Bases para la planificación sostenible de áreas marinas en la Macaronesia

PLASMAR

Finding the balance of Blue Growth sustainable development within ecosystem approach - ANALYSIS OF THE AQUACULTURE INDUSTRY IN MACARONESIA UNDER MSFD.

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I. Context

1 Introduction

The biogeographical region of Macaronesia is composed by three European Overseas Regions, the Portuguese archipelagos of Azores and Madeira, and the Spanish archipelago of the Canary Islands. These outermost regions are located in the Northeast Atlantic, extending from the north-western extreme of Azores south to Madeira and the Canaries, which are closer to the African coast. The three volcanic archipelagos show high levels of both animal and plant endemisms, hence they are considered the most important centres of biodiversity in the Mediterranean bioclimatic region (Martín *et al.* 2008) and one of Europe's most prominent biodiversity hotspot. Due to its biodiversity importance and large number of endemic taxa, Macaronesia is an extremely vulnerable region to human impacts (Madruga *et al.* 2016).

In the frame of the PLASMAR project, 'Setting the bases for Sustainable Maritime Spatial Planning in Macaronesia', (Interreg POMAC 2014-2020), working groups from Canary Islands, Madeira and Azores are actively involved in developing Blue Growth around these European outermost regions. Following European environmental legislation framework (Marine Strategy Framework Directive on Good Environmental Status - MSFD/GES), the PLASMAR project aims to identify relevant environmental issues for each maritime activity for Blue Growth development. The identification of areas applying ecosystem approach is performed, as well as the development of a framework for environmental impact assessment for each analysed maritime activity. Following this approach, PLASMAR project expects to demonstrate how Marine Spatial Planning is linked to the ecosystem approach, thus contributing to promote Blue Growth and ecological sustainability.

Within the Marine Strategy Framework Directive, the Decision 2017/848/EU lays down criteria and methodological standards on Good Environmental Status of marine waters and specifications and standardised methods for monitoring and assessment. 11 qualitative descriptors (QD) of GES, assessed by an overall of 42 criteria, are presented:

- Descriptor 1: Biodiversity.
- Descriptor 2: Invasive species.
- Descriptor 3: Commercial fish stocks.
- Descriptor 4: Food webs.
- Descriptor 5: Eutrophication.
- Descriptor 6: Sea-floor integrity.
- Descriptor 7: Hydrography.
- Descriptor 8: Contaminants.
- Descriptor 9: Contaminants in seafood.
- Descriptor 10: Marine litter.
- Descriptor 11: Energy.

Marine aquaculture in the Canary Islands and Madeira is a fast-growing established sector that contributes to the economy, while in Azores it is in an early stage of research, development & innovation. For both archipelagos, and mainly due to the lack of coastal space for land-based farms, priority was given for the development of cage fish farming systems (Hernández-Cruz 1992; Andrade and Gouveia 2008).

The target of the present technical report is the identification of relevant environmental issues related to the finfish aquaculture activity in Macaronesia, integrating the concepts of Blue Growth and MSFD to achieve Good Environmental Status for sustainable development.

2 Methodology

The structure given by the MSFD on GES (2017/848/EU) was followed to assess the potential impact of the finfish aquaculture industry (*i.e.* sea farms) on the descriptors and criteria proposed by the Commission Decision. Among the 11 qualitative descriptors, secondary criteria were only analysed whenever primary criteria were implemented.

Additionally, an in-depth analysis of state-of-the-art aquaculture activities in Macaronesia was performed following an adapted methodology, where specific tables were filled for each applying QD and criterion. Briefly, environmental issues and likely solutions were identified for each QD and criterion through the review of scientific literature and technical reports. Priority was given to Macaronesian-based studies, with a broader view to worldwide documents on the aquaculture sector in order to enhance the analysis. For each designated environmental impact, the spatial extent was assessed, as well as feasible solutions for the environmental pressure and mitigation measures. Finally, available monitoring methods were identified with the most efficient and cost-effective techniques. Table field values are presented as follows:

1. **Environmental impact,** values: **YES/NO**; if **YES** please fill the rest of table fields and describe in additional text below the table the following factors:
    - Description of the impact - significant adverse effect on the environment (if more than one, please include relevant one or all);
    - Direct / indirect impact;
    - Probability /Intensity/complexity of the impact;
    - Expected onset, duration, frequency and reversibility of the impact;
    - Expected cumulation with other types of adverse effects linked to this maritime activity;
    - Currently relevant for the Macaronesia or expected to be relevant in the future (due to expected development of the MA).

2. **Environmental impact spatial extent**, values:
    a. Impact area is **less** than operative maritime activity area
    b. Impact area **equal** to operative maritime activity area;
    c. Impact area **broader** than operative maritime activity area;

3. **Maritime Activity (MA) pressure solution,** values: **YES/NO**; if **YES** please identify:
    a. If solution is envisaged to avoid, prevent, reduce or offset the pressure;
    b. If measure is a reasonable alternative in terms of technical complexity, cost and expected success in reduction of impact;
    c. If the MA pressure solution is relevant for the Macaronesia.

4. **Impact mitigation measures,** values: **YES/NO**; if **YES** please identify:
    a. If solution is envisaged to avoid, prevent, reduce or offset the impact/adverse effect;
    b. If measure is a reasonable alternative in terms of technical complexity, cost and expected success in reduction of impact;
    c. If the impact mitigation measure is relevant for the Macaronesia.

5. **Monitoring method** available, values: **YES/NO**; if **YES** please identify:
    a. The viability of the monitoring method in terms of cost-effectiveness, complexity and relevance for the Macaronesia.
    b. Should monitoring start before the construction phase or with the operational phase?

Further, a workshop entitled ‘Good Environmental Status and Aquaculture’ (Fernández-Palacios *et al*. 2018) was organized with the contribution of international experts, to widen the expertise fields and inputs to the analysis of the aquaculture activity under MSFD approach. Experts were invited to participate in a dynamic session that included the identification and validation of relevant methods chosen for the report, such as significant QD and criteria for the Macaronesian aquaculture. The output involved a detailed review of the aquaculture interactions with the marine environment, which was deeply considered to develop the results of this report.

II. Qualitative Descriptors on Aquaculture

From the list of qualitative descriptors given by the MSFD, 5 out of 11 descriptors, assessed by 10 out of 42 criteria, were found to monitor environmental impacts associated to finfish aquaculture in Macaronesia. Differences on the degree of interaction were found between descriptors and the maritime activity, based on their applicability to characterise the current situation in Macaronesia. Descriptors with *high degree of interaction* were considered as those regarding biodiversity (QD1), invasive species (QD2), commercial fish stocks (QD3), sea-floor integrity (QD6) and marine litter (QD10). On the other hand, descriptors such as food webs (QD4), eutrophication (QD5), hydrography (QD7), contaminants (QD8), contaminants in seafood (QD9) and energy (QD11) were categorised with *low degree of interaction*.

Based on the performed analysis, the main results for each applying criterion are presented within each qualitative descriptor.

3 High degree of interaction

3.1 Descriptor 1: Biodiversity

QD1 Species groups of birds, mammals, reptiles, fish and cephalopods (relating to Descriptor 1)							
QD	**Criteria (element)**	**CODE Criteria**	**Env. Impact**	**Env. impact spatial extent**	**MA pressure solutions**	**Impact mitigation measures**	**Monitoring method**
QD1	The mortality rate of birds, mammals, reptiles and non-commercially-exploited species of fish and cephalopods from incidental by-catch is below levels which threaten the species, such that its long-term viability is ensured.	D1C1	NO				
	The population abundance of the species is not adversely affected due to anthropogenic pressures, such that its long-term viability is ensured. Member States shall establish a set of species representative of each species group, selected according to the criteria laid down under 'specifications for the selection of species and habitats', through regional or subregional cooperation. These shall include the mammals and reptiles listed in Annex II to Directive 92/43/EEC and may include any other species, such as those listed under Union legislation (other Annexes to Directive 92/43/EEC, Directive 2009/147/EC or through Regulation (EU) No 1380/2013) and international agreements such as Regional Sea Conventions.	D1C2	NO				
	The population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity, and survival rates) of the species are indicative of a healthy population which is not adversely affected due to anthropogenic pressures. Primary for commercially-exploited fish and cephalopods and secondary for other species	D1C3	YES	Broader	No data	YES	YES
	The species distributional range and, where relevant, pattern is in line with prevailing physiographic, geographic and climatic conditions. Primary for species covered by Annexes II, IV or V to Directive 92/43/EEC and secondary for other species.	D1C4	YES	Broader	No data	YES	YES
	The habitat for the species has the necessary extent and condition to support the different stages in the life history of the species. Primary for species covered by Annexes II, IV and V to Directive 92/43/EEC and secondary for other species	D1C5	NO				

QD1 Pelagic habitats (relating to Descriptor 1)							
QD	**Criteria (element)**	**CODE Criteria**	**Env. Impact**	**Env. impact spatial extent**	**MA pressure solutions**	**Impact mitigation measures**	**Monitoring method**
QD1	The condition of the habitat type, including its biotic and abiotic structure and its functions (e.g. its typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), is not adversely affected due to anthropogenic pressures.	D1C6	NO				

D1C3: Population demographic characteristics.

1. Environmental impact: YES. Sea-cages act as Fish Aggregating Devices (FADs) where numerous wild species are congregated around these floating structures (Dempster *et al.* 2002; Tuya *et al.* 2005; Riera *et al.* 2017a). Direct changes on the body size and metabolism of associated species, compared to other wild specimens, have been demonstrated (Fernandez-Jover *et al.* 2007; Arechavala-Lopez *et al.* 2012a; Abaad *et al.* 2016) due to their proximity to fish farms and feeding on wasted manufactured pellets. Negative ecological effects between aquaculture and wild fish stocks have been documented (Naylor *et al.* 2000; Barrett *et al.* 2018) in terms of transmission of disease and parasites, and transfer of antibiotics used in feeds (Arechavala-Lopez *et al.* 2013). However, positive effects could also be reflected on ecosystem services (Alleway *et al*. 2018), such as juvenile recruitment (Fernandez-Jover *et al.* 2009) and increase of spawning ability by better body condition (Izquierdo *et al.* 2001). The expected duration of the effect could be extended until the farming activity stops (Tuya *et al.* 2006), with assemblages returning to normal conditions prior to the beginning of the activity (Andrade and Gouveia 2001). Restrictions on fishing within the leasehold area may enhance the production of local fisheries by exporting adult biomass and increasing larval supply to enclosed locations (Dempster *et al.* 2002; Fernandez-Jover *et al.* 2007), similarly to Marine Protected Areas (Le Gouvello *et al*. 2017; Minuzzi Schemes 2018). Furthermore, wild fish could help to remove up to 80%

of the farming wastes (Vita *et al.* 2004), reducing potential environmental impacts (Dempster *et al.* 2005). Therefore, protecting wild fish assemblages around sea-cages is considered of relevance in Macaronesia.

2. Environmental impact spatial extent: Broader. Assemblages of farm-associated species appear to be relatively stable, suggesting residence periods of weeks to months around the sea-cages (Dempster *et al.* 2002). However, the improvement of body condition could lead to enlarging abundances of these species, hence altering the community structure in the surrounding environment.

3. Maritime Activity pressure solution: No data and information, needed further research.

4. Impact mitigation measures: YES. Mitigation measures are restricted to the choice of feedstuff and its management (López Alvarado 1997). The selection of feeds of high-quality raw materials and appropriate manufacturing methods prevents losses from breaking pellets and leaching of ingredients, thus improving digestibility of the ingredients, lowering FCR and reducing the associated wastes to the environment. The adoption of improved feed and feeding management methods may also reduce significantly feed wastes. Management methods include feed transport, handling and storage; weather/sea conditions/ water quality monitoring and associated feeding models; feed distribution and monitoring methods (*e.g.* video cameras).

5. Monitoring method: YES. A combination of visual counts and video for overall farm biomass estimation is advised as monitoring tool to assess demographic characteristics of the farm-associated population (Dempster *et al.* 2005). Besides, the use of morphometric measurements (Arechavala-Lopez *et al.* 2012a), combined with fatty acids as biomarkers, are suggested to characterise the structure and dynamics of food webs around fish farms (Fernandez-Jover *et al.* 2007, 2009) during the operational phase. Similarly, scales and otoliths analysis (Arechavala-Lopez *et al.*

2012b, 2016) could be helpful to reflect both genetic and environmental factors, allowing the identification of wild fish associated with sea-cages (Abaad *et al.* 2016).

D1C4: Species distributional range.

1. Environmental impact: YES. Aggregated wild fish around sea-cages, combined with the presence of farmed fish, may influence the distributional range of several migratory species and/or predators, such as larger fish species (Tuya *et al.* 2006; Arechavala-Lopez *et al.* 2015; Loiseau *et al.* 2016), reptiles (Helsley 2007), seabirds (Aguado-Giménez *et al.* 2016; Díaz López 2017) and marine mammals (Güçlüsoy and Savas 2003; Díaz López 2006). This is currently relevant as the Macaronesian region constitutes a unique biodiversity hotspot, with a wide presence of endangered species (Madruga *et al.* 2016), such as the loggerhead turtle (*Caretta caretta*), the monk seal (*Monachus monachus*) and the common bottlenose dolphin (*Tursiops truncatus*) (Directive 92/43/EEC). Migratory species have been recorded in the sea-cages vicinity (Arechavala-Lopez *et al.* 2014a), hence indirect modifications in natural migratory routes might be produced due to increased foraging opportunities (King *et al.* 2010). Fish farming may create a dependence effect and alter the spatial and temporal patterns of wild species. Changes on the behaviour and distribution (Arechavala-Lopez *et al.* 2010; Díaz López 2017) could modify the structure of the local ecosystem by increasing the predation pressure (Arechavala-Lopez *et al.* 2015), with unpredictable consequences after the cessation of the farming activity (Aguado-Giménez *et al.* 2016). Future considerations should be taken into account to develop a framework for understanding the interaction of sea-cages with animals that are exploiting an artificial and variable source (Goodbrand *et al.* 2013; Díaz López 2017).

2. Environmental impact spatial extent: Broader. Several farm-associated species have been found to move among different aquaculture facilities (Dempster *et* *al.* 2002; Uglem *et al.* 2009; Arechavala-Lopez *et al.* 2010, 2015), used as 'feeding stations'.

3. Maritime Activity pressure solution: No data and information, needed further research.

4. Impact mitigation measures: YES. Management strategies, including site selection programmes based on the existing knowledge about the migratory pathways of wild species (Arechavala-Lopez *et al.* 2014), are strongly encouraged for the development of a sustainable aquaculture industry and consequent aquaculture-environment interactions (Price *et al.* 2017).

5. Monitoring method: YES. Visual counts by SCUBA divers (Boyra *et al.* 2004) and underwater video system (Dempster *et al.* 2010) are advocated as monitoring methods, in terms of cost-effectiveness, to assess the presence of endangered species in the fish farm area. Nonetheless, more specific alternatives, such as acoustic telemetry transmitters (Uglem *et al.* 2009) or hydroacoustic measurements (Goodbrand *et al.* 2013), are available to provide a detailed spatial-temporal distribution of farm-associated organisms. Species assessment is highly recommendable in Macaronesia during the operational phase of the aquaculture activity.

3.2 Descriptor 2: Invasive species

QD2 Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems							
QD	Criteria (element)	CODE Criteria	Env. Impact	Env. impact spatial extent	MA pressure solutions	Impact mitigation measures	Monitoring method
QD2	Newly-introduced non-indigenous species.	D2C1	YES	Broader	YES	YES	YES
	Abundance and spatial distribution of established non-indigenous species, contributing significantly to adverse effects on particular species groups or broad habitat types	D2C2 — Secondary	NO				
	Proportion of the species group or spatial extent of the broad habitat type which is adversely altered due to non-indigenous species, particularly invasive non-indigenous species.	D2C3 — Secondary	NO				

D2C1: Newly-introduced non-indigenous species.

1. Environmental impact: YES. Offshore aquaculture activities might be critical vectors for the introduction of non-indigenous species (NIS; *e.g.* attached species to boat hulls) (Nunes *et al.* 2014; Campbell *et al.* 2017). Still, the major risk of this maritime activity is the culture of alien species by intentional introduction. Despite gilthead sea bream (*Sparus aurata*) and European sea bass (*Dicentrarchus labrax*) are considered native species in some Macaronesian islands like the eastern Canaries (Dooley *et al.* 1985), they are considered NIS in other areas of the Macaronesian region (*e.g.* western Canaries and Madeira) (Alves and Alves 2002; Gonzalez-Lorenzo *et al.* 2005). Escapes during harvesting or massive events (*e.g.* storms, sabotage) might have direct impacts on the environment (Toledo-Guedes *et al.* 2009; Ramirez *et al.* 2015), as they can compete with native species of similar ecological and feeding habitats for the exploitation of natural resources (Balart *et al.* 2009). These events could also lead to the spread of parasites and/or diseases to the wild communities (Toledo-Guedes *et al.* 2012; Arechavala-Lopez *et al.* 2013). Though mature gonads have been found in some escaped individuals in the Canary islands (Toledo-Guedes *et al.* 2009, 2012; Ramirez *et al.* 2015), there is still a lack of evidences on the reproductive potential of escaped fish. Therefore, one might assume that the impact could be of limited duration, or even reversed through time, if there is no further recruitment from farm escapees, as well as due to the high fishing pressure, failure to adapt or due to predation. Nonetheless, escapees could establish and be able to reproduce if they somehow manage to find their 'essential fish habitat' (Toledo-Guedes *et al.* 2012).

2. Environmental impact spatial extent: Broader. Escaped individuals of introduced species from aquaculture facilities have demonstrated a strong dispersion capacity (Toledo-Guedes *et al.* 2009; Ramirez *et al.* 2015).

3. Maritime Activity pressure solution: YES. The introduction of NIS in aquaculture is regulated by existing legal frames, from European (Regulation (EU) 304/2011) to Regional level (RAM-Decreto Legislativo Regional nº 27/99/M; RAA-Decreto Legislativo Regional nº 22/2011/A; BOC-Ley 17/2003). A specific authorisation is required for any introduction of alien species, subject to prior environmental risk assessment. Considering the constant expansion of human activities at sea, prioritisation of management measures should be taken to reduce the risk associated to the introduction of NIS, which might be invasive and highly detrimental for the local environment (Nunes *et al.* 2014). This pressure solution is considered highly relevant for Macaronesia due to its biodiversity importance and large number of endemic taxa, which makes this region extremely vulnerable to human impacts (Madruga *et al.* 2016).

4. Impact mitigation measures: YES. Effective strategies to prevent and mitigate accidental releases of aquaculture facilities are available (Izquierdo-Gomez *et al.* 2014a, 2014b) in order to reduce economic losses to fish farms, interactions with local fisheries and environmental impacts to coastal ecosystems (Jensen *et al.* 2010; Arechavala-Lopez *et al.* 2018). Contingency plans in case of escapes (BOC 2018/058) are also important mitigation measures that need to be developed and established. Even if many attempts of recapturing escapees have been unsuccessful (Dempster *et al.* 2016), targeted recapture may be effective where escapees are clearly identifiable into areas where these species do not occur naturally (Toledo-Guedes *et al.* 2014). Other approaches to minimise risks could be through behavioural modification of fish pre-escape (Zimmermann *et al.* 2012; Papadakis *et al.* 2013), the avoidance of 'escape through spawning' (Uglem *et al.* 2012) or by tools for reproductive containment of farmed fish (Felip *et al.* 2001). Both pre- and post-escape measures are feasible alternatives to the Macaronesia in order to reduce the impact of these accidental events.

5. Monitoring method: YES. Sampling surveys are recommended to evaluate the presence of escapees in coastal habitats through spatial-temporal scale (Toledo-Guedes *et al.* 2014). This way, distribution patterns in the wild could be explained (Toledo-Guedes *et al.* 2009) and the gradient of escapees could be identified. This monitoring method is viable and relevant for Macaronesia, since the current farmed species live in shallow habitats and visual census could be carried out by snorkelling (Toledo-Guedes *et al.* 2014). Monitoring should start with the operational phase of the aquaculture activity to provide data of escapees. Moreover, fishing programmes should be encouraged in case of escapees, to monitor and mitigate the impact (Arechavala-Lopez *et al.* 2014b).

3.3 Descriptor 3: Commercial fish stocks

QD3 Populations of all commercially-exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock							
QD	**Criteria (element)**	**CODE Criteria**	**Env. Impact**	**Env. impact spatial extent**	**MA pressure solutions**	**Impact mitigation measures**	**Monitoring method**
QD3	The *Fishing mortality* rate of populations of commercially-exploited species	D3C1	NO				
	The *Spawning Stock Biomass* of populations of commercially-exploited species	D3C2	YES	Broader	YES	YES	YES
	The age and size distribution of individuals in the populations of commercially-exploited species is indicative of a healthy population. This shall include a high proportion of old/large individuals and limited adverse effects of exploitation on genetic diversity.	D3C3	NO				

D3C2: Spawning Stock Biomass.

1. Environmental impact: YES. Current farmed species are newly introduced in Macaronesia and therefore do not contribute to this criterion. Nevertheless, recent aquaculture advances suggest a future farming activity focused towards potential native species (*e.g.* EU-7FP DIVERSIFY project), such as the greater amberjack (*Seriola dumerili*) or the white sea bream (*Diplodus sargus*). In this case, the spawning stock biomass of the wild counterparts could be directly affected by hybridization with the farmed escapees (Braaten 2007). The probability of the impact could be avoided, or at least offset, by means of good husbandry practices. However, inbreeding depression might happen among escaped farmed individuals due to the offspring of generations artificially cultivated (Han *et al.* 2018), leading to a reduction in population fitness and productivity (McGinnity *et al.* 2003). Local stocks of sedentary species, such as the white sea bream, could be more affected by this inbreeding process.

2. Environmental impact spatial extent: Broader. As aforementioned under QD2, the strong dispersion capacity of escaped farmed individuals could enlarge the impact spatial extent, especially in the case of pelagic species.

3. Maritime Activity pressure solution: YES. Good husbandry practices, including the regular diversification of the broodstock, are encouraged to improve the genetic diversity of the fry output (Han *et al.* 2018). The effort should be directed towards the capture of wild individuals, acclimatization and rearing in captivity, but resulting in higher logistics complexity and costs (Roo *et al.* 2014; Sarih *et al.* 2018). This pressure solution is feasible in Macaronesia, where mariculture centres are present and future commercialisation of these native species is considered.

4. Impact mitigation measures: YES. The implementation of effective strategies to avoid genetic interactions between escaped farmed individuals and wild stocks include sales strategy to implement harvesting and commercialization of stock before reaching breeding size (Izquierdo-Gomez *et al*. 2014a, 2014b) or change of sex (Piferrer 2009). Supplementary genetic technologies may provide selective breeding programmes (Felip *et al.* 2001; Zhu and Ge 2018), which are considered specifically relevant for Macaronesia, whenever native species are cultured.

5. Monitoring method: YES. DNA analysis of the stock is suggested as monitoring method to evaluate the genetic diversity by microsatellite markers (Han *et al.* 2018), therefore contributing to improve the production efficiency. A primary analysis of the broodstock during the construction phase would provide the genetic profile to be compared during the operational phase of the aquaculture activity (McGinnity *et al.* 1997). Further genomic technologies are widespread used in breeding programmes to improve disease resistance, feed conversion efficiency and tolerance to environmental stressors, among others (Abdelrahman *et al.* 2017; Elaswad and Dunham 2017).

3.4 Descriptor 6: Sea-floor integrity

QD6 Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected							
QD	Criteria (element)	CODE Criteria	Env. Impact	Env. impact spatial extent	MA pressure solutions	Impact mitigation measures	Monitoring method
QD6	Spatial extent and distribution of physical loss (permanent change) of the natural seabed	D6C1	NO				
	Spatial extent and distribution of physical disturbance (including intertidal areas) pressures on the seabed.	D6C2	YES	Broader	YES	YES	YES
	Spatial extent of each habitat type which is adversely affected, through change in its biotic and abiotic structure and its functions (e.g. through changes in species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), by physical disturbance.	D6C3	YES	Broader	YES	YES	YES

QD1&QD6 Benthic habitats (relating to Descriptors 1 and 6)							
QD	Criteria (element)	CODE Criteria	Env. Impact	Env. impact spatial extent	MA pressure solutions	Impact mitigation measures	Monitoring method
QD1&QD6	The extent of loss of the habitat type, resulting from anthropogenic pressures, does not exceed a specified proportion of the natural extent of the habitat type in the assessment area.	D6C4	NO				
	The extent of adverse effects from anthropogenic pressures on the condition of the habitat type, including alteration to its biotic and abiotic structure and its functions (e.g. its typical species composition and their relative abundance, absence of particularly sensitive or fragile species or species providing a key function, size structure of species), does not exceed a specified proportion of the natural extent of the habitat type in the assessment area.	D6C5	NO				

D6C2: Spatial extent and distribution of physical disturbance pressures.

1. Environmental impact: YES. Sea-cages mooring systems and the daily waste input (*e.g.* uneaten food, fish faeces) may cause direct physical disturbances on the seafloor, with indirect impacts on associated communities (Riera *et al.* 2015a). The intensity of the impact mainly depends on the production scale of the maritime activity (Vergara Martín *et al.* 2005) and the carrying capacity of the local environment (Serpa and Duarte 2008; Aguilar-Manjarrez *et al.* 2017). Accumulation of adverse repercussions on the seabed may occur due to increasing input of organic matter, including the presence of carcases on the bottom (Vergara Martín *et al.* 2005) or additional faeces of wild fish aggregated to the floating structures (Dempster *et al.* 2005). This issue is becoming relevant, since in some areas of Macaronesia, such as the Canaries (PEACAN 2014), and Madeira (Direção Regional de Pescas da Madeira, unpublished data), the aquaculture industry has recently increased its overall production capacity and *per* site production and it is expected to continue developing.

2. Environmental impact spatial extent: Broader. Although in other regions of the globe the affected areas by offshore cages may reach up to several kilometres (Holmer *et al.* 2008), in Macaronesia, due to the local oceanographic and bathymetric conditions, it is expected that the major negative effects are found within the fish farm lease area and its immediate vicinity (Vergara Martín *et al*. 2005), decreasing with greater distance from farming operations (Serpa and Duarte 2008).

3. Maritime Activity pressure solution: YES. Appropriate marine spatial planning and site selection are essential to reduce the maritime activity pressure and achieve a sustainable development of the aquaculture industry (Pérez *et al.* 2005; Aguilar-Manjarrez *et al.* 2017). Greater depths and high-energy environments are easily found closer to the coast due to the steep shelf of the Macaronesian archipelagos (Brito Hernández 2010), therefore the oceanographic conditions allow the deployment of fish-cages in areas with high hydrological renewal and larger dispersion of particulate wastes (Riera *et al.* 2015b).

4. Impact mitigation measures: YES. Similarly to D1C3 mitigation measures, investment on technology, high quality feeds and good management practices may contribute to the reduction of physical impacts on the seafloor. Automated feeding systems based on fish behaviour (*e.g.* feeding sensors) are reasonable and cost-effective alternatives that could contribute to minimise these environmental impacts (Dunn 2008).

5. Monitoring method: YES. Since Spanish and Portuguese legislations do not specifically contribute to aquaculture regulation in terms of environmental impact assessment (BOE-Ley 6/2010; Decreto Lei nº 152B/2017), a defined and specific programme should be developed for the Macaronesian region, similarly to the one proposed by JACUMAR (2012). Modelling tools should be used beforehand to predict environmental disturbances according to the productivity of the maritime activity (Riera *et al.* 2017b) and carrying capacity of the selected area (Ross *et al.* 2013; Aguilar-Manjarrez *et al.* 2017). This method is feasible and relevant for Macaronesia, since a specific tool is already available for this region: MACAROMOD (Riera *et al.* 2017b).

D6C3: Spatial extent of each habitat type affected by physical disturbance.

1. Environmental impact: YES. Most of the existing aquaculture activities in the Macaronesian region are held on soft substrata bottoms, categorised as 'infralittoral sand' benthic broad habitat type under the EUNIS Habitat Classification (Level 2, code MB5: Evans *et al.* 2016). Soft bottoms under sea-cages are usually composed by fine sands (Riera *et al.* 2015a), which tend to accumulate more organic matter than coarse grain (Gray 1981). Physical disturbances on the sea bottom may conduct to changes and modifications of both biotic (*i.e.* benthic faunal composition) and abiotic structures (*i.e.* sediment composition) (Riera *et al.* 2015b). These effects are even more harmful when high-value ecosystems exist nearby the fish farms (Tuya *et al.* 2014), as it occurred with *Cymodocea nodosa* seagrass meadows located nearby a farm site in the Canary archipelago (Riera *et al.* 2015b).

2. Environmental impact spatial extent: Broader. Although generally, both biotic and abiotic effects on soft bottoms are found in the proximity of the fish farm

(Riera *et al.* 2015a, 2015b), the extension of the affected area may consistently vary by the local hydrodynamic conditions and could affect beyond the operative maritime area of the fish farms (Borja *et al.* 2009; Riera *et al.* 2015a).

3. Maritime Activity pressure solution: YES. There is an overall knowledge gap on Portuguese habitats characterisation (https://www.eionet.europa.eu). Further research on habitat mapping, identified within EUNIS, is suggested as an effective, and needed, pressure solution in order to quantify the natural extent of the different habitat types prior the beginning of aquaculture activities. Still, *Cymodocea nodosa* meadows should also be included as special areas of conservation (Decision 2016/2330/EU) outside Marine Protected Areas (BOC-Ley 4/2010), since they play a wide variety of ecosystem services (Tuya *et al.* 2014) on Macaronesian seabeds. Maritime activities, such as aquaculture, should be kept to an appropriate distance from seagrass meadows (*e.g.* 500 m) in order to mitigate the impact with the establishment of a buffer zone (Riera *et al.* 2015a).

4. Impact mitigation measures: YES. Same mitigation measures as those aforementioned on D6C2 are suggested.

5. Monitoring method: YES. Periodic monitoring programmes should be carried out during the operational phase to assess the environmental impact on biotic and abiotic parameters (Edgar *et al.* 2010; JACUMAR 2012), by means of biodiversity indexes (Borja *et al.* 2009) and/or benthic markers (*e.g.* DNA, stable isotopes). Furthermore, there is a need to define appropriate benthic indicators for the Macaronesian region based on habitat approach (Van Hoey *et al*. 2010).

3.5 Descriptor 10: Marine litter

QD10 Properties and quantities of marine litter do not cause harm to the coastal and marine environment							
QD	Criteria (element)	CODE Criteria	Env. Impact	Env. impact spatial extent	MA pressure solutions	Impact mitigation measures	Monitoring method
QD10	The composition, amount and spatial distribution of litter (excluding micro-litter, classified in the following categories : artificial polymer materials, rubber, cloth/textile, paper/cardboard, processed/worked wood, metal, glass/ceramics, chemicals, undefined, and food waste) on the coastline, in the surface layer of the water column, and on the seabed are at levels that do not cause harm to the coastal and marine environment.	D10C1	YES	Broader	YES	YES	YES
	The composition, amount and spatial distribution of micro-litter (particles < 5mm) on the coastline, in the surface layer of the water column, and in seabed sediment, are at levels that do not cause harm to the coastal and marine environment.	D10C2	YES	Broader	YES	YES	YES
	The amount of litter and micro-litter classified in the categories 'artificial polymer materials' and 'other' ingested by marine animals (birds mammals, reptiles, fish or invertebrates.) is at a level that does not adversely affect the health of the species concerned.	D10C3 — Secondary	YES	Broader	YES	No data	NO
	The number of individuals of each species which are adversely affected due to litter, such as by entanglement, other types of injury or mortality, or health effects.	D10C4 — Secondary	YES	Broader	YES	YES	NO

D10C1: Composition, amount and spatial distribution of litter (excluding micro-litter).

1. Environmental impact: YES. The generation and accumulation of anthropogenic marine debris caused by aquaculture labours is a ubiquitous problem in coastal ecosystems (Campbell *et al.* 2017), due to wear and tear of different structures, as well as severe weather conditions (Lusher *et al.* 2017). According to the MSFD Technical Subgroup on Marine Litter (2013), marine debris originating from aquaculture facilities are mainly classified as: artificial polymer materials (bags, ropes, fish-cage nets, buoys, cable ties), rubber (tyres), metal (weights) and food waste; which can be accumulated on the seabed or drift away (Thiel *et al.* 2011). Direct impacts might be produced via ingestion or by the entanglement of organisms on floating litter (Kühn *et* *al.* 2015), while indirect impacts could be the spread of NIS associated to fish farms by this means (Campbell *et al.* 2017). The occurrence and intensity of debris mainly depends on management practices, making possible its reversibility before producing additional damages. The severity of marine debris relies on the type and size of the items and the organisms that encounter it (Werner *et al.* 2016). Aquaculture-originated litter may be accumulated with other anthropogenic marine debris coming from the coast, increasing the impact on the marine environment and related species (Campbell *et al.* 2017). This issue is currently relevant for Macaronesia, since it is a well-developed tourist destination and negative effects may collide with other socio-economic activities.

2. Environmental impact spatial extent: Broader. The abundance and distribution of anthropogenic marine debris show considerable spatial variability (Galgani *et al.* 2015), reaching the coastline or the open ocean by drifting of floating structures (Campbell *et al.* 2017) and concerning ecological disturbances, hazards for animals, boat traffic and fishers (Lusher *et al.* 2017).

3. Maritime Activity pressure solution: YES. Good management practices should be developed and promoted to combat sea-based sources of marine litter (NOWPAP-MERRAC 2015; OSPAR 2015), through maintenance and gear recovery to avoid equipment loss. Furthermore, a risk assessment framework should be employed for decision support in site selection of aquaculture facilities (UNEP 2016), by evaluating possible risk management actions and identifying potential intervention points.

4. Impact mitigation measures: YES. There are guidelines for clean-up methods according to different environmental compartments (Galgani *et al.* 2013), with low-medium technical and expertise requirements (Vlachogianni *et al.* 2017).

5. Monitoring method: YES. Regular underwater surveys and cleanings should be performed around the fish farm lease to remove the accumulated litter (Veiga *et al.* 2016). Complementary surveys along the coastline might provide data to identify local areas with higher litter accumulation and therefore adapt and harmonise monitoring according to regional differences (Galgani *et al.* 2013). Knowledge of the oceanographic characteristics of the coast and modelling might help to select clean-up areas and reduce the effort. Lastly, integration of marine litter protocols with other MSFD descriptors should be coordinated to reduce monitoring costs (MSFD Technical Subgroup on Marine Litter 2013) during the operational phase of the maritime activity.

D10C2: Composition, amount and spatial distribution of micro-litter.

1. Environmental impact: YES. Aquaculture-originated litter classified as 'artificial polymer materials' are mostly made of polyethylene (PE) and polyamide (PA), including polyvinyl chloride (PVC) and expanded polystyrene (EPS) (Lusher *et al.* 2017). Plastic products are directly introduced in the marine environment through aquaculture operations and degrade slowly over time, leading to the embrittlement and fragmentation of the material into smaller sizes (*i.e*. secondary microplastics) and, eventually, to undetectable dimensions (UNEP 2016). Similarly, boring fauna in aquaculture structures may release microplastics into the marine environment (Davidson 2012). During the breakdown process, these microparticles may be directly harmful to marine organisms via ingestion or absorption (Lusher 2015). Further adverse and cumulative effects may arise from plastics with adsorbed contaminants from the surrounding environment (Camacho *et al*. 2018).

2. Environmental impact spatial extent: Broader. The distribution of microplastics mostly depends on the polymer density, showing great variation at all spatial scales (GESAMP 2015). The widespread extension can be explained by ocean circulation patterns (Cole *et al.* 2011) and mixing process (Kukulka *et al.* 2012), either by drifting away or by sinking. The dropping process may be accelerated when the plastic surface is colonised by organisms and therefore the weight is increased (Lusher *et al.* 2017).

3. Maritime Activity pressure solution: YES. The occurrence and degradation of debris depends mainly on management practices. Working protocols to minimise subsequent cost implications and to prevent hazards of microplastics in fish are encouraged to be implemented, as they will directly increase the economic value of the maritime activity and the ecological value of the surrounding environment.

4. Impact mitigation measures: YES. In order to remove microplastics from the marine environment, clean-up protocols are suggested for mass removal with sinks (Sherman and van Sebille 2016), based on oceanographic models to identify optimal locations (van Sebille *et al.* 2012). Regardless, the most effective mitigation measures should be focused on the reduction of the plastic waste by the maritime activity itself, control of the facilities degradation and search for environmental-friendly materials throughout the Macaronesian region.

5. Monitoring method: YES. Monitoring of microplastics depends mostly on the marine compartment to be extracted from (Cole *et al.* 2011) and the size limit imposed by analytical techniques (Löder and Gerdts 2015). Although it is very difficult to correlate the amount and kind of microplastics with the maritime activity, quantification and categorisation of microparticles can easily be performed by automatic counting (Lorenzo-Navarro *et al*. 2018) in order to possibly identify potential sources and pathways (MSFD Technical Subgroup on Marine Litter 2013). Plankton nets are mostly used for surface waters sampling, while subtidal sediments can be collected by different approaches (*e.g.* Van veen grab, multicorer) (Löder and Gerdts 2015). The standardisation of methodologies is suggested to reduce variations among studies (Herrera *et al*. 2018); however, the choice of the monitoring method might be according to local availability and the characteristics of the area to be sampled.

D10C3-secondary: Amount of litter and micro-litter ingested by marine animals.

1. Environmental impact: YES. Discarded or lost aquaculture gear may be ingested by both cultured and wild marine organisms, either intentionally (*e.g.* foraging strategy) or accidentally (*e.g.* filter-feeding) (Niaounakis 2017). This subject is of relevance in Macaronesia, since several protected species (*e.g.* the monk seal *Monachus monachus*) are frequent visitors to aquaculture facilities (Güçlüsoy and Savas 2003). Anthropogenic marine debris classified as 'artificial polymer materials' tend to be indigestible by animals and therefore may accumulate in their stomachs, with direct consequences in fitness, reproduction and survival (Kühn *et al.* 2015). The probability of ingestion by organisms may vary upon the size and colour of the particles encountered, as well as the food availability; increasing the intensity with the accessible amount of litter in the marine environment (Wright *et al.* 2013). Though the reversion of ingested debris is possible through egestion (Lusher 2015) or regurgitation (Kühn *et al.* 2015), chemical substances added during manufacture (*e.g.* antifouling on net pens), could originate separate or cumulative effects to debris ingestion (Rochman 2015) and amplify the complexity of the impact. The potential damaging effects of ingestion of microplastics affects not only the natural ecosystem of Macaronesia but also local populations, if humans are the end consumers of those animals (Herrera *et al*. 2019).

2. Environmental impact spatial extent: Broader. As aforementioned in D10C1 and D10C2, the widespread distribution of litter and microlitter (Cole *et al.* 2011; Kukulka *et al.* 2012) facilitates its accessibility to a wide range of marine organisms and the transfer through the food chain, both in distance and depth (Wright *et al.* 2013; Lusher 2015).

3. Maritime Activity pressure solution: YES. Similar pressure solutions to D10C1 and D10C2 are suggested, namely based on good management practices to combat sea-based sources of marine litter (OSPAR 2015; Lusher *et al.* 2017).

4. Impact mitigation measures: No data and information, further research is needed. No mitigation measures have been found to diminish the impact by ingestion. Nevertheless, those previously suggested under D10C2 might indirectly reduce repercussions by ingestion. Further research is therefore needed.

5. Monitoring method: NO. Despite the growing evidence of detrimental effects caused by debris ingestion at individual level on many species (Kühn *et al.* 2015), it is difficult to quantify the possible population-level effects (UNEP 2016) and, even more, to identify the origin related to aquaculture activities.

D10C4-secondary: Individuals affected due to litter, such as by entanglement.

1. Environmental impact: YES. Litter originated from aquaculture operations (*e.g.* nets, ropes) might cause entanglement incidents, resulting in injury or even death of the animals (Niaounakis 2017). Cetaceans, marine turtles, seals and seabirds become frequently entangled in loop-shaped items such as synthetic fishing gear (Kühn *et al.* 2015). Likewise, prey fish, which use debris as a shelter, may increase entanglement risk for predators (Kühn *et al.* 2015). Entangled organisms have reduced foraging ability, higher exposure to predators, and are subject to exhaustion, starvation and drowning (Niaounakis 2017). Aquaculture-originated debris may also impact the seabed by smothering the underneath sediment and associated fauna, leading to eventual senescence of above-ground biomass (Kühn *et al.* 2015). Injuries by entanglement entail a welfare issue and an increase of mortality (UNEP 2016), which might be critical for the success of endangered species in Macaronesia.

2. Environmental impact spatial extent: Broader. As aforementioned in D10C1, the abundance and distribution of anthropogenic marine debris show considerable spatial variability (Galgani *et al.* 2015), facilitating encounter and entanglement incidents with marine organisms.

3. Maritime Activity pressure solution: YES. Similar pressure solutions to D10C1 and D10C2 are also suggested to reduce the possibility of entanglement of marine organisms, which might affect the Macaronesian biogeographical region as a biodiversity hotspot (Madruga *et al.* 2016).

4. Impact mitigation measures: YES. International initiatives to promote the safe and effective rescue of entangled animals are currently performed to help reversing the impact of marine debris on the wild fauna (UNEP 2016). These programmes provide guidance and training to the general public, to make them part of the solution and therefore raise awareness (*i.e.* citizen science), which is necessary and at a reasonable cost to be accomplished in Macaronesia.

5. Monitoring method: NO. Damaged individuals related to aquaculture facilities should be reported in order to improve the database on marine litter issues.

4 Low degree of interaction

4.1 Descriptor 4: Food webs

QD1&QD4 Ecosystems, including food webs (relating to Descriptors 1 and 4)							
QD	**Criteria (element)**	**CODE Criteria**	**Env. Impact**	**Env. impact spatial extent**	**MA pressure solutions**	**Impact mitigation measures**	**Monitoring method**
QD1&QD4	The diversity (species composition and their relative abundance) of the trophic guild is not adversely affected due to anthropogenic pressures.	D4C1	NO				
	The balance of total abundance between the trophic guilds is not adversely affected due to anthropogenic pressures.	D4C2	NO				
	The size distribution of individuals across the trophic guild is not adversely affected due to anthropogenic pressures.	D4C3 — Secondary					
	Productivity of the trophic guild is not adversely affected due to anthropogenic pressures.	D4C4 — Secondary					

As stated under D1C3, aquaculture sea-cages attract a variety of fish that directly feed upon uneaten food pellets (Dempster *et al.* 2004) and subsequently may attract larger predators (Sanchez-Jerez *et al.* 2011). Farmed-associated species that feed on Particulate Organic Matter (POM) may significantly modify the dynamics of nutrient flows (Dempster *et al.* 2005), whenever occurring in high numbers. In addition, particulate and dissolved organic matter may influence zooplankton fatty acid composition through the microbial and protozoan loop (Brett *et al.* 2009), consequently reflecting changes in the fatty acid profile ('footprint') of juvenile fish associated to the cages (Fernandez-Jover *et al.* 2009). Nevertheless, given the Macaronesian physical and oceanographic features, and the location of fish farms in open waters, there is no obvious tendency for accumulation of organic matter. Further studies are still needed to evaluate the effect on diversity and the balance of total abundance between trophic guilds of local food webs. Hence, there is no clear evidence of the impacts from the Macaronesian aquaculture industry on both QD4 criteria.

4.2 Descriptor 5: Eutrophication

QD5 Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters							
QD	**Criteria (element)**	**CODE Criteria**	**Env. Impact**	**Env. impact spatial extent**	**MA pressure solutions**	**Impact mitigation measures**	**Monitoring method**
QD5	Nutrient concentrations (Dissolved Inorganic Nitrogen (DIN), Total Nitrogen (TN), Dissolved Inorganic Phosphorus (DIP), Total Phosphorus (TP)) are not at levels that indicate adverse eutrophication effects.	D5C1	NO				
	Chlorophyll a concentrations are not at levels that indicate adverse effects of nutrient enrichment.	D5C2	NO				
	The number, spatial extent and duration of harmful algal bloom (e.g. cyanobacteria) events are not at levels that indicate adverse effects of nutrient enrichment.	D5C3 — Secondary					
	The photic limit (transparency) of the water column is not reduced, due to increases in suspended algae, to a level that indicates adverse effects of nutrient enrichment.	D5C4 — Secondary					
	The concentration of dissolved oxygen is not reduced, due to nutrient enrichment, to levels that indicate adverse effects on benthic habitats (including on associated biota and mobile species) or other eutrophication effects.	D5C5	NO				
	The abundance of opportunistic macroalgae is not at levels that indicate adverse effects of nutrient enrichment.	D5C6 — Secondary					
	The species composition and relative abundance or depth distribution of macrophyte communities achieve values that indicate there is no adverse effect due to nutrient enrichment including via a decrease in water transparency	D5C7 — Secondary					
	The species composition and relative abundance of macrofaunal communities, achieve values that indicate that there is no adverse effect due to nutrient and organic enrichment	D5C8 — Secondary					

Criteria under QD5 do not apply to the current situation in Macaronesia, even though human-induced eutrophication could be originated from aquaculture activities by direct discharge of organic and inorganic wastes into the environment (Serpa and Duarte 2008), especially when high-trophic level species are farmed. According to the Macaronesian physical and oceanographic conditions, characterised by open coastal areas, oligotrophic water with high-energy environments (Brito Hernández 2010), and the future perspective on finfish production (Fernández-Palacios et al. 2019), it is unlikely to occur an eutrophication event or oxygen deficiency in bottom waters during regular operation of the fish farms (Vergara Martín *et al.* 2005; Braaten 2007).

4.3 Descriptor 7: Hydrography

QD7 Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems							
QD	**Criteria (element)**	**CODE Criteria**	**Env. Impact**	**Env. impact spatial extent**	**MA pressure solutions**	**Impact mitigation measures**	**Monitoring method**
QD7	Hydrographical changes to the seabed and water column (including intertidal areas).Spatial extent and distribution of permanent alteration of hydrographical conditions (e.g. changes in wave action, currents, salinity, temperature) to the seabed and water column, associated in particular with physical loss (7) of the natural seabed.	D7C1 — Secondary	NO				
	Spatial extent of each benthic habitat type adversely affected (physical and hydrographical characteristics and associated biological communities) due to permanent alteration of hydrographical conditions.	D7C2 — Secondary	NO				

Secondary criteria belonging to QD7, concerning the permanent alteration of hydrological conditions, are related to the primary criterion D6C1, which refers to a permanent change (physical loss) of the natural seabed structure. Since permanent changes on the seafloor are not expected to occur due to the aquaculture activity, criterion D6C1 was not implemented during the analysis, and therefore corresponding QD7 criteria were not subsequently analysed.

4.4 Descriptor 8: Contaminants

QD8 Concentrations of contaminants are at levels not giving rise to pollution effects							
QD	**Criteria (element)**	**CODE Criteria**	**Env. Impact**	**Env. impact spatial extent**	**MA pressure solutions**	**Impact mitigation measures**	**Monitoring method**
QD8	Concentrations of contaminants (ubiquitous persistent, bioaccumulative and toxic substances - Article 8a(1)(a) of Directive 2008/105/EC) do not exceed the established (WFD) threshold values in water, sediment or biota.	D8C1	NO				
	The health of species and the condition of habitats (such as their species composition and relative abundance at locations of chronic pollution) are not adversely affected due to contaminants including cumulative and synergetic effects.	D8C2 — Secondary	NO				
	The spatial extent and duration of significant acute pollution events (Dicharging oil and noxious liquid substances - MARPOL 73/78Article 2(2) of Directive 2005/35/EC) are minimised.	D8C3	NO				
	The adverse effects of significant acute pollution events on the health of species and on the condition of habitats (such as their species composition and relative abundance)	D8C4	NO				

QD8 criteria, regarding concentrations of contaminants, do not accomplish enough evidence of contaminant pollution in the marine environment from the Macaronesian aquaculture industry. Still, this is a relevant issue to be considered and should be monitored regardless, with a necessary cooperation among stakeholders to develop less polluting products. Good management practices, according with the capacity of the farming system, are essential to maintain healthy stocks (Boison and Turnipseed 2015). Decrease of the stocking densities inside the sea-cages may improve the fish welfare by diminishing disease outbreaks and risk of transmission (Arechavala-Lopez *et al.* 2013; Saraiva *et al*. 2018). Also, strong regulating measures are needed for the use of chemicals in aquaculture, which are hazardous to human health and the environment (FAO 1995). In the case of anti-fouling chemicals, the use of environment-friendly biocides with non-stick coatings is one option that could be promoted to prevent the adhesion of organisms (Amara *et al.* 2017).

4.5 Descriptor 9: Contaminants in seafood

QD9 Contaminants in fish and other seafood for human consumption do not exceed levels established by Union legislation or other relevant standards							
QD	**Criteria (element)**	**CODE Criteria**	**Env. Impact**	**Env. impact spatial extent**	**MA pressure solutions**	**Impact mitigation measures**	**Monitoring method**
QD9	The level of contaminants in edible tissues (muscle, liver, roe, flesh or other soft parts, as appropriate) of seafood (including fish, crustaceans, molluscs, echinoderms, seaweed and other marine plants) caught or harvested in the wild (excluding fin-fish from mariculture) does not exceed Regulation (EC) No 1881/2006	D9C1	NO				

QD9 refers to the level of contaminants in edible tissues of seafood, caught or harvested in the wild, and does not apply to finfish from mariculture. Analysis of the contaminants included in QD9 and regulated by European legislation (Regulation (EC) 1881/2006), revealed that contamination in wild fish stocks by aquaculture practices is quite unlikely.

4.6 Descriptor 11: Energy

QD11 Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine							
QD	**Criteria (element)**	**CODE Criteria**	**Env. Impact**	**Env. impact spatial extent**	**MA pressure solutions**	**Impact mitigation measures**	**Monitoring method**
QD11	The spatial distribution, temporal extent, and levels of anthropogenic impulsive sound sources do not exceed levels that adversely affect populations of marine animals.	D11C1	NO				
	The spatial distribution, temporal extent and levels of anthropogenic continuous low-frequency sound do not exceed levels that adversely affect populations of marine animals.	D11C2	NO				

Despite finfish aquaculture operations do not directly contribute as anthropogenic impulsive sound or continuous low-frequency sound sources, there is a need to evaluate the effects of higher frequencies and the impacts on the marine environment. Underwater noise contamination may be generated by mid- to high-frequency boats on offshore facilities, which might generate stress in farmed fish and lead to poor welfare (Filiciotto *et al.* 2013). Considering the Macaronesian biodiversity hotspot (Brito Hernández 2010; Madruga *et al.* 2016) and the presence of endangered species associated to aquaculture facilities, preventive measures as speed and distance limitations are strongly advocated (Li *et al.* 2015).

III. Conclusion

As the aquaculture activity continues to expand in Macaronesia, it must constantly consider its environmental, economic and social sustainability in such vulnerable environment. This report is a contribution for the development of a sustainable maritime activity integrated in the Blue Growth Strategy for Macaronesia, aiming to be used as a tool to define a regional programme of environmental impact assessment for the aquaculture industry.

The proposed analysis, summed up in Table 1, successfully related qualitative descriptors on good environmental status with the most relevant environmental issues of present date situation of aquaculture in the Macaronesian biogeographical region.

Table 1. Summary of the relationship between the analysed descriptors and environmental issues in Macaronesia.

QD	Env. Impact	Env. Impact spatial extent	MA pressure solutions	Impact mitigation measures	Monitoring method
1. Biodiversity	High	Broader	No data	Yes	Yes
2. Invasive species	High	Broader	Yes	Yes	Yes
3. Fish stocks	High	Broader	Yes	Yes	Yes
4. Food webs	Low	-	-	-	-
5. Eutrophication	Low	-	-	-	-
6. Sea-floor	High	Broader	Yes	Yes	Yes
7. Hydrography	Low	-	-	-	-
8. Contaminants	Low	-	-	-	-
9. Seafood cont.	Low	-	-	-	-
10. Marine litter	High	Broader	Yes	Yes	Yes
11. Energy	Low	-	-	-	-

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