Received: 3 August 2019 | Revised: 23 December 2019 | Accepted: 10 January 2020

DOI: 10.1111/tbed.13482

REVIEW

Transboundary and Emerging Diseases WILEY

Mapping the knowledge of the main diseases affecting sea bass and sea bream in Mediterranean

Ana Muniesa[1,2] | Bernardo Basurco[2] | Cristóbal Aguilera[3] | Dolors Furones[3] | Carmen Reverté[3] | Anna Sanjuan-Vilaplana[3] | Mona Dverdal Jansen[4] | Edgar Brun[4] | Saraya Tavornpanich[4]

[1]Faculty of Veterinary Medicine, Instituto Agroalimentario de Aragón IA2 (Universidad de Zaragoza - CITA), Zaragoza, Spain

[2]Mediterranean Agronomic Institute of Zaragoza - CIHEAM-IAMZ, Zaragoza, Spain

[3]Institute of Agrifood Research and Technology, Tarragona, Spain

[4]Norwegian Veterinary Institute, Oslo, Norway

Correspondence
Saraya Tavornpanich, Norwegian Veterinary Institute, Oslo, Norway.
Email: saraya.tavornpanich@vetinst.no

Funding information
European Commission Horizon 2020, Grant/Award Number: 727315

Abstract

Good knowledge on the disease situation and its impact on production is a base mechanism for designing health surveillance, risk analysis and biosecurity systems. Mediterranean marine fish farming, as any aquaculture production, is affected by various infectious diseases. However, seabass and seabream, the main produced species, are not listed as susceptible host species for the notifiable pathogens listed in the current EU legislation, which generates a lack of systematic reporting. The results presented in this study come from a survey directly to fish farms (50 hatchery and on-growing units from 10 Mediterranean countries), with data from 2015 to 2017, conducted by the H2020 project MedAID. Seabass showed a higher survival rate (85%) through a production cycle than seabream (80%) in spite of equal mortality due to pathogen infections (10%). The differences in survival may be explained by mortality 'of other causes'. Seabream and seabass have different disease profiles, and the profile is slightly different between geographical regions. Among the most important diseases, tenacibaculosis and vibriosis were identified in seabass and *Sparicotyle chrysophrii* (a gill fluke) and nodavirus in seabream. Correlating mortality data to management variables showed that increasing density, buying fingerlings from external sources and treatments due to disease are factors that negatively influence mortality rate. Most of the surveyed farms did not keep sufficient quality data to implement good health status reports and perform detailed impact studies, which shows the necessity of updating the current legislative framework to provide the basis for better reporting of relevant pathogens in the Mediterranean basin.

KEYWORDS

aquaculture, disease impact, disease situation, Mediterranean, seabass, seabream

1 | INTRODUCTION

Intensive production of European seabass (*Dicentrarchus labrax*) and Gilthead seabream (*Sparus aurata*) in the Mediterranean is a relatively young industry that began in the late 80s, grew exponentially in the 90s and has continued its expansion during the following two decades. Although the sector has faced several crises, the production increased every year during the 2011–2017 period, from 268,952 tonnes in 2011 to 426,744 tonnes in 2017 (FAO, 2018). About 90% of the seabass and seabream production is concentrated in 6 countries: Turkey (37%), Greece (25%), Egypt (14%), Spain (9%), Tunisia (4%) and Italy (4%).

As well as in livestock production, the aquaculture sector is vulnerable to exotic, endemic and emerging diseases (FAO, 2018). Good knowledge on the disease situation and its impact on production is a base mechanism for designing of health surveillance, risk analysis and biosecurity systems. Disease is one of the major reasons for trade barriers on aquaculture products and live fish (e.g. Alam & Tomossy, 2017; Håstein et al., 2008) and constrains the expansion of the aquaculture industry worldwide.

As regards seabass and seabream farming, most of the knowledge describing diseases in the sector comes from references about diagnosed outbreaks of different pathogens and subsequent research on different related aspects, that is, epidemiology, pathogen characterization, diagnostic methods, development of vaccines (Vendramin et al., 2016). Reviews or analysis about disease problems or health status by fish species at the regional level are scarce and based on bibliography analysis and/or consultation with fish pathologists, for example, Rodgers and Furones (1998), the EU-project PANDA 2007 and have been presented in specialized conferences, that is, EAFP. Vendramin et al. (2016) from the Workshop on 'Fish health in Mediterranean Aquaculture, past mistakes and future challenges' held at the 17thEAFP Conference (Las Palmas 2015) referred to nodavirus, *Vibrio anguillarum*, *Photobacterium damselae* subps. Piscicida and gill flukes, as the most important problems in Mediterranean mariculture.

Being aware of the need of having a better knowledge of the health status of Mediterranean marine fish farming, the European Union Reference Laboratory (EURL) for Fish Diseases makes, since 2012, an annual analysis, through a consultation with fish pathologists, to follow trends and highlight emergence of new fish diseases in the Mediterranean. The aim of this initiative is to set up a platform that can link authorities and stakeholders aiming to target the main sanitary issues in the basin and focus future research activities on these topics (EURL Fish 2018). More recently, the Federation of Veterinarians of Europe (FVE) established in December 2015 the FishMed + Coalition, with the aim of getting more information about critical fish diseases for which few authorised or no treatment options are available (De Briyne, 2017). Moreover, according to FVE, there is a need to prevent further use of non-authorized products. Consequently, the current situation poses a serious constraint on the prevention and treatment of diseases, leading to welfare problems and hampering the growth of Mediterranean Aquaculture.

MedAID (Mediterranean Aquaculture Integrated Development) is a four-year project, funded by the European Union in the frame of Horizon 2020, grant agreement number 727315. The overarching goal of MedAID is to increase the overall competitiveness and sustainability of the Mediterranean marine fish-farming sector, throughout the whole value chain. Currently, Mediterranean aquaculture is lacking or has fragmented knowledge on epidemiology, impact of diseases, harmonized and coordinated diagnostics, or strategies and tools for a proper local, regional or even Pan Mediterranean health management. One of the project work packages is health management and diseases and fish welfare addresses these issues of improving disease management by using risk assessment tools for relevant new and emerging pathogens in the Mediterranean basin.

This present study is part of a multidisciplinary sustainability assessment of Mediterranean marine fish-farming sector, conducted to obtain an integrated view of the sector, including an analysis of the economic background, zootechnical and fish health problems, product development and marketing and governance issues. The analysis was performed through a series of surveys directly conducted to fish farms managers and/or technical personnel in ten countries, with the aim to gain further knowledge directly from the producers.

The results presented in this study are part of the work aiming to describe mortality rates, disease occurrence and distribution based on farmers own records data of existing diseases at a regional scale and their impact on production.

2 | MATERIALS AND METHODS

The data in this study come from a sustainability assessment of the Mediterranean marine fish-farming sector, conducted at the beginning of the H2020 project MedAID, during the year 2018. The assessment was implemented through a holistic multidisciplinary survey designed by the Institute of Agrifood Research and Technology (IRTA), together with leaders of other project thematic Work packages. The survey was structured into different questionnaires, including zootechnical, environmental, social, diseases and health management, economic and governance information. The contents of the questionnaire on diseases and health management were designed by the Norwegian Veterinary Institute, NVI (leader of Work package on Health management and diseases and fish welfare), in collaboration with the rest of partners participating in that WP. It covered questions on-farm information, production data, management practices and biosecurity, disease occurrence, diagnostics, management and reporting. Interviewees were asked to report data for the period 2015 to 2017, with monthly disease diagnoses data requested.

To carry out the survey, a Data Collection Working Group (DCWG) was established with MedAID partners, from the different participating countries. The group was trained by IRTA through web seminars and video calls to collect the requested data, in a homogenous way, through face to face interviews, taking into account the characteristics of each country and company. In order to get the required data, different experts from each company were interviews. For the section on diseases and health management, the interviews required the participation of the company expert in charge of those issues, either a veterinarian, a health manager or the production manager.

All the information obtained from the companies participating in the survey was processed, while maintaining the principle of confidentiality and privacy, to guarantee the use of the data, without compromising personal data protection regulations. Once the surveys were completed, a database was established and the data analysed.

Briefly, 50 production units belonging to 27 companies from 10 Mediterranean countries, both from European Union (Croatia, Cyprus, France, Greece, Italy, Portugal and Spain) and Non-European Union (Egypt, Tunisia and Turkey) were surveyed. The seabass and seabream production of these 10 countries represents more than 95% of the whole production in the Mediterranean. Although, there are no available statistics about the number of production units the MedAID project assessment showed that the number of on-growing operating farms is estimated to be around 950, and the number of marine hatcheries to be 91. The companies to be surveyed were selected not only to cover the maximum number of countries producing seabass and seabream in the region, but also to include different company structures.

To preserve confidentiality (geographic location and farm profile) of participating companies during the mapping analysis, the Mediterranean area was divided into five regions: central Mediterranean (Adriatic coast of Italy, Greece and Croatia), eastern Mediterranean (Turkey and Cyprus), southern Mediterranean (Tunisia and Egypt), western Mediterranean (Tyrrhenian coast of Italy, France & Spain) and outer Mediterranean (Portugal and Atlantic Spain and France).

Data management and statistical analyses were performed using R (R Core Team, 2019). Differences in survival and mortality levels between sea bass and sea bream were assessed using the Mann–Whitney *U* test. A p-value < .05 was considered statistically significant. As the assessment of the data by Kolmogorov–Smirnov test showed left skewness, median was chosen as the mid-value for use in the analyses.

3 | RESULTS

3.1 | Description of study population

A total of 50 production units (31 with on-growing, 16 with hatchery or nursery and three with processing plants) from 27 companies, located in 10 Mediterranean countries (Croatia, Cyprus, Egypt, France, Greece, Italy, Portugal, Spain, Tunisia and Turkey), participated in the survey. Nine additional companies were contacted and refused to participate in this study. All hatchery and nursery culture was under intensive conditions with different water sources, and the majority of the on-growing was intensive production in sea cages, except for three units that reported to use lagoon, natural resurgence and water from lake and river as their water source.

Table 1 shows the number of production units from which diseases were reported, by region. Thirty-eight production units out of the 50 surveyed units reported the occurrence of one or more disease events during the survey period; 27 sea bass production units (15 on-growing, 9 hatcheries and 3 pre-growing) and 11 sea bream production units (9 on-growing and 2 hatcheries).

3.2 | Disease situation in Mediterranean seabass, seabream farms based on survey

Bacterial infections dominated the reports (75.0%) for sea bass, while parasitic infections (57.0%) were the most frequently reported infections in sea bream. When performing a more detailed categorization of the reported diseases, as well as categorizing the reporting units by production type, there appear to be some differences between the two fish species (Table 2).

Vibriosis (Vibrio sp.) was the most frequently reported bacterial infection in sea bass in the on-growing phase, followed by tenacibaculosis and photobacteriosis. Vibriosis was reported from all stages throughout the production chain, while tenacibaculosis and photobacteriosis seem to be more problematic for on-growing sites. Viral encephalopathy and retinopathy-Viral nervous necrosis (VER-VNN) was the only viral infection reported in sea bass production, occurring mainly in the on-growing phase with a low

TABLE 1 Overview of the production units that reported diseases in the survey during 2015 to 2017

	Sea bass			Sea bream		
	On-growing	Hatchery	Pre-growing	Growing	Hatchery	Pre-growing
Central Mediterranean	3	1	0	3	0	0
Eastern Mediterranean	4	3	2	2	0	0
Western Mediterranean	3	4	1	2	2	0
Southern Mediterranean	4	1	0	2	0	0
Outer Mediterranean	1	0	0	0	0	0
Total	15	9	3	9	2	0

Note: The units are divided according to fish species, unit type and Mediterranean region.

TABLE 2 Overview of the number of disease records for the survey units over a 3 years period (2015–2017), categorized by pathogen and production unit type

	Sea bass					Sea bream			
	On-growing	Hatchery	Pre-growing	Total sum		On-growing	Hatchery	Pre-growing	Total sum
Bacteria					Bacteria				
Vibrio sp.	68 (11)	15 (4)	12 (1)	95	Vibrio sp.		8 (1)		8
Tenacibaculosis	23 (4)	9 (2)		32	Photobacteriosis	2 (1)	1 (1)		3
Photobacteriosis	24 (2)		1 (1)	25	Tenacibaculosis		3 (1)		3
Aeromona sp.		1 (1)		1	Virus				
Virus					VER-VNN		5 (1)		5
VER-VNN	22 (4)	2 (1)		24	Lymphocystis	3 (1)	1 (1)		4
Parasite					Parasite				
Crustacean	3 (1)			3	Sparicotyle	70 (7)			70
Sparicotyle		3 (1)		3	Dactylogyrus	3 (1)			3
Amyloodimium	1 (1)			1	Cryptocarion		2 (1)		2
Dactylogyrus	1 (1)			1	Enteromyxum	1 (1)			1
Trichodines		1 (1)		1	Other				
Other					Winter Syndrome	16 (3)			16
Not significant pathologies	18 (5)	2 (1)	3 (1)	23	Not significant pathologies		2 (1)	3 (1)	5
Malformations		4 (1)		4	Red Rash	4 (1)			4
Canibalism		2 (1)		2					

Note: The number of production units from which each disease was reported is given in parenthesis.

number of reports from the hatchery phase. A number of different parasitic infestations were reported; however, all were reported to have a low level of occurrence. Parasitic infestations that had more than one reported case included non-specified crustacean infestation in the on-growing phase and Sparicotyle (gill fluke) in the hatchery phase.

As for sea bream production, the most frequently reported disease was caused by *Sparycotyle chrysophrii* (gill fluke) which is affecting production in the on-growing stage. It is also worth noting the 'Winter Syndrome', another frequently reported disease problem at this production stage, frequently affecting sea bream during the period January to May during all three years covered by the survey. Bacterial infections are mostly reported from hatcheries, with vibriosis being most common. VER-VNN seems to cause minor problems for sea bream production and was reported from the hatchery phase only.

The monthly time series of the major diseases are presented in Figure 1 (sea bass) and Figure 2 (sea bream). While there is a general seasonality of the occurrence of some diseases in both species, overall sea bream shows a lower reported disease occurrence (overall and monthly number of reported disease cases) than sea bass.

Vibrio sp. infection was present throughout the year and was a dominant infection in sea bass while it was less of a problem for sea bream. Tenacibaculosis (also known as flexibacteriosis) was the second most reported disease for sea bass and was reported throughout the year in 2017. This was in contrast to 2016 when there were no reports during the summer months (July–August).

VER-VNN occurs during the spring for sea bream while it is a summer–autumn disease for sea bass. The occurrence seems to be quite stable through these three years of study for sea bass while there is no registration of VER-VNN for sea bream in 2017; however, the results should be interpreted in the light of the short duration of our study.

3.3 | Mortality patterns

The median survival percentage of surveyed farms during on-growing phase was found to be 85.0% and 80.0% for sea bass and sea bream, respectively (Table 3), while the median disease-related mortality rate was 10.0% for both species (Table 3).

The only statistically significant difference in mortality between the two species was found for mortality by other causes (refer to non-pathogen infections), with median sea bass mortality (5.0%) being significantly lower than that of the sea bream (10.0%).

3.4 | Impact on the mortality of selected diseases

A wide range in mortality was observed for diseases affecting farmed sea bass. The reported mortality associated with Vibrio sp. infection, ranged from 0.003% to 4.00% in sea bass on-growing units, while it was higher in both hatchery units (0.2%–10.0%)

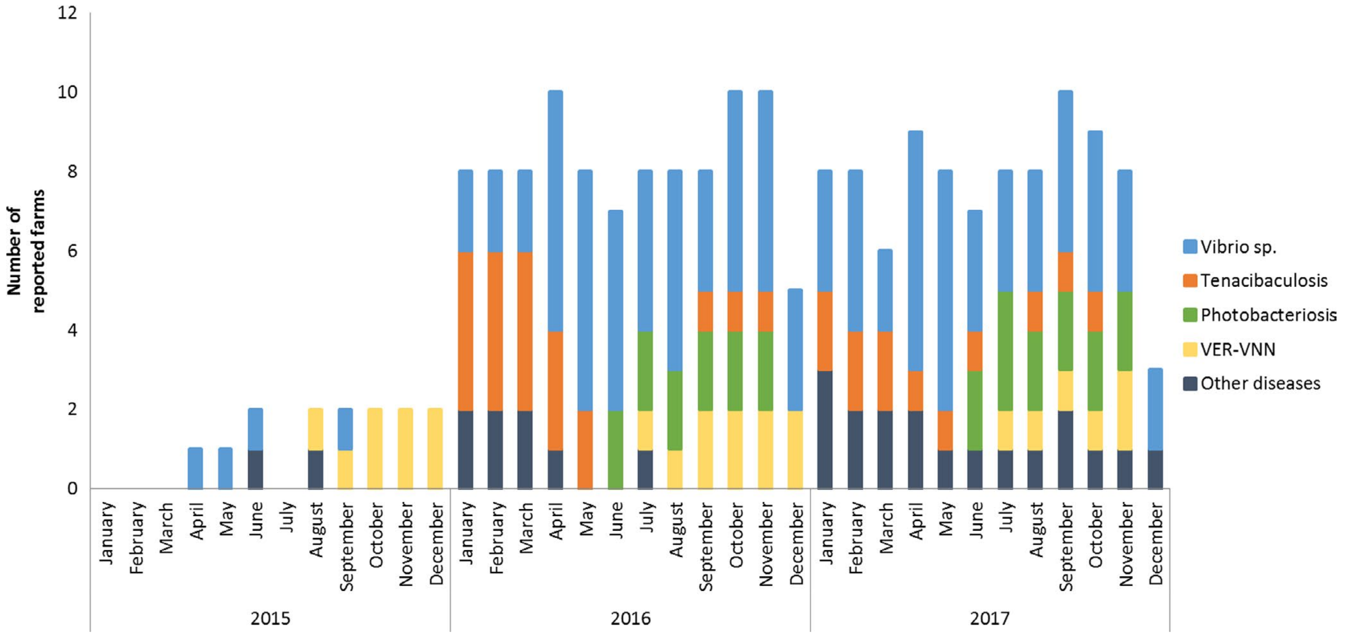

FIGURE 1 Monthly records of the four most common diseases reported for 27 sea bass farms from 2015 to 2017. Vibrio sp., Tenacibaculosis, Photobacteriosis, VER-VNN were reported for 95, 32, 25 and 24 times respectively during the survey period (total number of reports = 215)

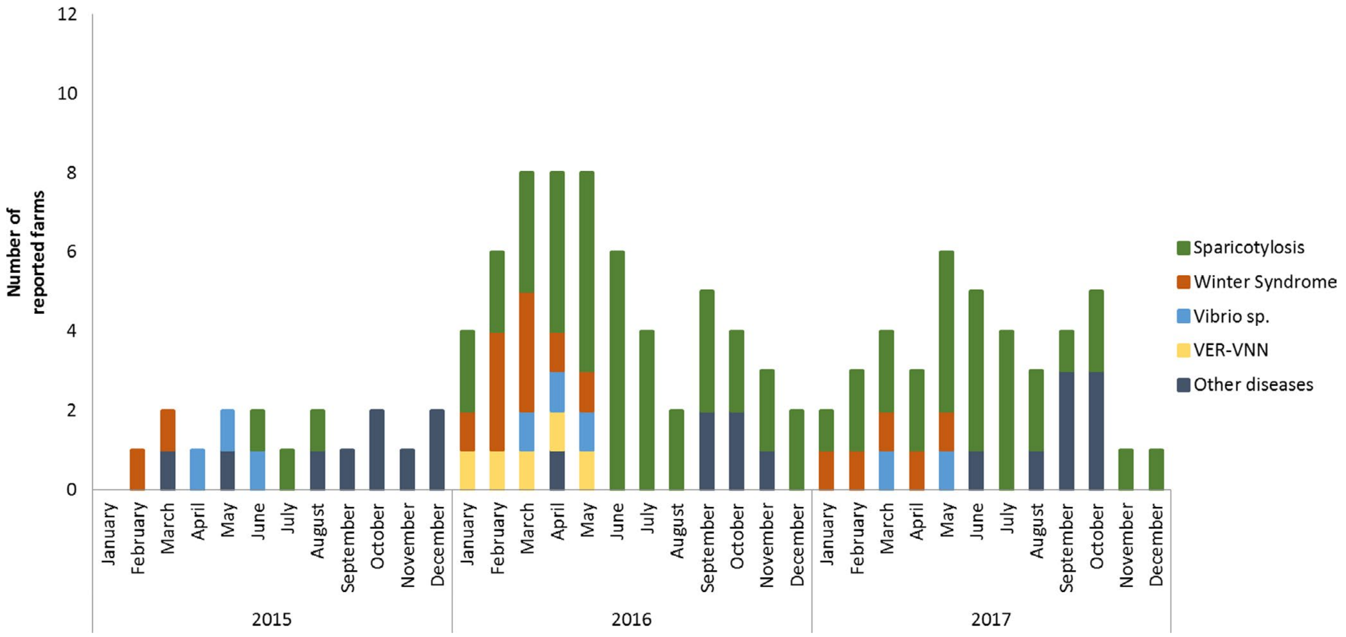

FIGURE 2 Monthly records of the four most common diseases reported for 11 sea bream from 2015 to 2017. Sparicotylosis, Winter Syndrome, Vibrio sp., VER-VNN were reported for 70, 16, 8 and 5 times respectively during the survey period (total number of reports = 124)

and pre-growing units (0.2%–5.0%). A similar pattern was seen for tenacibaculosis, with 0.5%–5.0% being reported in on-growing units while both hatchery and pre-growing units reported maximum mortality level of 14.0%, with the median mortality level being four times that of the on-growing units. For Photobacteriosis the mortality levels ranged from 0.80% for hatchery units to 5.5% in pre-growing units. VER-VNN was only reported in the on-growing phase and mortality levels ranged from 0.1% to 7.5% while the median observed mortality level was 2.0%.

For sea bream, there were generally lower levels of mortality associated with diseases with all medians being at 1.00%; however, for Sparicotyle mortalities up to 30.00% were reported. No information was available in relation to other factors that might have contributed to such a high level of mortality.

TABLE 3 Survival (%) at the end of the on-growing period, and mortalities (%) due to diseases and other causes (%), for sea bass and sea bream. n is the number of cohorts put to sea (Source: Fish-Farm Survey)

	% survival end of period		% mortality by pathology		% mortality by other causes	
Statistical	Sea bass	Sea bream	Sea bass	Sea bream	Sea bass	Sea bream
n	67	58	55	44	55	44
Mean	84.2	80.8	10.3	9.6	6.6	10.5
SD	10.1	7.7	9.2	6.2	5.4	7.1
Median	85.0	80.0	10.0	10.0	5.0	10.0
Q3-Q1	15.0	4.5	13.0	9.7	5.	11.5
Mode	80.0	80.0	15.0	10.0	5.0	5.0
Minimum	64.0	58.4	0.0	0.0	0.0	1.0
Maximum	100.0	99.0	36.0	18.0	24.6	27.2
p	.074		.823		.003	

Note: Sig. (*p*) U de Mann–Whitney.

3.5 | Hatchery and pre-growing production units

A total of 10 hatcheries from Croatia, Cyprus, France, Greece, Spain, Tunisia and Turkey participated in the study. Data on 61 batches of fingerlings (33 for sea bass and 28 for sea bream) were available. The number of batches per production unit was relatively stable, ranging from 1 to 7 batches per unit in 2015, 1–6 batches in 2016 and 1–5 batches in 2017. With respect to the live fish origin, the majority of broodstock (72.0%) was self-cultured, while 28.0% were bought. For larvae origin, 62.0%, 30.0% and 8.0% were self-cultured, bought and from both sources, respectively.

The main water sources for the hatcheries were borehole (60.0%), lagoon (21.0%), estuarine (8.00%) and open seawater (5.0%). As for the treatment of inlet waters, 88.0% reported using one or both of the following methods: mechanical filtration and ultraviolet radiation (UV). Amongst the 12.0% that reported no treatment for inlet water, all had borehole as their water source. No information was available on the treatment of outlet water.

Only three pre-growing production units participated in the survey. Borehole and open seawater were indicated as the source of inlet waters in two out of three units, but no water treatment was applied at either unit. The unit that failed to report on water inlet source indicated using both filtration and UV treatment.

Due to a limited number of hatcheries and pre-growing units that reported disease occurrence, further analyses of the data were not possible.

3.6 | On-growing production units

The survey data contained information on 136 fish batches, of which 74 were contained sea bass, 62 contained sea bream and one being a mix of both species. These batches were reared in 20 on-growing units from June 2013 to September 2017. The majority of the production was on-growing open sea cages, except for three units that reported to use lagoon, natural resurgence and water from lake and river as their water source. No physicochemical water treatment was applied except for one recirculation aquaculture systems (RAS) unit that reported using ozone treatment with 15.0%–20.0% daily water exchange. About 76.0% of juveniles were self-cultured, and 24.0% were bought.

The initial size of juveniles ranged from 1 to 100 g for sea bass, and from 2 to 40 g for sea bream. These were graded either by automatic or manual procedures. A few did not perform any grading. Fifty-eight per cent of the sea bass went through some kind of treatment, while the figure for sea bream was 45.0%.

Most on-growing units use round-shaped cages with an exception of two units using square-shape cages. The cage diameter ranged from 12 to 50 m (mean = 29, median = 25, *SD* = 11) for the round-shaped cages. Cage maximum biomass density ranged from 1.77 to 23 kg/m^3 (mean = 11, median = 10, *SD* = 4.7) for sea bass, and from 8 to 70 kg/m^3 (mean = 21, median = 15, *SD* = 19.8) for sea bream.

The relationships between '% mortality by pathogen' and selected management characteristics were visualized using boxplots for categorical variables, and scatter plots for continuous variables (Figures 3 and 4, respectively). Seabream appeared to have a higher median mortality than sea bass (Figure 3, panel a); however, there was a considerable variation within the two groups, and more data is needed for further analyses. The last two years (2016 and 2017) tended to have a somewhat higher mortality than 2015 (Figure 3, panel b), although uneven numbers of reported batches with disease may be influential for any significant difference. Within a year, the rising spring temperatures and high summer temperatures appeared to correlate with more frequently reported disease occurrences (Figure 3, panel c). The data supported a higher mortality rate in batches that are 'bought' compared to self-cultured supply (Figure 3, panel d), as well as that batches that have undergone treatments for the diseases in the study period show the highest mortality (Figure 3, panel e). Sites that do not practice grading appeared to have the highest mortality compared to those that use manual or automatic grading (Figure 3 panel f). However, more data would be required in order to assess the differences for statistical significance.

There was an indication of a correlation between increasing cage biomass density and increasing mortality (Figure 4, panel d) while no such

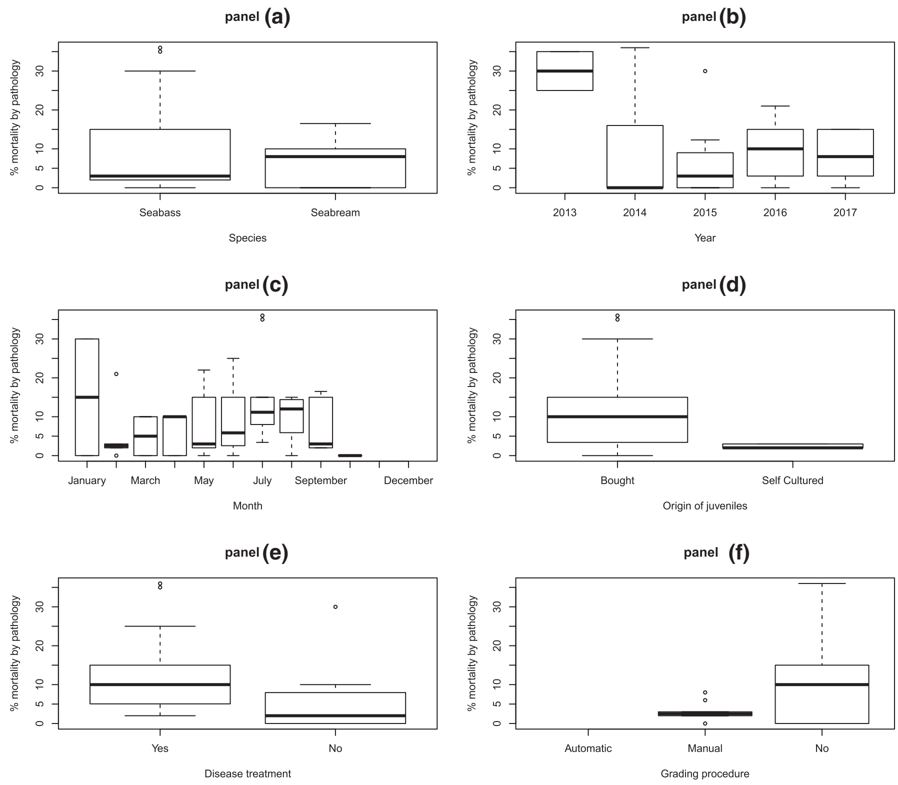

FIGURE 3 Distribution of % mortality due to pathology by various explanatory variables (total number of observations = 78)

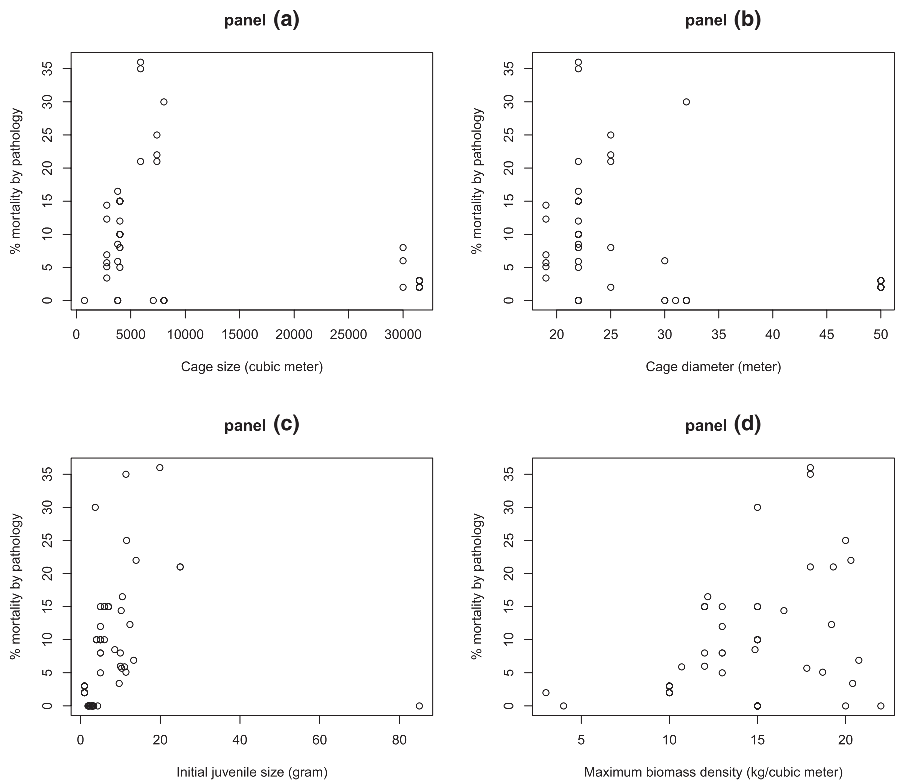

FIGURE 4 Scatter plots between % mortality due to diseases and various continuous explanatory variables

effect was seen for size of juveniles at sea transfer (Figure 4, panel c). Cage size did not show to be correlated with a reduced mortality (Figure 4, panel a), and increasing cage diameter appeared to correlate, although not significantly with a somewhat reduced mortality (Figure 4, panel b).

3.7 | Geographical maps of main reported diseases

Disease occurrence was further investigated in relation to their geographical distribution by region. Figures 5 and 6 show the

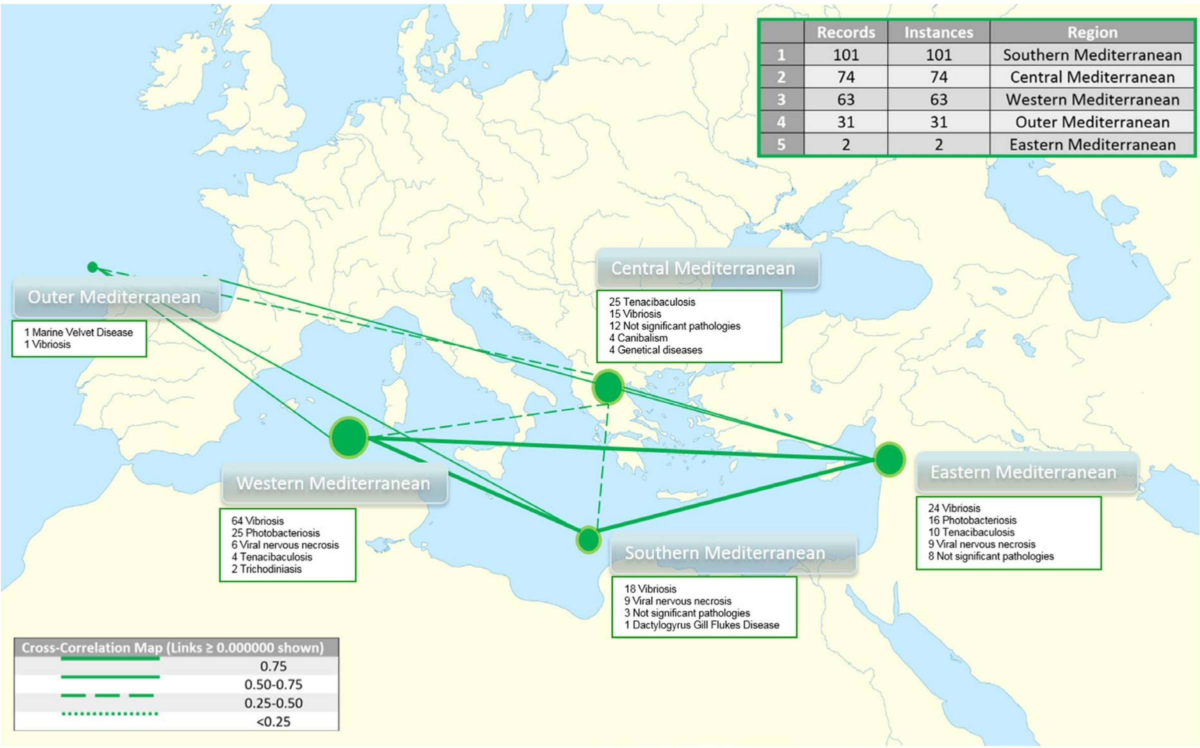

FIGURE 5 Maps showing the geographical distribution of reported diseases in sea bass according to disease survey data (2015–2017)

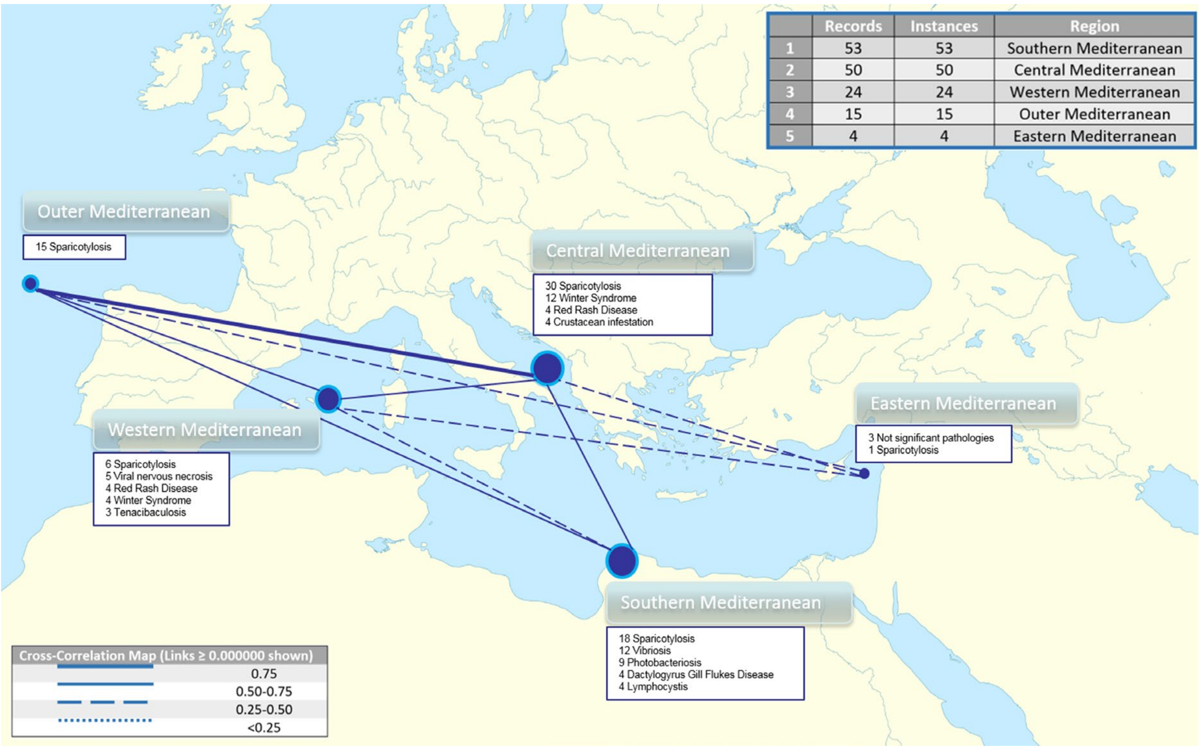

FIGURE 6 Maps showing the geographical distribution of reported diseases in sea bream according to disease survey data (2015–2017)

geographical distributions of the reported diseases in sea bass and sea bream, respectively. For sea bass, the region having the highest disease occurrence was western Mediterranean with 101 records followed by eastern (74), central (63), southern (31) and outer (2) Mediterranean, respectively. Vibriosis was found in all regions and was the most reported disease by three regions (western, southern and eastern Mediterranean). Tenacibaculosis was mostly reported by central Mediterranean, but also reported from eastern and western

Mediterranean as well. Photobacteriosis was reported by both western and eastern Mediterranean. VER-VNN was reported by western, southern and eastern Mediterranean. A lower number of disease occurrences, and a different disease ranking, were observed in sea bream. The frequency of disease occurrences in southern, central, western, outer and eastern Mediterranean were 53, 50, 24, 15 and 4, respectively. Sparicotyle was most frequently reported and was found in all regions. Winter syndrome was reported by western and central Mediterranean. Western Mediterranean was the only region to report VER-VNN.

4 | DISCUSSION

Seabass and seabream are the main species produced in Mediterranean marine fish farming, with a production of 426,744 tonnes in 2017 (FAO, 2018). However, they, as other marine farmed species (e.g. meagre, sole, tuna), are not listed as susceptible host species for the notifiable pathogens listed in the current EU legislation (Council Directive 2006/88/EC) (EU, 2006), which generates a lack of systematic reporting for this sector. Most of the knowledge describing diseases in the sector comes from literature reporting diagnosed outbreaks of different pathogens and subsequent research on different related aspects, as well as from consultation with fish pathologists (Vendramin et al., 2016). Given these sources, it is difficult to get an accurate overview of the prevalence and distribution of those main, described diseases.

This study provides a necessary, new and complementary approach for determining the presence of diseases at a regional scale. Moreover, it also provides information about the survival and mortality rate at the farm level, something not yet reported for the seabass and seabream sector. The Council Directive 2006/88/EC includes the obligation of notifying increases in mortality in aquaculture animals, to the competent authority or a private veterinarian for further investigations. However, the definition of 'increased mortality' leaves space for interpretation, as the Directive define this term as 'unexplained mortalities significantly above the level of what is considered to be normal for the farm or mollusc farming area in question under the prevailing conditions. What is considered to be increased mortality shall be decided in cooperation between the farmer and the competent authority'.

The mortality pattern of farmed fish populations is an important indicator of their health status. An abnormal increase should prompt investigations into the cause of mortality and mitigating measures should be implemented in order to prevent potential spread of an infection and maximize the survival rate for every production cycle. Seabass showed a higher survival rate (85.0%) through a production cycle than seabream (80.0%) in spite of equal mortality due to pathogen infections (10.0%; Table 3). The difference is explained by mortality 'of other causes' (non-pathogen infections) which is highest for sea bass; however, this category is not defined further and cannot be further explained by our data. Besides the mean survival rates themselves, in seabass and seabream present respectively a standard deviation (*SD*) of 11.1 and 7.6, with minimum survival of about 64.0% and maximum of 100.0%. These data not only provide some information about average mortality/survival rates, but also points out that many farms in the Mediterranean have room for a significant improvement to reduce their mortality rates.

The production of sea bream and sea bass is not homogeneously distributed between the Mediterranean countries and this could be a confounding factor for the figures in Table 3. Thus, to properly evaluate differences in survival between these two species, it is necessary to stratify by country and species in order to assess such confounding. More accurate results would, however, require a larger dataset (sample size) than the number of consulted farms of this work (50 units). Thus, caution is needed when drawing conclusions based on the findings of this report.

It is pointed out that the number of consulted farms (50), from 27 companies, was lower than the number initially planned, as some companies (9) were reluctant to participate arguing confidentially reasons. At the regional level, the information obtained by MedAID about prevalence of diseases (coming from surveyed farms) is in accordance with the information annually compiled by the European Union Reference Laboratory (EURL) through consultation with a group of fish pathologists. In the case of Spain the results of this study are quite similar to those available by the Spanish Federation of Health Protection Groups (FEADA), which are reported by associated companies to the veterinarians of the different of the Health Protection Groups (J. López, FEADSA coordinator, personal communication). Thus, although the sample size of this study was lower than initially planned, the results are believed to be representative and gives an improved picture of the prevalence and distribution of diseases in Mediterranean aquaculture.

The reluctance by a part of the sector to participate in the MedAID study, exemplifies a potential difficulty that administrations could face if seeking to implement disease surveillance programmes for seabass and seabream, which up to date are not listed as susceptible host species for the notifiable pathogens listed in the current European legislation (Council Directive 2006/88/EC). Besides that possible reluctance, it was noticed that some farms do not keep adequate health records and do not differentiate between mortality rates for diseases or other causes. Moreover, there is no common interpretation of what an 'increased mortality' may be ('…shall be decided in cooperation between the farmer and the competent authority'), which reduces compliance with the above mentioned Directive.

For seabass, we found bacterial infections, especially vibriosis and pasteurellosis, to be the dominant problems. A potential 'newcomer' or emerging infection may be tenacibaculosis, which was reported especially from the western and central part of the Mediterranean. Our study does not cover a sufficient time period to indicate if this is a new, emerging trend. While tenacibaculosis, photobacteriosis and vibrioses were also reported from seabream, the great majority of cases were in hatcheries as opposed to in the on-growing stage as was seen for sea bass. As reviewed by Toranzo, Magariños, and Romalde (2005), economically important bacterial infections in Gilthead sea bream and European sea bass include tenacibaculosis, photobacteriosis and vibriosis. Gilthead sea bream were additionally reported to be affected by pseudomonadiasis (Toranzo et al., 2005), while streptococcosis and mycobacteriosis, as well as Rickettsia-like organisms, were reported to affect sea bass (Toranzo et al., 2005). More recently, the bacteria causing furunculosis in salmonids and turbot, *Aeromonas salmonicida* subsp. salmonicida, has been isolated from farmed seabass in the Mediterranean coast of Spain (Fernández-Álvarez, Gijón, Álvarez, & Santos, 2016). A study specifically investigating bacterial infections in farmed sea bass in Spain found *V. harveyi* and *V. splendidus* to be most abundant, followed by *V. ichthyoenteri*-like isolates, *Photobacterium damselae* ssp. damselae and *V. fisheri* (Pujalte, Sitjà-Bobadilla, Álvarez-Pellitero, & Garay, 2003). It is hoped that future studies can shed further light on the prevalence of these bacterial pathogens in the Mediterranean sea bass and sea bream farms. The bacteria causing these infections are all indigenous in the seawater environment.

The viral disease VER-VNN occurs all over the Mediterranean as the dominant viral disease (Bovo et al., 2011; Haddad-Boubaker et al., 2013; Le Breton, Grisez, Sweetman, & Ollevier, 1997). While in our study it was mostly reported in the on-growing phase of sea bass and less frequently as a hatchery problem, it was only reported in the hatchery phase for sea bream. While information from the EURL Fish meeting appears to suggest that VER-VNN is decreasing in importance care should be taken given the scarcity of available official data. As there were no commercially available vaccines against nodavirus for seabass or seabream at the time of writing this paper, the lack of effective treatment options in the event of infection, surveillance for VER-VNN should be considered.

Our findings, based on farm data, are in concordance with the opinions of experts and the National Reference Laboratories for Fish Diseases, as reported at the Annual meeting organized by the EURL Fish in 2018 (Vendramin, 2018). For European seabass, tenacibaculosis was considered the most important disease followed by vibriosis (*Vibrio spp.*), with VER-VNN ranked third (as opposed to the previous year (2017) when this was considered the most important disease). For Gilthead sea bream, parasitic infections by *S. chrysophrii* (a gill fluke) is ranked first, followed by 'red rash' (unknown aetiology), with VER-VNN again being assigned third rank (Anonymous, 2018).

Both our survey data and expert opinion from the EURL Fish meetings show the other major infectious agent affecting the industry to be the parasitic gill fluke infection (*S. chrysophrii*) in sea bream, which occurs throughout the year although there may be some seasonal variation. In 2017 the EURL experts ranked the gill fluke as the most important infectious agent for the industry as a whole and as the most important disease in sea bream specifically. The importance of this parasite in seabream production in Spain has previously been highlighted in the scientific literature (Sitjà-Bobadilla, Redondo, & Alvarez-Pellitero, 2010). Gill infections in general may reduce growth rate and make the fish vulnerable to stress due to, for example, handling and environmental challenges and may be the underlying cause of mortalities reported in the category 'other causes'.

This suggests that there may be a need for more knowledge on how to effectively control *S. chrysophrii* - infection, particularly in sea bream farms. Most parasites are normally present in small number on their hosts. Intensive farming in an area gives an increasing number of fish and high densities will drive the burden of parasites in the area and increase exposure to hosts; both farmed and susceptible wild fish (Jansen et al., 2012). Parasites are challenging to control, as vaccines have been difficult to develop and parasites develop resistance to frequently applied chemical treatments. An example of this is Atlantic salmon farming where challenges in controlling salmon lice (a copepodite) is one of the major obstacles for further growth of the industry (Hjeltnes et al., 2018). Sustainable control of *S. chrysophrii* - infection should therefore be given highest priority.

The sea bream and sea bass production in the Mediterranean is mainly based on hatchery produced fingerlings. The use of wild caught fingerlings is minor and only practiced in a few locations (e.g. Egypt). The MedAID project has estimated the balance between supply and demand for fingerlings in the region and found fingerlings to be a transboundary trading commodity. Fingerlings are transported across the Mediterranean basin, with France and Greece being the two countries with the biggest surplus for export. This situation highlights the need for transparent systems to prevent the potential spread of infectious diseases from hatcheries. Such systems should include well-documented and de facto high-level biosecurity and sanitary condition in hatcheries. Additionally, there is a need for health services, transparency of important disease information and harmonized procedures across the countries to provide trustworthy and reliable data and diagnostics.

It is worth noting that our data show that batches of fish which are 'self-cultured' show a lower mortality rate due to pathogens than batches brought to the farm by external trade. If connected to a high transboundary trade activity of fingerlings, this further emphasizes the need for reliable and harmonized animal health management systems.

Maximum biomass density (kg/m^2 water) is often used as a welfare indicator. In our data there was a correlation between this density variable and mortality by pathogens. This effect was not reflected in cage size, but tended to be more correlated to surface area of the cage. It should be noted that this tendency of correlation was based on univariate comparison, and testing for significant association using univariable regression analysis and multivariable analysis should be next step.

Conclusions from the two independent data sources, MedAID survey and EURL Fish, are supportive of each other, suggesting that the data reflect the real disease situation for the seabream and seabass aquaculture industry in the Mediterranean. The MedAID survey provides information about the distribution of diseases, as well as the survival/mortality rates, a Key Performance Indicator that can help competent authorities in the implementation of Council Directive 2006/88/EC. Despite of this the need for caution when interpreting these data should be emphasized.

For both data sources, there are relatively few participants supplying data. Even more important, the farms may have different systems for recording and keeping disease data and diagnoses, and diagnostic procedures are not harmonized across all laboratories and countries. Disease reporting may also be missing as an issue relating to company reputations. In our study, it was also difficult to separate between outbreaks with long-lasting impact compared to new or shorter duration outbreaks.

One should also take into account that increased focus and awareness on diseases in itself may create more diagnoses. A higher number of a specific diagnosis may therefore just reflect higher competence and academic profiles with increased interest in disease research. These issues underlines the cautious approach needed to these data and their results.

An EFSA risk assessment of sea bass and sea bream aquaculture concluded that the majority of the farms were monitoring health to a high standard (EFSA, 2008). As the current legal framework does not provide the basis for an official harmonized reporting of the relevant pathogens in the Mediterranean basin, improved reporting of the disease status of aquaculture farms in the region may not be simple to implement. It is hoped that the findings of this study provide additional background information in order to aid the development of improved disease data collection to facilitate the growth of the Mediterranean aquaculture industry.

5 | CONCLUSIONS

Seabream and seabass have different disease profiles, which also differ according to production systems/phases (on-growing/hatcheriey) and geographical regions. As a result, they should be monitored separately and both geographical factors and production characteristics should be further investigated. Among the most important diseases identified were tenacibaculosis and vibriosis in sea bass and *S. chrysophrii* (a gill fluke) and nodavirus in sea bream.

Currently, farms do not keep and/or report sufficient quality data to ensure high quality health status reports of Mediterranean sea bass and sea bream aquaculture. Detailed disease impact studies should be performed and the risk analysis approach needs to be taken on board in the Mediterranean basin aquaculture to provide technical based guidance for its improvement. There is also a need to conduct further studies to better determine what should be understood for normal mortality/survival rates, which should also consider different productions systems and/or phases. It is necessary to define how to measure mortality rate at a farm scale (farm, batch, time scale, etc.), in order to better apply the current regulation, which demands the communication of 'increased mortality' events.

While VER-VNN was reported less frequently than bacterial disease in our dataset. Its potential economic importance, coupled with the lack of available prevention and treatment measures, suggests that this should be a prioritized agent for surveillance programs in the Mediterranean region.

Transparent knowledge and information sharing are essential for the running of a sustainable aquaculture production in the Mediterranean basin. Transportation of live animals is common practice in the whole Mediterranean basin and impose a great risk, if there is a lack of control and biosecurity measures.

Of primary importance is the need for harmonized diagnostic procedures and a standardized recording and reporting of a set of critical disease data in order to get a representative picture of the disease situation in the Mediterranean aquaculture industry. Such a system is crucial for developing biosecurity and contingency plans at company, industry and national level.

ACKNOWLEDGEMENTS

This research has received funding from the European Commission Horizon 2020 (H2020) Framework Programme through grant agreement no 727315 MedAID project (Mediterranean Aquaculture Integrated Development). The authors deeply acknowledge the MedAID partners that have participated in the Survey on the sustainability assessment of the Mediterranean marine fish-farming sector, and the aquaculture companies that have participated in this study.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

ORCID

Ana Muniesa https://orcid.org/0000-0003-3074-5778
Saraya Tavornpanich https://orcid.org/0000-0002-9713-6881

REFERENCES

Alam, S., & Tomossy, G. (2017). Overcoming the SPS concerns of the Bangladesh fisheries and aquaculture sector. *Journal of International Trade Law and Policy*, *16*, 70–91. https://doi.org/10.1108/JITLP-01-2017-0002

Anonymous (2018). *Report from the 22nd Annual workshop of the National Reference Laboratories for Fish Diseases*. Retrieved from: http://www.medaid-h2020.eu/wp-content/uploads/2018/07/22nd-AW-report-2018.pdf.

Bovo, G., Gustinelli, A., Quaglio, F., Gobbo, F., Panzarin, V., Fusaro, A., … Fioravanti, M. L. (2011). Viral encephalopathy and retinopathy outbreak in freshwater fish farmed in Italy. *Diseases of Aquatic Organisms*, *96*, 45–54.

De Briyne, N. (2017). *Fish diseases lacking treatment: gap analysis outcome*. FVE - Federation of Veterinarians of Europe.

EFSA (2008). Scientific report of EFSA on Animal welfare aspects of husbandry systems for farmed European sea bass and Gilthead sea bream. (Question No EFSA-Q-2006-149). *Annex I to the EFSA Journal*, *844*, 1–89.

EU COUNCIL DIRECTIVE 2006/88/EC (2006). Official Journal of the European Union, L328/14-56. Retrieved from: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:328:0014:0056:en:PDF

FAO. (2005–2018). *Cultured Aquatic Species Information Programme. Dicentrarchus labrax. Cultured Aquatic Species Information Programme*. Text by Bagni, M. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 18 February 2005. [Cited 31 October 2018].

Fernández-Álvarez, C., Gijón, D., Álvarez, M., & Santos, Y. (2016). First isolation of *Aeromonas salmonicida* subspecies salmonicida from diseased sea bass, *Dicentrarchus labrax* (L.), cultured in Spain. *Aquaculture Reports*, *4*, 36–41. https://doi.org/10.1016/j.aqrep.2016.05.006

Haddad-Boubaker, S., Bigarré, L., Bouzgarou, N., Megdich, A., Baud, M., Cabon, J., & Chéhida, N. B. (2013). Molecular epidemiology of betanodaviruses isolated from Sea Bass and Sea Bream cultured along the Tunisian Coasts. *Virus Genes*, *46*, 412–422. https://doi.org/10.1007/s11262-012-0869-8

Håstein, T., Binde, M., Hine, M., Johnsen, S., Lillehaug, A., Olesen, N., … Wright, B. (2008). National biosecurity approaches, plans and programmes in response to diseases in farmed aquatic animals: Evolution, effectiveness and the way forward. *Revue Scientifique Et Technique (International Office of Epizootics)*, *27*, 125–145.

Hjeltnes, B., Bang-Jensen, B., Bornø, G., Haukaas, A., & Walde, C. S. (Eds.) (2018). *The health situation in Norwegian aquaculture 2017*. Oslo: Norwegian Veterinary Institute.

Jansen, P. A., Kristoffersen, A. B., Viljugrein, H., Jimenez, D., Aldrin, M., & Stien, A. (2012). Sea lice as a density-dependent constraint to salmonid farming. *Proceedings of the Royal Society of Biological Sciences*, *279*, 2330–2338. https://doi.org/10.1098/rspb.2012.0084

Le Breton, A., Grisez, L., Sweetman, J., & Ollevier, F. (1997). Viral nervous necrosis (VNN) associated with mass mortalities in Cage-Reared Sea Bass, *Dicentrarchus Labrax* (L.). *Journal of Fish Diseases*, *20*(2), 145–151.

PANDA (2007). *Final activity report of PANDA (Permanent network to strengthen expertise on infectious diseases of aquaculture species and scientific advice to EU policy) Coordination Action, Project no. SSPE-CT-2003-502329*. Retrieved from https://cordis.europa.eu/docs/publications/1247/124722881-6_en.pdf.

Pujalte, M. J., Sitjà-Bobadilla, A., Álvarez-Pellitero, P., & Garay, E. (2003). Carriage of potentially fish-pathogenic bacteria in *Sparus aurata* cultured in Mediterranean fish farms. *Diseases of Aquatic Organisms*, *54*, 119–126. https://doi.org/10.3354/dao054119

R Core Team (2019). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.

Rodgers, C. J., & Furones, M. D. (1998). Disease problems in cultured marine fish in the Mediterranean. *Fish Pathology*, *33*, 157–164. https://doi.org/10.3147/jsfp.33.157

Sitjà-Bobadilla, A., Redondo, M. J., & Alvarez-Pellitero, P. (2010). Occurrence of *Sparicotyle chrysophrii* (Monogenea: Polyopisthocotylea) in gilthead sea bream (*Sparus aurata* L.) from different mariculture systems in Spain. *Aquaculture Research*, *41*, 939–944. https://doi.org/10.1111/j.1365-2109.2009.02369.x

Toranzo, A. E., Magariños, B., & Romalde, J. L. (2005). A review of the main bacterial fish diseases in mariculture systems. *Aquaculture*, *246*, 37–61. https://doi.org/10.1016/j.aquaculture.2005.01.002

Vendramin, N. (2018). *Update on fish disease situation in the Mediterranean basin 2017*. Presentation at the Annual Workshop of the National Reference Laboratories. European Union Reference Laboratory (EURL) for Fish Diseases. Kgs. Lyngby, Denmark.

Vendramin, N., Zrncic, S., Padrós, F., Oraic, D., Le Breton, A., Zarza, C., & Olesen, N. (2016). Fish health in Mediterranean Aquaculture, past mistakes and future challenges. *Bulletin- European Association of Fish Pathologists*, *36*, 38–45.

How to cite this article: Muniesa A, Basurco B, Aguilera C, et al. Mapping the knowledge of the main diseases affecting sea bass and sea bream in Mediterranean. *Transbound Emerg Dis*. 2020;00:1–12. https://doi.org/10.1111/tbed.13482