medium jellyfish densities are usually neglected or under-documented.

For this reason, the main objectives of this work were a) to assess the extent of impact on caged finfish (detection of epidermal damage, gill disorders and/or fish mortality) induced by JB in central and western Mediterranean farms, and b) to investigate the general awareness of JB impacts among Mediterranean aquaculture professional workers. Also, this research aimed to verify whether (c) the perception of JB impacts may change among different countries, different professional categories of aquaculture workers, or operators with different level of experience.

2. Methods

2.1. Study area

Structured interviews were carried out between February 2014 and February 2015 with fish farmers of four countries (Italy, Spain, Tunisia and Malta) in the framework of the European project Med-Jellyrisk (http://jellyrisk.eu) for the integrated transnational monitoring of JB across the Western and Central Mediterranean Sea. The visited facilities were all represented by grow out offshore floating cages.

2.2. Survey structure and data collection

A total of 42 finfish aquaculture facilities were contacted, obtaining the collaboration of 21 of them. Fish farm facilities were identified through information provided by Unimar Institute from Roma and from the Technical Secretary of the FAO/GFCM Aquaculture Committee in Rome, Dr. Alessandro Lovatelli. Surveys were performed face-to-face or by telephone, depending on the availability of fish farm workers. Workers were interviewed individually to minimize 'group effect' bias. Interviews were performed in the native or official language of each country. People were interviewed on the basis of a structured questionnaire (appendix A) which included 19 questions organized in 3 different sections: (I) *general knowledge on jellyfish and their blooms* (e.g. which jellyfish sp. the interviewees recognized and which are the most frequently sighted, the frequency of jellyfish blooms, etc.); (II) *JB qualitative impacts on farm's activity* (i.e. on structures and material, health of workers and farmed fish); (III) *JB quantitative impacts* (categorical estimation of potential impact on aquaculture economy). Answers were structured in a categorical and dichotomous formats (yes/no), with the exception of the economic impact valuation, where an increasing number scale from 0 to 5 was presented (0= mean none effect of JB on aquaculture activity, 1–2= low effect, 3–4= medium economic effect and 5= high economic impact). The answers to the open-ended questions were subsequently converted into discrete values in order to perform the data analysis. Fish farmers were also invited to provide any further information they deemed useful to substantiate their answers. To facilitate species identification, jellyfish pictures of the most commonly blooming taxa were shown to the respondents.

2.3. Statistical analysis

The jellyfish species mentioned in each interview were used to build a presence/ absence dataset, in which each survey was considered as an independent sample with the different species as variables. This dataset was explored through the application of multivariate analyses, so as to test for possible relationships between the recorded jellyfish species and both social and geographic factors. To test for any differences between the factors "location" (fixed with 4 levels) and "professional profile" of workers (fixed with 6 levels and orthogonal with "location") a two-way permutational multivariate analysis of variance (PERMANOVA [28]) was performed. The same statistical analysis was used to test for any differences between the "location" and "years of experience" in the sector factors (fixed with 5 levels and orthogonal to "location") and between the "location" and "farmed fish species" in the involved facilities factors (fixed with 2 levels and nested in "location"). A one-way PERMANOVA analysis was also carried for testing the factor "season" (4 levels).

Answers to perception questions about the impact of JB on anthropogenic activities were similarly organized in a matrix and two-way PERMANOVA analysis was carried out with the same experimental design previously used for the jellyfish matrix. In addition, one-way PERMANOVA analysis (for location factor) was performed to test different respondents' answers about the potential economic impact of JB on aquaculture.

Subsequently, post hoc Pair-wise t-test and Similarity Percentage analysis (SIMPER) were performed on the factor interactions for which significant differences were identified to determine the independent variable level which contributed most to the observed differences [29]. Statistical analyses were performed with the PRIMER6 & PERMANOVA+ software package [30].

3. Results

3.1. Characteristics of the respondents

A total of 51 fish farmers were interviewed (9 from Italy; 11 from Spain; 7 from Tunisia and 24 from Malta) hailing from 21 different fish farms (6 from Italy; 5 from Spain; 4 from Tunisia and 6 from Malta). Interviewed employees all had a number of years of aquaculture experience behind them, ranging from 3 to 50 years, with 43% of them having worked in this sector for more than 10 years. The interviewed professional profiles varied from field technicians, divers or skippers to fish farm directors, veterinarians, administrators and technical, production and quality managers. Over the course of an entire calendar year, the average number of hours spent at sea per day by field workers was 6.

3.2. General knowledge on jellyfish and their blooms

General knowledge of jellyfish held by respondents varied much among countries. The jellyfish species that interviewees were able to identify were significantly different among places (F_3=6.67, p=0.001), except for Italy and Spain (t=1.58, p=0.057); but in all cases, *Pelagia*

[1] The tentacles of stinging jellyfish (phylum Cnidaria) are covered by cnidocytes, specialized cells able to fire – upon contact – penetrating filaments and inject venoms, with a variety of cytotoxic, neurotoxic, hemolytic properties.